Safeguards in Prototype Fast Breeder Reactor Monju

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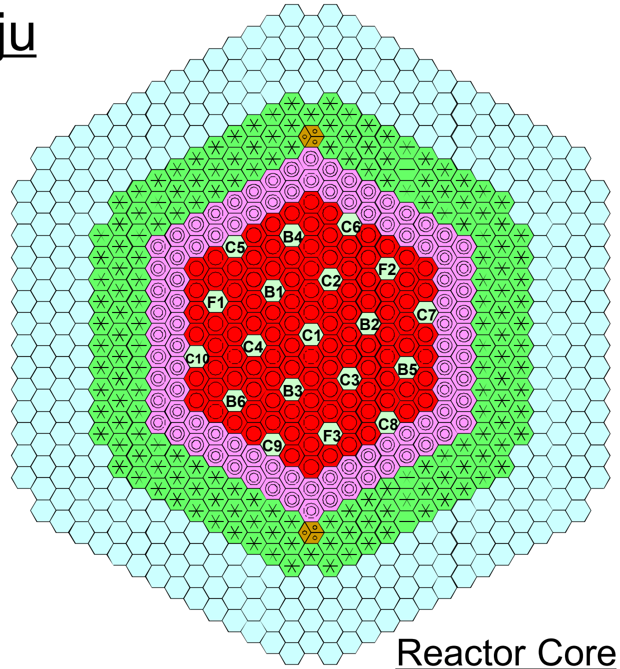
1. Principal Design of Monju (1/2)

Principal Design and Performance Data of Monju

Reactor type : Sodium-cooled loop-type
Thermal power : 714MW
Electrical power : 280MW
Fuel material : PuO_2-UO_2

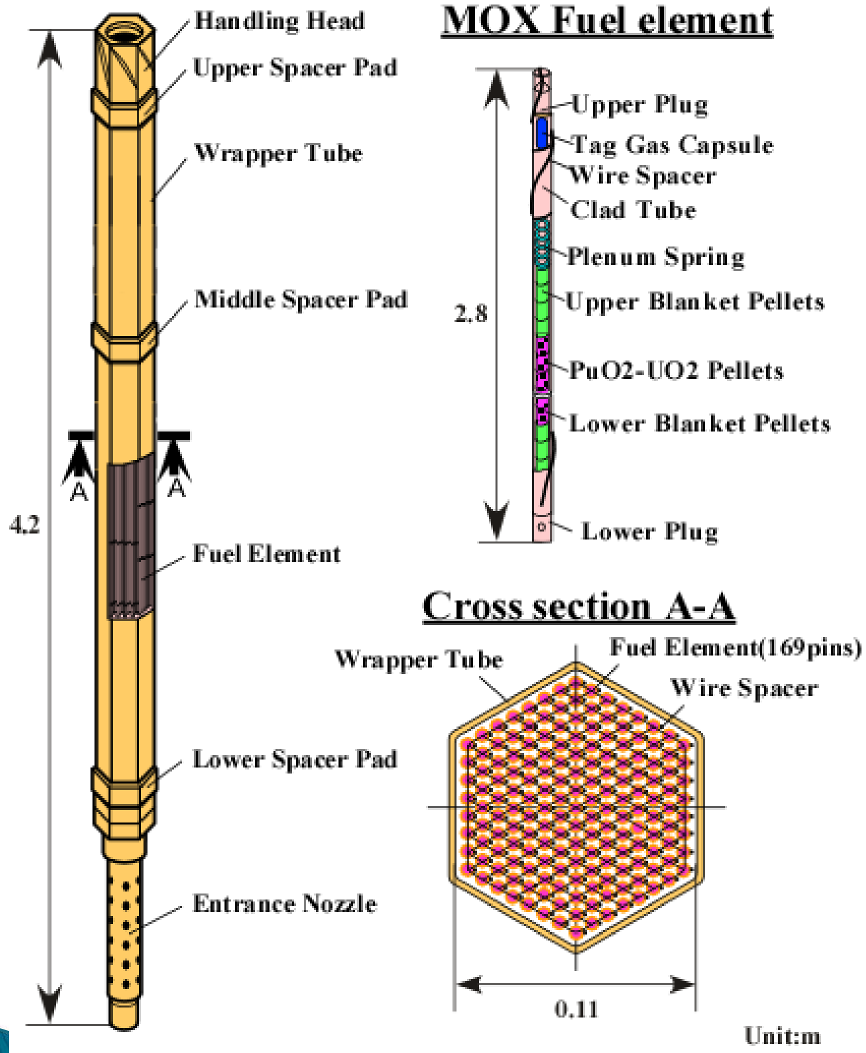
Core Dimension	
Equivalent Diameter / Height	1.8 / 0.93 m
Blanket Thickness	
Upper / Lower / Radial Equivalent	0.3 / 0.35 / 0.3 m
Plutonium Fissile Enrichment	(Inner Core / Outer Core)
Fuel of Initial Core Type 1	15 / 20 wt%
Type 2	16 / 21 wt%
Type 3	16 / 21 wt%
Fuel of Equilibrium Core	16 / 21 wt%
Fuel Inventory	
Core (U+Pu+Am-241 metal)	5.9 ton
Blanket (U metal)	17.5 ton
Average Burnup	
Equilibrium Core	80,000 MWd/t
Cladding Material	SUS316
Cladding Outer (Diameter/Thickness)	6.5 / 0.47 mm



