BWR Control Rods Performance

Department of Nuclear Regulation
Atomic Energy Council, R.O.C

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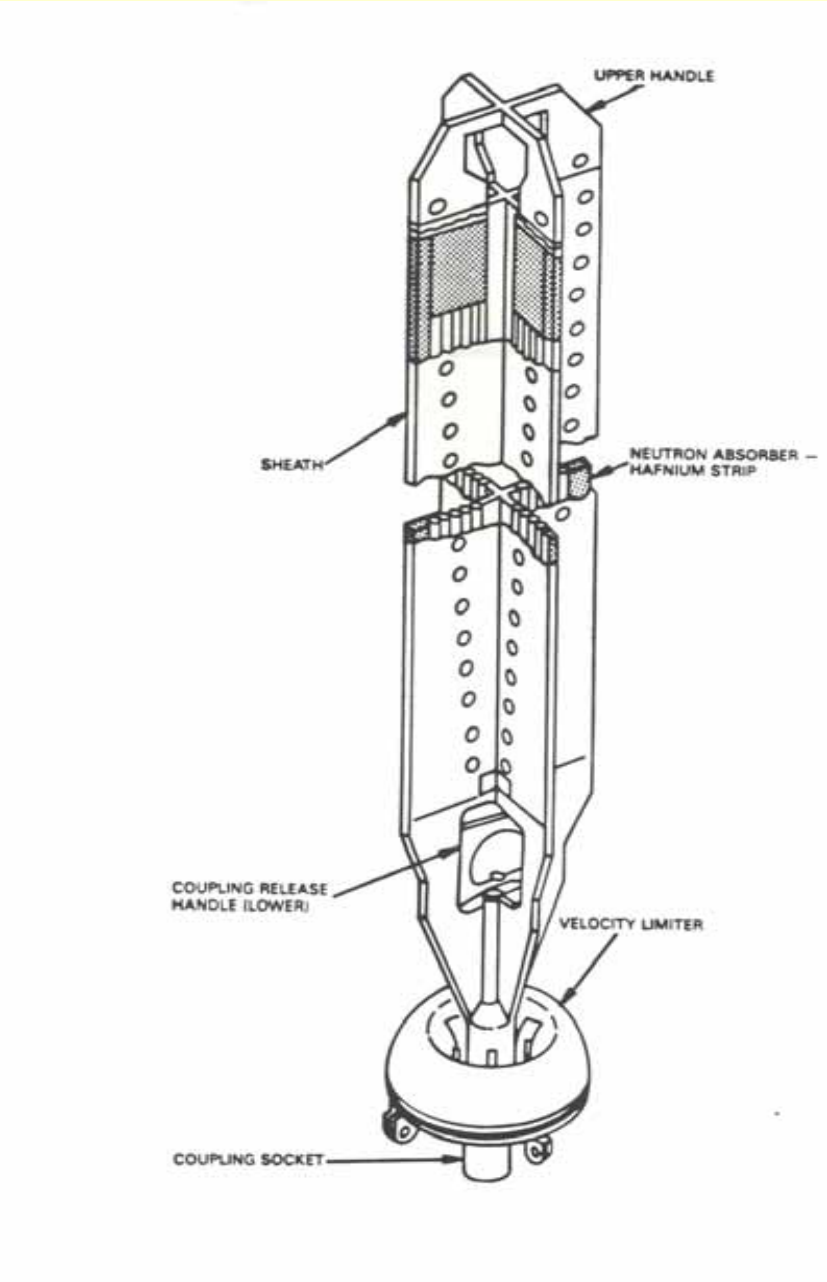
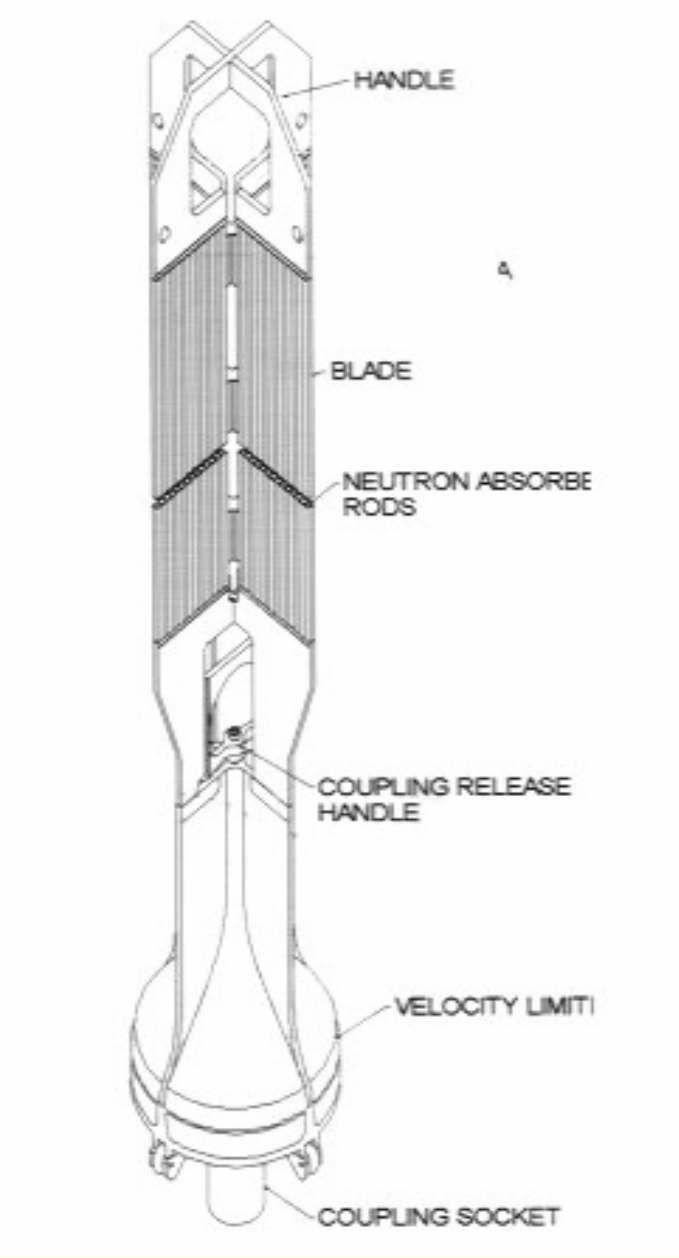
Background

