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# Inspection of Control Rod Guide Assemblies in Belgian NPPs

International Workshop on Age-Related Degradation of Reactor Vessels and Internals, USNRC, Washington, 23-24/5/2019

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**TRACTEBEL**



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23/05/2019

Age-Related Degradation of Reactor Vessels and Internals, USNRC, Washington

# Background

- International guidelines and recommendations

- EPRI report MRP-227-A (2011): ‘PWR Internals Inspection and Evaluation Guidelines’
- Westinghouse NSAL-10-1 (2010): RCCA Guide Card Wear -> Lifetime expectations
- Westinghouse WCAP-17451-P (2013): Westinghouse Fleet Operational Projections  
-> Effective Full Power Years (EFPY) for baseline inspections

GT design	Units	Minimum operational EFPY (85% slot opening) – NSAL-10-1	EFPY for baseline inspections in WCAP-17451-P
14x14	Doel 1-2	> 40	38 to 42
15x15	Tihange 1	36	40 to 44
17x17 AS 17x17 AXLR	Tihange 2 / Doel 3 Tihange 3 / Doel 4	>40 >40	34 to 38 32 to 36

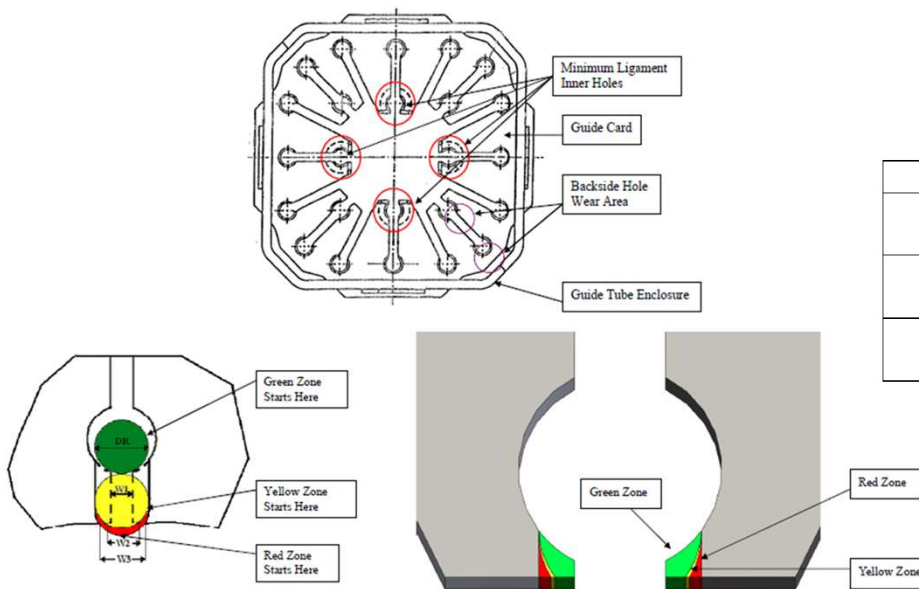
- Westinghouse NSAL-17-1 (2017): Recent operating experience with wear measurements in plants with 17x17 A or 17x17 AS guide tubes operating with ion-nitride RCCAs:  
-> Higher wear rate than expected -> Criteria defined in WCAP-17451-P are potentially non-conservative

# Wear criteria

- GCWM inspection decided after NSAL 17-1
- Wear criteria

## Guide Card Slot Opening Criteria Widths

$W_1$  = Nominal width of unworn guide card slot  
 $W_2$  = 0,8 x RCCA rodlet diameter (DR)  
 $W_3$  = 0,85 x RCCA rodlet diameter (DR)



## Cards

Criteria Zone	Range
Green Zone	Measured slot width less than $W_3$ at all guide cards
Yellow Zone	Measured slot width equal to or greater than $W_3$ for one to $(n - 1)$ consecutive guide card holes
Red Zone	Measured slot width equal to or greater than $W_3$ for $(n)$ consecutive guide card holes

-> Tihange 3/Doel 4: Six consecutive open cards ( $n = 6$ ) is an acceptable criterion

## Continuous Section

Criteria Zone	Zone Range <sup>(1)</sup>
Green Zone	Ligament wear less than $W_2$
Yellow Zone	Ligament wear equal to or greater than $W_2$ and less than $W_3$
Red Zone	Ligament wear equal to or greater than $W_3$

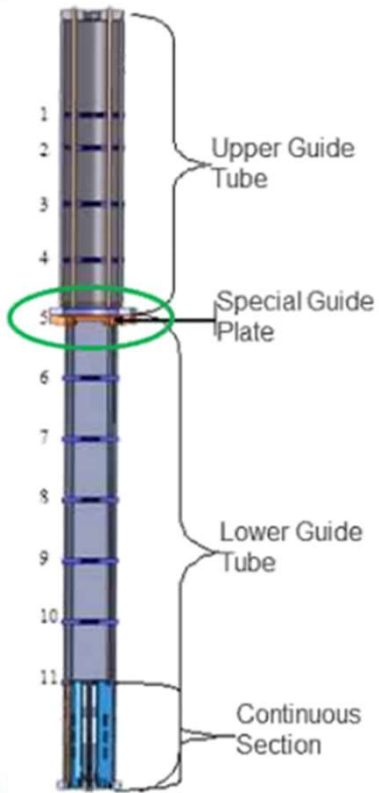
## Tihange 3 GT and RCCA characteristics

