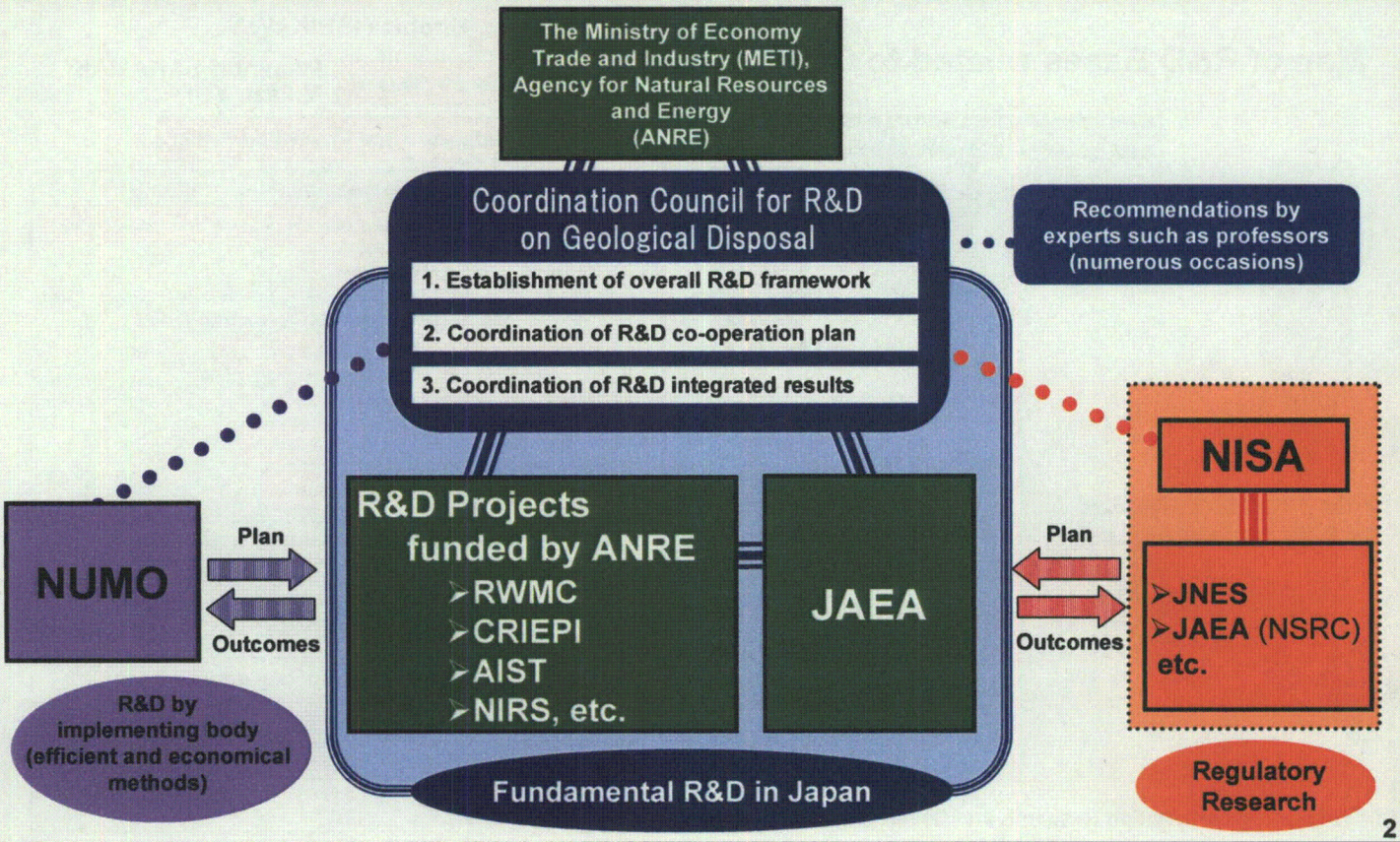
US NRC Visit
Facility Tour in Tokai R&D Center
Nuclear Fuel Cycle Engineering Laboratory
May 26, 2010

Status of JAEA Geological Isolation Research and Development Directorate Tokai (ENTRY & QUALITY)

Japan Atomic Energy Agency (JAEA)

Structure of R&D organization in Japan



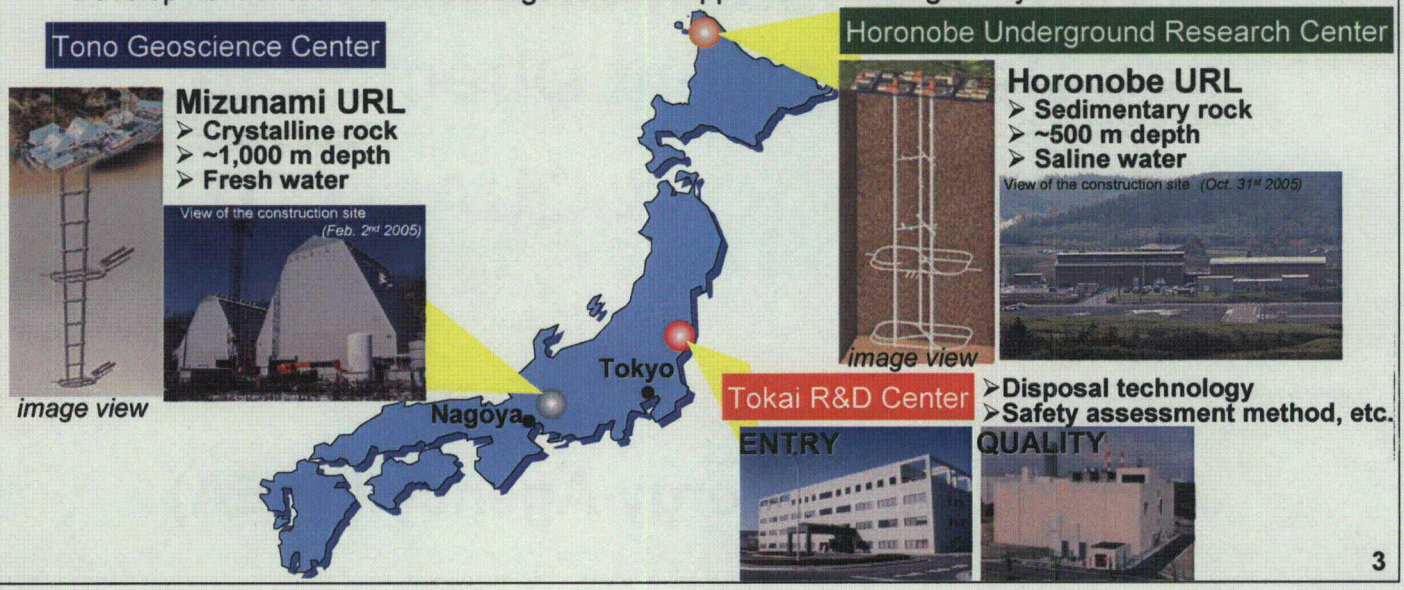
JAEA's R&D Facilities on HLW Disposal

OBJECTIVE:

- Development of technical basis for the implementation of disposal and for formulation for safety regulations

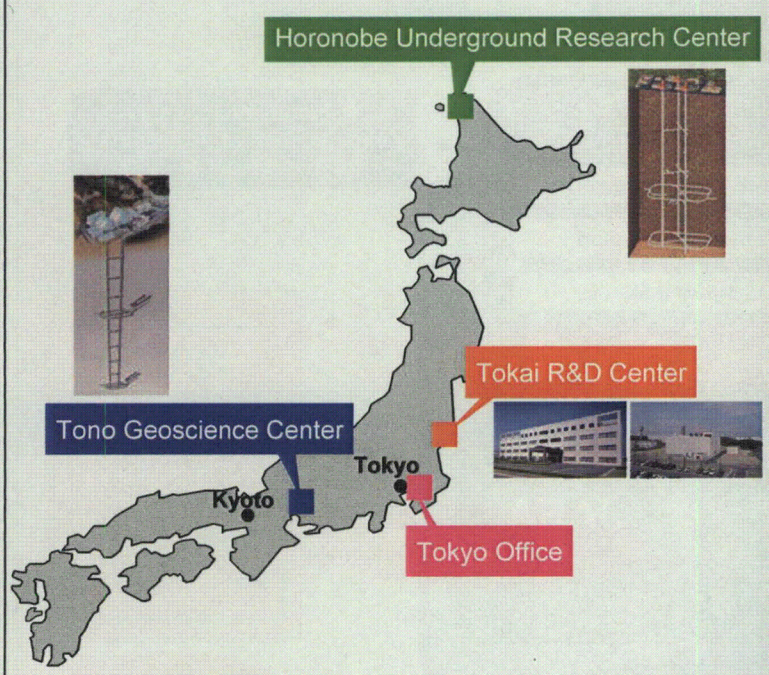
ACTIVITIES:

- R&D for engineering technology and safety assessment methods
- Development of integrated methods and techniques for characterizing the deep geological environment and demonstrating their applicability
- Development of technical knowledge base to support a convincing safety case



Organizational Chart of Geological Isolation Research and Development Directorate

Map of R&D Bases related to GIRDD



- **Director General** — Hirohisa ISHIKAWA
  - **Deputy Director General** — Masanori SAKAMAKI, Mikazu YUI
  - **R&D Co-ordination and Promotion Office**
  - **Research and Development Integration Unit**
    - Research and Development Planning and Co-ordination Group
    - Knowledge Management Group
  - **Geological Isolation Research Unit**
    - Performance Assessment Research Group
    - Near-Field Research Group
    - Radionuclide Migration Research Group
    - TRU Waste Disposal Research Group
  - **Horonobe Underground Research Unit**
    - Sedimentary Environment Engineering Group
    - Sedimentary Environment Research Group
  - **Tono Geoscientific Research Unit**
    - Crystalline Environment Engineering Group
    - Crystalline Environment Research Group
    - Neotectonics Research Group

GIRDD: Geological Isolation Research and Development Directorate

Mizunami Underground Research Facility

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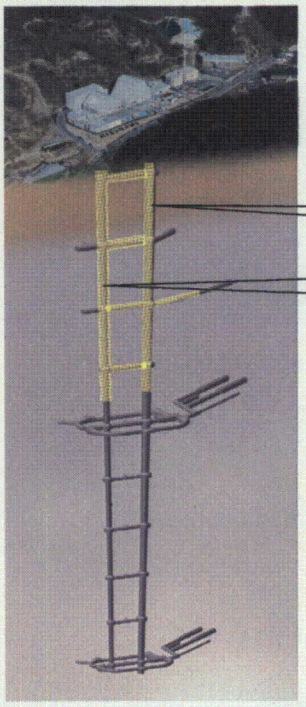


Current depth
(as of May 14)

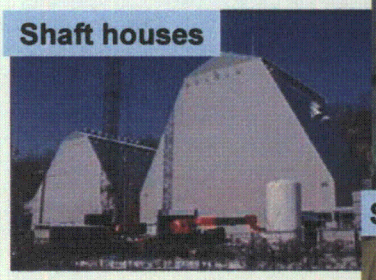
Main Shaft
459.6 m

Ventilation
Shaft
459.8 m

- Number of shafts: 2
  - Main shaft: Ø6.5 m
  - Ventilation shaft: Ø4.5 m
- Spacing of shafts: 40 m
- Bottom stage: 1,000 m depth

Image of underground facility
(Shaft sinking started in July 2003)

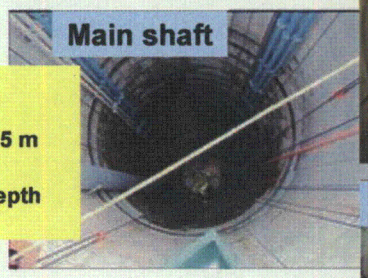
Shaft houses



Access Gallery at 300 m level

Scaffold

Main shaft



Drilling derrick

Main shaft

Horonobe Underground Research Facility

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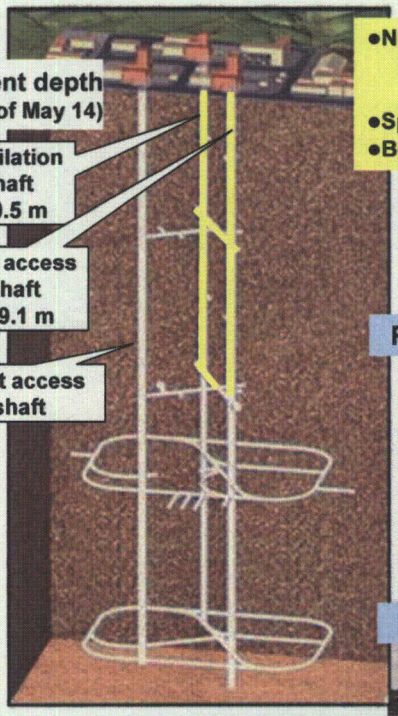


Current depth
(as of May 14)

Ventilation
shaft
250.5 m

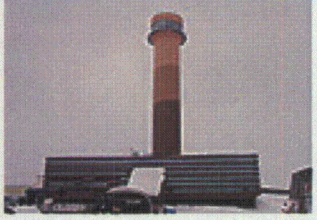
East access
shaft
249.1 m

West access
shaft

- Number of shafts: 3
  - two access shaft: Ø6.5 m
  - Ventilation shaft: Ø4.5 m
- Spacing of shafts: 70 m
- Bottom Stage: 500 m depth

Research and administration office/workshop

Public information house



Ventilation shaft

Underground facility area

Image of underground facility
(Shaft sinking started in Nov 2005)

ENTRY

ENgineering-scale **T**est & **R**esearch Facilit**Y**

QUALITY

QUantitative **A**ssessment Radionuclide Migration Experiment Faci**LITY**

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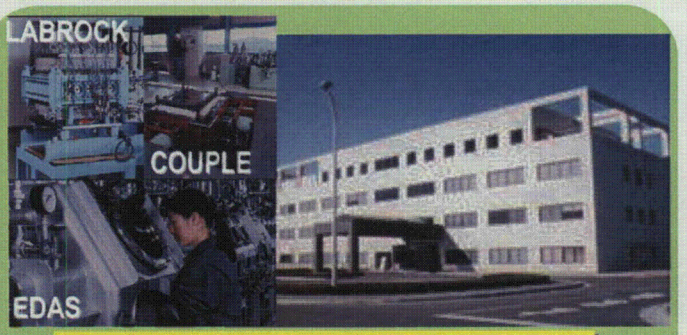
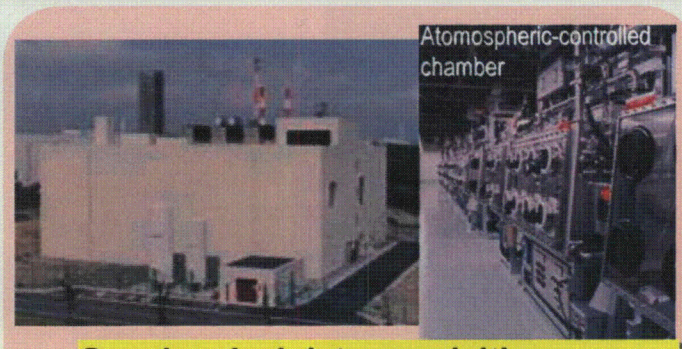


Model development & validation and data acquisition

- **PA Scenario Simulation**
  Bentonite extrusion and erosion, Colloid migration, Gas migration, Displacement of disposal pit, etc.
- **Geochemical and Coupling Process**
  T-H-M-C coupling process in NF
- **Flow and Mass Transport Modeling**
  Fracture flow, Density flow
- **Data Acquisition for Near-field PA**
  Corrosion (under anaerobic conditions)
  Bentonite properties, etc.



Geochemical data acquisition using radionuclides

Specification

Atomospheric-controlled chamber (O_2 < 1 ppm)
LPAS, FT-IR, XRD, etc.

On going experiments

Solubility, Sorption on betonite/rock/colloid,
Diffusion in bentonite/rock,
Effects of natural organics, etc.