- Since the Japanese Tokai nuclear plant unit 2 control rod (GE supplied type D-120) cracking indications on the handle roller pinhole area were identified during its outage inspection in 1999, the TAEC has required the Taipower's BWR plants, Chinshan and Kuosheng, to inspect the control rod blades in the nearest routine outage.
- The types of the control rods adopted are D-100 and D-215 for Chinshan, and D-100 and D-230 for Kuosheng. However, the Marathon type (original design)was used to replace the defect rods only for Chinshan unit 2 in cycle 19 (February, 2002)and the Improved Marathon type has been used to replace the defect rods for Chinshan and Kuosheng units since September,2002 .



Duralife Control Rod



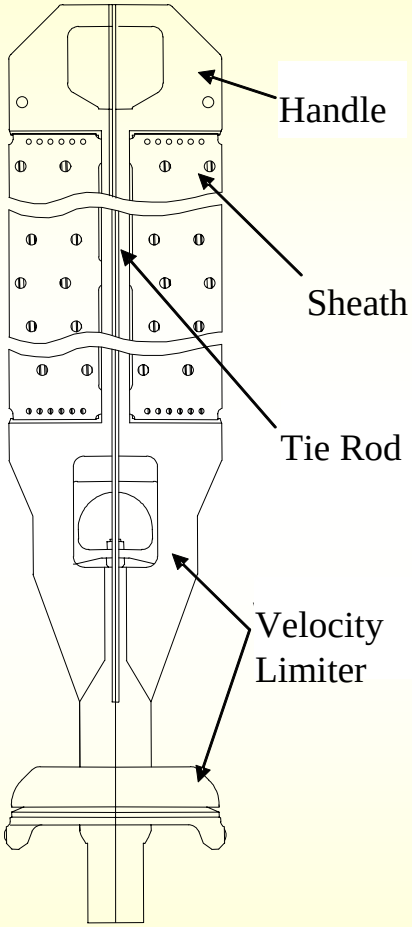
