Enhancing Operational Experience Feedback: Regulatory control during outages and refueling

Senior Regulators' Meeting
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Introduction

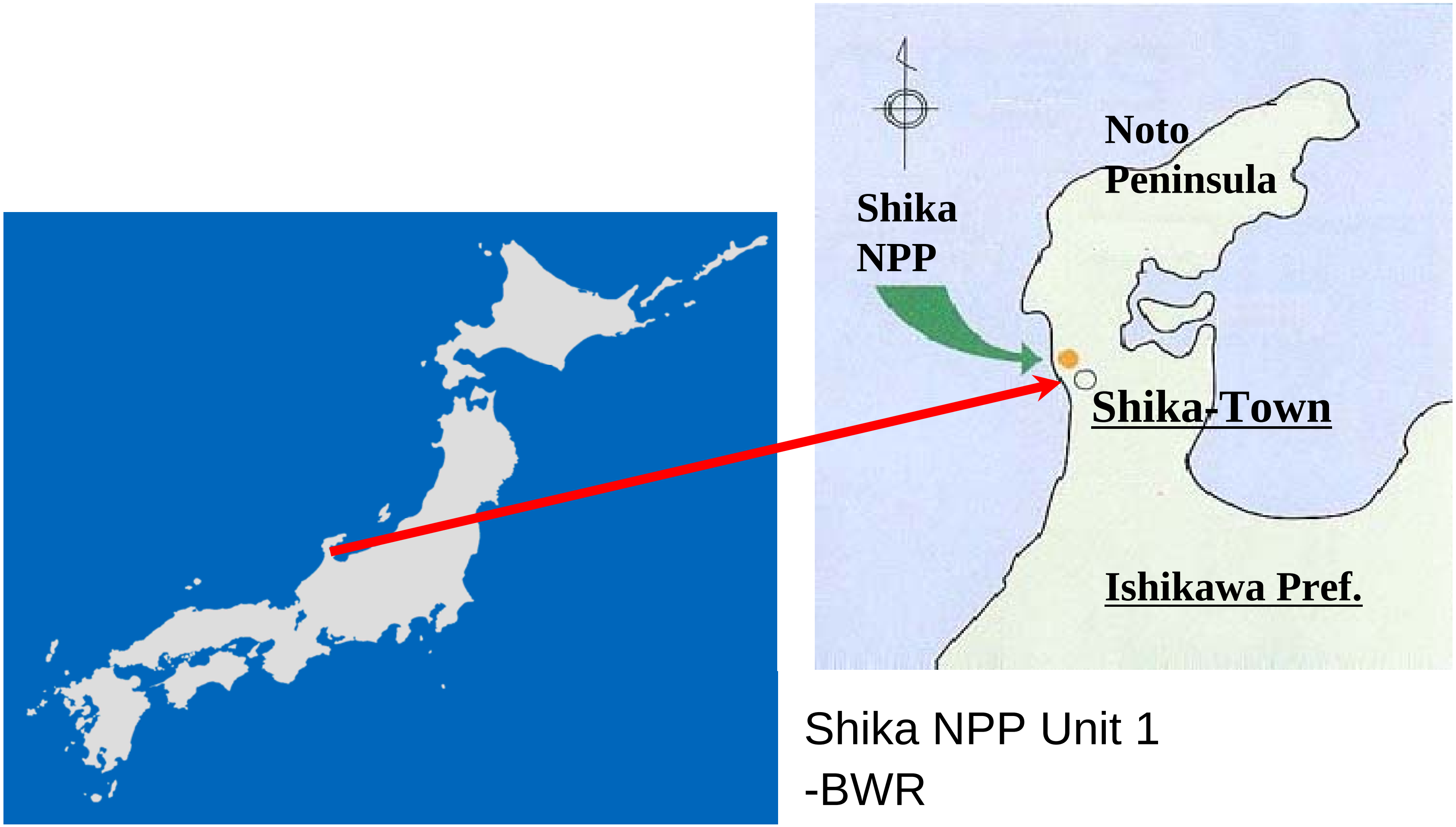
- Licensees' Comprehensive Checks of their power facilities

In November 2006, The Ministry of Economy, Trade and Industry (METI) ordered Licensees Comprehensive Checks. (see Appendix)

- data falsification, inadequacy of the required legal procedure in the past at all power generation facilities

- Through the Checks, criticality event caused by control rod slipping during shutdown in Shika NPP was found.

Shika NPP, Hokuriku Electric Power Company



Shika NPP Unit 1

-BWR

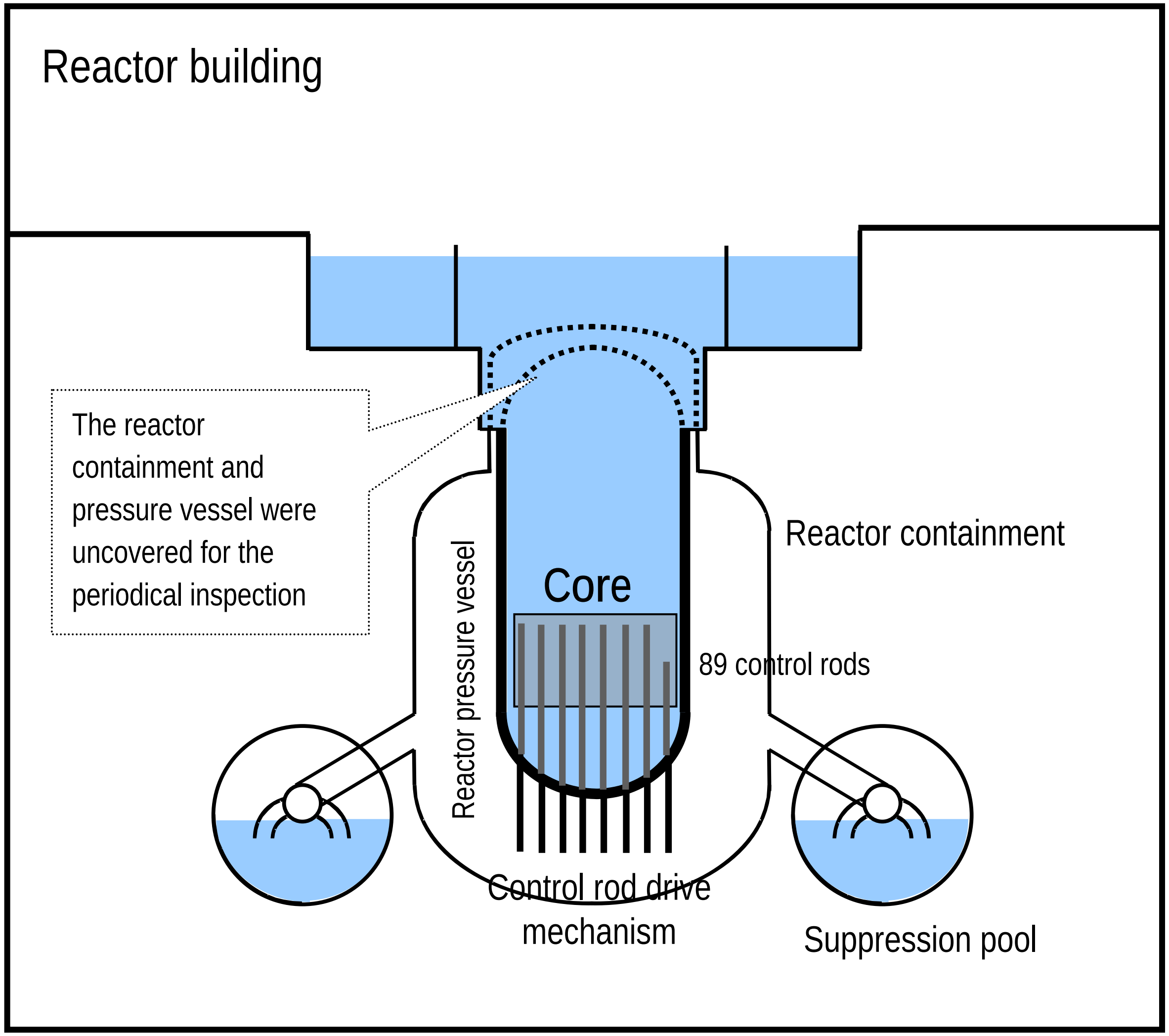
-540 MWe

-July, 1993 Start of Operation

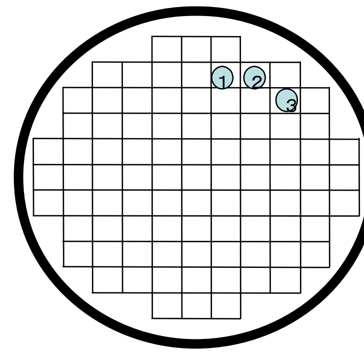
Outline of the Shika NPP Unit 1 accident

- On June 18, 1999, construction works were done to enhance reactor shutdown redundancy for Shika Unit 1. Valves related to the CRD were operated as a preparatory work for the function verification test.
- Then three control rods partially slipped, and the reactor went into a critical state.
- As the reactor went into a critical state, the reactor automatic stop signal was issued, and the slipping of the control rod stopped. However, the control rods were not inserted back immediately.
- It took about 15 minutes to insert the three control rods completely by opening the valves that had been closed for the preparatory work.

