Investigations into Surface Treatment Methods for Reduction of Recontamination of BWR Reactor Systems

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Background (1/2)

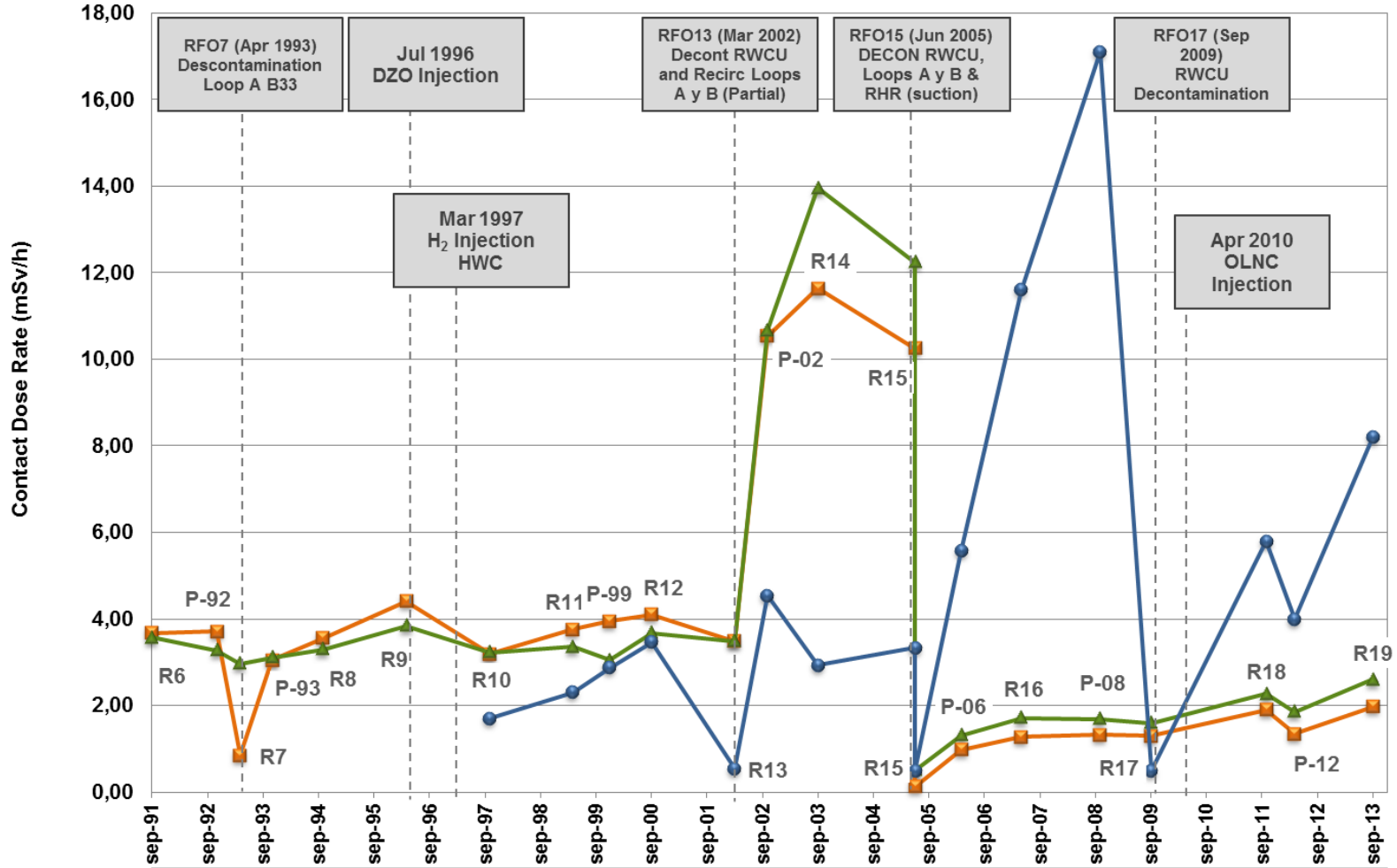
- The NPP Cofrentes is a 1100 MW_e-class GE BWR 6, located in Valencia province, East of Spain.
- The plant went commercial in March 1985
- The primary system has two external recirculation loops with Jet Pumps internals to the Reactor Vessel. The system is made of Stainless Steel (SS)
- The Reactor Water Clean Up (RWCU) piping is made of Carbon Steel
- Water chemistry operation history:
  - Zinc injection since June 1996
  - Normal Water Chemistry operation (NWC) until March 1997, Moderate Hydrogen Water Chemistry operation (HWC-M) until April 2010
  - HWC/OLNC/Zn chemistry until today (OLNC^{TM}; the process is patented by General Electric).
- The usual cycle length of the plant is 24 months since mid 2000's