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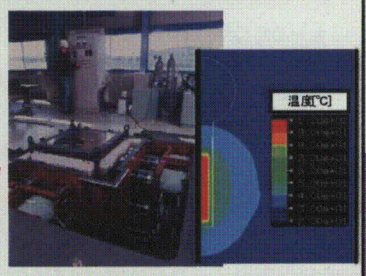
Linkage between Laboratory and In-situ Experiment

Laboratory Experiment
- Data Acquisition under Controlled Condition
- Model/Code Development
- Radionuclide Data Acquisition

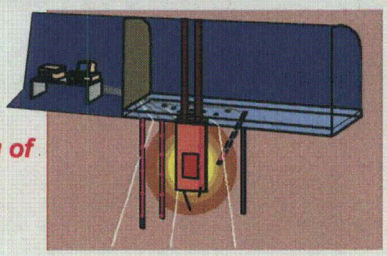


Mechanistic Understanding of Long-term Behaviors

inform ⇦

⇨ apply

In-situ Experiment
- Geoscientific information
- Applicability of design and PA methodology



Understanding of Geological Uncertainty

Numerical Experiment / Natural Analogue / International Collaboration

Improving the Reliability of Disposal Technologies
Development of Advanced Safety Assessment Methods

Long-term Corrosion of Carbon Steel 〔EDAS Series〕

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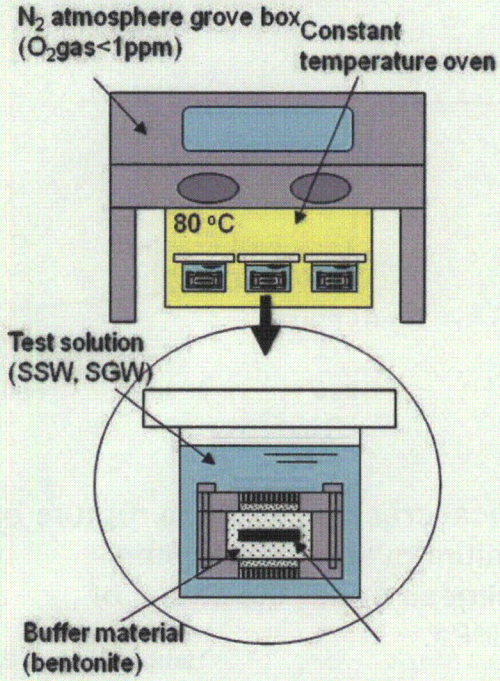
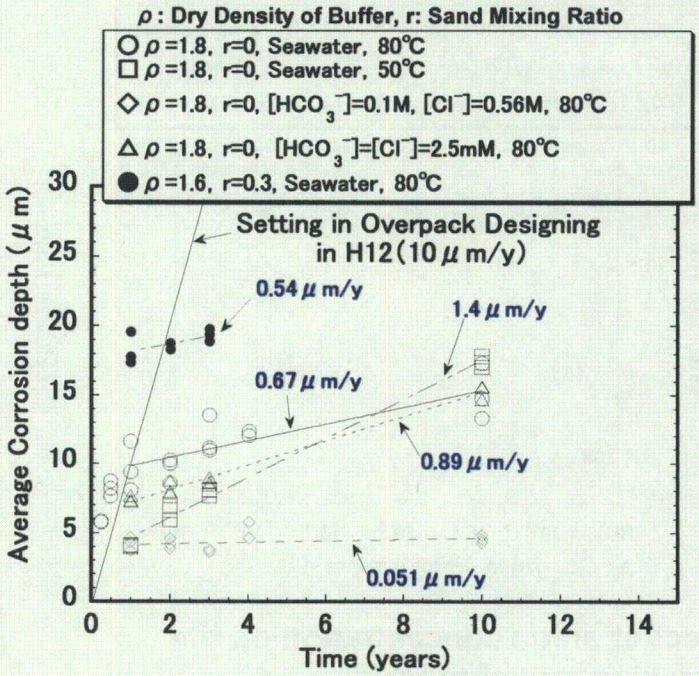
Corrosion Experiment

Immersion test of carbon steel in bentonite





Measured Corrosion rate : 0.051～1.4 μm/y
≪Setting in Overpack Designing : 10 μm/y

Taniguchi et al. 2008

Long-term Corrosion of Carbon Steel 〔EDAS Series / Natural Analogue〕

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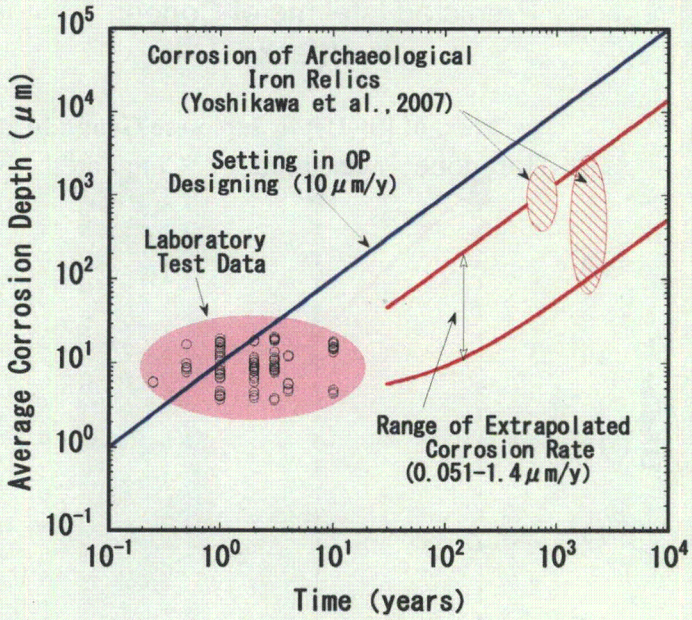
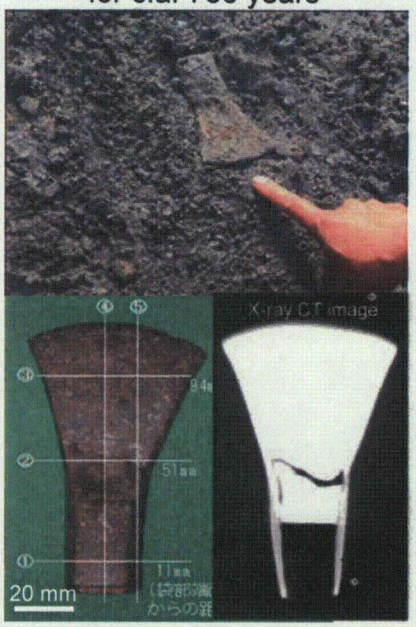
Long-term Extrapolation of Experimental Data and Comparison with NA Data



Natural Analog Study

Iron hand axe buried in soil for c.a. 750 years



The corrosion rate of 10 mm/y in the life time assessment in H12 was sufficiently conservative compared with realistic corrosion rates.

Hydrogen Embrittlement Lifetime of Titanium Overpack 〔EDAS Series〕

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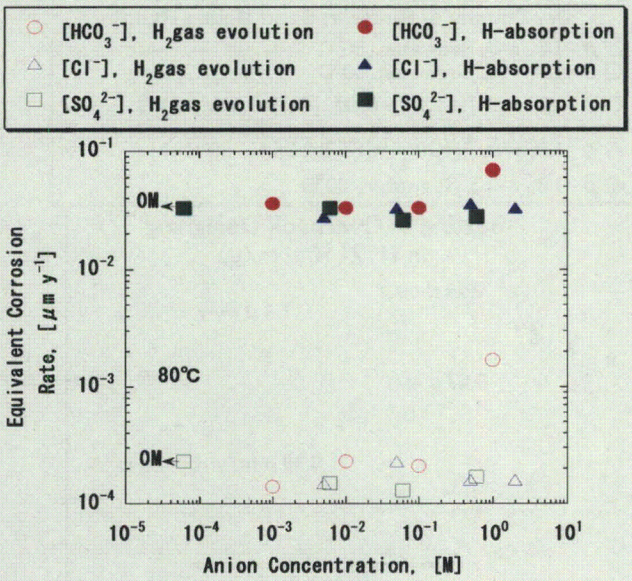
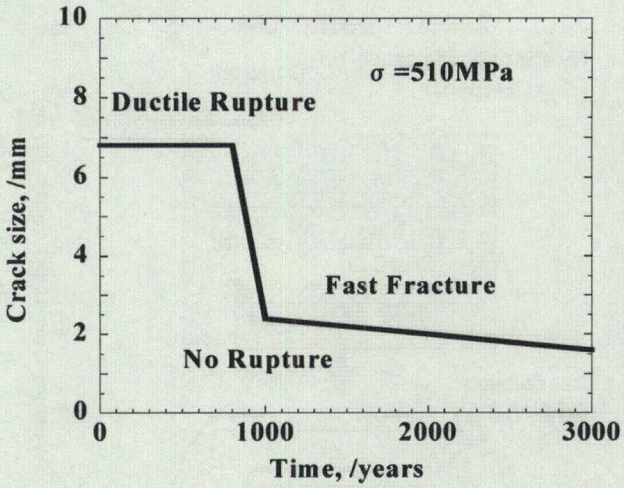


Effect of anion concentration on the corrosion rate of pure Ti
(Corrosion rates were calculated from the amount of Hydrogen).



Critical crack size for the rupture of titanium overpack with 6mm-thickness under the stress of 510MPa.

Taniguchi et al. 2007

Corrosion Lifetime of Copper Overpack as a Function of [S(-II)] 〔EDAS Series〕

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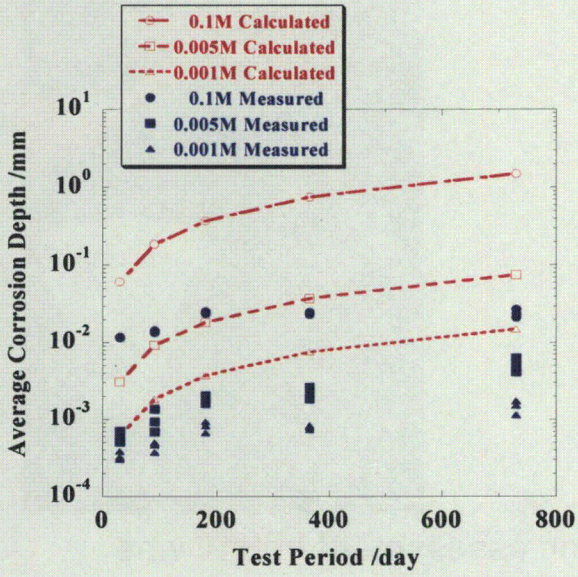
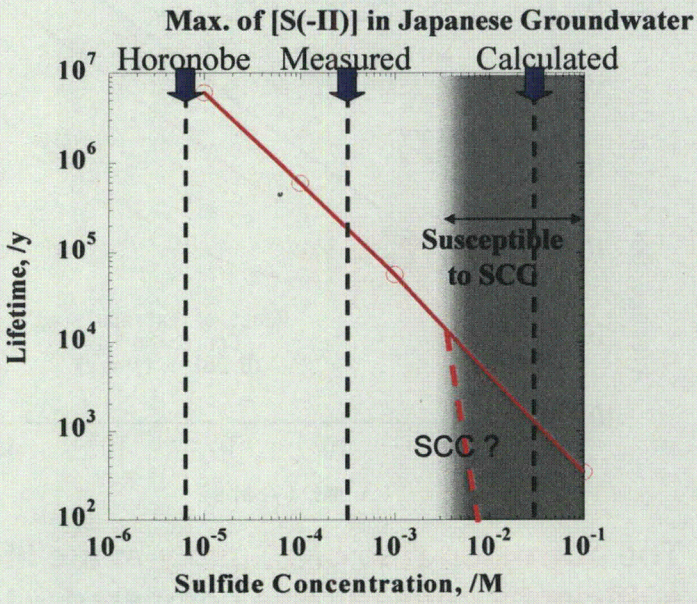
Lifetime was assumed to be the Period for 10mm penetration

Comparison of the Experimental Data with Calculated Results



Predicted Lifetime of Copper overpack



Data Acquisition on Buffer Material Properties

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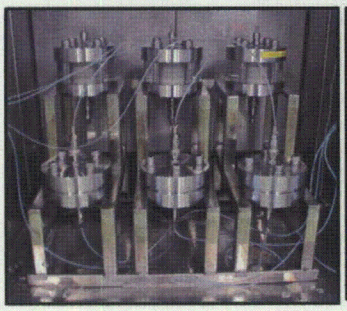
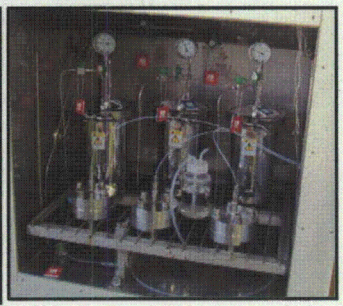
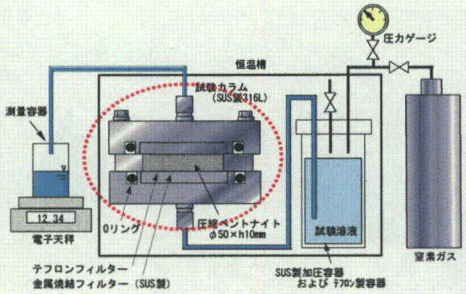
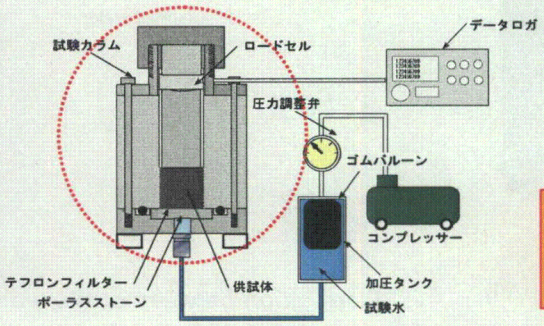
Hydraulic Conductivity Measurement







Swelling Stress Measurement



Accumulation of data under Saline GW, Horonobe GW, Alkaline (cement co-existing) conditions, etc

- **Standardization of measurement procedures**
- **Database development**

Data Base Development for the Fundamental Properties of the Buffer

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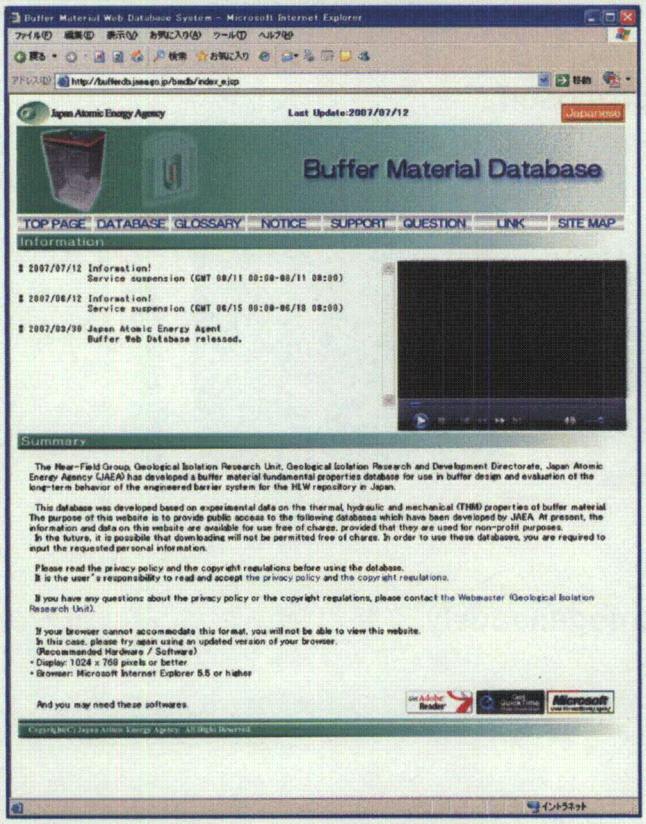
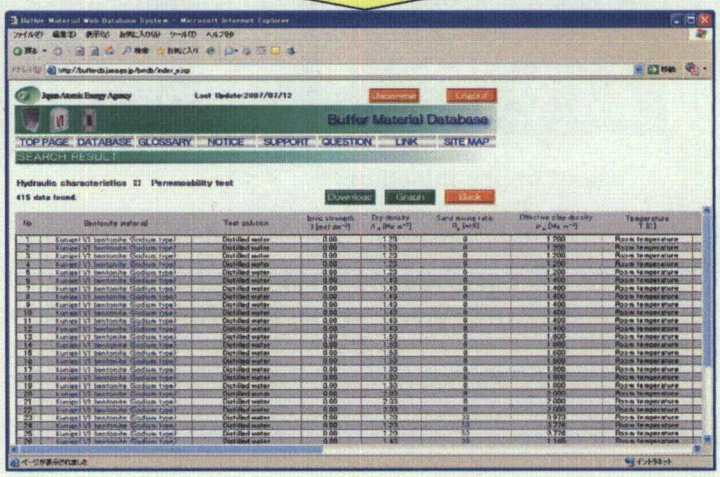