Marathon Control Rod

Duralife Control Rods-Inspection Results

- The inspection results (detailed as attached) showed that the control rod cracking indications were found in all four units of our BWR plants.
- The locations of the control rod cracking indications are falling into 5 categories: handle roller pinhole outboard, handle roller pinhole inboard, handle-to-sheath, sheath-to-tie rod, and B_4C absorber rod.
- Unless the aforementioned indications are severe ,these rods can be used for additional cycles.

Duralife CRB

- Chinshan
  - D-100 (SS304)
  - D-215 (SS316)
- Kuosheng
  - D-100 (SS304)
  - D-230 (SS316)



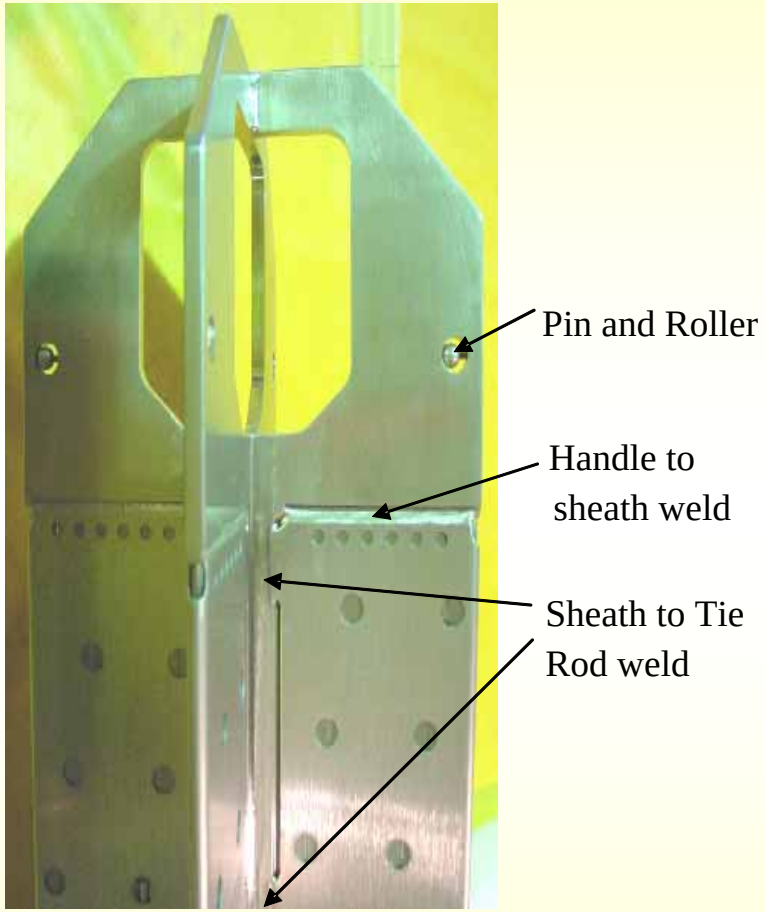
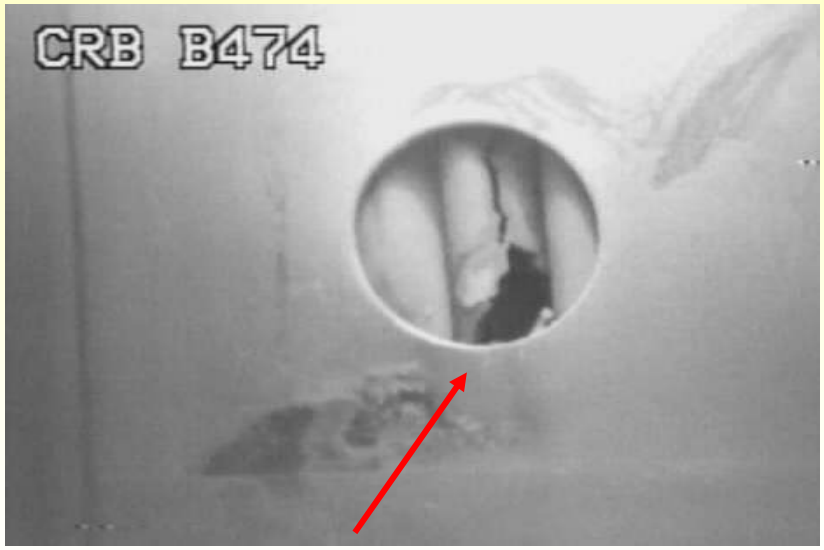
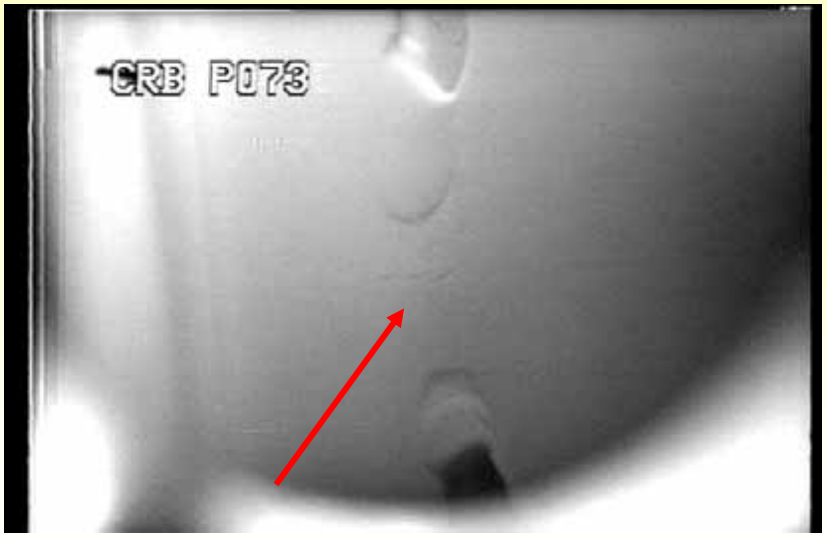