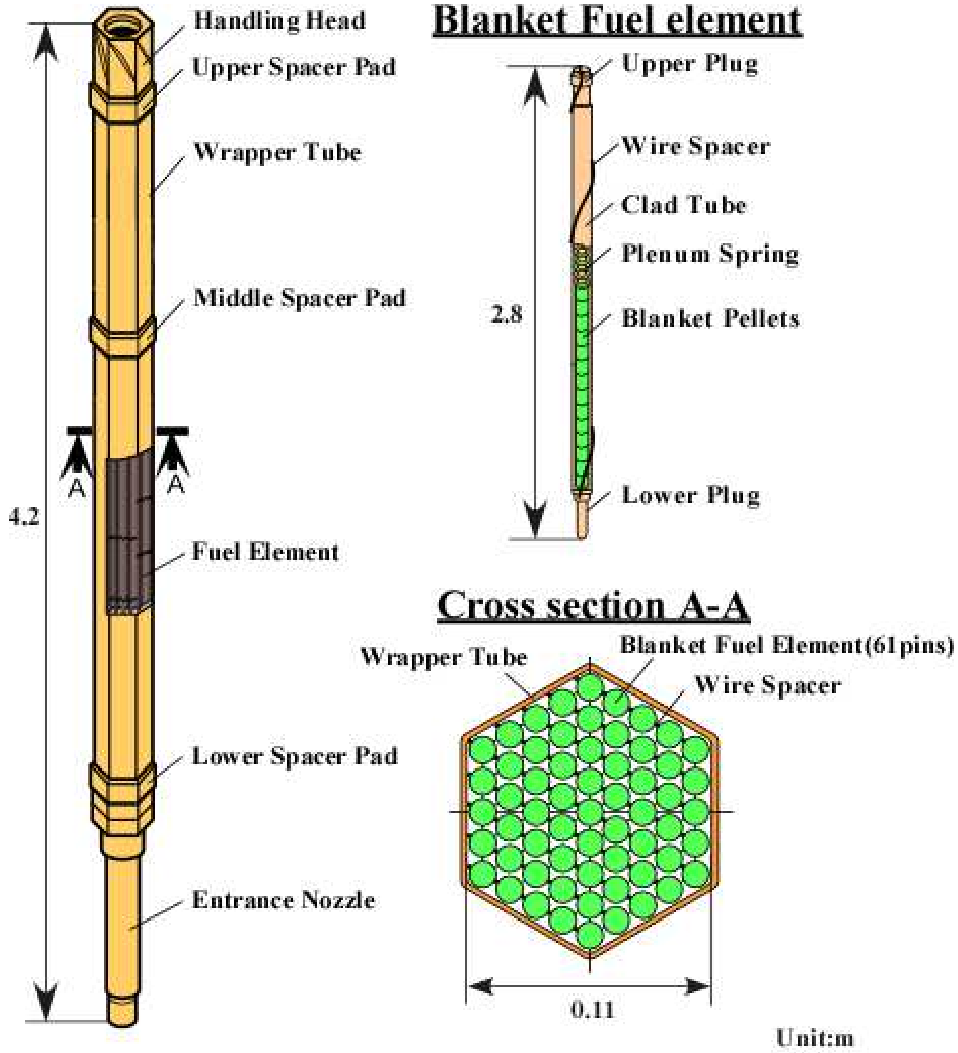
Reactor Core

Core Zone	Inner Core		108
	Outer Core		90
Radial Blanket			172
Control Rod	Fine Control Rod (FCR)	F	3
	Coarse Control Rod (CCR)	C	10
	Backup Control Rod (BCR)	B	6
Neutron Source			2
Neutron Shield			324