Top page of the database for buffer material

- This database includes hydraulic, swelling, thermal, and mechanical properties of Kunigel V1 bentonite saturated with distilled and saline waters.
- All of the data can be accessed at the homepage mentioned previously with functions, which include data search and diagram drawing.
- <u>Required data can be downloaded from the website as a CSV file.</u>



Bentonite Extrusion / Erosion 〔X−ray CT〕〔BENTFLOW〕

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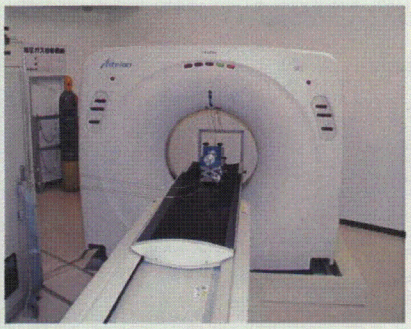
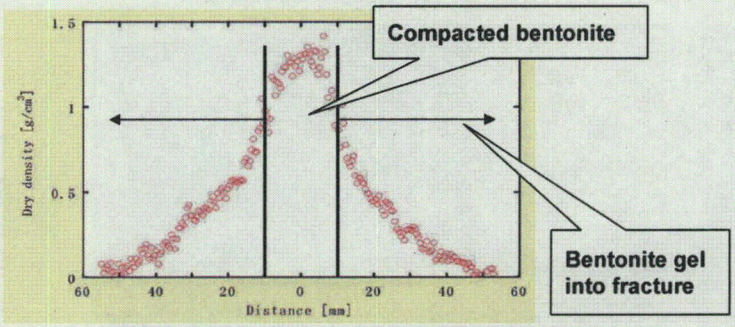
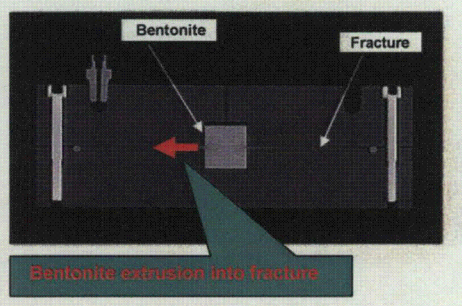
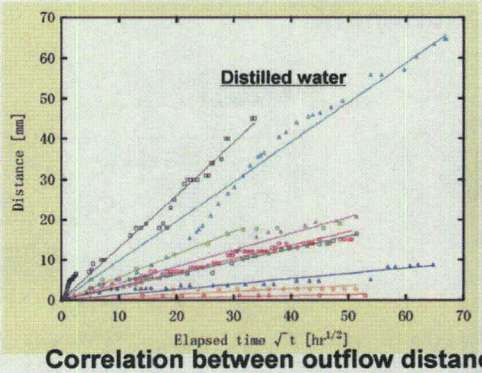




Distribution of bentonite density into fracture



X-ray CT Scanner (TOSHIBA, Asteion VI)



Experimental
Bentonito:kunigel V1
Specimen size: ϕ 50 × H50mm
Dry density:1.6,1.8g/cm³
Fracturewidth:0.5,1.0,1.5mm
Type of water:Distilled water

Correlation between outflow distance and time

Observation of Gas Migration through Compacted Bentonite 〔 X−ray CT 〕

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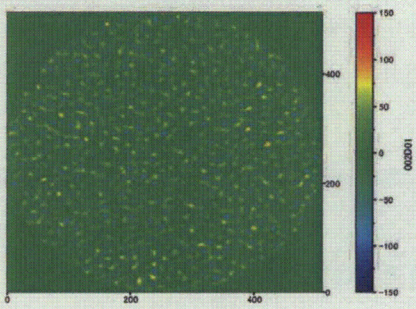
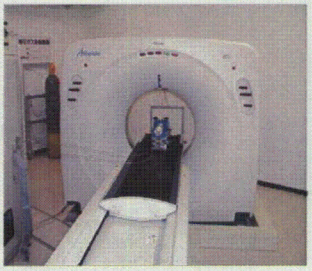
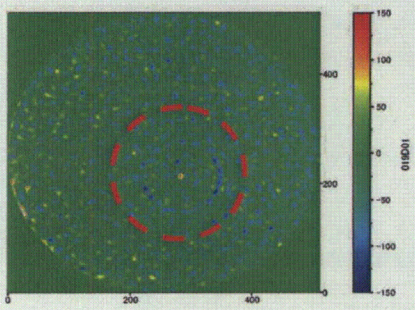
➢ Various gas migration models have been proposed, but no observation was reported.



start of gas injection





96 days after gas injection

- X-ray CT indicates that gas migrates not homogeneously, but through formation of dominant pathway.

Model Test on Shear Behavior by Fault Movement [BORE-SHEAR]

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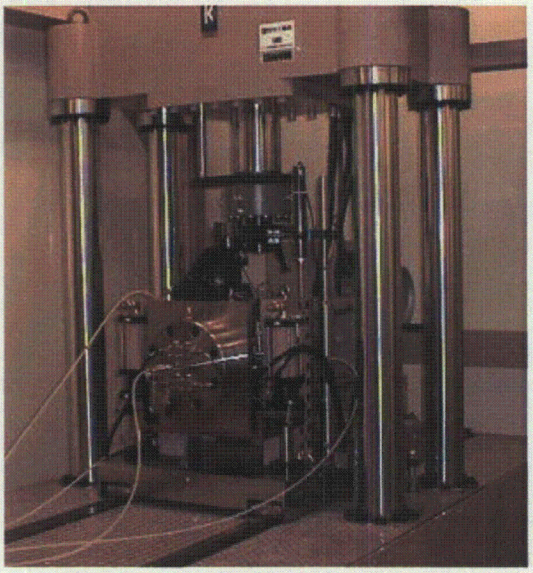
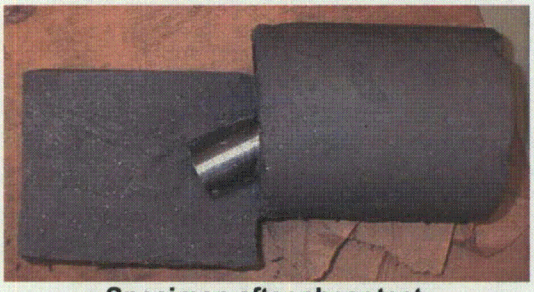
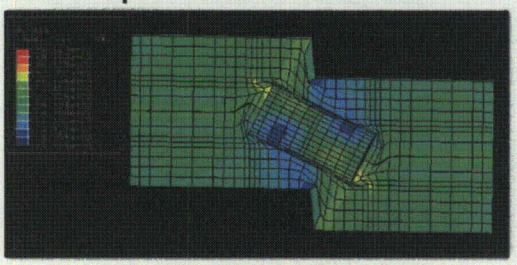


BORE-SHEAR experimental equipment



Specimen after shear test



Result of simulation analysis

•Overpack was not damaged by the shear deformation of 80 cm as converted real size.

Thermal-Hydrological-Mechanical-Chemical (THMC) Modelling Studies

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R&D on coupled THMC modeling

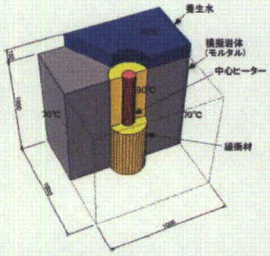
Evaluation of long term behavior in near-field

Development of model/code

Verification / Validation

Lab. Test / Engineering scale test

Test in controled boundary condition

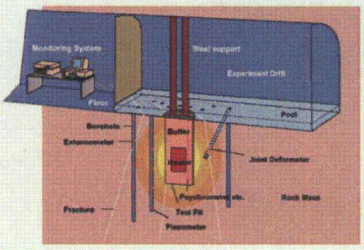


"COUPLE" experiment

Verification / Validation

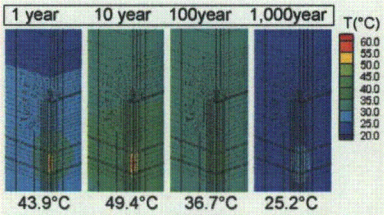
In-situ test

Test in real boundary condition

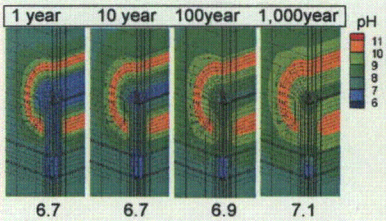


In-situ test at Kamaishi mine

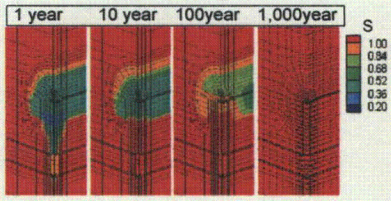
Temperature



pH

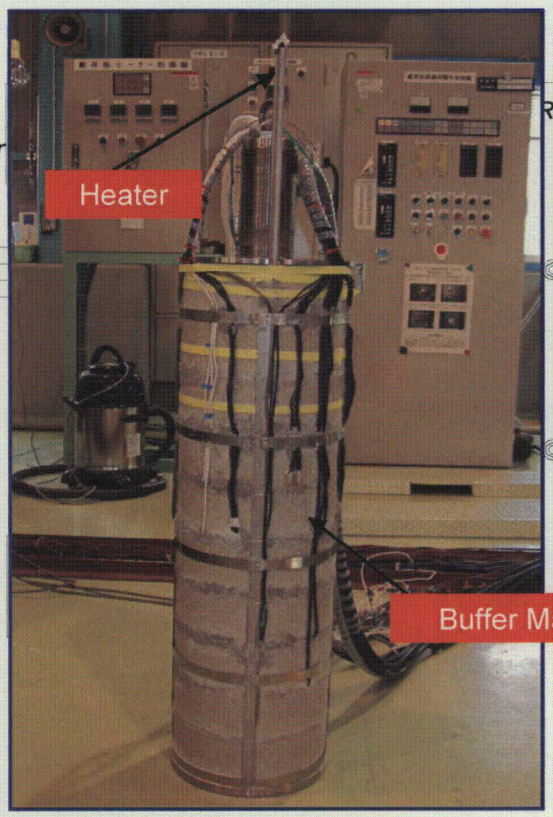


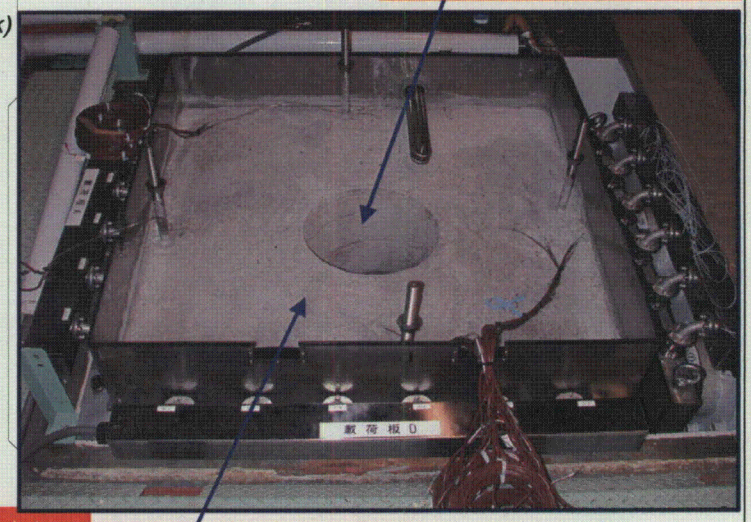
Saturation



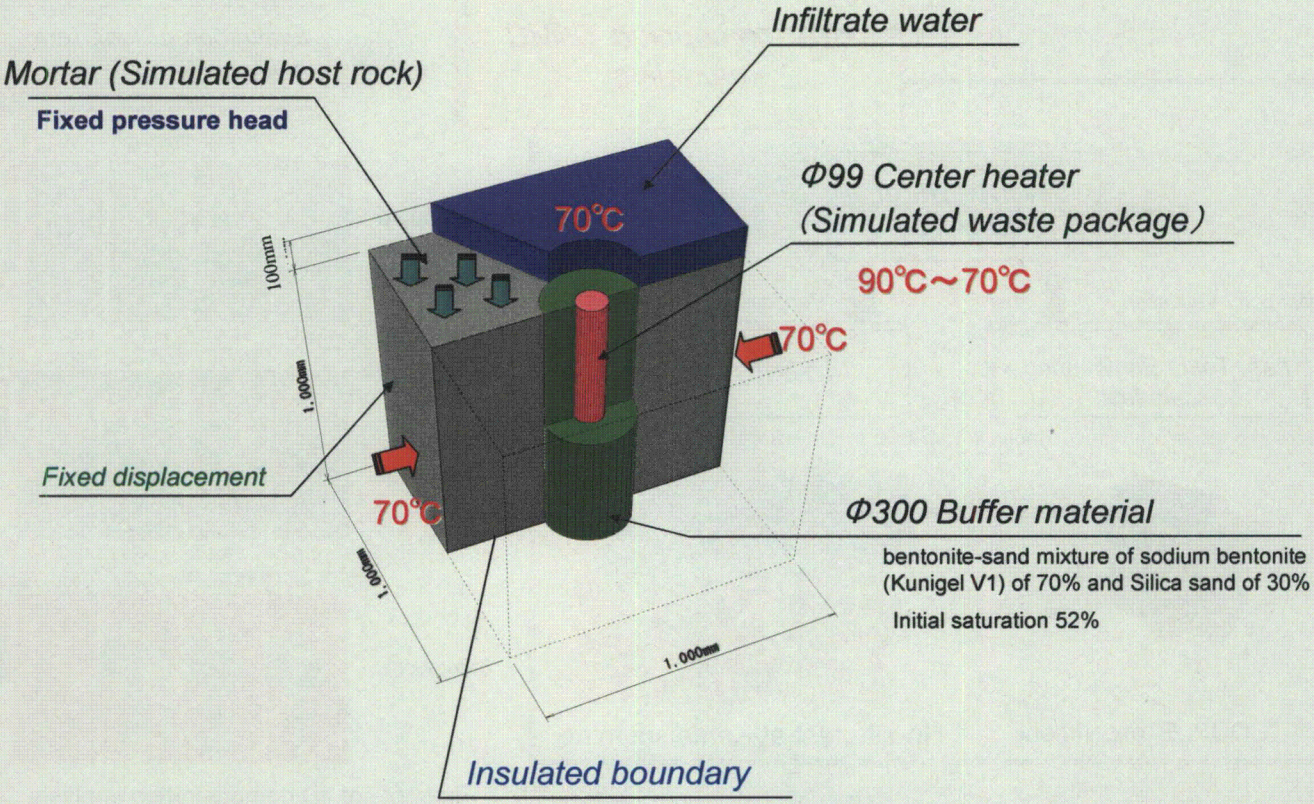
Example of 3D demonstration analysis

COUPLE Equipment

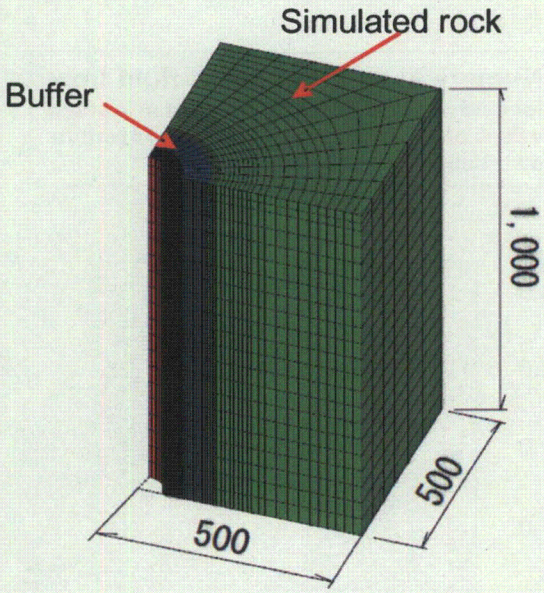




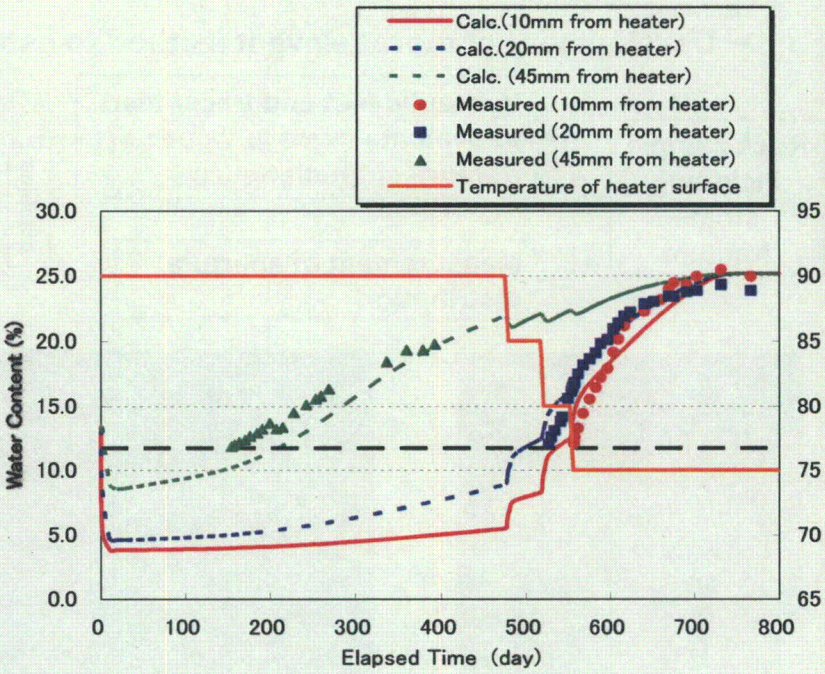
Experimental Condition〔COUPLE〕



Modeling Result by TH analysis [COUPLE]