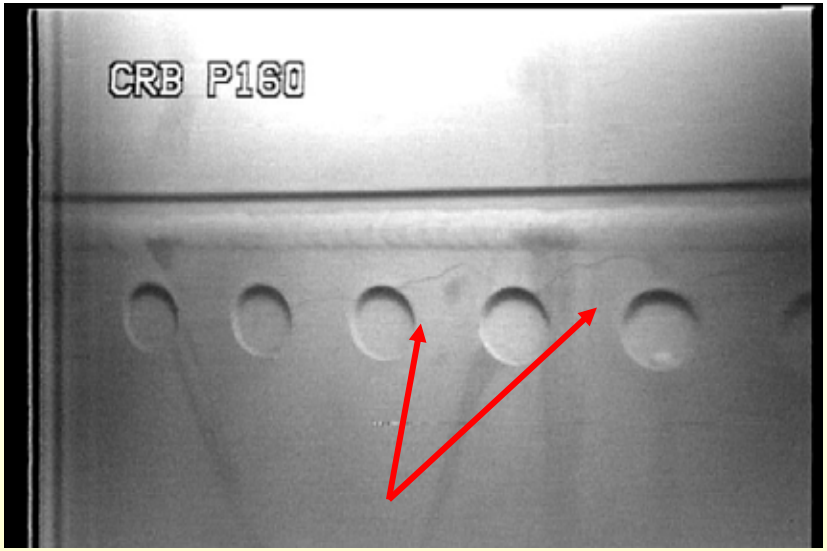
Illustration and Handle Area Photo of a Typical Duralife CRB



