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Decontamination and post-decon Passivation treatment of the RRS Loops and RWCU System as a measure for Collective Dose Reduction and Recontamination Reduction at the NPP Cofrentes in Spain

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- Investigated post-decon surface treatments
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NPP Cofrentes

- 1100 MWe-class GE BWR 6
- Located in Spain
- Operated by IBERDROLA
- The plant went commercial in March1985
- Two recirc loops, system made of stainless steel
- RWCU piping made of carbon steel
- Normal cycle length is 24 months since mid 2000´s

Background

- The RWCU piping sections upstream the heat exchangers were decontaminated with the AREVA CORD® CS process in 2002, 2005 and in 2009
- 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
- NPP Cofrentes therefore planned another decontamination of the RWCU system in 2015 to reduce the collective radiation exposure during the outage maintenance works and then wanted to minimize the recontamination effect

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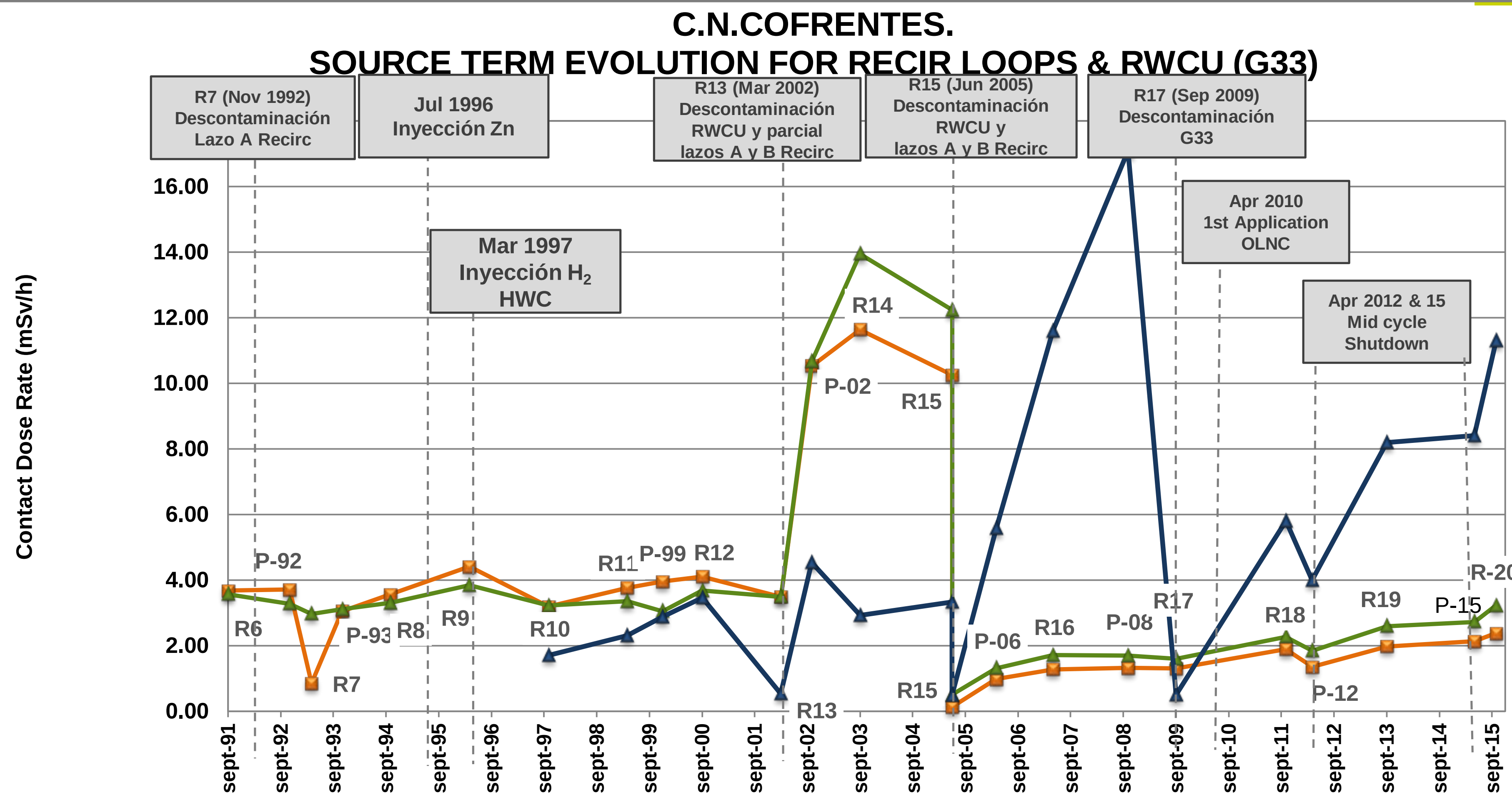
Water chemistry history and dose rate trends at NPP Cofrentes



	sept-91	nov-92	avr-93	nov-93	oct-94	avr-96	oct-97	avr-99	déc-99	sept-00	mars-02	oct-02	sept-03	juin-05	juin-05	avr-06	mai-07	oct-08	sept-09	oct-11	avr-12	sept-13	mai-15	sept-15
Lazo A Recirc	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	2.13	2.38
Lazo B Recirc	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	2.73	3.23
ASPIRACIÓN G33 (mSv/h)							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	8.40	11.30