Central Nuclear de Cofrentes

Background (2/2)

- The RWCU piping sections upstream the heat exchangers in the NPP Cofrentes were decontaminated with the AREVA CORD® CS process in 2002 (RFO 13), 2005 (RFO 15) and in 2009 (RFO 17).
- A fast and climbing recontamination of the piping sections was observed after each decontamination treatment.
- Transitioning of the plant to HWC/OLNC/Zn operation in 2010 did not result in the expected decrease in dose rates in RFO 18 in 2011.
- The NPP Cofrentes therefore considers another decontamination of the RWCU system in 2015 (RFO 20).

SOURCE TERM EVOLUTION AT RECIRC. LOOPS (B33) & RWCU (G33)



	sep-91	nov-92	abr-93	nov-93	oct-94	abr-96	oct-97	abr-99	dic-99	sep-00	mar-02	oct-02	sep-03	jun-05	jun-05	abr-06	may-07	oct-08	sep-09	oct-11	abr-12	sep-13
Recic LOOP A	3,68	3,71	0,85	3,05	3,56	4,41	3,19	3,77	3,96	4,11	3,49	10,54	11,64	10,25	0,13	0,98	1,28	1,32	1,30	1,90	1,35	1,98
Recirc LOOP B	3,58	3,28	2,97	3,11	3,30	3,84	3,23	3,36	3,05	3,68	3,49	10,67	13,95	12,24	0,51	1,31	1,71	1,69	1,60	2,28	1,85	2,60
RWCU Suction							1,70	2,30	2,87	3,46	0,54	4,54	2,93	3,33	0,49	5,57	11,60	17,10	0,50	5,80	4,00	8,20

Objective of the reported work

- Elaborate surface treatment methods for prevention of quick recontamination of BWR reactor coolant systems after decontamination treatments
- Test the mitigation effectiveness of the selected methods by an in-plant exposure program
- Apply the most effective method after the next decontamination treatment at the plant

- The work is performed in a joint R&D program of IBERDROLA, the operator of NPP Cofrentes, and AREVA
- The work was started in 2013
- Results after three months exposure of test tubes in the reactor system of NPP Cofrentes are reported in the following slides

Selected surface treatments

(1) Reference condition for these surface treatments and the in-plant exposure tests [1)]:
Carbon steel surfaces representative for decontaminations with the AREVA process CORD® CS

(2) Platinum deposition (so-called Low Temperature NobleChem process LTNC™, the process is patented by General Electric)

(3) Application of a Self-Assembling Monolayer SAM (patent application of AREVA GmbH pending)

(4) Platinum deposition followed by the application of a SAM

[1)] The surface treatments were elaborated and applied in a decontamination test facility of AREVA after a previous decontamination treatment

Visual appearance of the samples before in-plant exposure; Mitigation Principles

Post CORD CS treatment

Mitigation Principles

- Fe oxide film post decon (i.e. after the Fe oxalate destruction step and system rinse) is desirable for corrosion protection of the carbon steel surfaces until plant start-up after the outage
- Film properties not optimized yet for prevention of activity pick-up (this work)

Visual appearance of the samples before in-plant exposure; Mitigation Principles

Post decon plus Pt

Mitigation Principles

- Positive influence of Pt doping on stainless steel pipe dose rates proven by lab tests and plant operation experience
- Same effect is expected for carbon steel pipe work
- Provide Pt doped surfaces from start of the subsequent fuel cycle (LTNC™ process patented by General Electric)

⇒ Adjustment of Pt treatment parameters to carbon steel required: Pt content 1 - 2 % by weight determined by SEM EDX