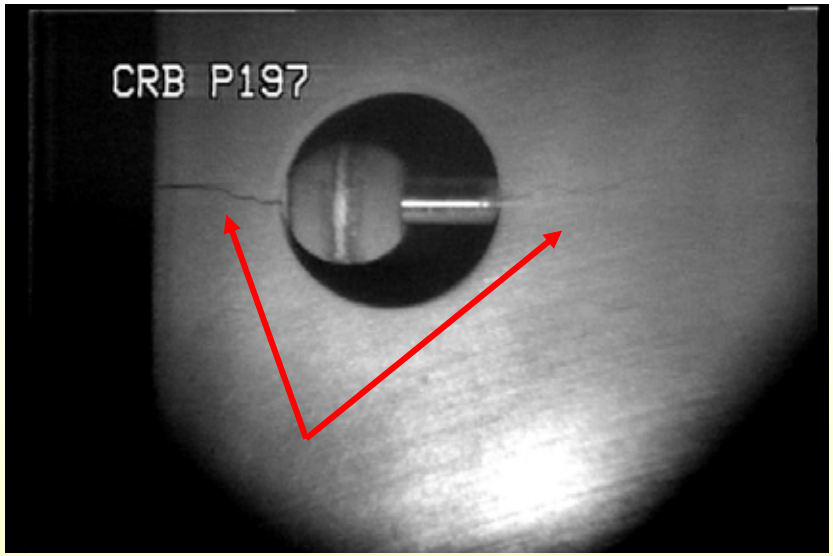
B_4C absorber rod crack



Sheath to tie rod crack



Handle to Sheath crack



Handle roller pinhole outboard and inboard crack

Duralife Control Rods- Regulatory Actions

- The TAEC organized a special safety review taskforce to evaluate the integrity of the control rods, and several regulatory actions were enforced which include:

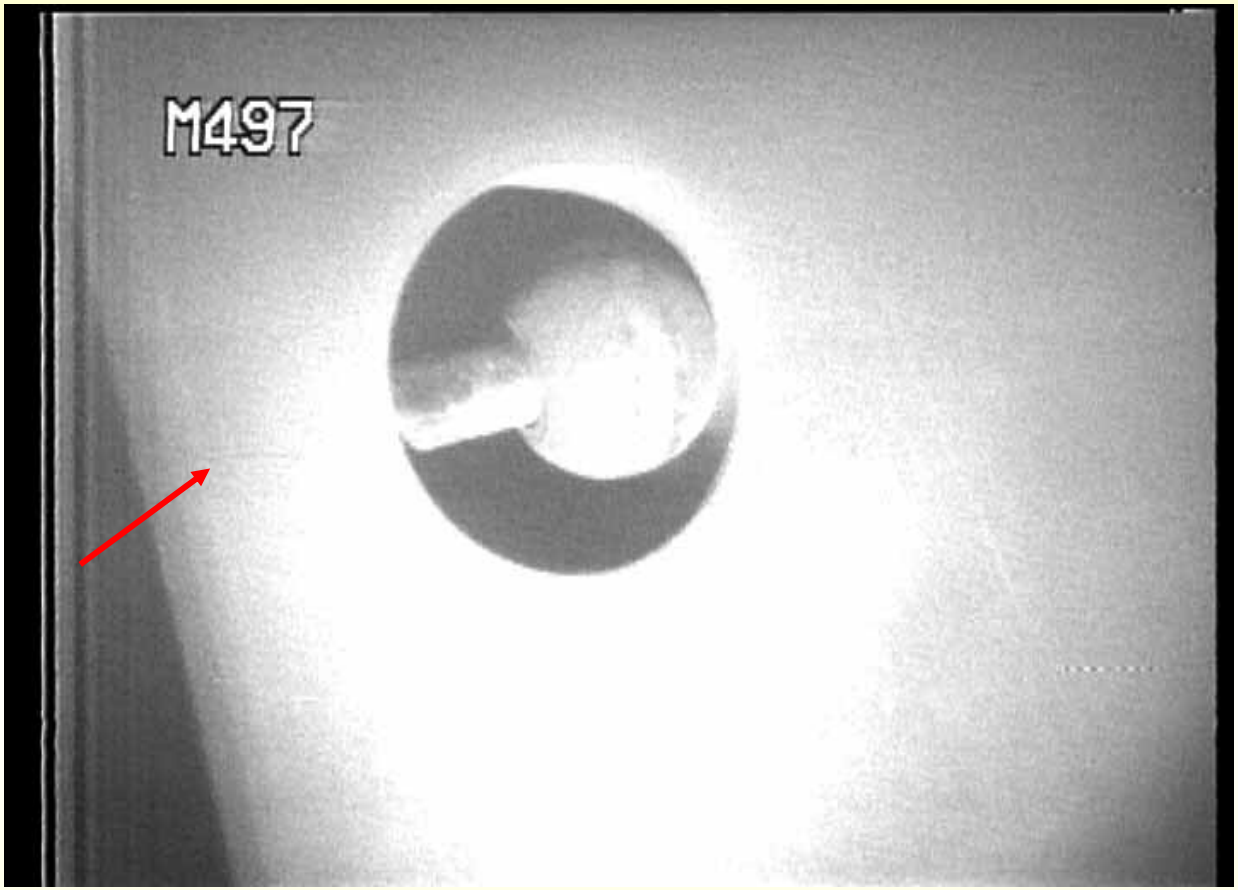
- replacing defective rods which exhibit safety concerns,
- monitoring reactor coolant boron concentration,
- conducting control rod functional tests (including buffer monitoring, notch testing, and friction testing),
- establishing control rod inspection and replacement program and performing root cause identification.