State of the reactor when the control rods slipped



Locations of the control rods that slipped



[Degree of slipping]

① Control rod [26-39]

Position 16 (about 1/3)

0: fully inserted
48: fully withdrawn

② Control rod [30-39]

Position 20 (about 2/5)

③ Control rod [34-35]

Position 8 (about 1/6)

Cause of Criticality

The CR slipped down since the water pressure stressed toward the side of withdrawing the CR, which was caused by neglecting the authorized procedure on manual.

Started to isolate all but one of the 89 control rod hydraulic control units (HCUs) in preparation for conducting an alternate rod insertion (ARI) test.

Procedure of the ARI test

Step1 : Withdraw CR (core location 14-31) from the core

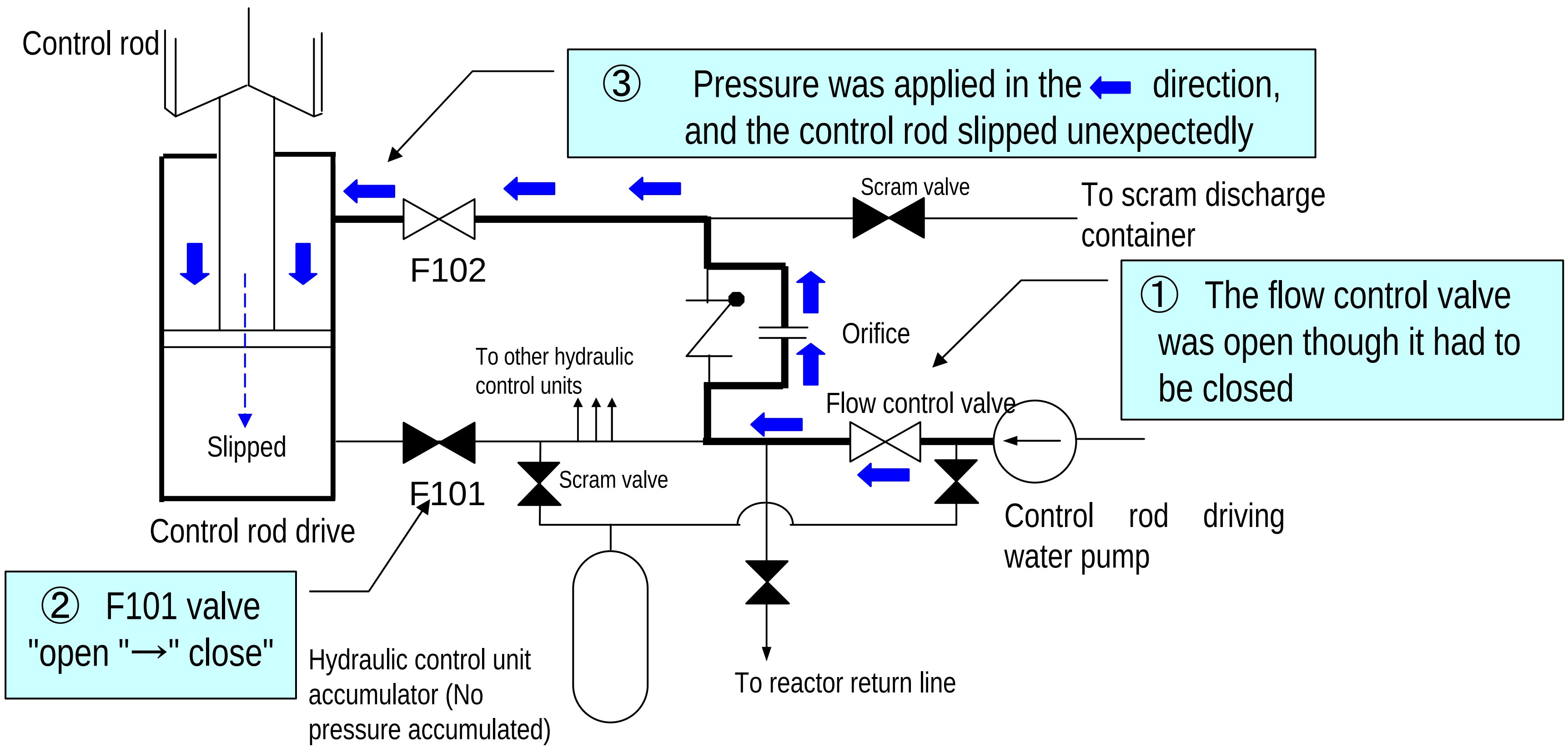
Step2 : Perform the system flow “0” (Close the system flow control valve (FCV))

Step3 : Close all but the one (core location14-31) insert isolation valves (101) and the withdrawal isolation valves (102) of the 89 HCUs

Infact, performed both Step2 and Step3 in parallel.

As personnel started to close the 101, 102 valves of 88 HCUs while system flow was 125ℓ/min, the system pressure Increased enough to withdraw control rods from the core.