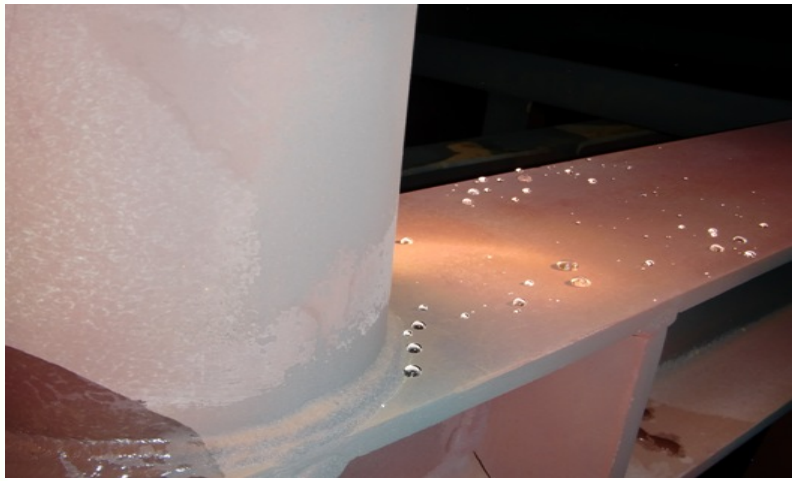
Visual appearance of the samples before in-plant exposure; Mitigation Principles

Post decon plus SAM

Mitigation principles

- Produce a more compact oxide film: SAM treatment removes loosely adherent oxide particles
- Prevent penetration of oxidants (i.e. O_2, H_2O_2) and nuclides into the oxide film: SAM treatment produces a water-repellent film on the carbon steel surfaces
- High film durability in water and steam proven by plant operation experience post SAM applications
- High radiation resistance of the films in reactor systems expected

SAM coats Properties and Application



Plant components after SAM treatment

- The coats consist of a water repellent film
- Application possible with decon equipment

Visual appearance of the samples before in-plant exposure; Mitigation principles

Post decon plus Pt & SAM

Mitigation principles

- Same as for Pt and SAM

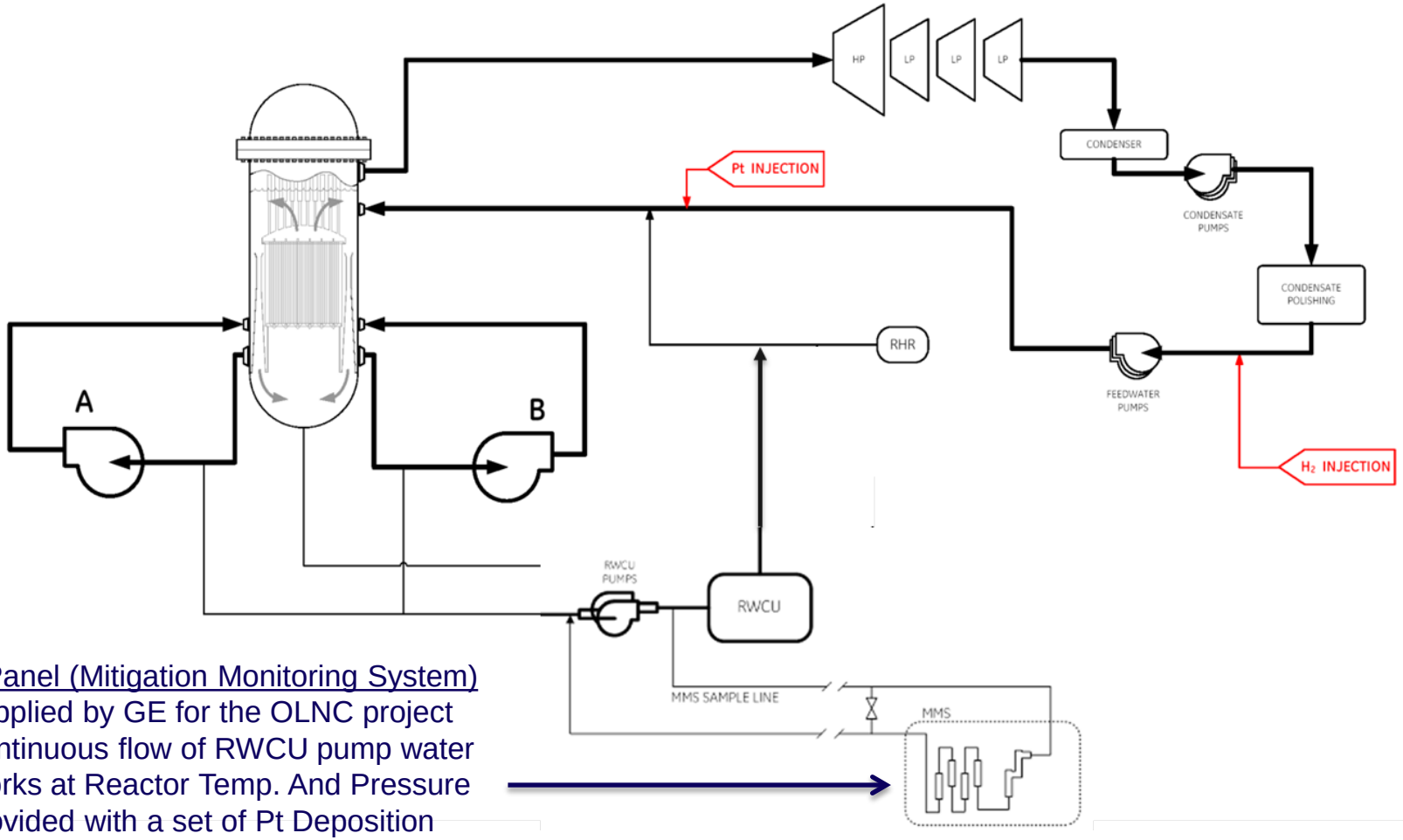
⇒ Is further reduction of recontamination by a combination of the positive effects of Pt and SAM possible?