Original Marathon Control Rods-Inspection Results

- During the Chinshan unit 2 EOC-19 outage inspection (September 2003), 15 out of 17 original Marathon type control rods used in the unit for only one cycle has also shown crack indications on handle roller pinhole outboard locations.

Original Marathon Control Rods-Inspection Results (Cont'd)

- During Chinshan unit 2 Cycle 19, GE notified that part of the original Marathon CRBs which have been loaded in the core have possessing white spot problem. This problem is owing to the residual cleaning agent clung to absorber rod during manufacturing process and it will cause the etching of the rod during operating conditions. Therefore, TAEC request Taipower to examine one highest burn up CRB to see the effect during EOC-19 outage. The inspection results show there is no further indication due to the white spot.



Handle Roller Pin Outboard Indication of original Marathon Control Rod

Original Control Rods-Regulatory Actions

- Additional regulatory requirements are enforced which are the reconfirmation of the control rod quality documentation, and the one-cycle time limit for the root cause identification.
- According to GE and Taipower's root cause study ,there are three contributory factors to the original Marathon CRB cracking namely:

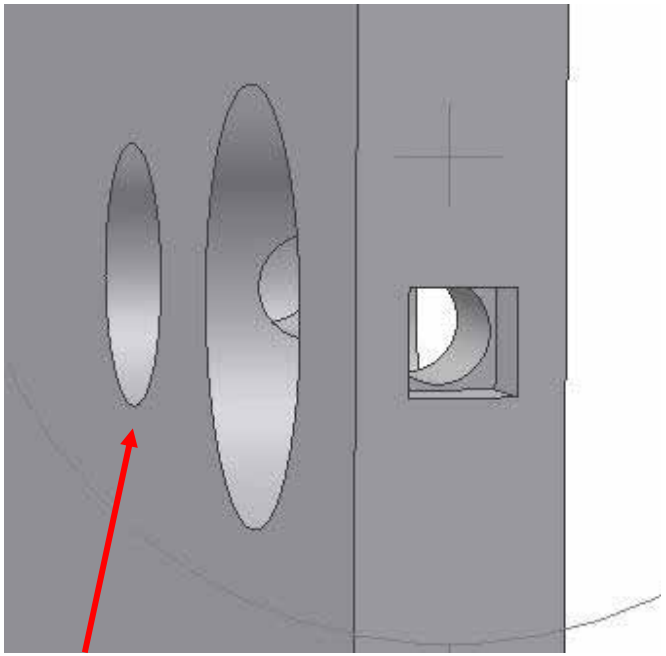
(1)Sulfur and Chlorine contamination of the roller pin-hole,
(2)Significant cold work hardening,
(3)Manufacturing residual stress.