Situation where the control rods slipped



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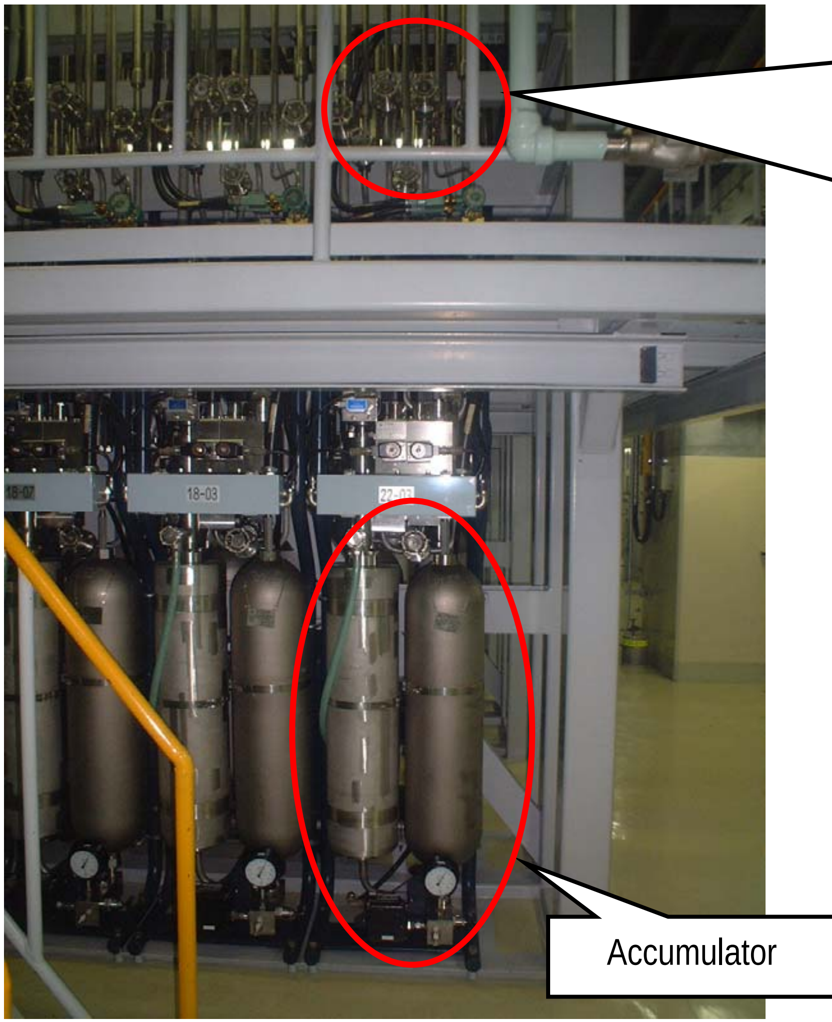
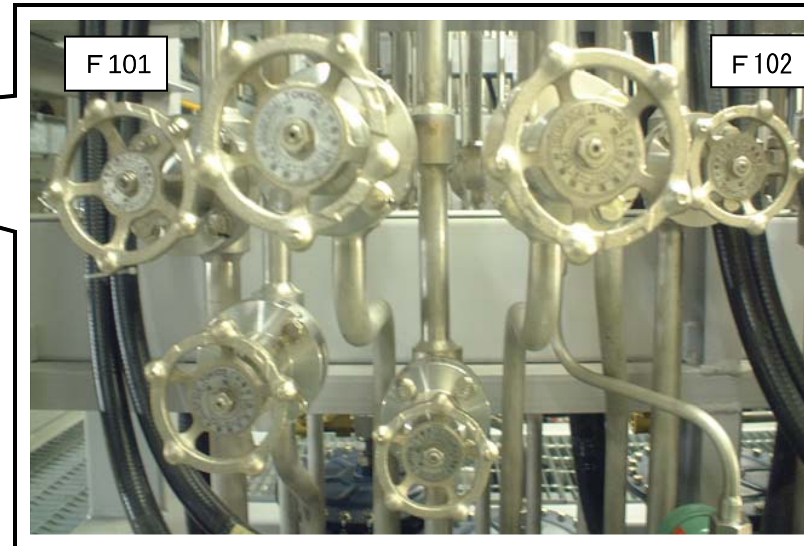
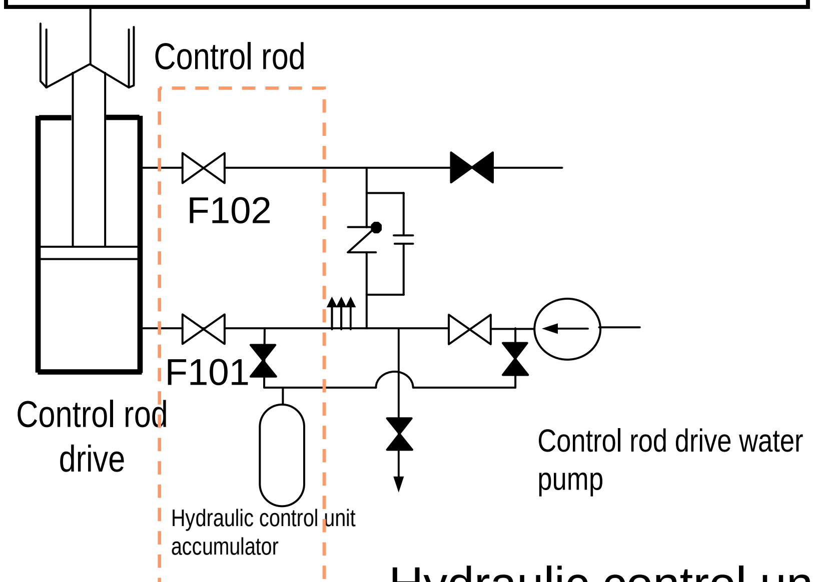
Hydraulic control unit







Hydraulic control unit

NISA Nuclear and Industrial Safety Agency

Problem in the field work management

- The maintenance division which was responsible for the whole testing did not grasp the entire work process. The works were performed without clear assignment of responsibility.

- The procedure manual did not presribed the concrete steps to set the system flow “0”, nor the manual approval process was not adequate.
- Communication among personnels who were in charge of the test was insufficient.
- Preparation had been insufficient for the ARI test which was done for the first time.

Problem of System and Component

- Before the ARI test, the reactor / CRD water pressure differential annunciation was disabled to do a single rod scram test. This is because frequent announces were annoying.

- As high pressure alarm and low pressure alarm are in common, high system pressure annunciation did not work to alert operators abnormal high system pressure.

Hokuriku E.P.C's behavior after the accident

(1) After recovery from the accident, the director of the NPP and other staff gathered and discussed the actions to be taken and the director decided not to notify any outsider about this accident. After that, a video conference with the head office was held and it was falsely reported.

(2) To conceal the accident, the accident was not described in the handover diary.

(3) The main reason why they concealed the accident is considered to be that they thought if the accident had been announced, the progress on Shika Unit 2 would be delayed.

Evaluation of the impact of the accident to Shika NPP Unit 1

(1) Hokuriku confirmed the integrity of the fuels in the core by the analytical method since neutronic data at the time of accident was not sufficiently recorded.

(2) The analysis conducted by Hokuriku assumed the most limiting conditions considering the ordinary criticality and prompt criticality. NISA considers that the integrity of the fuel was not affected and there was no exposure to the workers or the public.

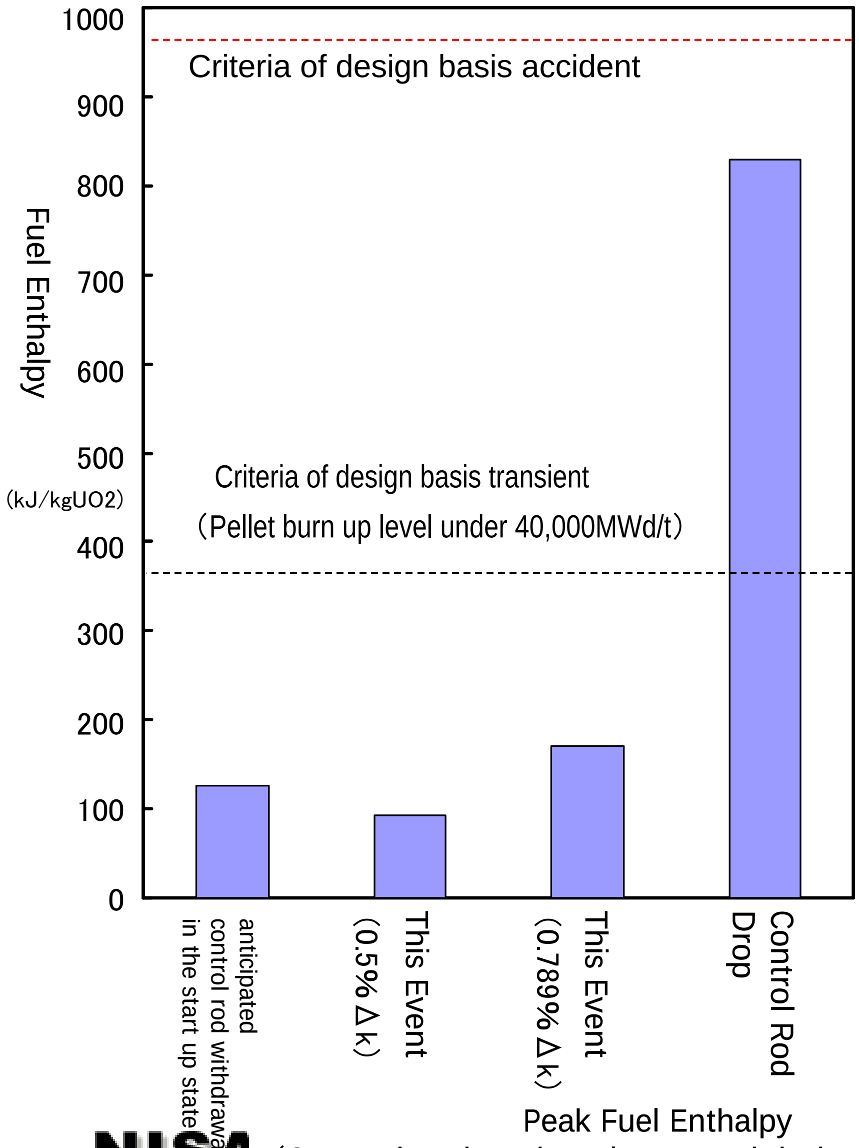
(3) This accident was rated as Level 2 in accordance with the International Nuclear Event Scale (INES).