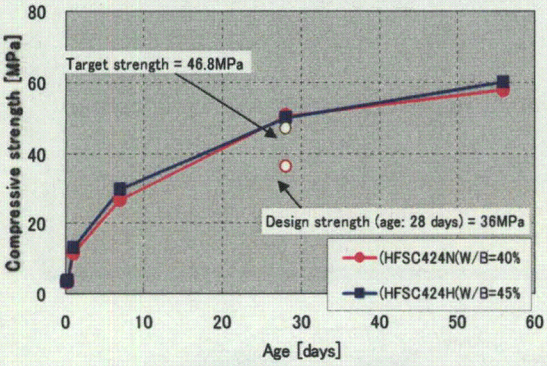
Model geometry



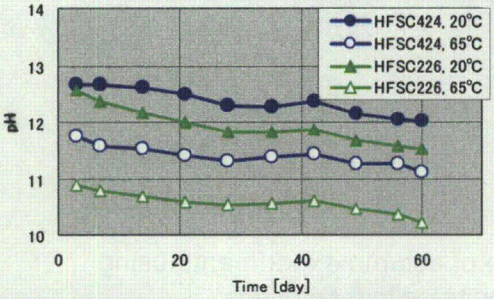
Evolution of water content

Low Alkaline Cement Development for Horonobe URL (Sedimentary Rock)

Low Alkaline Cement (HFSC: Highly Fly ash contained Silica fume Cement)



Compressive strength



pH Evolution as a Function of Time

Shotcreting test using mockup tunnel

- In-situ shotcreting demonstration test at Horonobe URL(140mL): July,2009

Hydrology and Mass Transport in Fractured Rock 〔LABROCK〕〔NETBLOCK〕

JAEA

➢ **Development of more relevant method to estimate realistic parameter values.**

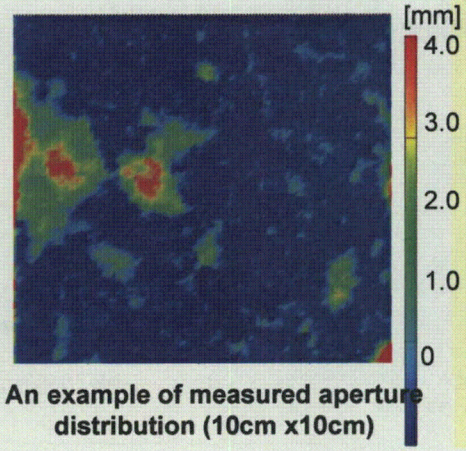
Rock sample including single fracture

→ **Hydraulic test and tracer test to evaluate average values of fracture characteristics**

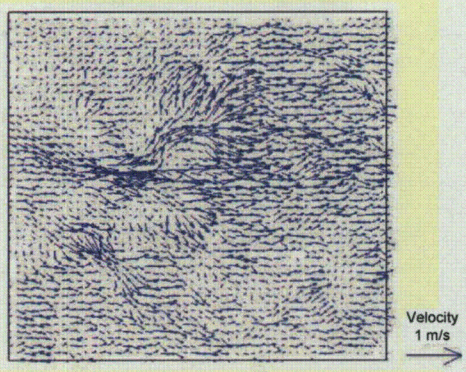
→ **Measurement of aperture distribution**

combine → **Numerical simulations of fluid flow** for studying the relationship between average values of fracture characteristics and aperture distribution

Aperture measurement by grinding method



An example of measured aperture distribution (10cm x10cm)



An example of numerical simulation result (Velocity distribution)

Migration Behavior of Bentonite Colloids through a Fractured Rock

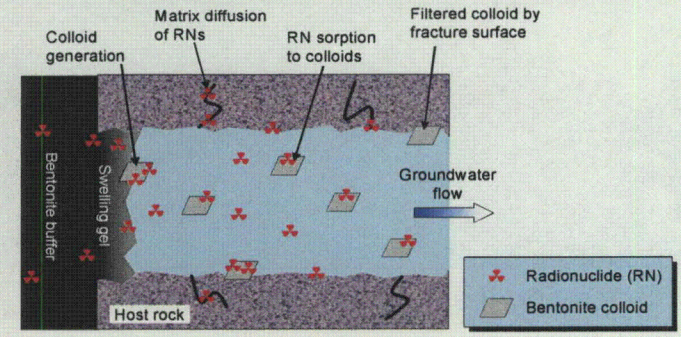
JAEA

The buffer is expected to swell into open rock fractures, which raises the possibility that colloidal particles of bentonite could form and be migrated away in flowing groundwater.

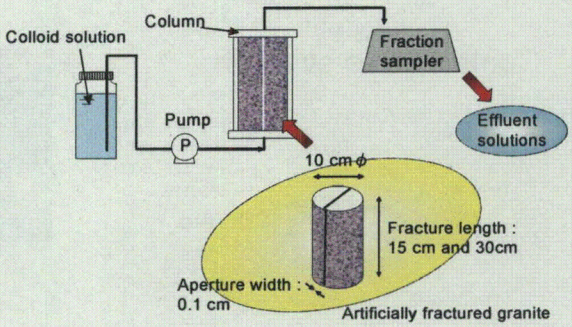
⇩

Colloidal migration of sorbed radionuclides could influence the migration of these elements from a HLW repository.

Column experiments were carried out to investigate the migration behavior of bentonite colloids in artificially fractured granite under slow-flow conditions.



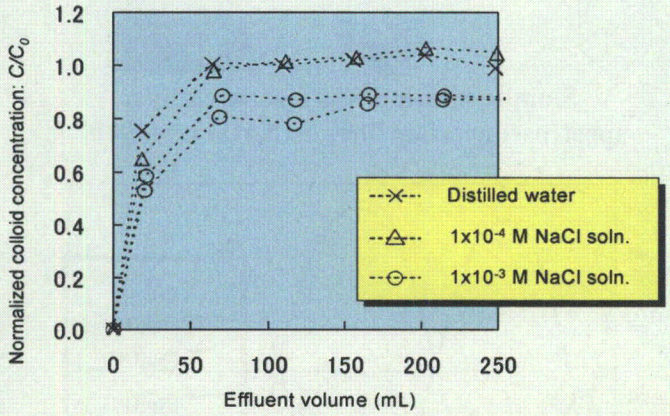
Schematic image of RN migration with bentonite colloids in a fractured rock



Setup of column experiments using bentonite colloid solutions

Sample of Experimental Results

JAEA



Migration behavior of bentonite colloids through a granite fracture (Fracture length : 15cm)

- Distilled water or 10^{-4} M NaCl solution : The C/C_0 value rapidly approached 1.

- 10^{-3} M NaCl solution : A rapid increase in the breakthrough curves was also observed initially, but the curves later evolved to an approximate steady-state with C/C_0 less than 1.

It may be reasonable to expect that bentonite colloids will be filtered by fractured granites if the colloid solution has a relatively high ionic strength (*i.e.*, equivalent to about 10^{-3} M NaCl, or higher).

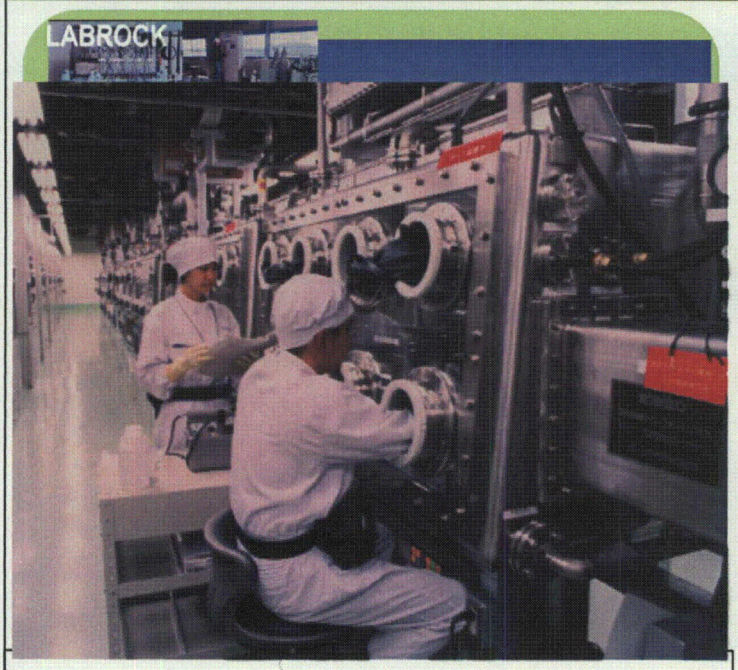
ENTRY

ENgineering-scale Test & Research FacilitY

QUALITY

QUantitative Assessment Radionuclide Migration Experiment FaciLITY

JAEA



17 sets of Glove Box
(12 sets; Atomosphere-controlled)

Experiment started in August, '99

Geochemical data acquisition using radionuclides

Specification

Atomospheric-controlled chamber (O_2 < 1 ppm)
LPAS, FT-IR, XRD, etc.

On going experiments

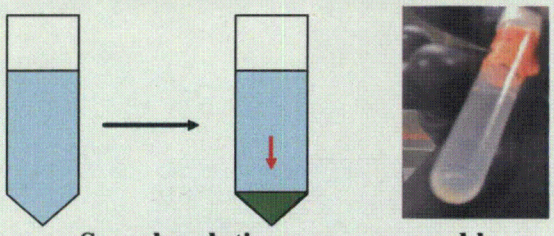
Solubility, Sorption on betonite/rock/colloid,
Diffusion in bentonite/rock,
Effects of natural organics, etc.

Measurement of Solubility of NpO_2(am)

JAEA

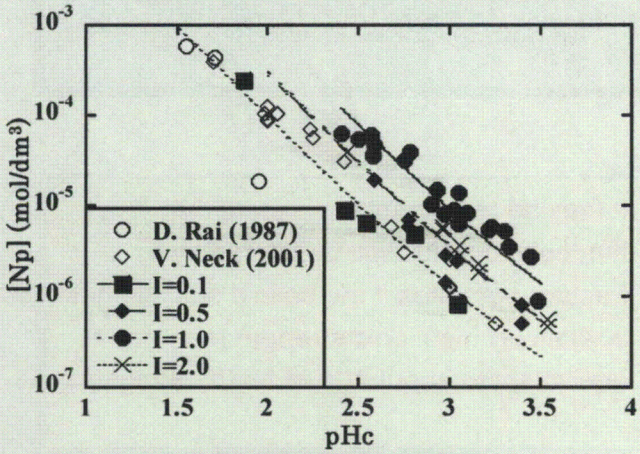
Experiment (oversaturation method)

Np(V)→Np(IV) 0.5% H_2-N_2 Gas
Initial [Np] : 10^{-3} M
$NaClO_4$ 0.1, 0.5, 1.0 2.0 M 4ml
pH Adjustment : $HClO_4$, NaOH

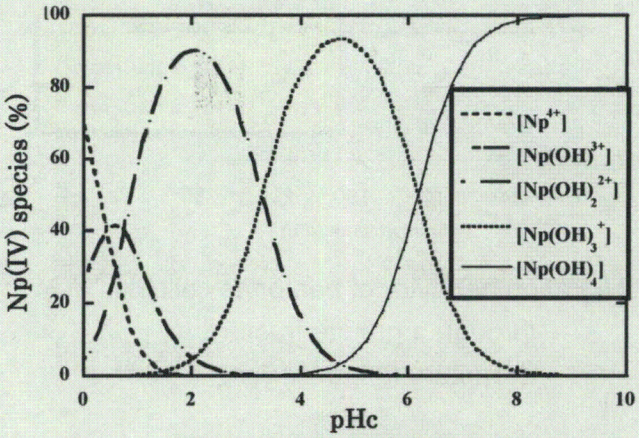


Sample solution was measured by α spectroscopy after filtrate (NMWL = 3000).

$$NpO_2 \cdot xH_2O \rightleftharpoons Np^{4+} + 4OH^- + (x-2)H_2O$$



Solubility of Np(IV)



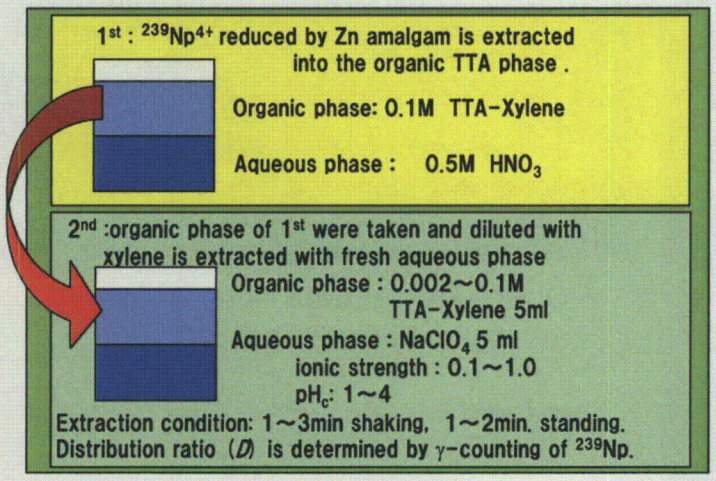
Ratio of Np(IV) species

Fujiwara et al. 2005 27

Measurement of Hydrolysis Constants of Np(IV) by Using Solvent Extraction Method

JAEA

Hydrolysis constants (β) of Np(IV) are needed for predicting the solubility of Np(IV).



$$Np^{4+} + nOH^- \rightleftharpoons Np(OH)^{(4-n)+} \quad : \beta_n$$

	This work	Duplessis (1977)
log β_1^0	13.91±0.23	14.5±0.2
log β_2^0	27.13±0.15	28.2±0.3
log β_3^0	37.70±0.30	not determined
log β_4^0	46.16±0.30	not determined

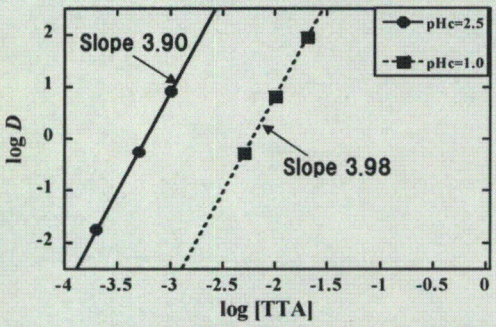


Fig. [TTA] dependence of log *D*.

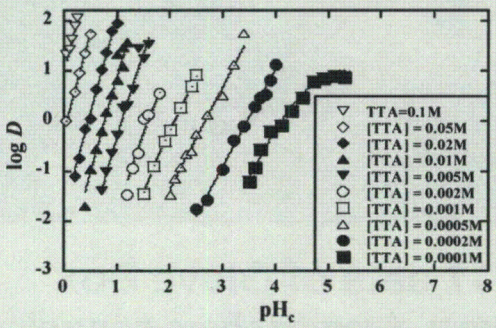
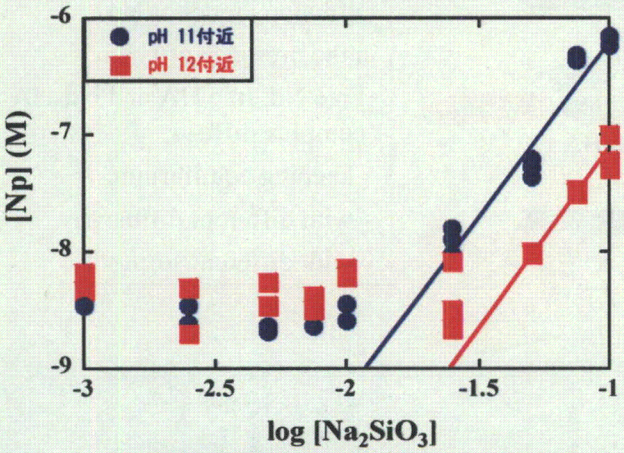


Fig. pHc dependence of distribution ratio of Np(IV).