1. Principal Design of Monju (2/2)



Structure of MOX Fuel Assembly



Structure of Blanket Fuel Assembly

2. Safeguards Features in Monju

(1) Since plutonium is contained in the fresh core fuel assemblies,

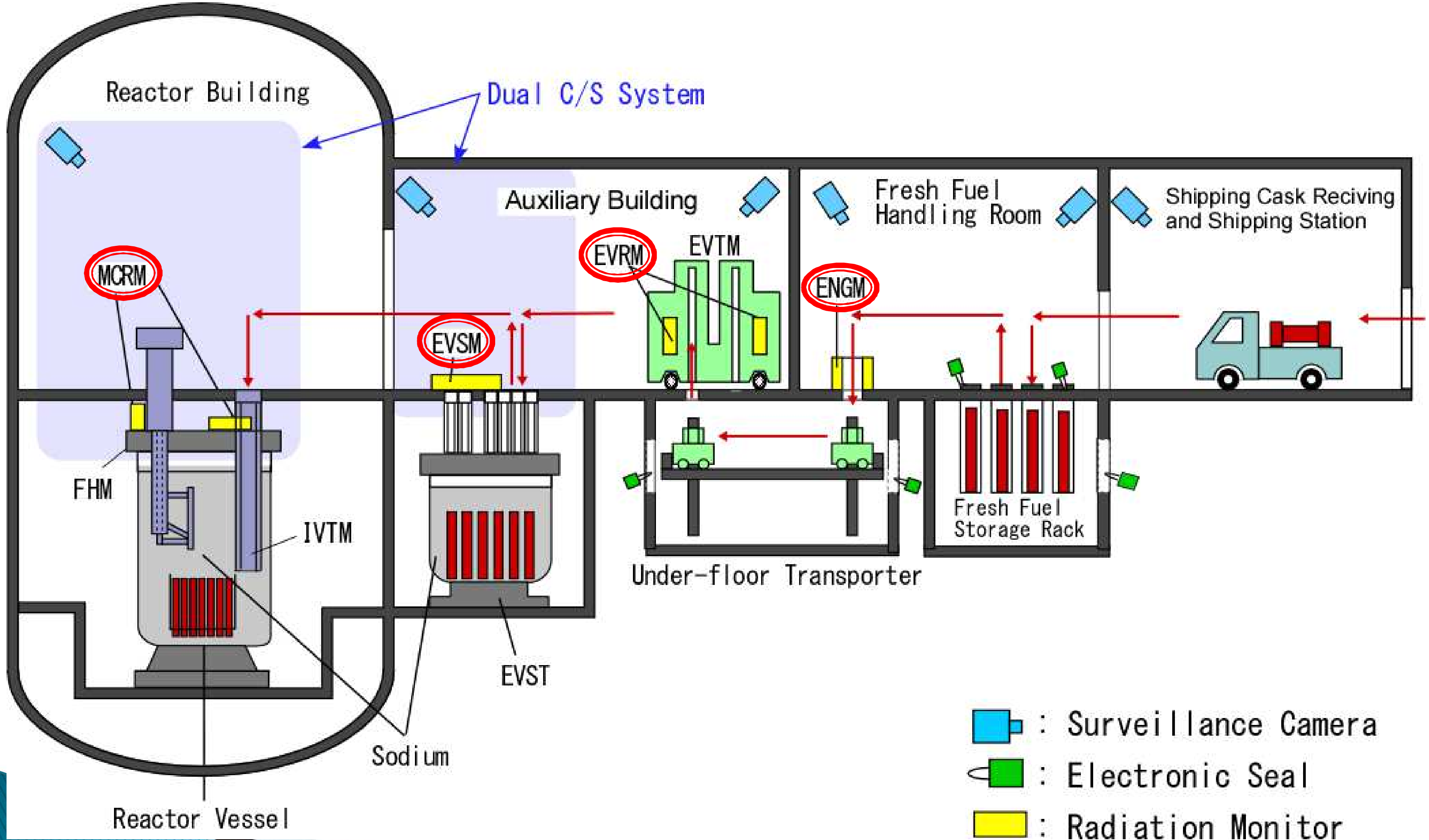
- the flows of fuel assemblies on all the fuel handling routes are required to be verified using the surveillance cameras, the radiation monitors and the seal systems.
- frequent inspections are needed.

(2) Since the assemblies loaded in the core and stored in the ex-vessel storage tank (EVST) are in the difficult to-access area filled with liquid sodium,

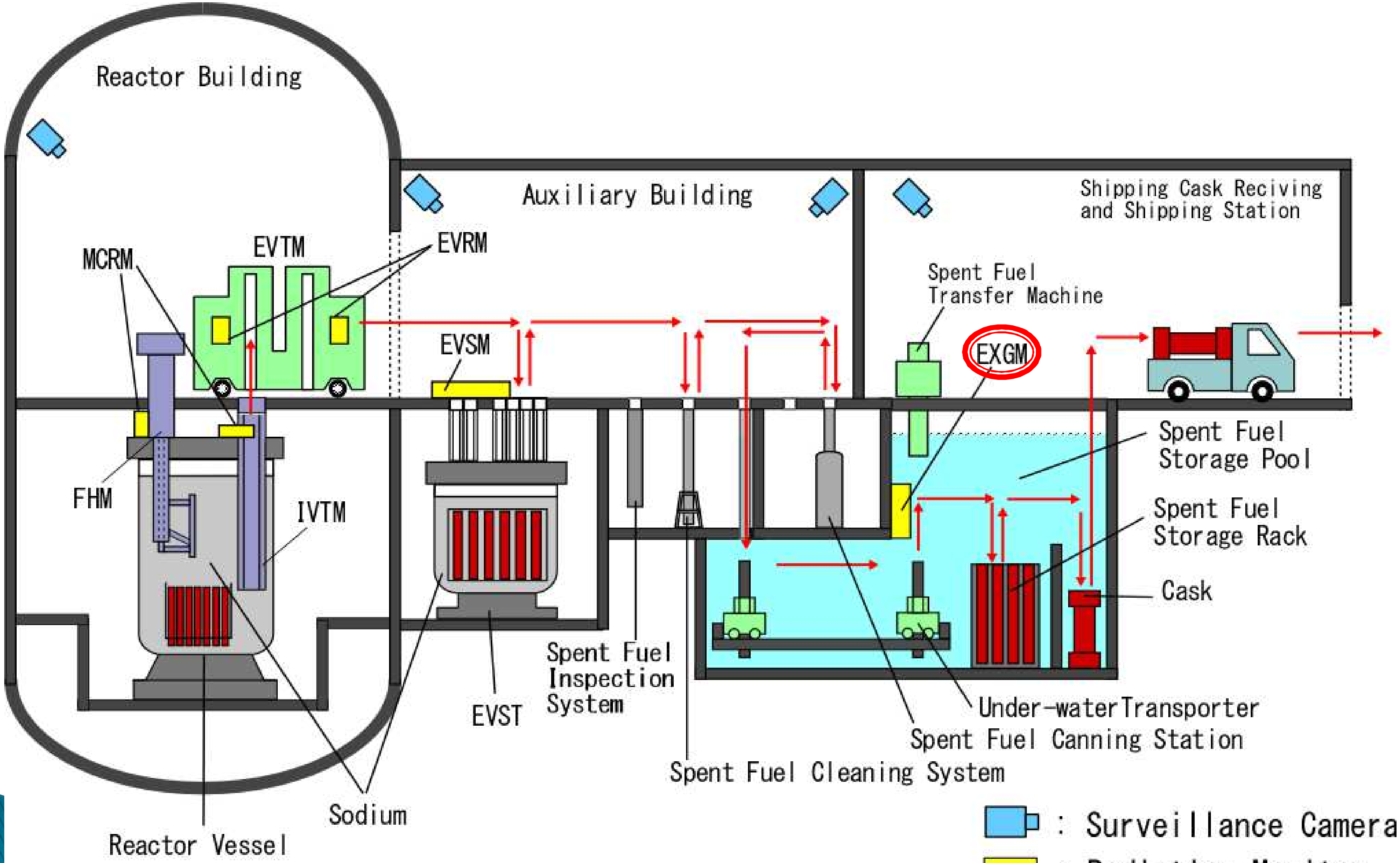
- a dual containment and surveillance (C/S) system * has been applied.