Result of Analysis

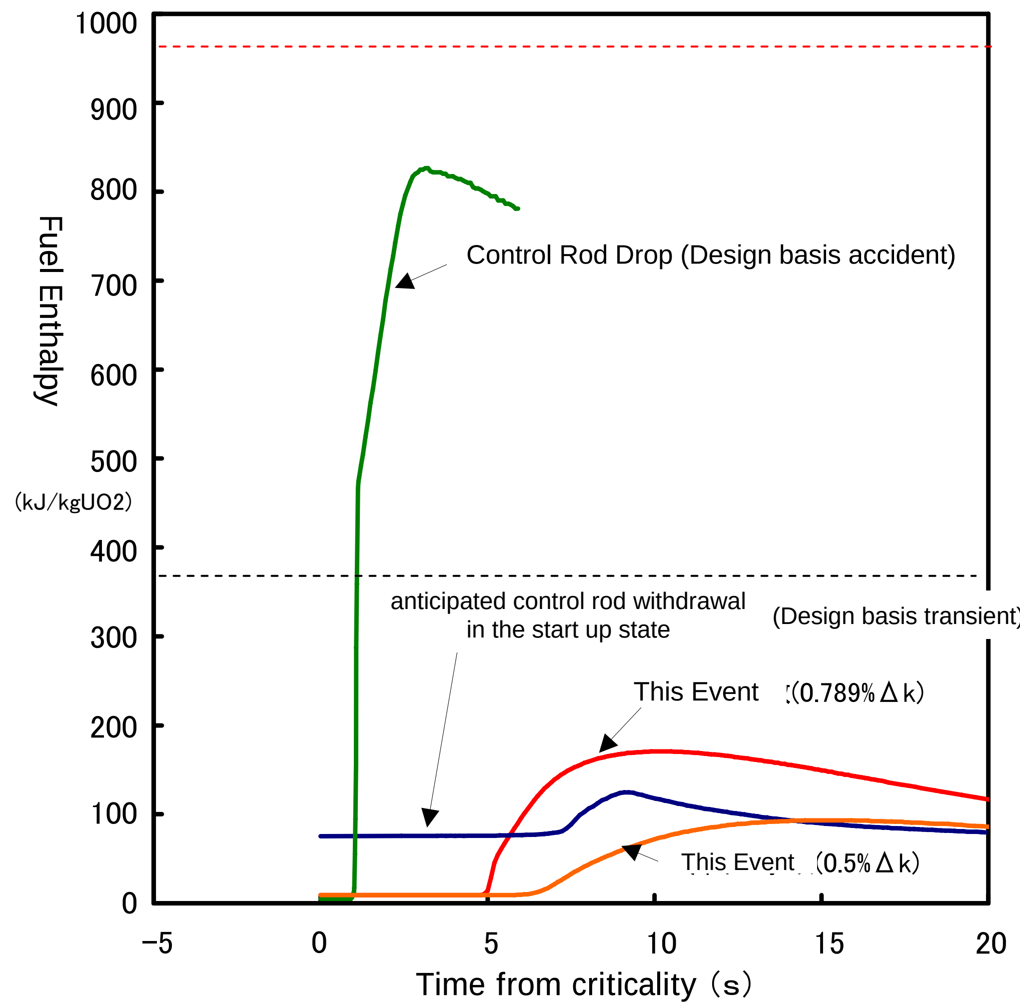
		Inserted control rod reactivity [%Δk]	control rod withdrawal speed [mm/s]	maximum fuel enthalpy [kJ/kgUO_2] ([kcal/gUO_2])		maximum increment in fuel enthalpy in peak output part [kJ/kgUO_2] ([kcal/gUO_2])	
				analytical value	criteria for judgment	analytical value	criteria for judgment
Analysis of this criticality accident	(1)	about 0.789	47	about 171 (about 41)	—	about 52 (about 13)	—
	(2)	about 0.5		about 93 (about 22)		—*4	
Safety Analysis	abnormal withdrawal of control rods when starting up a reactor	about 0.5	91	about 126 (about 30)	358*1 (92)	—*2	(a) *3
	control rod drop	1.5	950	about 830 (about 198)	963 (230)	—*2	—

(1) Inserted control rod reactivity is estimated by static calculation without feedback.
(2) Inserted control rod reactivity is estimated by dynamic calculation with feedback.
*1 The value assumes that the pellet burn up is below 40 GWd/t. The pellet burn ups for all 12 fuel assemblies around the withdrawn control rods were below 40 GWd/t.
*2 No results in the SAR. The "Deal with advanced burn up fuels in evaluating reactivity insertion events of light water reactor facilities (Special Committee on Nuclear Reactor Safety Commission)" is applied to safety review for high burn up fuel with a maximum fuel assembly burn up of 55,000 MWd/t.
*3 (a) 460 (110) for a pellet burn up of below 25 GWd/t and 355 (85) for a pellet burn up of 25 GWd/t or above and below 40 GWd/t
*4 Need not to evaluate because inserted reactivity is below 1$.

Result of Analysis



Peak Fuel Enthalpy
(Comparison btw the relevant and design basis event)



Transition of Fuel Enthalpy
(Comparison btw the relevant and design basis event)

Preventive Actions Taken at Shika NPP Unit 1

(1) Technical measure implemented;

- -lock of the valves to prevent possible slipping of CRs
- -warning signs

(2) Twenty-one Action Items aiming at the establishment of;

- -ethics for enhanced Safety Culture
- -further transparency of the company ethics

(3) Hokuriku was required by NISA to formulate a company-wide action plan to avoid the recurrence of the accidents.

Other unexpected control rod drop events during reactor outage

(1) Besides the accident at Shika Unit 1, nine control rod slipping events have been reported. Seven of them were caused by improper operation of the control rod drive hydraulic control system like the Shika event. Among them, criticality occurred in the event at Fukushima I Unit 3 in 1978. The other two events occurred because of improper operation of the power supply.

(2) A reason why these similar events were not prevented successively is such that the information of such accidents or events was not shared among the electric utilities and the manufacturers, so that adequate preventive measures were not taken.

List of Control Rod Drop events

	Shika Unit 1	Fukushima I Unit 3	Fukushima I Unit 5	Fukushima I Unit 2	Onagawa Unit 1	Hamaoka Unit 3	Fukushima I Unit 3	Kashiwazaki-Kariwa Unit 6	Fukushima I Unit 4	Kashiwazaki-Kariwa Unit 1
Occurred on (Started up on)	June 18, 1999 (July 30, 1993)	Nov. 2, 1978 (Mar. 27, 1976)	Feb. 12, 1979 (Apr. 18, 1978)	Sep. 10, 1980 (July 18, 1974)	July 9, 1988 (June 1, 1984)	May 31, 1991 (Aug. 28, 1987)	June 15, 1993 (June 21, 1985)	June 10, 1996 (Nov. 7, 1996)	Feb. 22, 1998 (Oct. 12, 1978)	Apr. 7, 2000 (Sep. 18, 1985)
Outline of event	Criticality accident occurred because control rods slipped	Critical state occurred because control rods slipped	Control rods slipped, but no change in neutron flux estimated	Control rods slipped, but no change in neutron flux estimated	Control rods slipped, but no change in neutron flux	Control rods slipped, but no change in neutron flux	Control rods slipped, but no change in neutron flux	Control rods slipped, but no change in neutron flux	Control rods slipped, but no change in neutron flux	Control rods slipped, but no change in neutron flux
Plant status	During outage	During outage	During outage	During outage	During outage	During outage	During outage	During outage	During outage	During outage
Status of reactor pressure vessel cover	Open	Closed	Open	Closed	Closed	Open	Closed	Open	Closed	Closed
Status of containment vessel cover	Open	Open	Open	Closed	Closed	Open	Closed	Open	Open	Open
Description of work	During preparatory work for function verification test for accident management measures	During work related to reactor pressure vessel hydraulic test	During preparatory work before in-core shipping (During HCU isolation)	During in-house inspection of containment isolation system functions	During preparatory work for reactor start-up	During work following the completion of inspection (in-house inspection) to verify the reactor protection system settings	During preparation for preliminary inspection of reactor containment leak rate	During scheduled outage in the trial run period before business operation	During pressure test of reactor pressure vessel	During preparation for preliminary inspection of reactor containment leak rate
Work that was being performed	Control rod separation valves other than that for control rod to be tested were being closed	Control rod separation valves were being closed	Control rod separation valves were being closed	Control rod separation valves were in separated position (No valve was being operated)	Control rod separation valves that had been in the fully closed positin were being opened	Control rod separation valves that had been in the fully closed positin were being opened	Control rod separation valves that had been in the fully open positin were being closed	Performance verification test of regurated power controller (APR) was being performed	Driving power was turned on by mistake for valve operation	Control rod separation valves that had been in the fully open positin were being closed
Number of control rods slipped (Number of all control rods)	3 (89)	5 (137)	1 (137)	1 (137)	2 (89)	3 (185)	2 (185)	4 (205)	34 (137)	2 (185)
Status of accumulator	Inactive	Active	Unknown (No scram signal was issued)	Unknown (No scram signal was issued)	Active	Active	Inactive	Active	Active	Inactive
Opening/closing of return-to-reactor valve	Closed	Closed	Closed	Closed	Closed	Closed	Closed	No valve concerned (because of motor-driven control rods)	Closed	Closed
Classification of event	Event at hydraulic pressure control unit (HCU) isolation	Event at hydraulic pressure control unit (HCU) isolation	Event at hydraulic pressure control unit (HCU) isolation	Event at hydraulic pressure control unit (HCU) isolation	Event at hydraulic pressure control unit (HCU) isolation	Event at hydraulic pressure control unit (HCU) isolation	Event at hydraulic pressure control unit (HCU) isolation	Operational error of power supply for control rod drive	Operational error of power supply for relief safety valve drive	Event at hydraulic pressure control unit (HCU) isolation