Improved Marathon Control Rods-Inspection Results

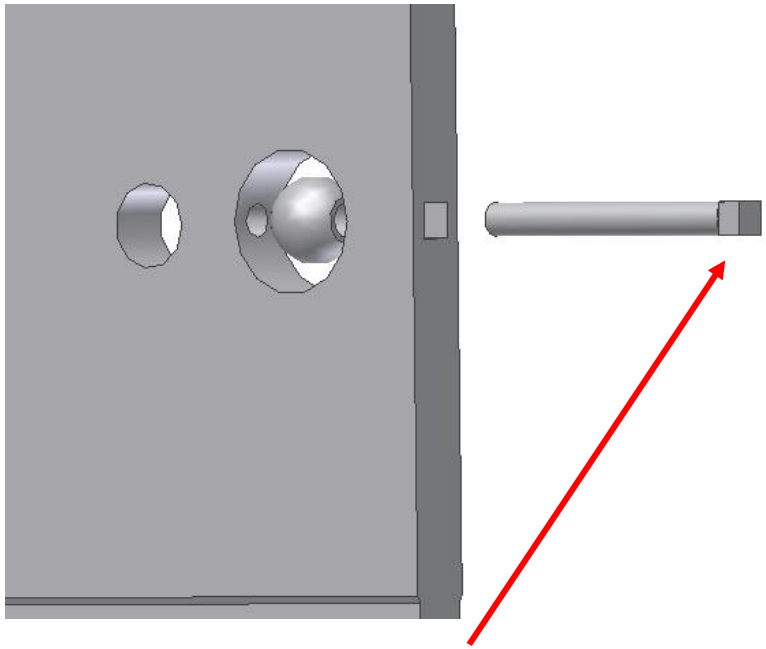
- In order to resolve the original Marathon CRB cracking issue, GE provided the Improved Marathon CRB for Chinshan and Kuosheng NPP to replace original Marathon CRB in 2002.
- After Chinshan unit 1 EOC-20 and Unit 2 EOC-20 (February 2004 and February 2005 respectively) outage inspection, there are 7 high burn up Improved Marathon CRBs being inspected and no indication being found.

Improved Marathon CRB

original Marathon CRB

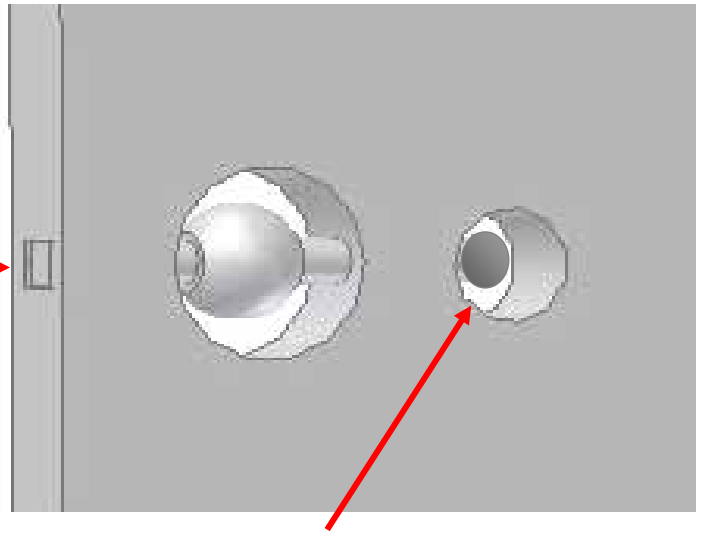


Extra Flow Hole



Outboard Square Pin

Capture weld Pin and Roller Assembly



Small weld deposit

Conclusions

For the last 5 years, Taipower has inspected all of their 4 BWRs' CRBs, and the results show that the cracking issue seems more severe than other countries. However, the cracking indications of those CRBs are still acceptable according to our safety evaluations.