* : Two monitoring devices, such as surveillance camera and radiation monitor that are functionally independent, constitute a dual C/S system.

3. Fresh Fuel Handling Route and Safeguards Equipments



3. Spent Fuel Handling Route and Safeguards Equipments



4. Radiation Monitors (Flow Monitors) (1/7)

4.1 Entrance Gate Monitor (ENGM)

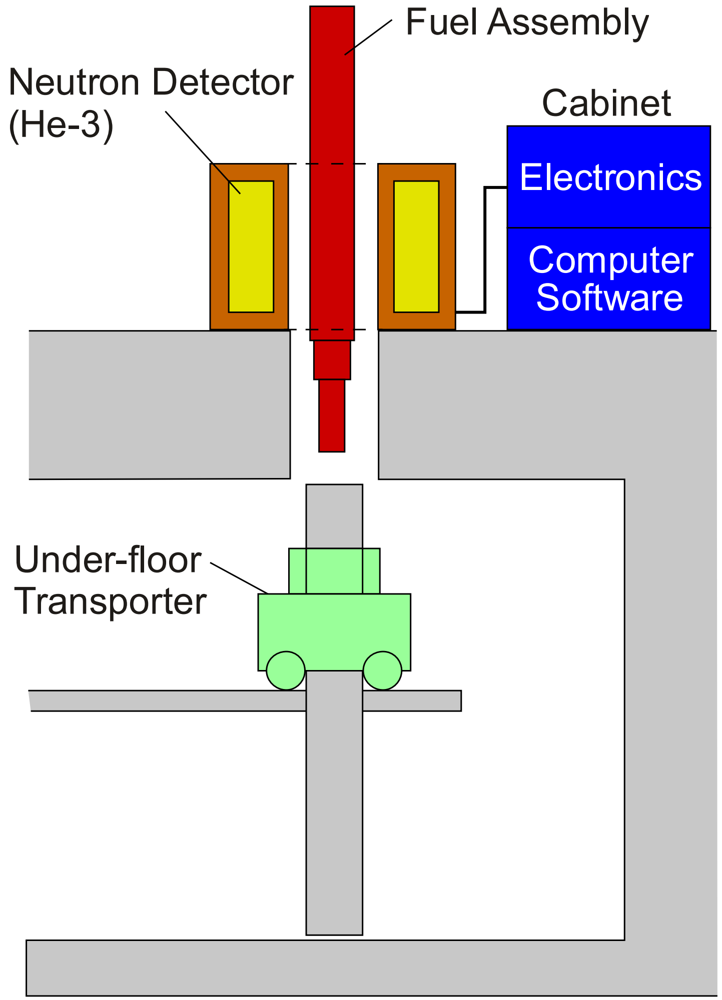
(Installed in November 1991)

(1) Capability of ENGM :

- Distinguish between fresh MOX fuel assemblies and other core elements
- Detect the movement direction of the core fuel assembly

(2) Composition of ENGM :

	System A	System B
Signal Processing	JSR-12	JSR-12
Data Save	PC	PC
Detector	^{3}He counters (24 neutron detectors)	



Conceptual diagram of ENGM

4.2 Ex-vessel Transfer Machine Radiation Monitor (EVRM) (1/2)

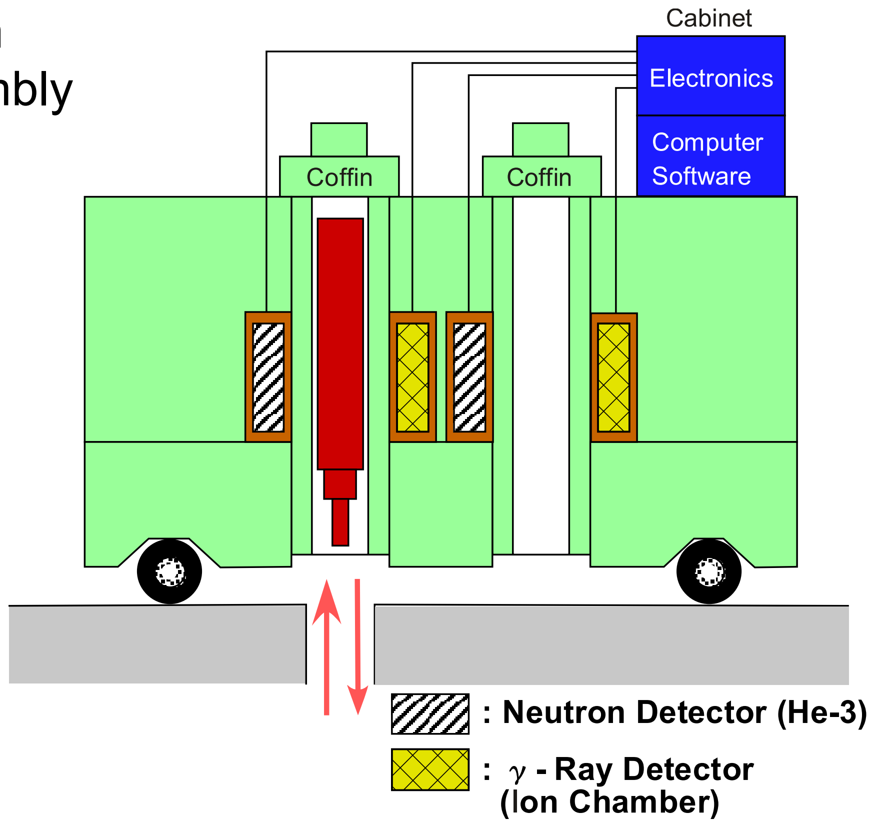
(1) Capability of EVRM :