NISA’s Requirements regarding Control Rod Drop Events

1. Inadvertent Control Rod movement shall be reported to NISA.

2. Actions to ensure safety management during plant shutdown shall be reported to NISA.

3. Adequate Work Procedures shall be prepared and safety activities shall be conducted according to the procedures.

4. Necessary procurement management shall be implemented for sharing the information related to the manufactures’ safety technology among electric power companies.

5. Registration to NUCIA (utilities’ information library) shall be encouraged for sharing the information on the insignificant incidents.

IAEA International Workshop

- IAEA Technical Meeting

–The Effective Management of Safety Reactivity Control during Operation and Shutdown in Nuclear Power Plants

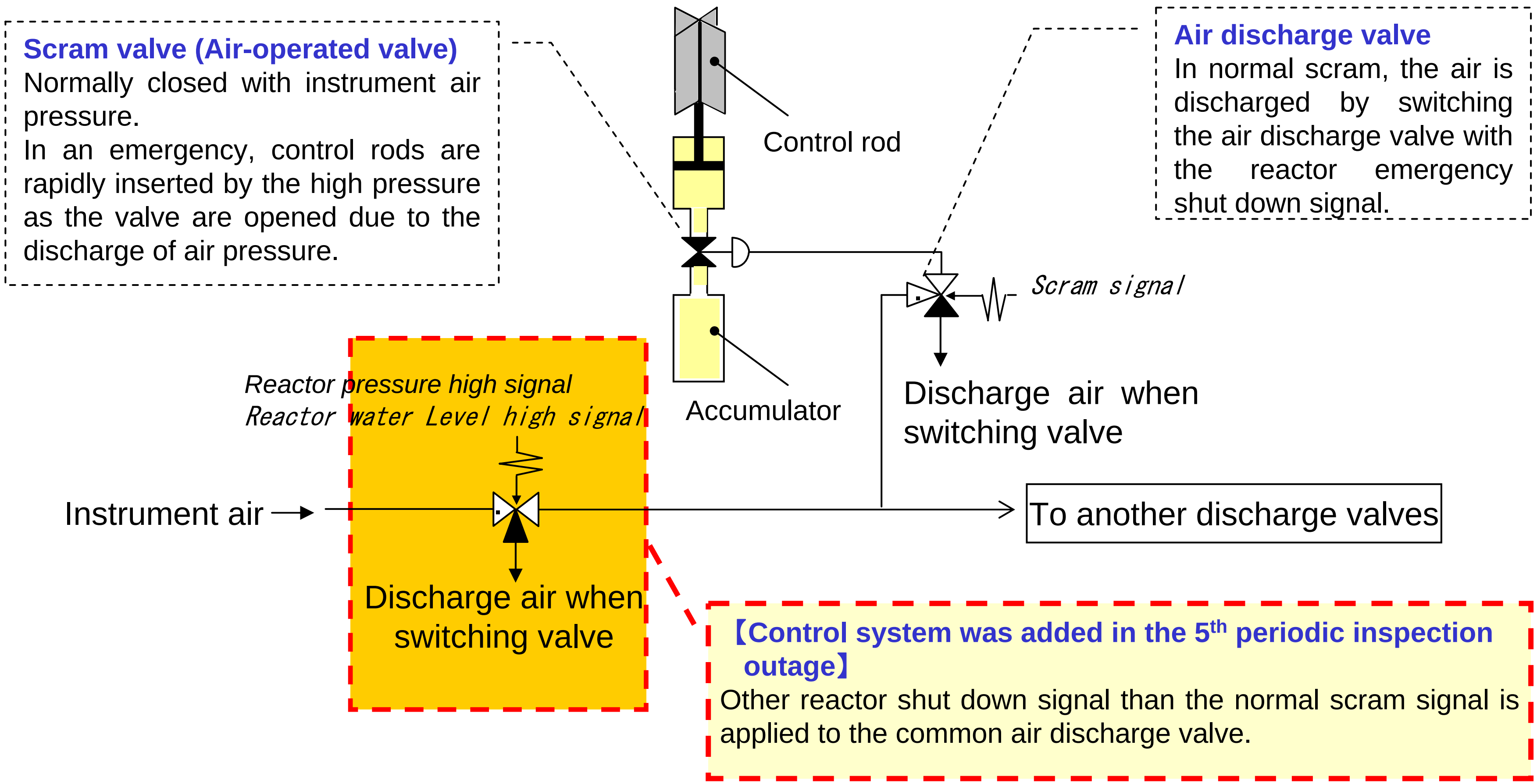
- 3 to 5 October 2007, Tokyo, Japan
- Hosted by NISA
- Program

-Section 1: Report of Events/Incidents
-Section 2: Technical Issues
-Section 3: Regulatory Aspects
-Section 4: Management Safety and Leadership