- Pt loading of the sample:
  Platinum content 0.6 – 1.1 % by weight determined by SEM EDX

In-plant exposure tests: Approach

- Use the mitigation monitoring system at NPP Cofrentes for the in-plant exposure tests (MMS panel)
- Installed several sets of test samples during the 19th refueling outage of the plant in Oct. 2013
- Remove and replace the first set before OLNC treatment of the reactor coolant system, three months after start of the 20th fuel cycle
- Remove and replace additional sample sets later in the cycle
- Measure contact dose rates and nuclide-specific activities as a function of the surface treatment methods
- Determine also other properties of the oxide layers before and after in-plant exposure (e.g. Pt loading)
- The test samples were machined from ¾“ carbon steel tubes
- The selected carbon steel grade ASME SA179 is representative of the steel grade used at NPP Cofrentes

Location of MMS panel at Cofrentes NPP



MMS Panel (Mitigation Monitoring System)

- Supplied by GE for the OLNC project
- Continuous flow of RWCU pump water
- Works at Reactor Temp. And Pressure
- Provided with a set of Pt Deposition Coupons
- ECP, Temp. and Flow rate Instrumentation

In-plant exposure tests: First Results

Contact dose rates measured three months after BOC

Surface treatment condition	Contact Dose Rate (uSv/h)
Coupon 1-Decon Step	4300
Coupon 2-Pt Treatment	1280
Coupon 3-Pt+SAM Treatm	1490
Coupon 4-SAM	580

- 1st set of coupons removed from MMS panel on Jan 31, 2014
- Dose rates are dominated by Co-60
- Extremely high effectiveness for recontamination reduction confirmed for
  - Pt treatment
  - SAM treatment.
- As of today, both treatment methods are promising options for an application after the next system decontamination at NPP Cofrentes
- Combination of the two methods did not result in a further decrease in contact dose rates as compared to Pt alone

Data provides an excellent basis for further investigations and continuation of the joint R&D program.

Summary and Conclusions

- Pt and SAM treatment methods have been proven very effective for reduction of recontamination of carbon steel
- The effectiveness of the two methods will be confirmed for longer in-plant exposure times
- It is expected that both processes can be applied without difficulties at NPP Cofrentes after a decontamination treatment
- Adaption of the two processes to Cofrentes-specific conditions has to be examined with regard to
  - Time needed for their application
  - Dosing equipment and parameters
  - Process monitoring and control program
  - General robustness of the two processes.

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THANK YOU !