- Detect neutron and gamma radiation from each EVTM coffin containing a fuel assembly
- Monitoring the movement of the fuel assemblies

(2) Composition of EVRM :

	System A	System B
Signal Processing	Mini-GRAND	Mini-GRAND
Data Save	PC	PC
Detector	Neutron : 2 ^{3}He counters Gamma : 2 Ionization Chambers	

(Installed in March 1992)



Conceptual diagram of EVRM

4. Radiation Monitors (Flow Monitors) (3/7)

4.2 Ex-vessel Transfer Machine Radiation Monitor (EVRM) (2/2)

(3) Improvement of EVRM :

1) Purpose

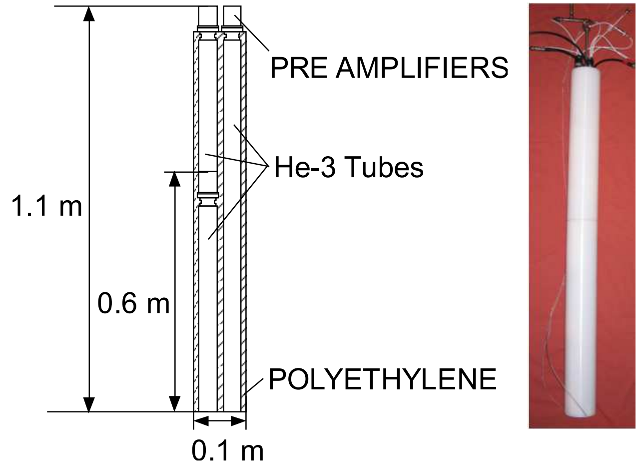
- Strengthen the monitoring of spent blanket fuel assemblies
- Improve the reliability of distinguishing between fuel assemblies and non-fuel items, as well as between fresh fuel assemblies and spent fuel assemblies

2) Contents of improvement

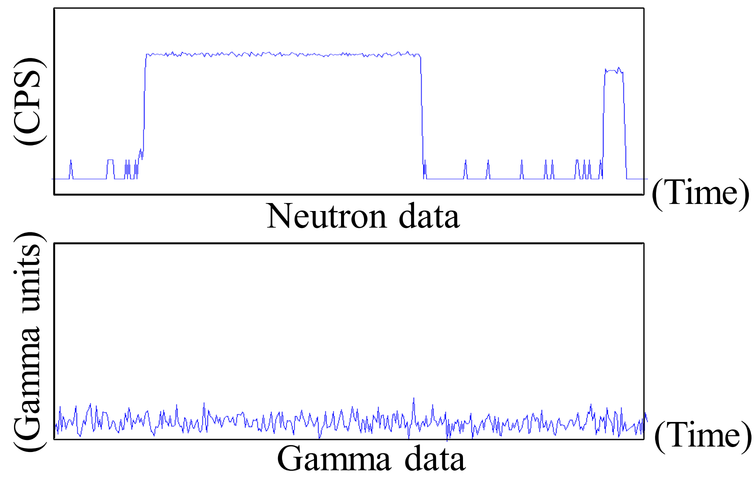
- Efficiency of the neutron detector improved to approximately 4 times by extending the length of the detector in February 2008

3) Improved outcomes

- Low burn-up spent blanket fuel assemblies (experienced approximately 40 EFPD operation) were able to be detected by the EVRM in June 2009.



Improved neutron detector of EVRM



Radiation data of EVRM

4.3 EVST Radiation Monitor (EVSM)

(1) Capability of EVSM :

- Monitor the fuel movements between the EVTM and the EVST

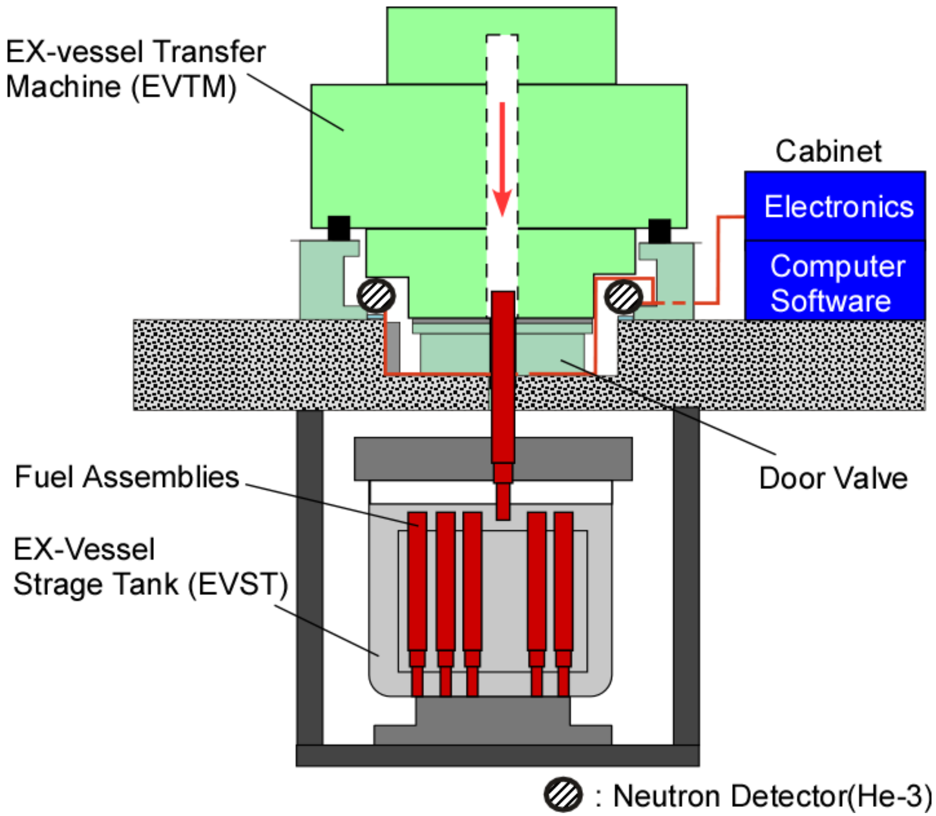
(2) Composition of EVSM :