- The guide tubes are of the 17x17 AXLR design (14 ft) and have 11 guide cards and a continuous guiding zone.
- The total number of RCCAs in Tihange 3 is 52.
  - 16 ion-nitride RCCAs were loaded for the first time at the beginning of cycle 10 (1995).
  - 36 more ion-nitride RCCAs loaded for the first time at the beginning of cycle 11 (1996).
- Between 19 and 20.1 EFPY of operation with ion-nitride rods (in 2018)
- There are no non ion-nitride RCCAs remaining in the core since 1996, with some exemptions since 2010 where a few non ion-nitride RCCAs were used occasionally

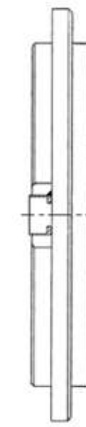
## Tihange 3 GCWM results

- GCWM inspection performed in 04/2018
- Extensive guide cards wear:
  - 35 guide tubes in “green” zone
  - 8 guide tubes in “yellow” zone
  - 9 guide tubes in “red” zone
- > 15 guide tubes were predicted not to be able to make two more fuel cycles → contingency measures
  - 2 guide tubes swapped with spare tubes already in reactor
  - 13 “Special Guide Plates” (specific feature of 17x17 guide tubes, where one guide plate is bolted and can be removed) replaced by Thicker Special Guide Plates (1.5 inch thick instead of 1 inch)

# Tihange 3 Thicker Special Guide Plates



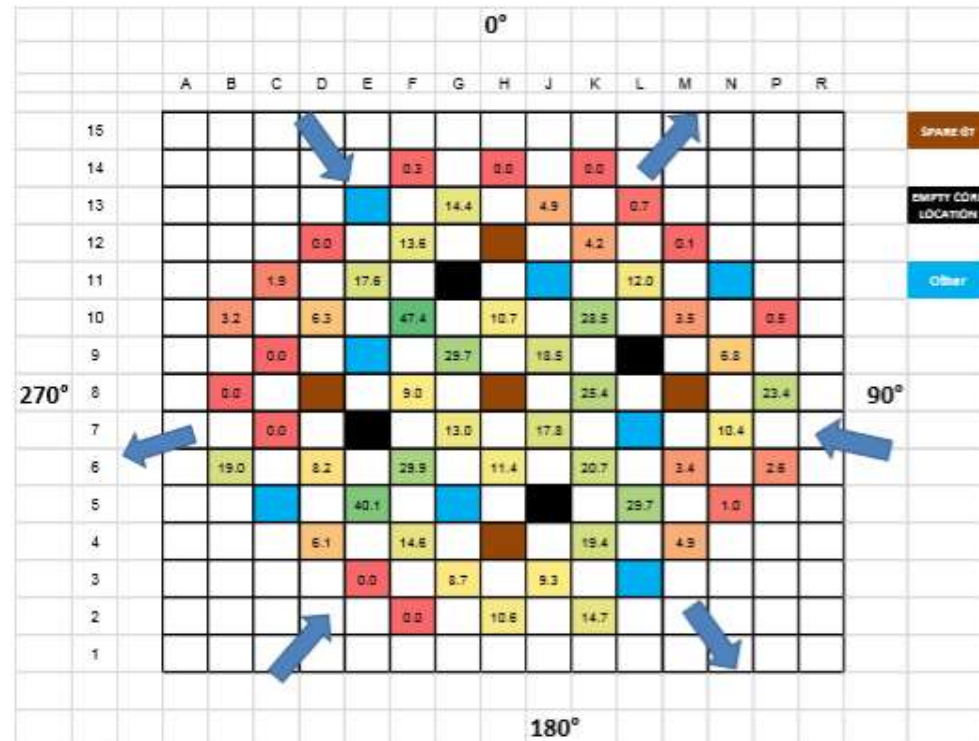
**Special Guide Plate (SGP)**



**Thicker Special Guide Plate (TSGP)**

# Tihange 3 GCWM results

- Core map with #EFPY to Red Zone:



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## Doel 4

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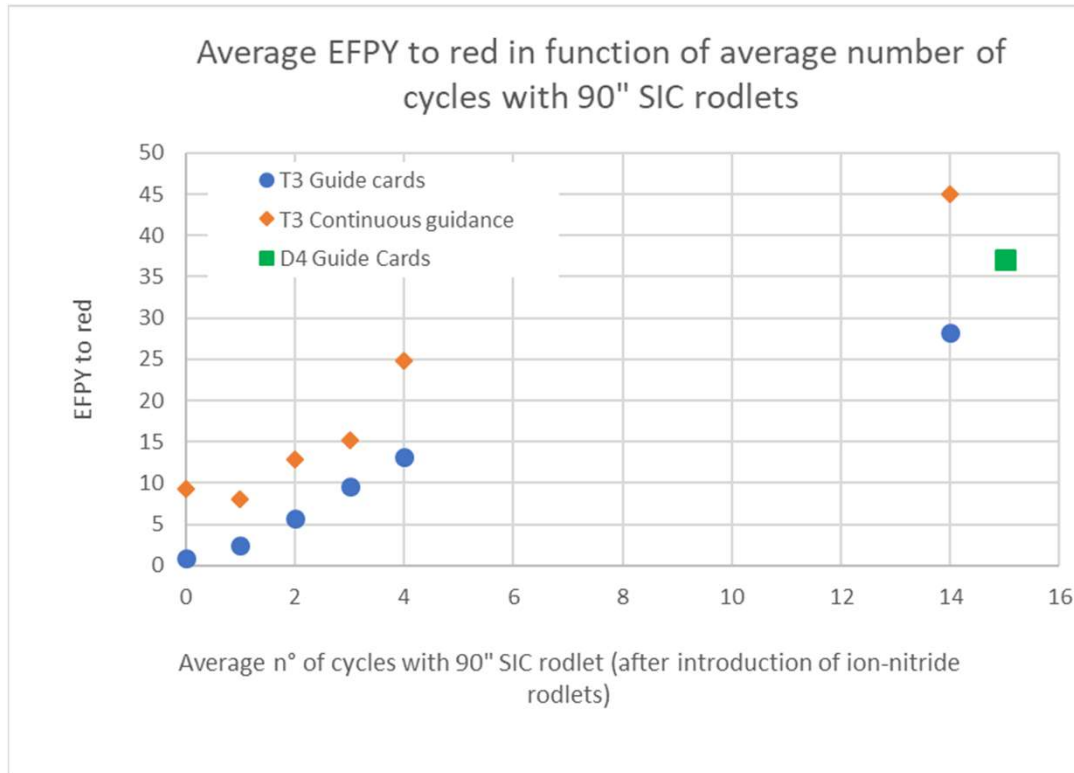
- Same design as Tihange 3
- All RCCAs are ion-nitride since cycle 15 (1999).
- 18.2 EFPY of operation with ion-nitride rods (in 2018)
- Following Tihange 3 inspection in 04/2018 significant wear was also expected in Doel 4.
- GCWM performed in 11/2018
- Surprisingly the results were very good, all guide tubes in green “condition”, minimum 12.7 EFPY before reaching “red” zone for most worn tube.



## Possible reason of differences between Doel 4 and Tihange 3

- Internal analysis: Both units use “hybrid” RCCAs with combination of Ag-In-Cd in lower part and B<sub>4</sub>C above; there is however one difference:
  - In Doel 4 all RCCAs have 90” Ag-In-Cd (two bars of 50” and 40”) since ion-nitride rods were introduced
  - In Tihange 3 most RCCAs were 40” Ag-In-Cd from 1996 to 2012, except for D and SD banks (where RCCAs with 90” Ag-In-Cd were used).
  - Since 2012, 90” Ag-In-Cd RCCAs are progressively introduced in all positions
  - Guide tubes of D and SD banks in Tihange 3 show much less wear (“green”)
  - 90” Ag-In-Cd RCCAs are heavier and stiffer, which influences vibration behaviour
  - There is a correlation between the number of cycles operated with 90” Ag-In-Cd RCCAs and the average number of EFPY to “red” condition, although the scatter is very high
- Westinghouse has been requested to come up with a reasoning – on-going

# Possible reason of differences between Doel 4 and Tihange 3



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## Doel 1&2

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- The 33 guide tubes are of the 14x14 design (8 ft). There are 7 guide cards and a continuous guiding zone.
- RCCAs with chrome-plated rodlets were introduced in 2005 to 2007 in Doel 1
  - In 2016, 7 of the 8 RCCAs introduced in 2005 were replaced by old standard RCCAs
- 20 RCCAs with chrome-plated rodlets were introduced in 2010-2011 in Doel 2, the remaining 13 are standard stainless steel rodlets.
- The guide cards and continuous section were inspected in all 33 guide tubes in Doel 1 and in Doel 2 in 06/2018 and only very limited wear was measured. All in “green” status
- Wear projections conclude it will be > 100 EFPY before any guide card or continuous section is projected to enter the red zone.

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## Doel 3 & Tihange 2

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- Guide tube of 17 x 17 AS design (12 ft, 10 guide cards and shorter continuous section than 17 x 17 standard)
- Ion-nitride RCCAs introduced between 1994 and 1999, all ion-nitride since 1999
- RCCAs are Ag-In-Cd type
- Based on WCAP-17451 Rev.1, GT had more than 34 EFPY before reaching “red” zone
- In 2018 Westinghouse reviewed FME videos from split pins replacement (2006 in D3, 2001 in T2)
- No significant wear identified, wear projection conclude to a time of 42.3 EFPY for next inspection
- This is beyond final shutdown date of 2022/2023.