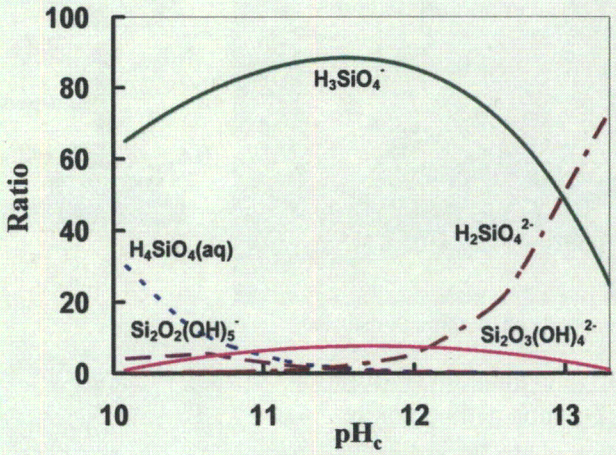
K. Fujiwara et al., Radiochim. Acta, 96, pp. 613-616 (2008). 28

Measurement of Solubility of Np(IV) in Si solutions

JAEA



$[Na_2SiO_3]$ dependence of [Np]



Ratio of Si species

Sample condition: (oversaturationmethod)
pH=11-12,
I = 1.0 NaCl
$[Na_2SiO_3]$= 0.1M-0.001M

Fujiwara et al. 2009

In this study, $H_3(SiO_4)_3^{2-}$ and Np(IV) are stable.

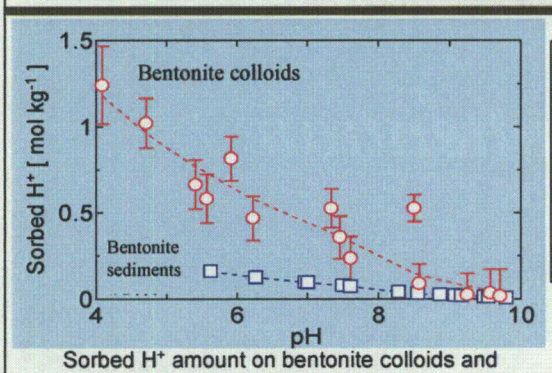
The solubility of Np(IV) dependence of $[Na_2SiO_3]$ and pH indicate the main species is $Np(OH)_3(H_3SiO_4)_3^{2-}$.

The fitting of the data, formation constants is
$\log K^\circ = -20.7 \pm 1.5$

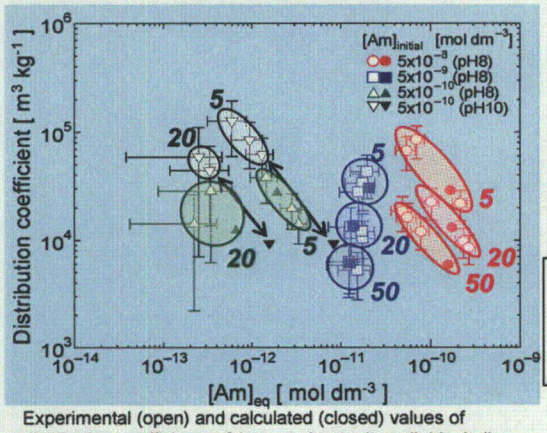
(for Th, $\log K^\circ = -27.8 \pm 0.7$, Rai et al. 2008)

Sorption Behavior of Americium onto Bentonite Colloids and Its Modeling

JAEA



Sorbed H^+ amount on bentonite colloids and sediments measured by acid titration.



Experimental (open) and calculated (closed) values of distribution coefficients of Am onto bentonite colloids. Italic numbers indicate colloids concentration (mg/L).

Sorption behavior of Am onto bentonite colloids is;

- evaluated by batch type sorption experiments,
- modeled based on the ion exchange and surface complexation,
  - with constants referred from previous works,
  - taking into account higher edge site density for bentonite colloids than bentonite sediments (measured by titration).

Ion exchange

$3(\equiv S^{IE}O\text{-}Na) + Am^{3+} \Leftrightarrow (\equiv S^{IE}O\text{-})_3Am + 3Na^+$

$${}^{Am}_{Na}K_C = \frac{(Am^{3+})[Na^+]^3\gamma_{Na}^3}{(Na^+)[Am^{3+}]\gamma_{Am}}$$

Surface complexation to edge site

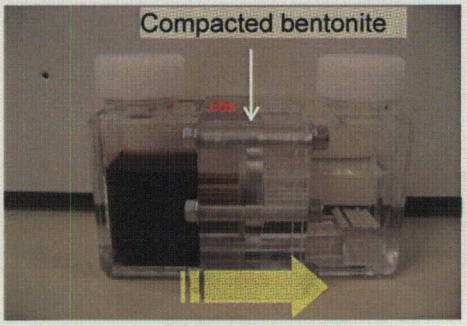
$\equiv S^SOH + Am^{3+} + yH_2O \Leftrightarrow \equiv S^SOAm(OH)_y^{2-y} + (y+1)H^+$

$${}^{S}K = \frac{[\equiv S^SOAm(OH)_y^{2-y}][H^+]^{y+1}}{[\equiv S^SOH][Am^{3+}]}$$

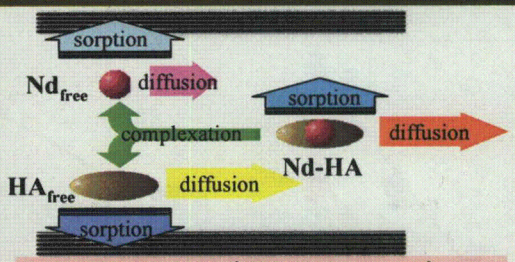
- Calculation agree with experimental values at pH 8.
- Distribution coefficients of RN onto bentonite colloids can be calculated by this model with constants in references.

K. Iijima et al., Radiochim. Acta, 96, pp.721-730 (2008).

Diffusion of Humic Acid (HA) and Nd in the Presence of HA in Compacted Bentonite



Experimental cell for through-diffusion.



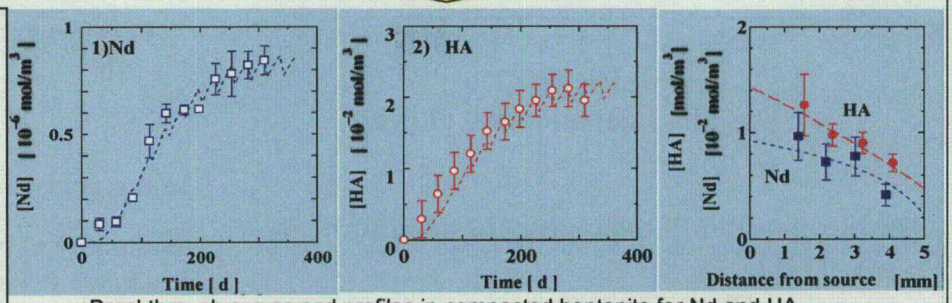
$$\left(1+\sum_{i=1}^{N} K_i\right)\frac{\partial C_0}{\partial t}=\left(\frac{De_0}{\alpha_0}+\sum_{i=1}^{N}\frac{De_i}{\alpha_i}K_i\right)\frac{\partial^2 C_0}{\partial x^2}$$

Diffusion model of Nd in the presence of HA:

- Free Nd, free HA and Nd-HA complex diffuse;
  - keeping equilibrium,
  - with different diffusivity,
  - with different sorptivity.

Quantitative evaluation of filtration effect of compacted bentonite

- Diffusion of HA is
  - difficult in 0.01M NaCl,
  - observed < 1.5 Mg/m^3 in 0.1M,
  - observed < 1.6 Mg/m^3 in 1M.
- MW of HA diffusing in compacted bentonite is;
  - < 3,000 in 0.1M NaCl,
  - < 3,000 - 5,000 in 1M.



Breakthrough curves and profiles in compacted bentonite for Nd and HA.

- The model equation is fitted to the breakthrough curves and profiles in compacted bentonite for Nd and HA.
- Diffusivity and rock capacity factors are evaluated for each species.

K. Iijima et al., Mat. Res. Soc. Symp. Proc., 1124 (2009, in press).

Overview of Tono Geoscience Center

Japan Atomic Energy Agency
Tono Geoscience Center
May 27th, 2010

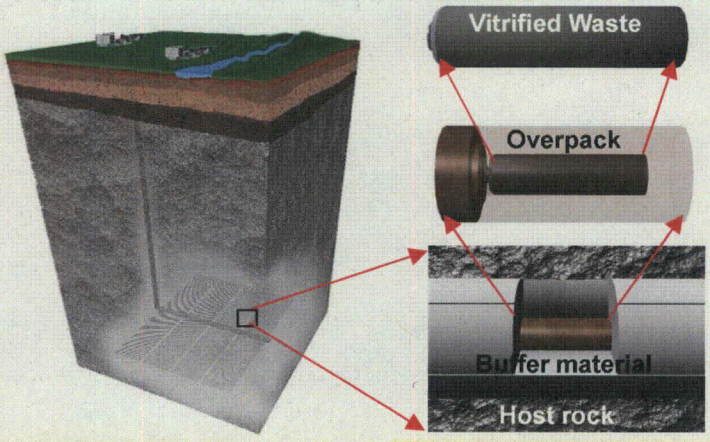
To Enhance Technical Reliability of Geological Disposal

H12 Report

Demonstrated technical feasibility of the reference disposal concept in Japan's geological environment on a generic basis.

Further improvement of the reliability

HLW Disposal Concept



Stable Geological Environment (deeper than 300m)

Massive EBS (Engineered Barrier System)

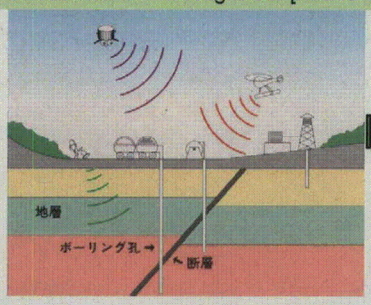
Key goal-1 Confirmation on applicability of disposal technologies to the actual geological environment

Key goal-2 Understanding of the long-term behavior of the geological disposal system

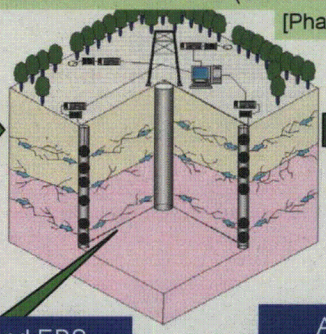
Key Goal-1 Confirmation on applicability of disposal technologies to the actual geological environment

Investigation techniques for the geological environment

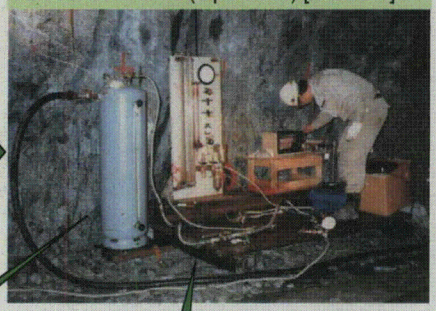
Surface-based investigations [Phase-1]



Excavation of shafts/drifts (Construction) [Phase-2]

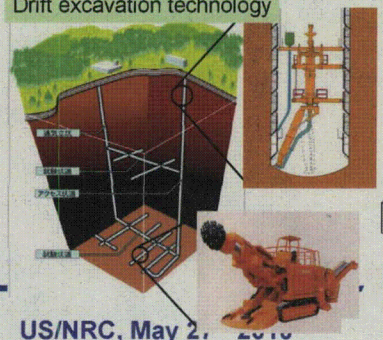


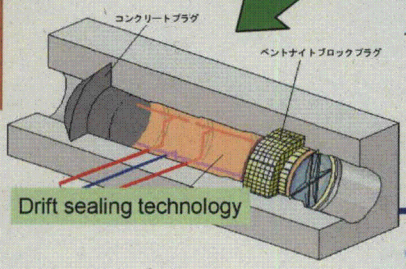
Research in drifts (Operation) [Phase-3]



Engineering technology of construction and EBS

Drift excavation technology

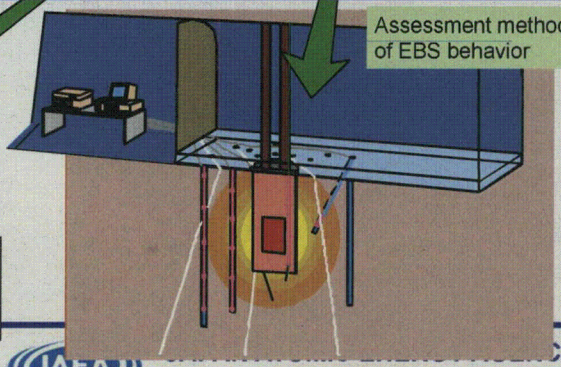




Drift sealing technology

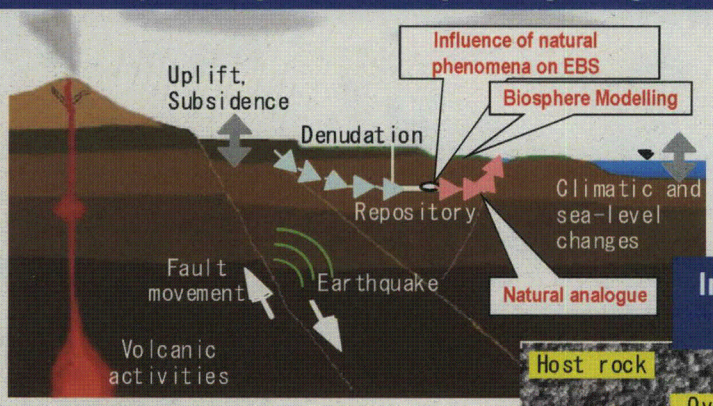
Applicability of design and PA methodology

Assessment method of EBS behavior

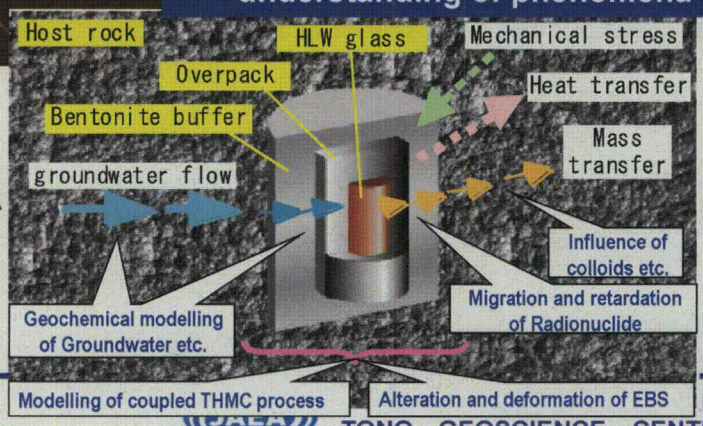


Key Goal-2 Understanding of the long-term behavior of the geological disposal system

Understanding of long-term changes of geological environment



Improvement of model based on the understanding of phenomena



Realistic assessment of long-term behavior of geological disposal system

JAEA's R&D Facilities for HLW Disposal

Tono Geoscience Center

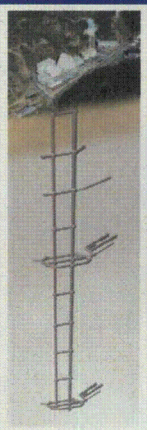
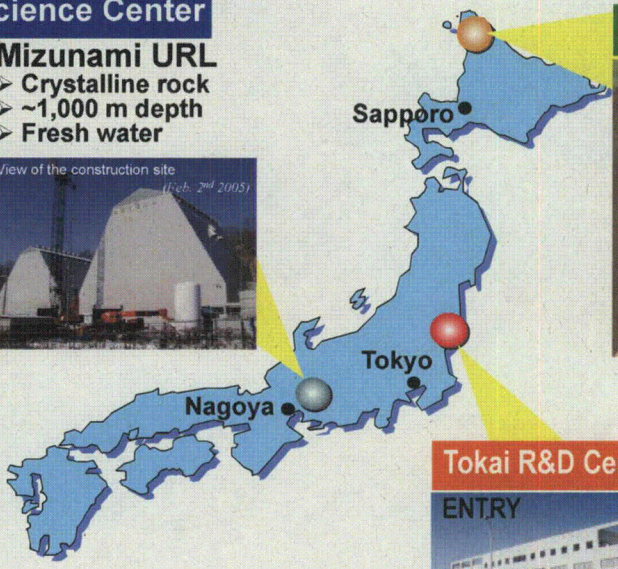


image view

Mizunami URL
- Crystalline rock
- ~1,000 m depth
- Fresh water



Horonobe Underground Research Center

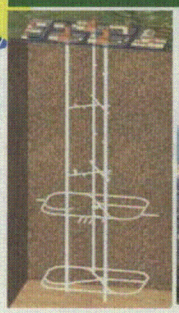
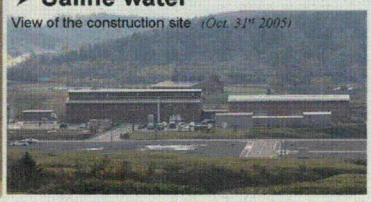


image view

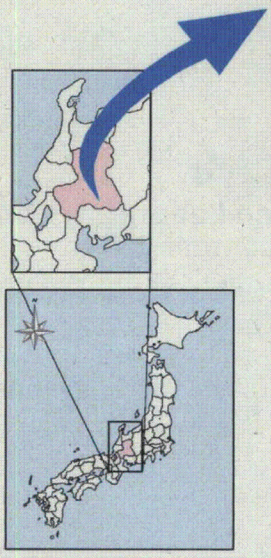
Horonobe URL
- Sedimentary rock
- ~500 m depth
- Saline water

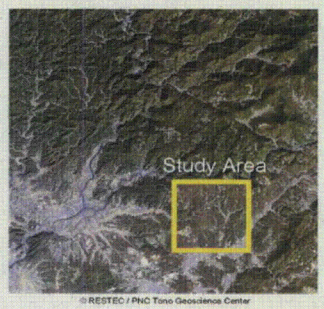


Tokai R&D Center
- Disposal technology
- Safety assessment method, etc.