	System A	System B
Signal Processing	JSR-12	JSR-12
Data Save	PC	PC
Detector	Neutron : 2 ^{3}He counters	

(3)Outcomes

- EVSM installation was contributed to construct dual C/S system.

(Additionally installed in April 2001)



Conceptual diagram of EVSM

4. Radiation Monitors (Flow Monitors) (5/7)

4.4 Monju Core Radiation Monitor (MCRM)

(1) Capability of MCRM :

- Monitor the fuel movements into and out of the reactor vessel

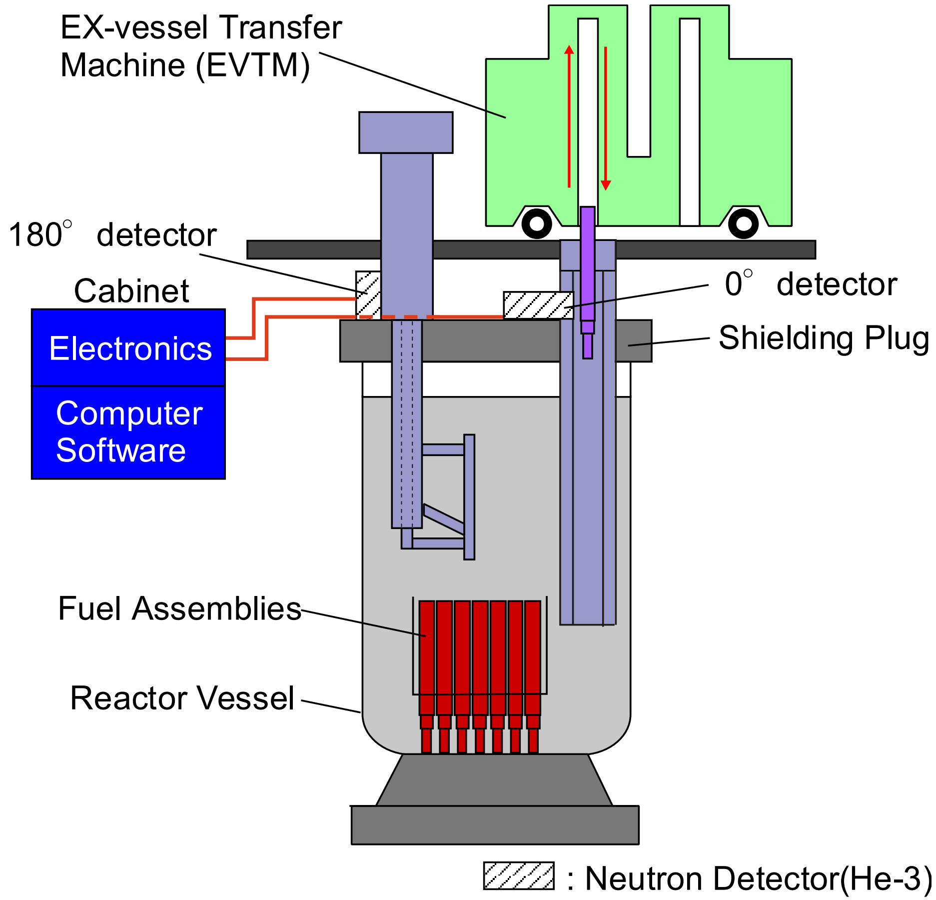
(2) Composition of MCRM :

	System A	System B
Signal Processing	JSR-12	JSR-12
Data Save	PC	PC
Detector	Neutron : 2 ^{3}He counters	

(3)Outcomes

- MCRM installation was contributed to construct dual C/S system.