Conclusions (Cont'd)

The recent improved Marathon CRB inspection results show that the root cause of the cracking may have been corrected, the TAEC still requires Taipower to take the following actions during routine outages:

(1)Taipower has to monitor one third of the CRBs which already have crack indications.

(2)Taipower has to choose one tenth of normal CRBs to follow up their integrity status.

(3)Taipower has to confirm that the Improved Marathon CRBs have no further crack indications.

Chinshan Unit 1 Control Rod Inspection Results

Inspection Cycle / Indication Category (No. of Indications / No. of Inspections)	EOC-17 (9/1999)	EOC-18 (2/2001)		EOC-19 (9/2002)	EOC-20 (2/2004)	
	D-215	D-215	D-100	D-215	D-215	#Marathon
Handle Roller Pinhole Outboard	1/8	19/65	1/23	20/75	9/26	0/6
Handle Roller Pinhole Inboard	0/8	0/65	0/23	7/75	0/26	0/6
Handle to Sheath*	0	0	0	23/75	1/26	0/6
Sheath to Tie Rod**	0	0	0	1/75	0/26	0/6
B_4C Absorber Tube	NA	NA	NA	0/75	NA	0/1

* Handle to Absorber Rod for Marathon
** Tie Rod to Absorber Rod for Marathon
# Marathon = Improved Marathon

Chinshan Unit 2 Control Rod Inspection Results

Inspection Cycle / Indication Category (No. of Indications / No. of Inspections)	EOC-17 (11/2000)		EOC-18 (2/2002)		EOC-19 (9/2003)			EOC-20 (2/2005)		
	D-215	D-100	D-215	D-100	D-215	D-100	Marathon	D-215	Marathon	#Marathon
Handle Roller Pinhole Outboard	10/66	1/22	26/75	0/22	4/33	0/1	15/17	4/19	2/8	0/1
Handle Roller Pinhole Inboard	0/66	0/22	3/75	0/22	0/33	0/1	0/17	1/19	0/8	0/1
Handle to Sheath*	0/66	0/22	13/75	0/22	3/33	0/1	0/17	2/19	0/8	0/1
Sheath to Tie Rod**	0	0/22	6/75	0/22	0/33	0/1	0/17	0/19	0/8	0/1
B_4C Absorber Tube	NA	NA	0/75	3/22	NA	0/1	NA	NA	NA	0/1

* Handle to Absorber Rod for Marathon
** Tie Rod to Absorber Rod for Marathon
# Marathon = Improved Marathon

Kuosheng Unit 1 Control Rod Inspection Results

Inspection Cycle / Indication Category (No. of Indications / No. of Inspections)	**EOC-15 (10/2001)**	**EOC-16 (5/2003)**	**EOC-17 (12/2004)**
	D-230	D-230	D-230
Handle Roller Pinhole Outboard	83/145	37/37	22/27
Handle Roller Pinhole Inboard	22/145	10/37	1/27
Handle to Sheath	60/145	13/37	7/27
Sheath to Tie Rod	0/24	0	0
Velocity Limiter to Sheath	0	0	0

Note: Type D-100 was used to replace the defective D-230 control rods.

Kuosheng Unit 2 Control Rod Inspection Results

Inspection Cycle / Indication Category	**EOC-14 (5/2001)**	**EOC-15 (12/2002)**	**EOC-16 (4/2004)**
	D-230	D-230	D-230
Handle Roller Pinhole Outboard	72/145	38/38	22/29
Handle Roller Pinhole Inboard	6/145	3/38	4/29
Handle to Sheath	54/145	9/38	6/29
Sheath to Tie Rod	0	0	0
Velocity Limiter to Sheath	0	0	0

Note: Type D-100 was used to replace the defective D-230 control rods.