TGC's Research Activities

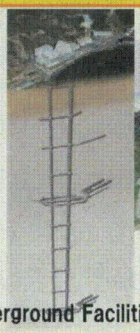
Regional Hydrogeological Study



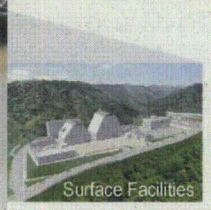


©RESTEC / PNC Tono Geoscience Center

Mizunami Underground Research Laboratory (MIU) Project

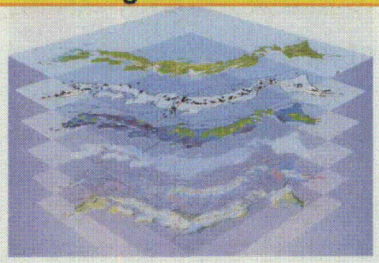


Underground Facilities



Conceptual Design of Facilities of MIU

Study on Long-term Stability of Geological Environment

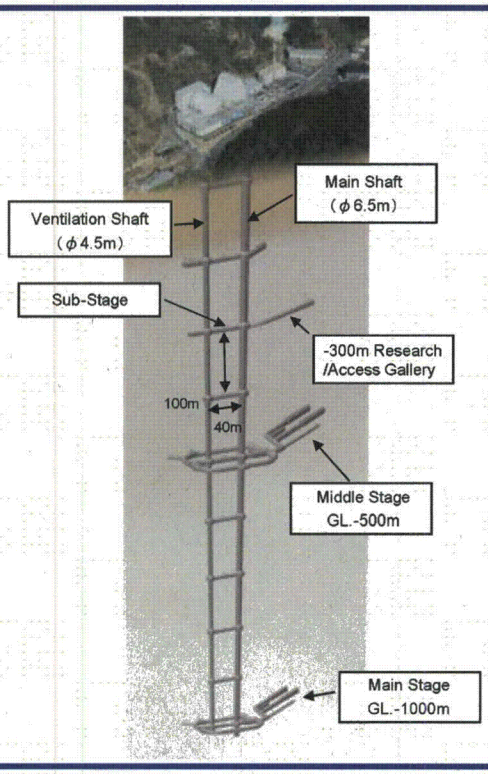


Facility of Tono Geoscience Center

History of Tono Geoscience Center

1962	First discovery of the outcrop of uranium mineralization along the former National route 21 by the Geological Survey of Japan
1965	Establishment of the Tono Exploration Office by Atomic Fuel Corporation (PNC's predecessor) in Toki City ※PNC＝Power Reactor and Nuclear Fuel Development Corporation
1973	Excavation of the Exploratory Shaft in the Tono Mine
1986	Commencement of Geoscientific Research
1991	Excavation of the No.2 Shaft in the Tono Mine
1992	Commencement of Regional Hydrogeological Study (RHS)
1995	Conclusion of an Agreement on Underground Research Laboratory Project with Gifu Prefecture, Toki City and Mizunami City (December 28th)
1996	Commencement of Mizunami Underground Research Laboratory Project
2001	Establishment of the Mizunami Geoscience Academy
2002	Conclusion of 'Lease contract' and 'Agreement associated with the lease Contract' of the Mizunami City-owned land (January 17th)
2003	Excavation of the Main and Ventilation Shafts (July)
2005	Merger of JNC and JAERI to form JAEA
2010	Both shafts reached 460m below the surface

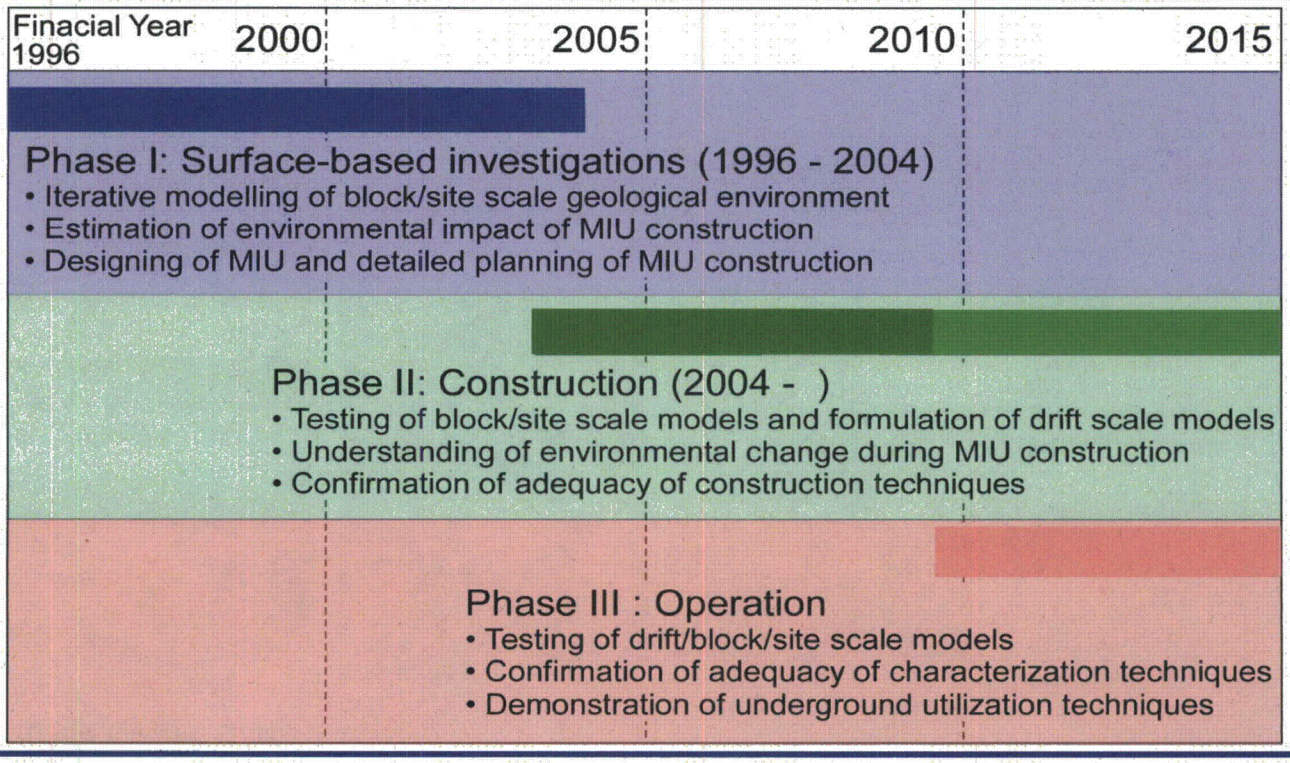
Design of MIU



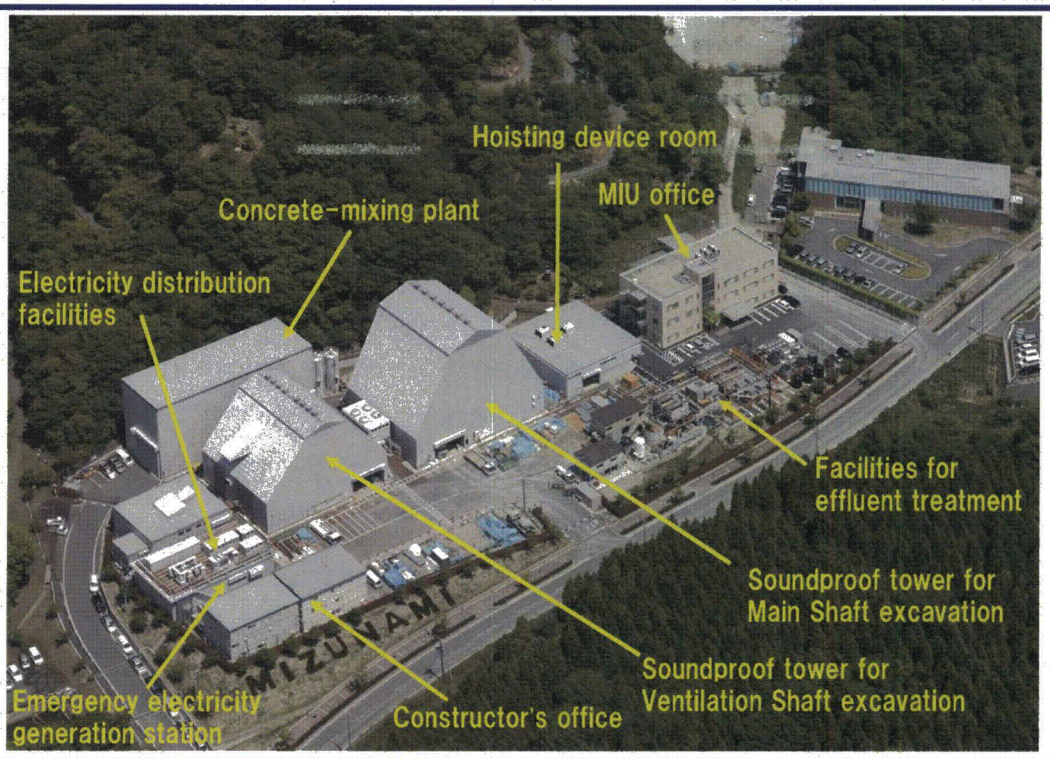
- Number of shafts: 2 Shafts
- Shape of shafts: Circular
- Max depth of shafts: 1,025mbgl
- Separation of shafts: 40m
- Inner diameter of Main Shaft: Ø6.5m
- Inner diameter of Ventilation Shaft: Ø4.5m
- Depth of Middle Stage: 500mbgl
- Depth of Main Stage: 1,000mbgl
- Interval of Sub Stages: 100m
- Depth of Research/Access Gallery:300mbgl

*Plan is subject to changes

Schedule of MIU Project (subject to changes)

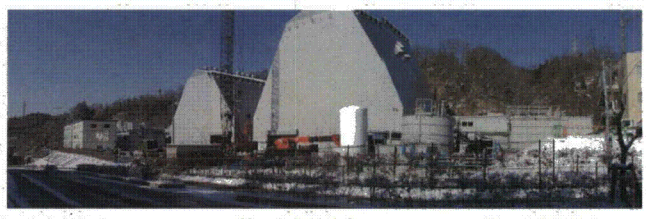


Layout of Surface Facilities



Excavation Facilities

Head Frame (Vent. Shaft)



Head Frame (Main Shaft)

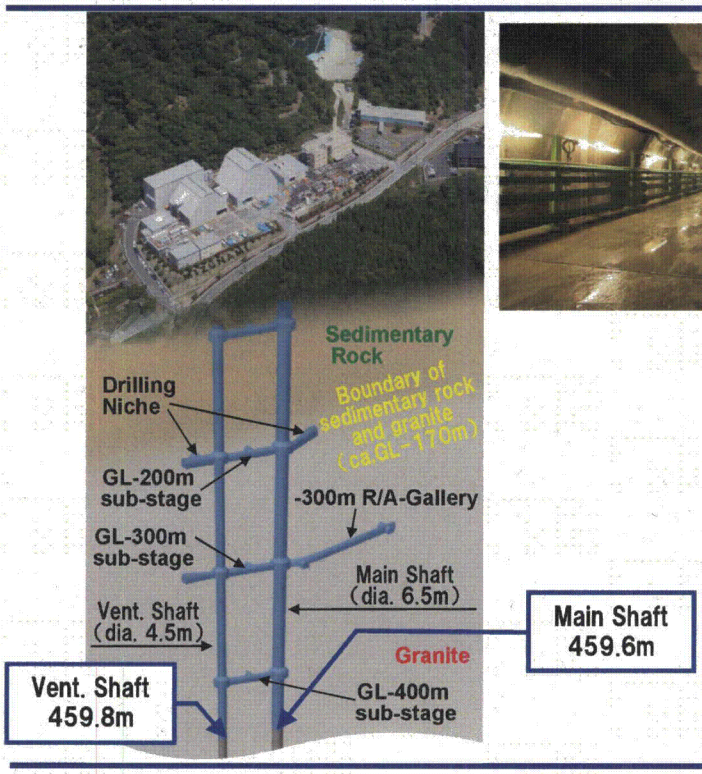
Concrete-mixing Plant

Scaffold (Vent. Shaft)

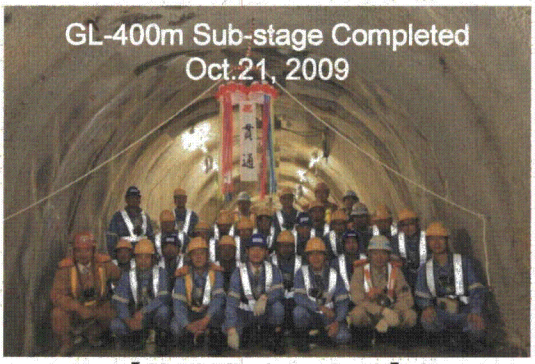
Drill Jumbo (Main Shaft)

Hoists (Main Shaft)

Current Status of MIU Construction



【GL-300m Access/ Research Gallery】



【GL-400m Sub-stage】

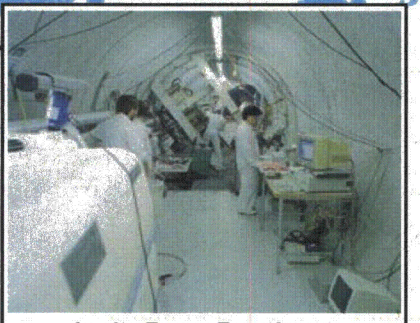
International Collaboration

International Organization

OECD/NEA Projects, etc.

- NEA TDB
- NEA Sorption
- DECOVALEX
- Mont Terri

Prototype Repository Project at SKB Äspö HRL



In-situ Tracer Experiment at Grimsel Test Site

International Research Project at Mont Terri Test Site

MIU Project and Regional Situations

Agreement on the Underground Research Laboratory Project (1995)

among Gifu prefecture, Mizunami city, Toki city and JNC

1. JNC will not bring nor use any radioactive wastes in the laboratory. The underground laboratory will never be a repository in the future.