(Additionally installed in April 2001)



Conceptual diagram of MCRM

4.5 Exit Gate Monitor (EXGM) (1/2)

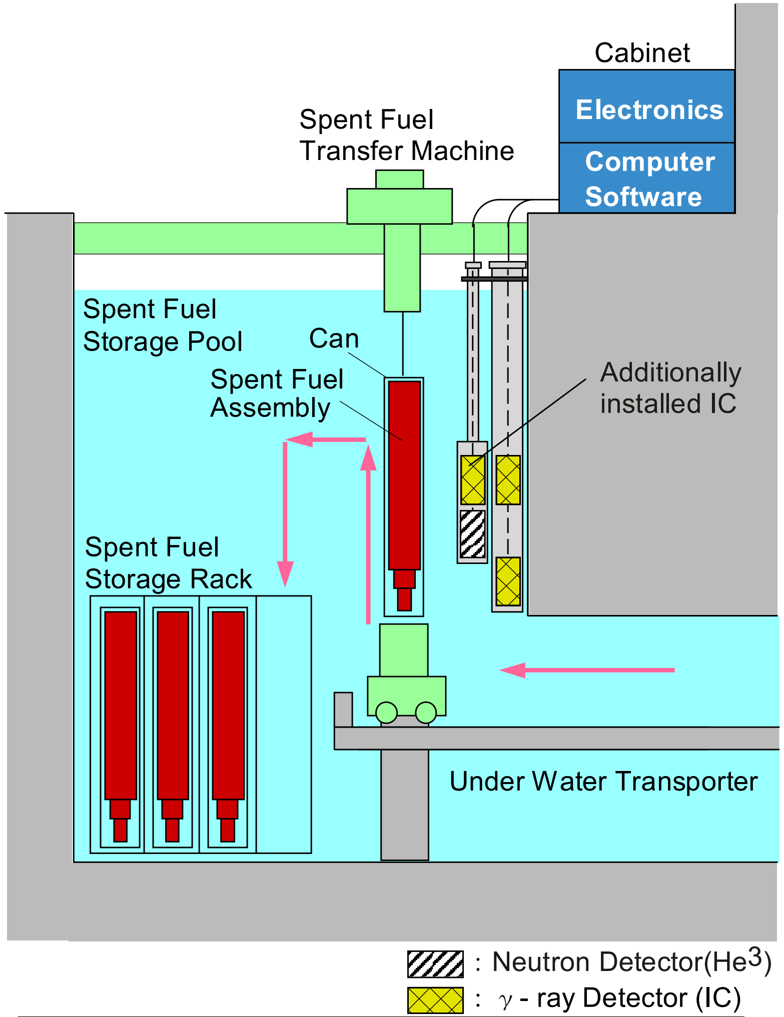
(Installed in March 1992)

(1) Capability of EXGM :

- Monitor the movements of spent fuel assemblies and the fuel inventory change in the fuel storage pool

(2) Composition of EXGM :

	System A	System B
Signal Processing	Mini-GRAND	Mini-GRAND
Data Save	PC	PC
Detector	Neutron : 1 ^{3}He counters Gamma : 3 Ionization chambers (two detectors are for detecting the direction)	



Conceptual diagram of EXGM

4. Radiation Monitors (Flow Monitors) (7/7)

4.5 Exit Gate Monitor (EXGM) (2/2)

(3) Improvement of EXGM :

1) Purpose

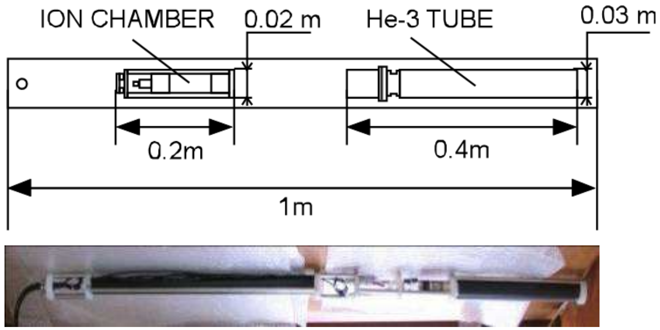
- Strengthen the monitoring of spent blanket fuel assemblies
- Improve the reliability of distinguishing between fuel assemblies and non-fuel items, as well as between fresh fuel assemblies and spent fuel assemblies

2) Contents of improvement

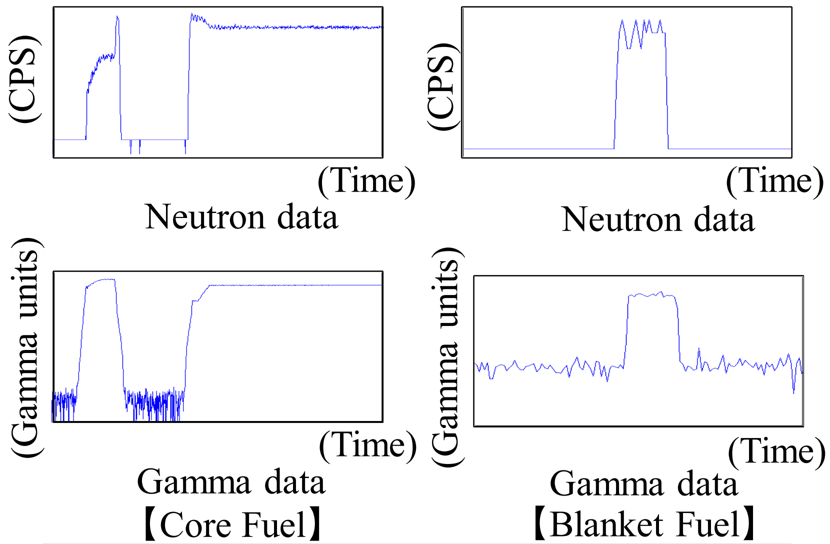
- The neutron detector was changed from the B-10 neutron counter to the He-3 neutron counter and new ionization chamber was additionally installed in May 2009.

3) Improved outcomes

- Low burn-up spent blanket fuel assemblies (experienced approximately 40 EFPD operation) were able to be detected by the EXGM.