Test which caused Criticality Event（1）

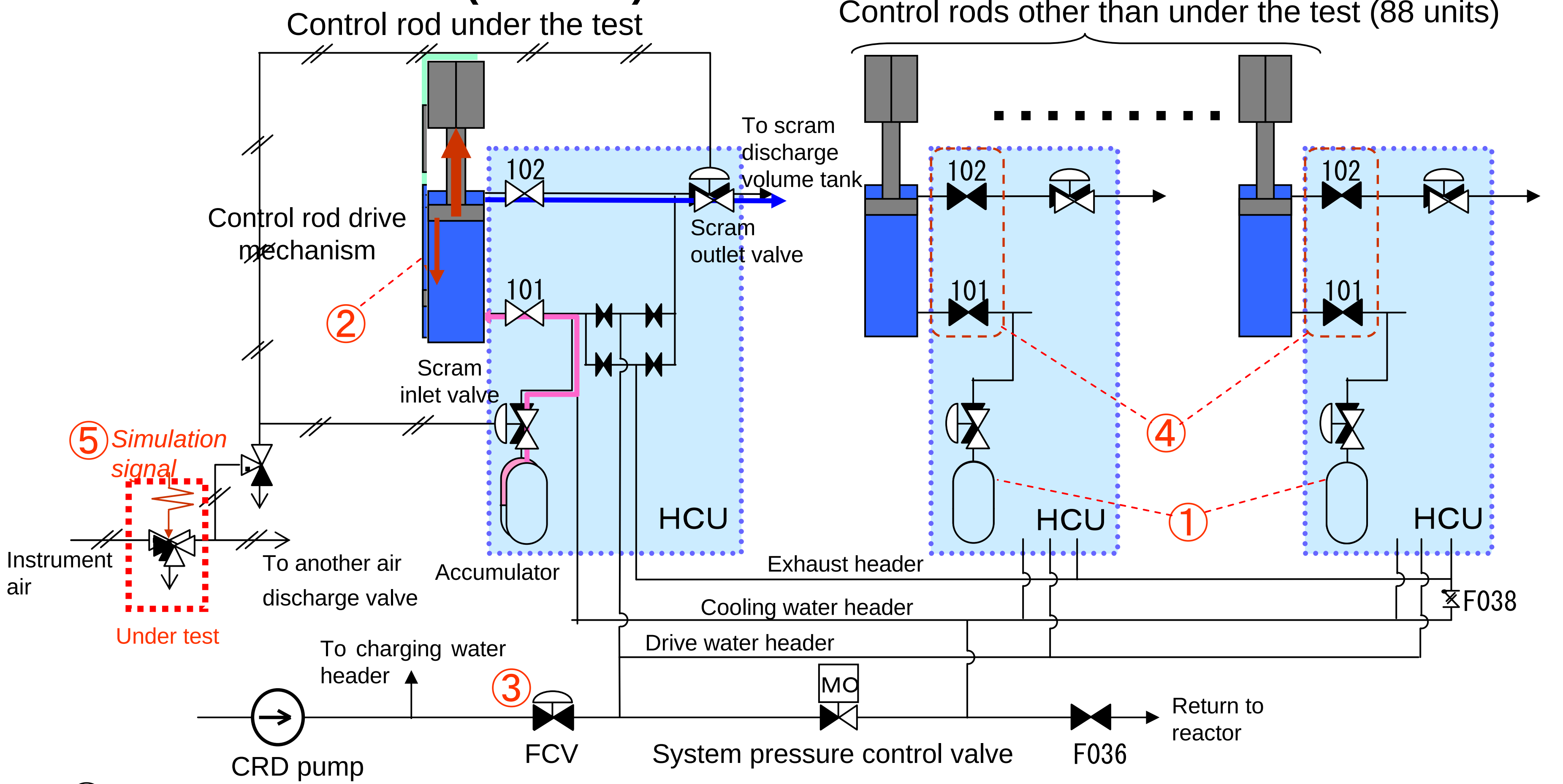
Reference 1

- The test was conducted to verify the added function of ARI (Alternative Rod Insertion) which was installed to enhance the function of reactor shutdown, as part of countermeasure for accident management.



Test which caused Criticality Event（2）

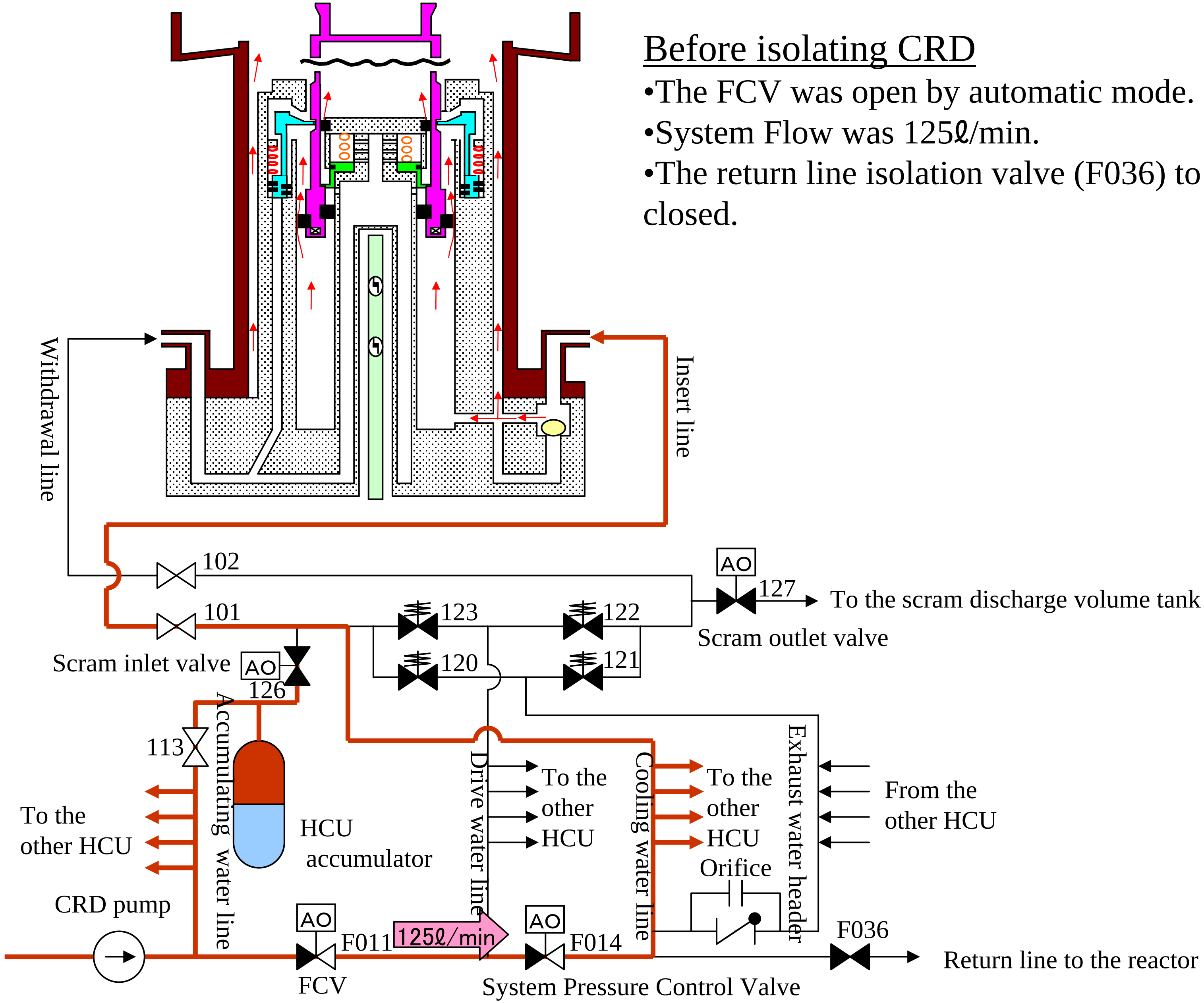
- **Method of the test to verify the modification for enhancing the function of reactor shutdown (ARI test)**



① Blow the accumulator discharging water of the control rods other than under the test
② Fully withdraw the control rod under the test
③ Set the flow of the control rod drive water to zero
④ Isolate the control rod drive mechanism other than under the test (88 units) (Close the isolation valves (101, 102)
⑤ Put in the simulation signal to the control rod drive under test (1 unit) for scram

Mechanism of Control Rod Withdrawal (1)