2. Local governments can require reports from JNC and inspect into the laboratory.

3. With respect to the local governments, JNC will promptly organize a committee with local governments and discuss uses of the laboratory after the completion of the MIU project.

etc.

- **JAEA organized a committee : Uses of the MIU after project completion**
- Mizunami city organized a committee to inspect our activities in the MIU.

*AFC(1956-1967)→PNC(1967-1998)→JNC(1998-2005)→JAEA(2005-)

MIU Project and Regional Situations

JAEA organized committee: Uses of the MIU after project completion

Organizer: JAEA (former PNC/JNC)

Committee member: JAEA executives, local governments, local residents, members of local assemblies, an officer from the Agency for Natural Resources and Energy, etc.

Agenda: Discussion on the ways to use the underground laboratory after completion of the MIU Project. Having some possible uses for Mizunami city. No possibility use as a repository site.

Achievements: The committee has been held nine times (since 1996). Ideas and requests related to the MIU construction site have been taken and adopted for better public relation activities.

MIU Project and Regional Situations

Our Public Relations

Webpage
(http://www.jaea.go.jp/04/tono/index.htm)

MIU News

Information exchange on Geoscience

Information Disclosure

MIU Project and Regional Situations

Our Public Relations

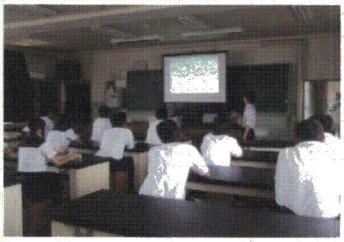
PR Activities

MIU Facility Tour

Exhibitions

Seminars

Educational Activities



Cooperation to school education

Summer Science Camp

Development of Regulatory Technology for Advanced Fuel Cycle

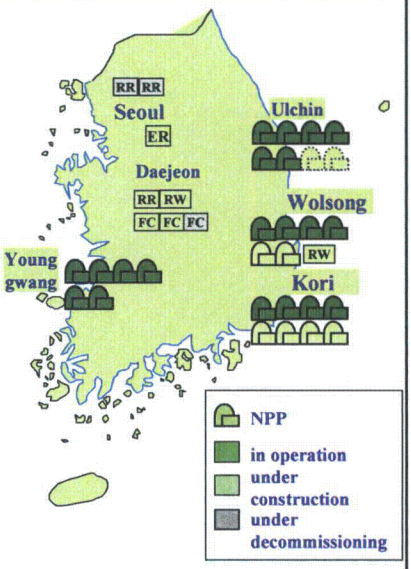
2010. 06. 03

Seung-Young Jeong, Ph.D.
k504jsy@kins.re.kr

Korea Institute of Nuclear Safety

Major Nuclear Facilities in Korea

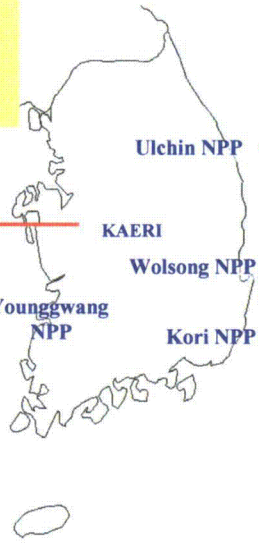
- Nuclear Power Plant (NPP)
  - 20 in Operation and 6 under Construction
  - 2 under Review
- Research Rector (RR) / Education Reactor (ER)
  - HANARO (RR)
  - KRR 1 and 2 (RR, under decommissioning)
  - AGN (ER)
- Nuclear Fuel Cycle Facility (FC)
  - Fuel Fabrication Plant for NPP
  - Fuel Fabrication Facility for RR
  - Post-Irradiation Examination Facility
  - Uranium Conversion Facility (under decommissioning)
- Radioactive Waste Management Facilities (RW)
  - RI Waste Management Facility
  - LILW Disposal Facility (under construction)



Inventory of SF in Korea

(until 2008. 12. 31)

- Total in Korea: 10,087.07 MTU
  - 10,083.24 MTU (99.96%) at NPPs
  - 3.83 MTU (0.04%) at KAERI
- Annual Generation (PWR): 320 MTU/y
- Annual Generation (PHWR): 380 MTU/y



Unit 1 Unit 2 Unit 3 Unit 4 Unit 5 Unit 6	1,293.52 [12.8%]

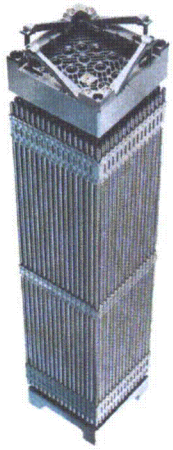
Hanaro	3.27
PIEF	0.56
Total	3.83 [0.04%]

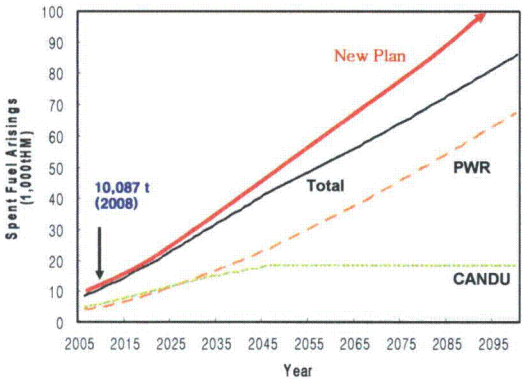
Unit 1 Unit 2 Unit 3 Unit 4 Dry Storage	5,481.3 [54.4%]

Unit 1 Unit 2 Unit 3 Unit 4 Unit 5 Unit 6	1,622.82 [16.1%]

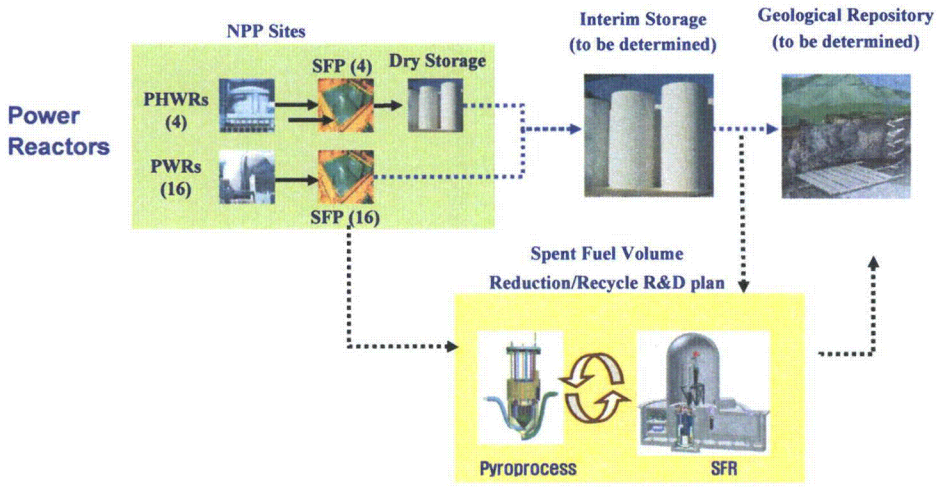
Unit 1 Unit 2 Unit 3 Unit 4	1,685.6 [16.7%]

Inventory of Spent Fuel

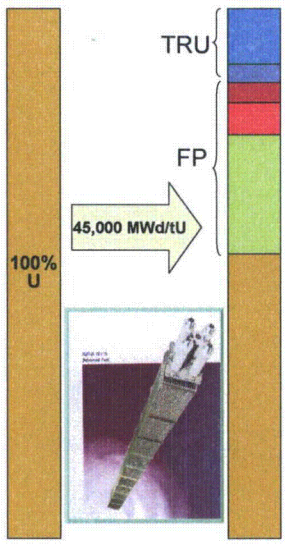




National Program of High Level Waste Management



Composition of PWR Spent Fuel



0.9% : Pu (to be burned as fuel)

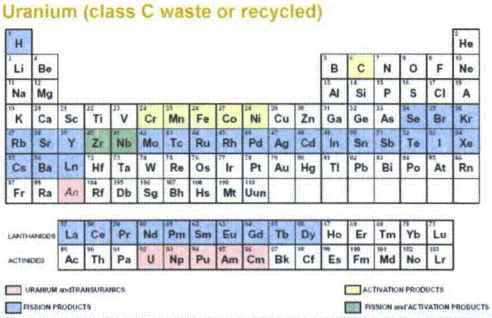
0.1% : Long-lived actinides (to be fissioned in FR or ADS)

0.1% : I_2 & Tc (long-lived FPs to be transmuted)

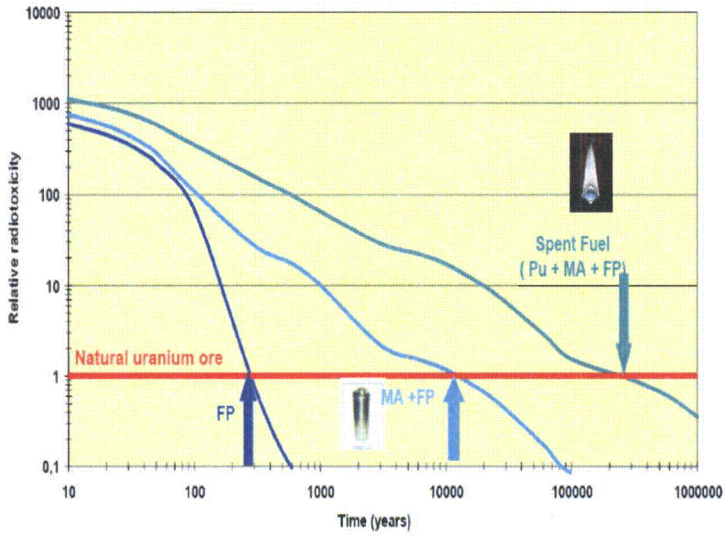
0.3% : Cs & Sr (primary near-term heat source to disposal)

3% : Stable or short-lived FPs (no challenge to disposal)

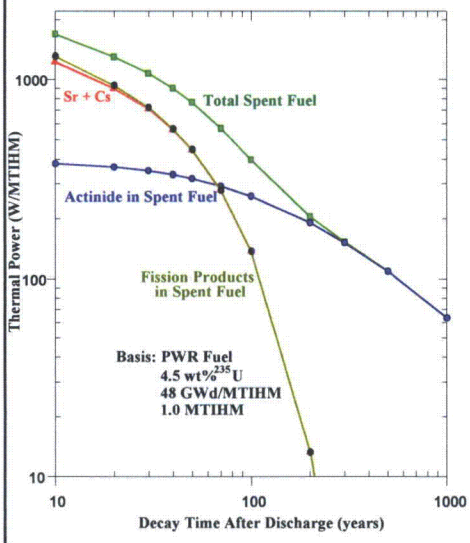
95.6% : Uranium (class C waste or recycled)

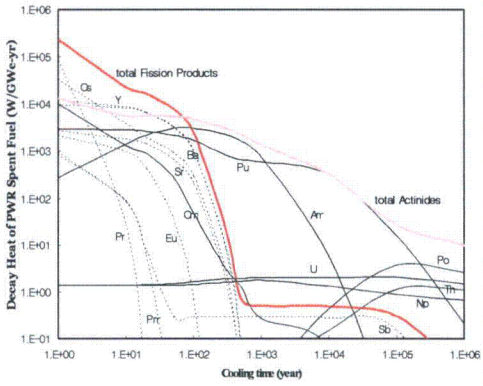


Radiotoxicity of Spent Fuel



Thermal Power Profiles of Spent Fuel





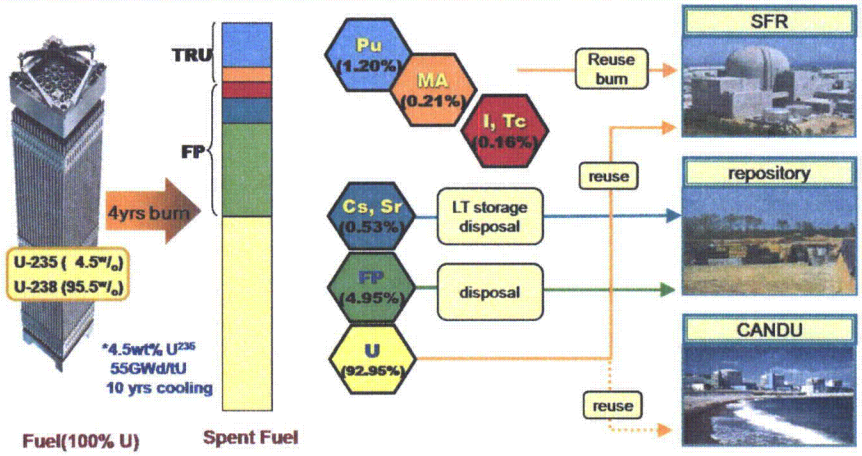
Optional Long-Term Plan for Korea Spent Fuels

Future Option for Spent Fuel	Content	Possibility
Direct Disposal	• SF disposal need huge geological site • need stable geological condition • need dry weather • long institutional control period for repository • PHWR SF need technology devl. / direct disposal	no/yes
Aqueous Reprocess	• US-Korea nuclear energy agreement (1974) • declaration of denuclearization of the Korea peninsula (1991)	no
Electrochemical Process (Pyroprocess)	• U/TRU recycle and produce advanced fuel (TRU metal fuel) for using at SFR • low purity products • control criticality • proliferation-resistance (AFCI report) • need renegotiation of US-Korea nuclear agreement (2014)	Yes/?

AFC Processes in Other Countries

	Korea	USA	Japan	France	Russia	China	India
Industrial Policy	Wait and See	Direct → Reprocessing	Reprocessing	Reprocessing	Reprocessing	Reprocessing	Reprocessing
Introduction Of AFC	-	~ 2020	~ 2025	2020 ~ 2040	~2020	~2020	~2020
Reprocessing or Recycling Technology R&D	Pyro	UREX+, Pyro	NEXT, Pyro	COEX /GANEX	Advanced Aqueous, Pyro, Vibro packing	Purex, Pyro	Purex, Pyro
Fast Reactor	SFR (Metal)	SFR (Metal, Oxide)	SFR (Oxide, Metal)	SFR (Oxide) GFR (Carbide, Nitride)	SFR (Oxide, Nitride)	SFR (Mixed oxide)	SFR (Mixed carbide, Oxide, Metal)

R & D of Volume Reduction and Recycle of Spent Fuel in Korea



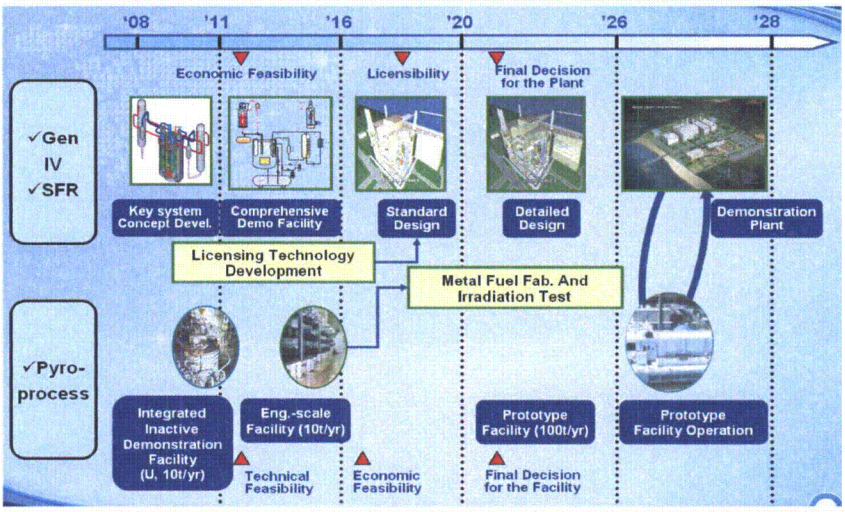
TRU :TransUranics
MA:Minor Actinides
FP:Fission Products