Improved neutron detector of EXGM



Radiation data of EXGM

5. Remote Monitoring System (RMS) in Monju

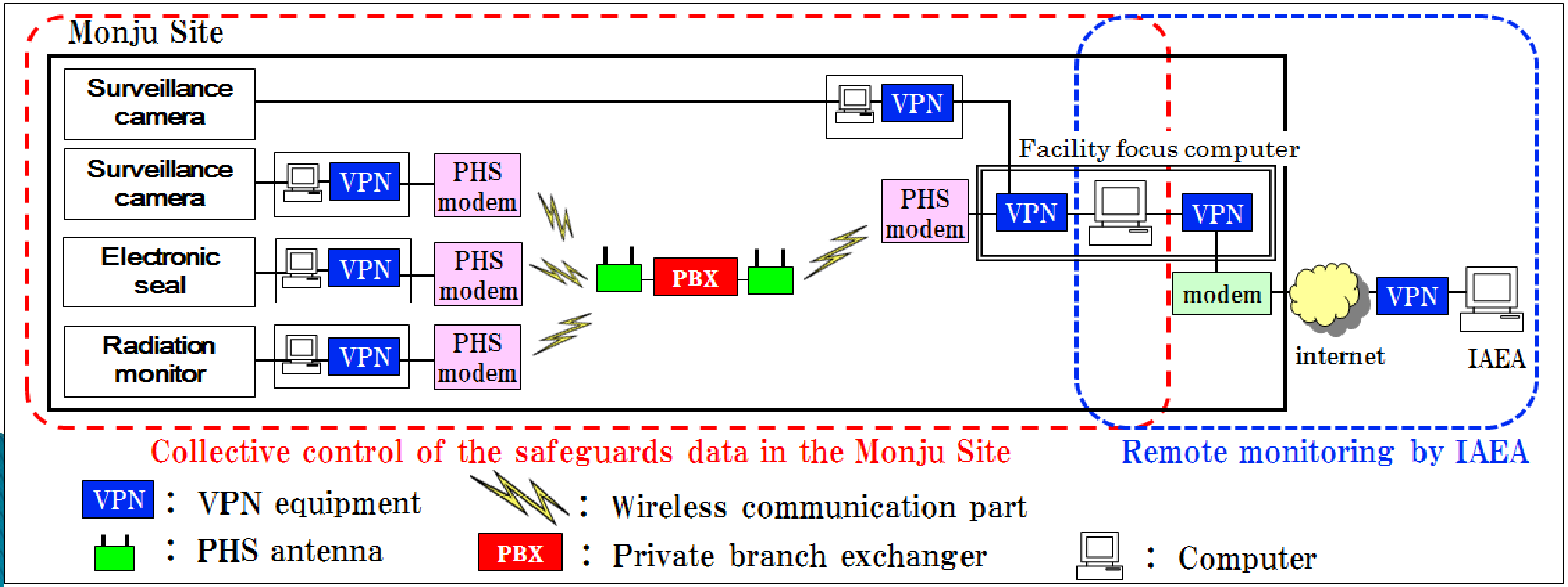
Development of Remote Monitoring System (RMS): (Installed in February 2008)

1) Purpose

- Strengthen the collection of monitoring data and the continuous surveillance
- Reduce the load of the inspection activities by shifting to the integrated safeguards

2) Contents of development

- The data of the safeguards equipments, which are located dispersedly, is collected in the "Facility focus computer" using the personal handy-phone system (PHS).
- IAEA is able to acquire the safeguards data and to grasp the state of the safeguards equipments from a remote place by accessing this computer on the internet.



6. Introduction of Integrated Safeguards Approach (ISA) (1/2)

(1) After introducing both the random inspection and the RMS, the ISA was applied to Monju in November 2009 in order to strengthen and improve the efficiency of the IAEA's safeguards activities.

(2) Application of the Random Interim Inspection (RII) :

- 2 Days Notification RII ： Application of the Interim Inventory Verification (IIV)
- 2 Hours Notification RII ： Application of the Receipt Verification

(3) Introduction of ISA :

- November 2007 ： Receipt of the ISA proposal from the IAEA
- November 2009 ： Introduction of ISA

	Before introduction of ISA		After introduction of ISA		
	IIV	PIV [1]	RII		PIV
Frequency	1 / Month	1 / Year	at least 5 / year		1 / Year
			2Days Notification RII	2Hours Notification RII	

1) Physical Inventory Verification

6. Introduction of Integrated Safeguards Approach (ISA) (2/2)

(4) Inspection achievements before and after introduction of ISA

- Strengthen the safeguards by introducing RII and RMS
- Improve the efficiency of the IAEA's safeguards activities
  - Inspection frequency (Reduced to about 1/3)
  - Inspection efforts (Reduced to about 1/5)

	Before introduction of ISA		After introduction of ISA		
	2008	2009	2010	2011	2012
PIV	1	1	1	1	1
Interim Inspection	11	10	4 (RII)	5 (RII)	5 (RII)
Emptiness Verification	2	4	0	0	0
Receipt Verification	3	1	1 (RII)	―	―
Shipment Verification	―	―	―	―	―
Total	**17 Times (36 PDI [1])**	**17 Times (32 PDI)**	**6 Times (7 PDI)**	**6 Times (7 PDI)**	**6 Times (7 PDI)**

1) Person Days Inspection

7. Conclusion

(1) The integrated safeguards approach (ISA) was applied to Monju in November 2009 after it was confirmed that fuel assemblies were able to be monitored in every fuel handling route using the safeguards equipments installed in Monju.

(2) A series of design, development and improvement related to safeguards in Monju, which were started in about 1985 (on the Monju construction stage), was finished by the shift to the ISA.

(3) The safeguards method in Monju is expected to be a future FBR safeguards model.

(4) In future, the reliability of safeguards equipments will be confirmed by accumulating the handling achievements of the spent fuel assemblies etc.