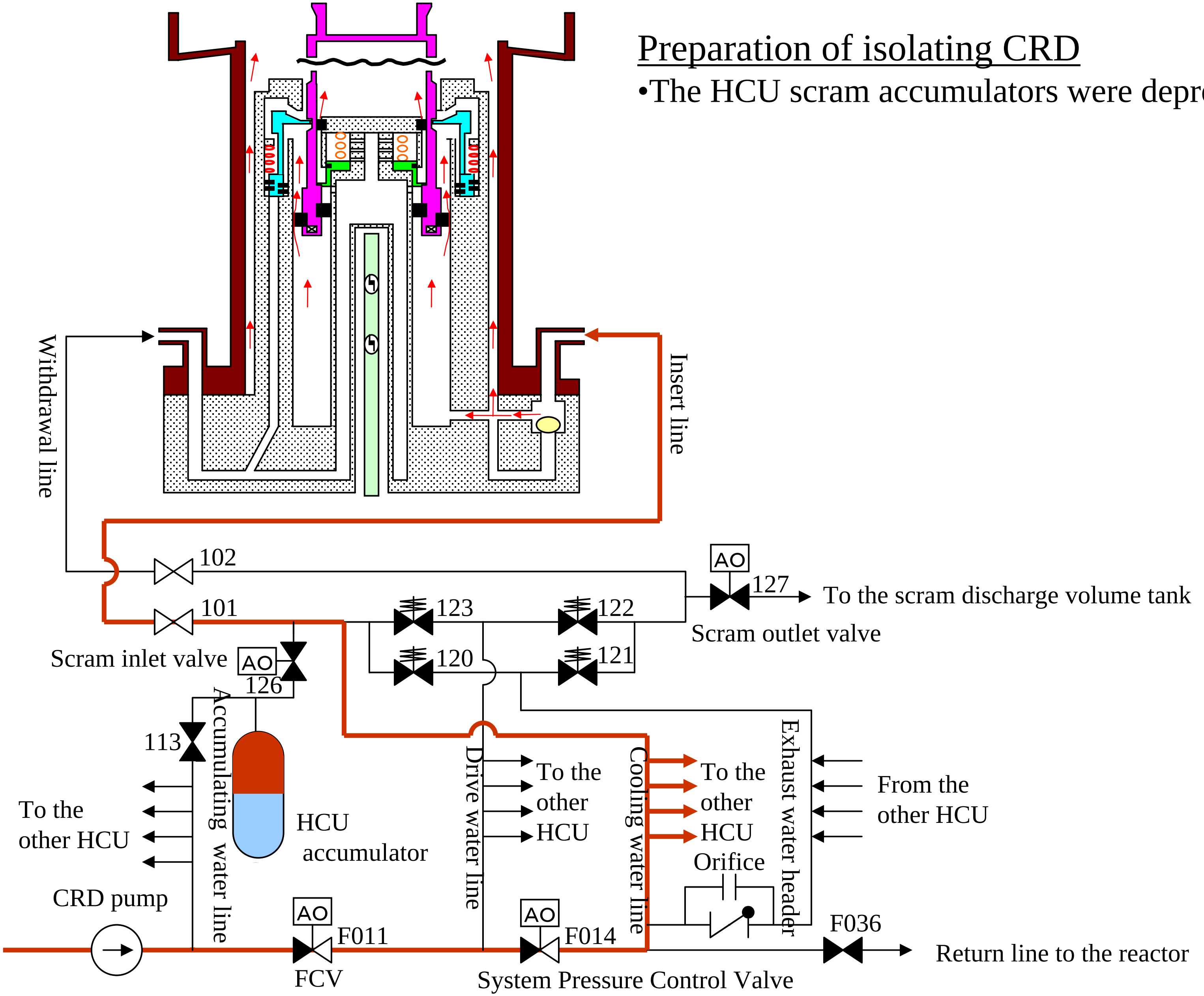
Reference 2



Before isolating CRD

- The FCV was open by automatic mode.
- System Flow was 125ℓ/min.
- The return line isolation valve (F036) to the reactor was closed.

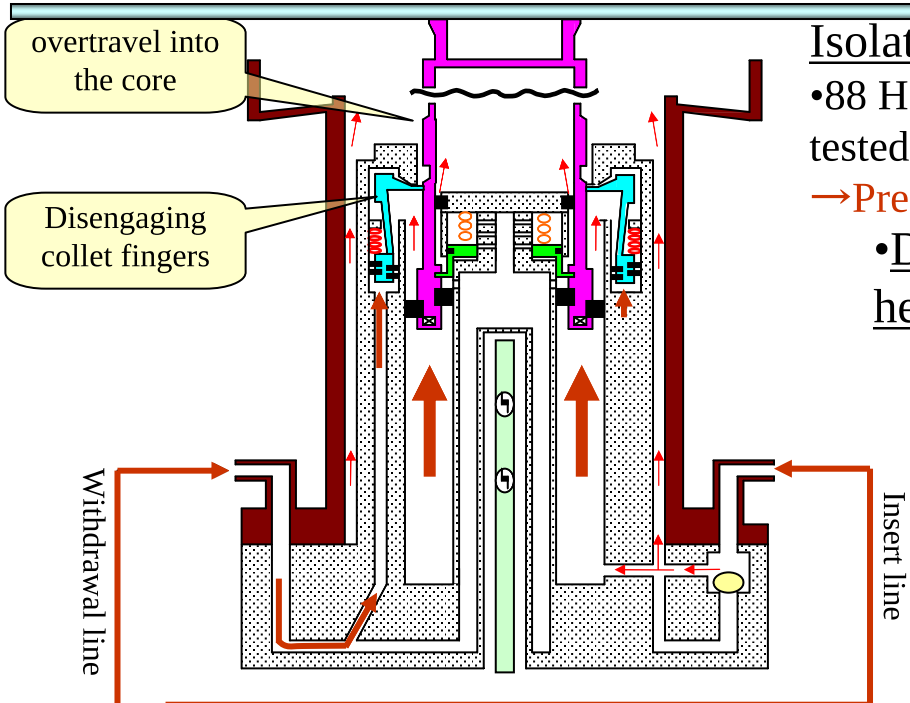
Mechanism of Control Rod Withdrawal (2)



Preparation of isolating CRD

- The HCU scram accumulators were depressurized.

Mechanism of Control Rod Withdrawal (3)