- volume : 1/20
- Heat : 1/100
- radiotoxicity : 1/1000

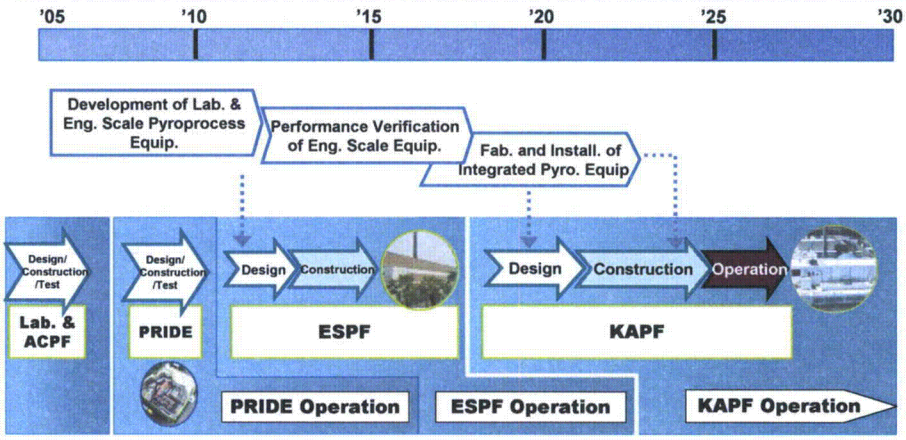
- repository efficiency: 100 times
- repository management period: 300yrs
- U usage: 100 times

Fast Reactor and Fuel Cycle Systems Development Plan

Long-term Development Plan for Future Nuclear Energy System
– Approved at the 255th AEC meeting (Dec. 22, 2008)) –



Action Plan for Pyroprocess R&D

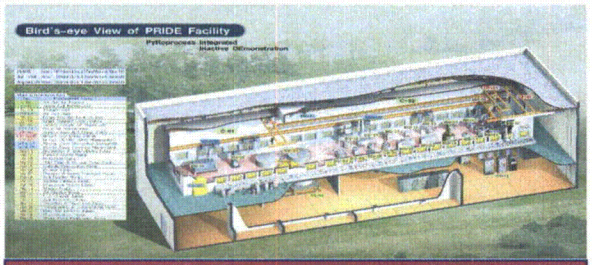


- ACPF : Advanced spent fuel Conditioning Process Facility
- PRIDE : PyRoprocess Integrated inactive DEmonstration facility (10 t/y)
- ESPF : Engineering-Scale Pyroprocess Facility (10 t/y)
- KAPF : Korea Advanced Pyroprocess Facility (100 t/y)

PRIDE Facility

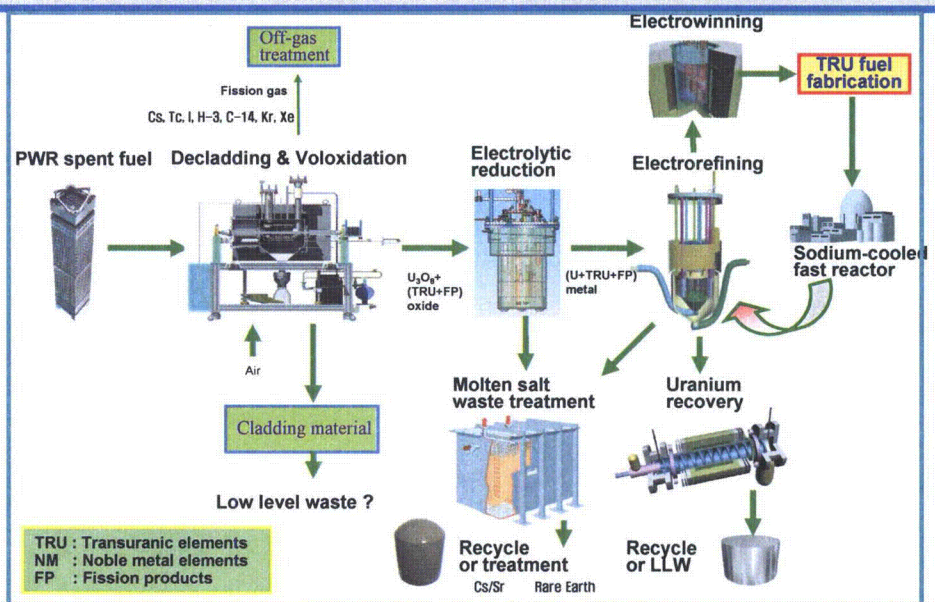
PRIDE : PyRoprocess Integrated inactive DEmonstration facility

ACP Facility (Lab. Scale)



PRIDE (Engineering Scale, Simfuel)

Electrochemical Processing of SF (Pyroprocess)



Pyro Mock-up Facility Process Condition (1)

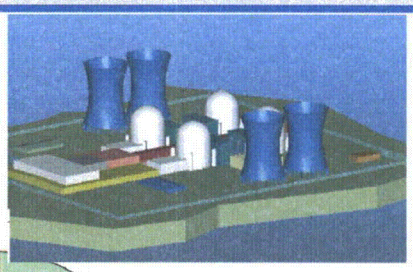
Each Process	Process Step	Condition	Target
Chopping & Cladding	Rod Cutting /Decadding	* Room Temp. * Air atmos.	* 99.99 %
Voloxidation	Powdering	* 1250 °C * Air atmos.	* 100 % * Cs : 2 % * VFP : 0 %
Electro-Reduction	Electro-Reduction	* 650 °C * Ar Atmos.	* U/TRU : 99.5 % * NM : 100 % * RE : 10 % * Cs/Sr : 0 %
	Cathode Consolidation	* 800 °C * Ar / vacuum atmos.	
Electro-Refining	Electro-Refining	* 500 °C * Ar atmos.	* U : 99.3 % *TRU : 5.7 % * NM : 0 % * RE : 37.5 %
	Salt Distillation	* 1300 °C * Ar / vacuum atmos.	
	U Melting		

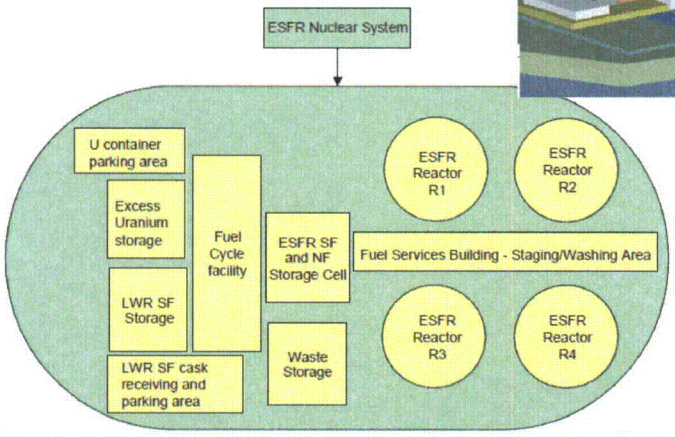
Pyro Mock-up Facility Process Condition (2)

Each Process	Process Step	Condition	Target
Electro-Winning	Electro-Winning	* 500 °C * Ar atmos.	*TRU : 98.3% *U : 100% *RE : 1.1%
	Cd Distillation	* 700 °C * Ar atmos.	
	TRU Draw Down	* 500 °C * Ar atmos.	*TRU : 100 % * RE : 10 %
Salt Waste Treatment	LiCl Purification	* 650 °C * Ar atmos.	
	LiCl-KCl Purification	* 650 ~1100 °C * Ar atmos.	
	Salt Waste Form Fabrication	* 650 ~1150 °C * Air atmos.	
Off-gas Treatment	VFP treat	* 1000 ℃ ~ room temp.	Air atmos.
	Cl_2 gas treat	* Capture in salt	

The Example Sodium Fast Reactor (ESFR) System

- Nuclear Energy System: Simplified GEN IV including Fuel Cycle Facilities (PR&PP Working Group, 2007)





Criticality Accidents in Reprocess Plant in Overseas

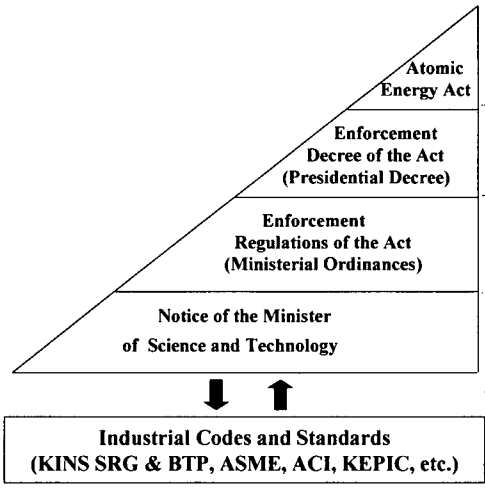
- Mayark (Russia 1953)- Accumulation of 842g of Pu
- Mayark (Russia 1957)- Large amount of U precipitated in U solution
- Mayark (Russia 1958)- Criticality, 90% U-235 Criticality Excursion
- Oak Ridge (USA 1958)- After 93% U-235 uranyl nitrate solution leaking in a tank, other tanks drained into 55 gal drum a criticality excursion occurred
- Idaho (USA 1959)-Highly enriched uranyl nitrate solution resulted the criticality in a Tank
- Idaho (USA 1961)-During evaporating 40L of 200 g/L uranyl nitrate solution, air entered the evaporator
- Hanford (USA 1962)-Pu solution spilled onto the floor of the hood and improper operation of valves became supercritical
- Mayark (Russia 1968)- Pu solution transferred into vessel and a criticality excursion occurred
- Idaho (USA 1978)-Highly enriched U was stripped from the organic solvent by water valve leaking
- Tokai-mura (Japan 1999)-18.8% U-235 solution precipitation tank

Industrial Accidents in Reprocess Plant in Overseas

- Mayark (Russia 1957)-Cooling system of the liquid high-level waste tanks failed, the temperature in tank rose to 350℃, and the tank evaporated to dryness, causing a massive explosion (equivalent to 75 tons of TNT)

- Tokai-mura (Japan 1997)-A fire in the bitumen waste facility (solidify of liquid radioactive waste) occurred by error chemical reaction monitoring, and an explosion occurred which ruptured the confinement of the facility

Framework for Nuclear Safety Regulation



- The Act provides the bases and fundamental matters concerning the development and utilization of atomic energy and safety.
- The Decree provides particulars entrusted by the Act and necessary for the enforcement of the Act.
- The Ordinances provides the technical standards and particulars entrusted by the Act and the Decree.
- The Notice provides detailed particulars for the technical guidelines.
- Codes and Standards for materials, design, test, and inspection of components and equipment

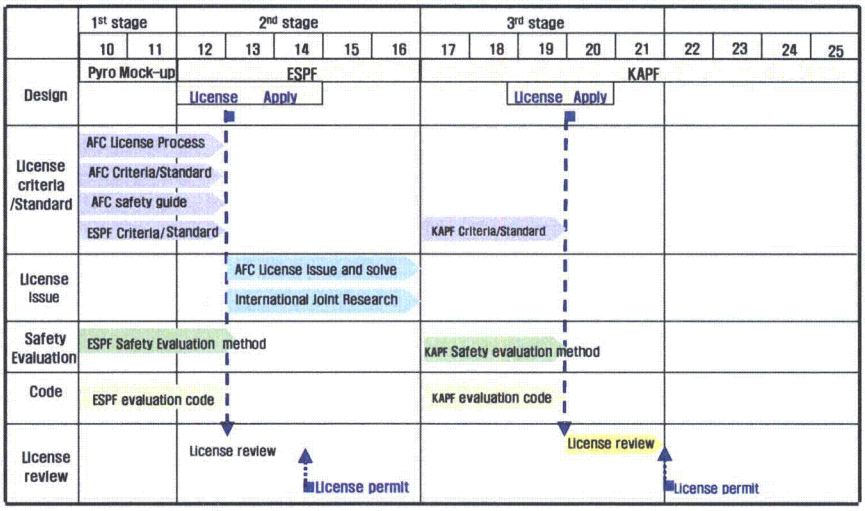
AFC Regulatory Technology Development

- **Development of the AFC Licensing Regulatory System**
  - Review the applicability of the nuclear energy act related to licensing AFC facility
  - Establishment of direction for the nuclear energy act amendment
- **Establishment of the Development Direction for the AFC Criteria and Standards:**
  - Establishment of the direction for the AFC regulation on the technical standards
  - Establishment of the direction for the AFC notices
  - Establishment of the reformation direction for the AFC regulatory standards and guides
- **Development of the safety evaluation technology for the AFC system:**
  - Safety evaluation technology survey and review for the AFC system

Development of the Safety Evaluation Technology

- Risk Assessment Technology
- Nuclear Criticality Safety Evaluation
- Materials and Components Safety Evaluation
- Fire Safety Evaluation
- Radiation Protection Evaluation
- Emergency Response/Management Evaluation
- Ventilation and Monitoring System Evaluation
- Environmental Protection Evaluation
- High-Level Rad. Waste Management/Storage Evaluation
- Spent Fuel and Nuclear Materials Movement/Storage Safety Evaluation
- Site Evaluation

AFC License Load-Map



Summary

- Need short/long term plan for storage, volume reduction, and disposal of spent fuel
- Need to develop the regulatory technology for spent fuel
  - establish licensing procedures
  - develop criteria, standards, and guides
  - Safety Evaluation Technology
- Need international cooperation for regulatory technology of spent fuel

Itinerary for NRC

Tour to JNFL Rokkasho Nuclear Fuel Cycle Facilities

Date; May 24 (Mon) – May 25 (Tue), 2010

Attendants;

- Mr. Jack R. Davis, Deputy Director, Div. of HLW Repository Safety in Office of Nuclear Material Safety and Safeguards, NRC
- Dr. Tae M. Ahn, Senior Materials Engineer, Div. of HLW Repository Safety in Office of Nuclear Material Safety and Safeguards, NRC
- Dr. John Stamatakos, Director, Southwest Research Institute, NRC

Accompanied by;

- Mr. Hidehiko Yamachika, General Manager, JNES Washington Office

May 24 (Mon)

18:27	Arrive at Misawa Station by JR Ltd. Express Tsugaru #23
18:30 – 18:40	Move to Hotel by car (check-in at Misawa City Hotel) http://www.misawa-cityhotel.com/ (Tel: 0176-52-7777)
19:00 – 20:30	Welcome Dinner hosted by JNFL

May 25 (Tue)

8:30	Check out of Hotel
8:40	Leave Hotel by car
9:30	Arrive at JNFL Rokkasho Visitor's Center
9:30 – 10:30	Briefing and Visitor's Center tour
10:30 – 12:00	Site tour; vitrification ? - Vitrified Waste Storage Center - Central Control room of Rokkasho Reprocessing Plant - Spent Fuel Receipt and Storage Facility
12:00 – 13:00	Lunch
13:00 – 14:00	Discussion - mixed - stored - Reprocessing process reused - Vitrified waste storage
14:00 – 14:40	Leave JNFL administration office and move to Noheji Station by car
15:20	Leave Noheji Station by JR Ltd. Express Hakucho #22
15:50	Arrive at Hachinohe Station and Change train
16:06	Leave Hachinohe Station by JR Shinkansen Hayate #22
19:08	Arrive at Tokyo Station

JNFL contact person: Mr. Hidehiko Nozawa, Mr. Nobuaki Sato, Corporate Planning Office
Tel: 0175-71-2375

The Handling of Sensitive Nuclear Technology Relative to Nuclear Nonproliferation

J N F L

London Guide Line

i. **Conforming to "NSG Guideline Part 1", reprocessing of spent fuel is considered as sensitive material and technology from the view point of nuclear nonproliferation, and its export becomes an object of a particularly strict regulation.**

Bilateral Agreement

Further,

i. Agreement For Cooperation Between the United States and Japan Concerning Peaceful Use of Nuclear Energy stipulates as follows in Article 2.1(b):
   - Not withstanding the provisions of sub-paragraph (a) above, restricted data and sensitive nuclear technology shall not be transferred under this Agreement.

   As a definition of "sensitive nuclear technology, Article 1 (j) of the said Agreement stipulates:
   - 'Sensitive nuclear technology' means any data which are not available to the public and which are important to the design, construction, fabrication, operation or maintenance of enrichment, reprocessing or heavy water production facilities, or such other data as may be so designated by agreement of the parties.

ii. Our Government strictly applies these stipulations.

iii. Accordingly, the export of Japanese reprocessing technology to the United States is virtually impossible.

Treatment in the past

i. In the past, there were circumstances in which technology (data) has been provided to the U.S. from the JNFL side under the GNEP, etc., but such technology (data) was entirely from the "public domain"

ii. However, from now on, the situation is becoming such that the information provided to the U.S. cannot satisfy the U.S. needs and the protection of Japan's commercial confidentiality, in case such information comes from the "public domain" only.

One of future approach

i. Accordingly, we would like to ask that the United States approach our Government positively regarding the definition and interpretation of sensitive and important nuclear technology under the Japan U.S. Bilateral Nuclear Agreement, so that it becomes possible for us to transfer the data required by the United States.