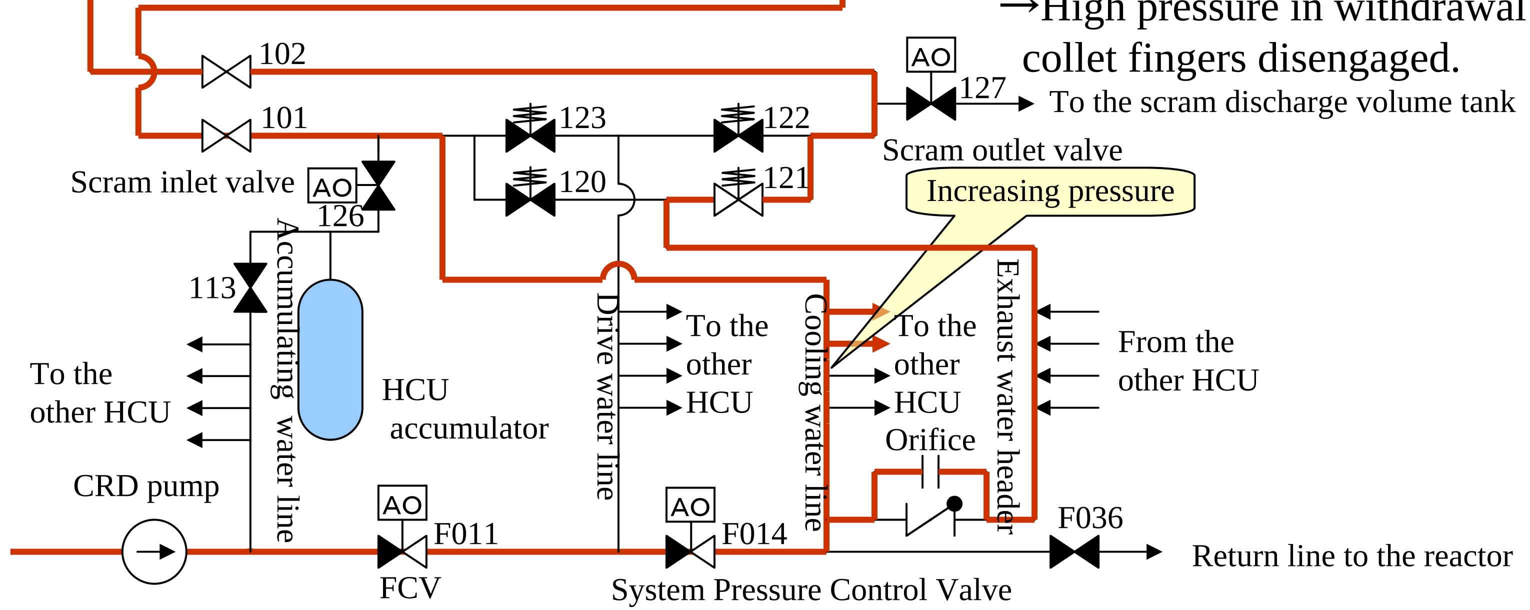


Isolating 88 CRDs

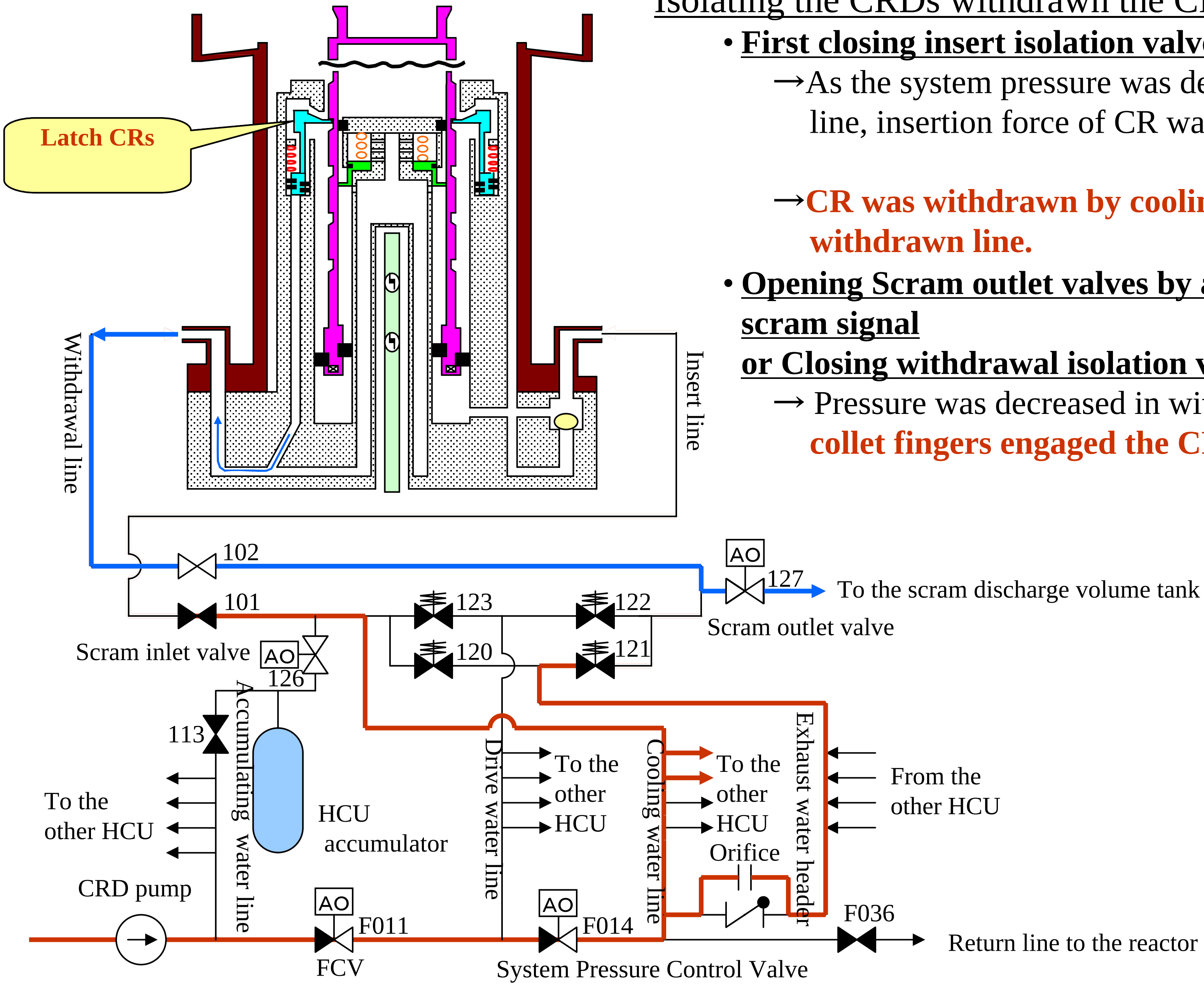
•88 HCUs was isolated by turns except for a HCU which was tested.

→Pressure was gradually increased in cooling water header.

- •Differential pressure (between cooling water header and reactor) > about 0.04MPa
  - →As control valves (121) was open, cooling water running through the orifice pressurized withdrawal line.
- •Differential pressure > about 0.7MPa
  - →High Pressure in insert line keep CR overtraveled into the core.
- •Differential pressure > about 1.0MPa
  - →High pressure in withdrawal line keep the collet fingers disengaged.



Mechanism of Control Rod Withdrawal (4)



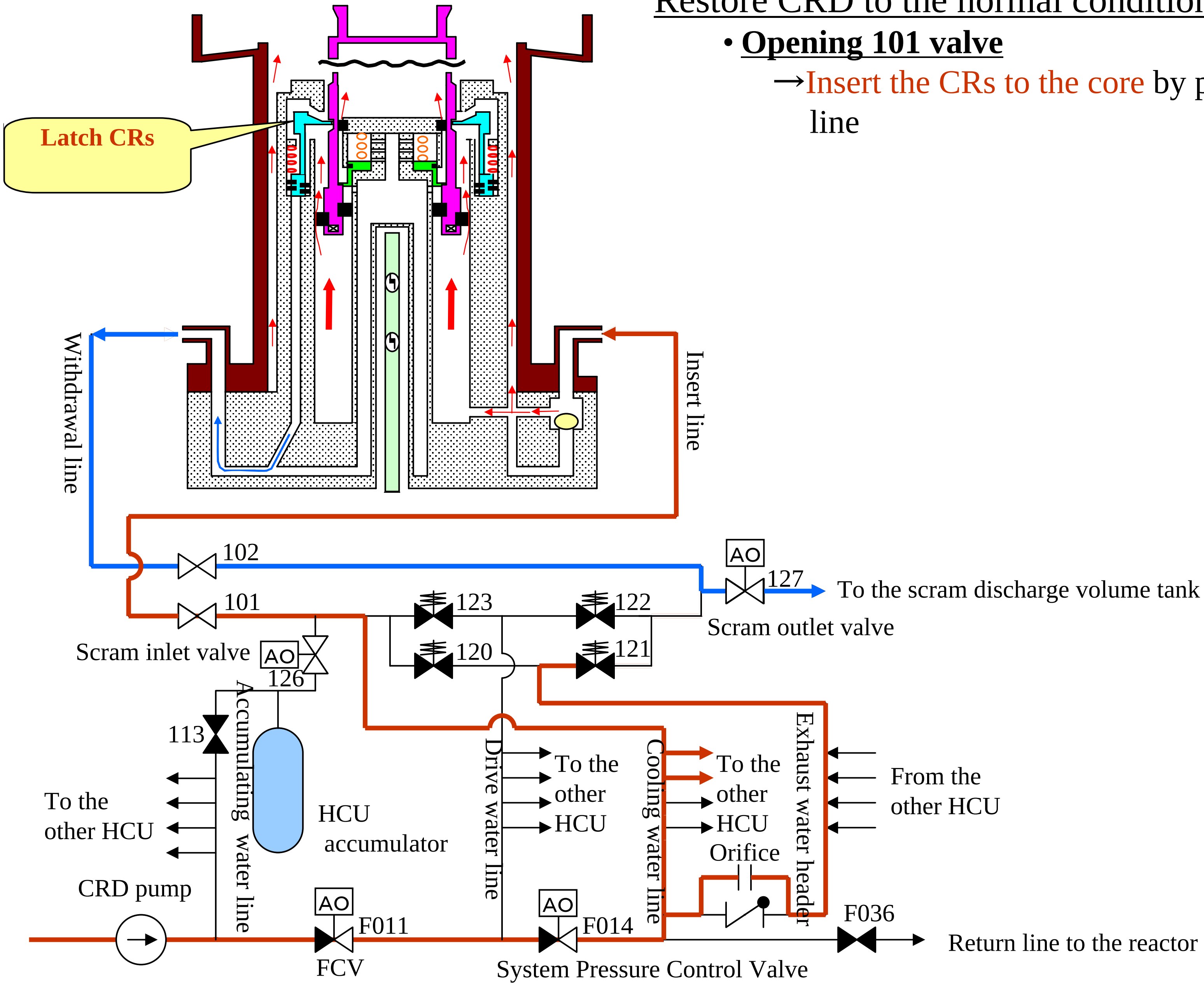
Isolating the CRDs withdrawn the CRs

- **First closing insert isolation valve（101）**
  →As the system pressure was decreased in insert line, insertion force of CR was decreased
  →**CR was withdrawn by cooling water in withdrawn line.**
- **Opening Scram outlet valves by automatic reactor scram signal or Closing withdrawal isolation valve (102)**
  → Pressure was decreased in withdrawal line and **collet fingers engaged the CRs**

Mechanism of Control Rod Withdrawal (5)

Restore CRD to the normal condition

- **Opening 101 valve**
  →Insert the CRs to the core by pressure in insert line



Reference3

Licensees' Comprehensive Checks of their power facilities (1)

- Current reinforced inspection system has introduced since 2003.
- Comprehensive Checks ordered by the Ministry of Economy, Trade and Industry (METI) in November 2006

  - some cases of data falsification before 2003 came to light on autumn 2006
  - data falsification, inadequacy of the required legal procedure in the past at all power generation facilities
  - the aim of the Checks;

    a) to root out the vicious circle; the past altering cause the next altering.

    b) to establish the system not to allow unfairness in operation.

    c) to share the information of incident and trouble among licensees for prevent the same incident happening again.

    d) to improve the structure of licensees

Licensees' Comprehensive Checks of their power facilities (2)

- result of the Checks on NPP:
  - 98 faults were reported
  - 11 (9 nuclear power plants) of them: Category I (infringed law and regulations)
  - no fault was found occurred after 2003
- NISA ordered all licensees a series of countermeasures:
  - 9 NPPs in Category I : change of operational safety program, implementation of the special inspection, and preparation of concrete action programs for preventing recurrence
- in Category I, criticality event caused by control rod slipping during shutdown in Shika NPP was found.