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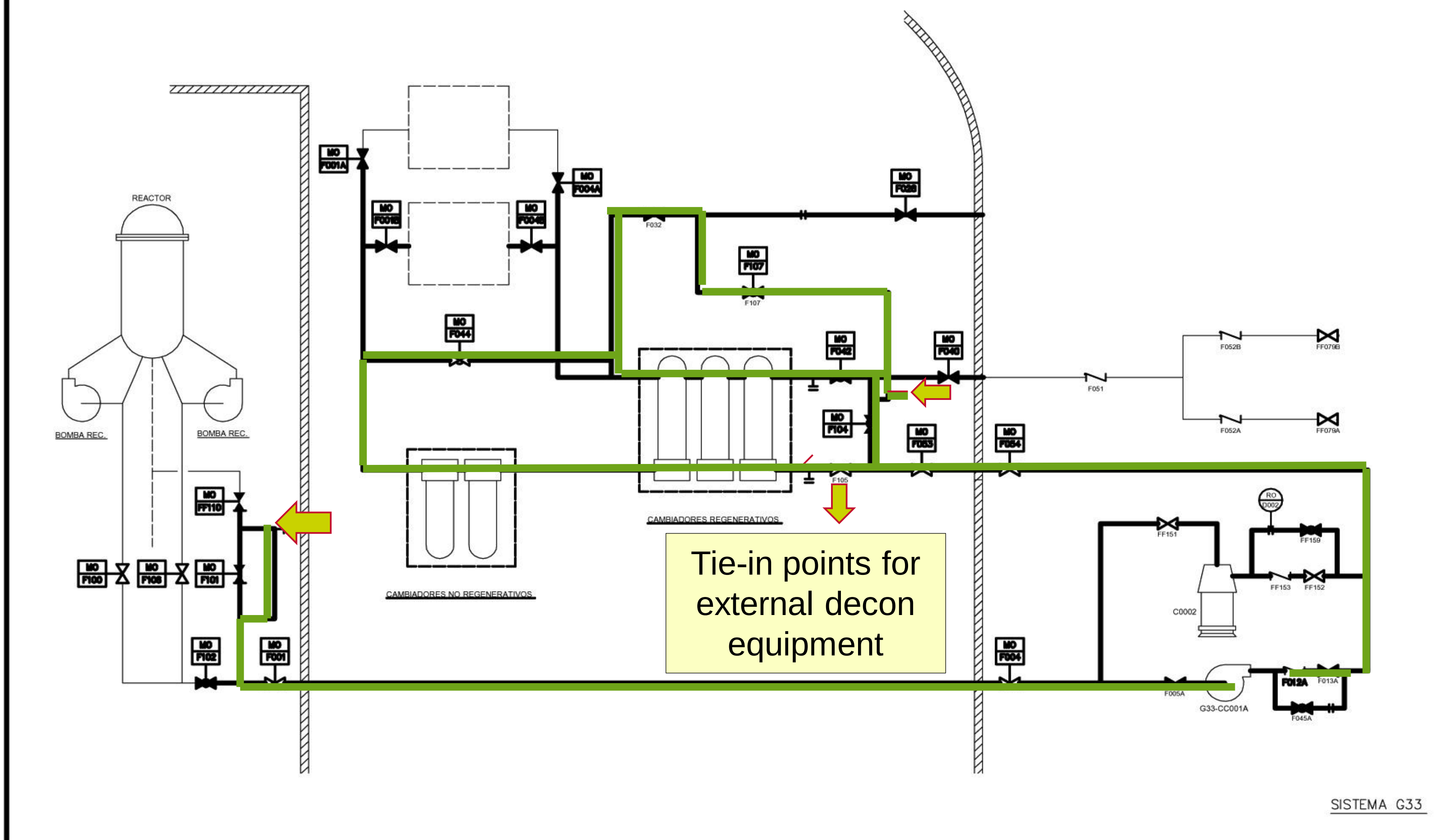
Chemical Decontamination at CN Cofrentes during Outage R20 in 2015

- **Decontamination Scope**
  - **Reactor Water Clean Up System RWCU (external circuit)**
  - **Reactor Recirculation System RRS (together with internal RWCU System)**
  - **Passivation treatment post decontamination to prevent quick recontamination**
- **Decontamination Target**
  - **Reduction of collective exposure for outage personnel for maintenance work (repair work on Recirc Loops shut-off valves and repair and substitution of several RWCU valves)**
  - **Average DF > 25 for both systems**
- **Given time frame during outage**
  - **3.5 days for RWCU external circuit (extension of time since out of critical path could be possible)**
  - **6.5 days for RRS and RWCU internal circuit**

Chemical Decontamination at CN Cofrentes during Outage R20 in 2015

Decontamination Area RWCU external system



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Decontamination of RWCU External system (out of containment)

- Decontamination circuit
  - Piping from Bottom Drain Line end cap till valve F105
  - From 2“ Decon outlet flange of RWCU Heat exchangers (including the RWCU regenerative and non-regenerative Heaters) till valve F105
- RWCU piping of carbon steel material
- Heat Exchanger tubes made of stainless steel
- System volume approx. 7 m^3
- Surfaces
  - 75m^2 carbon steel
  - 660 m^2 stainless steel
- Heat Exchangers not included in DF calculation

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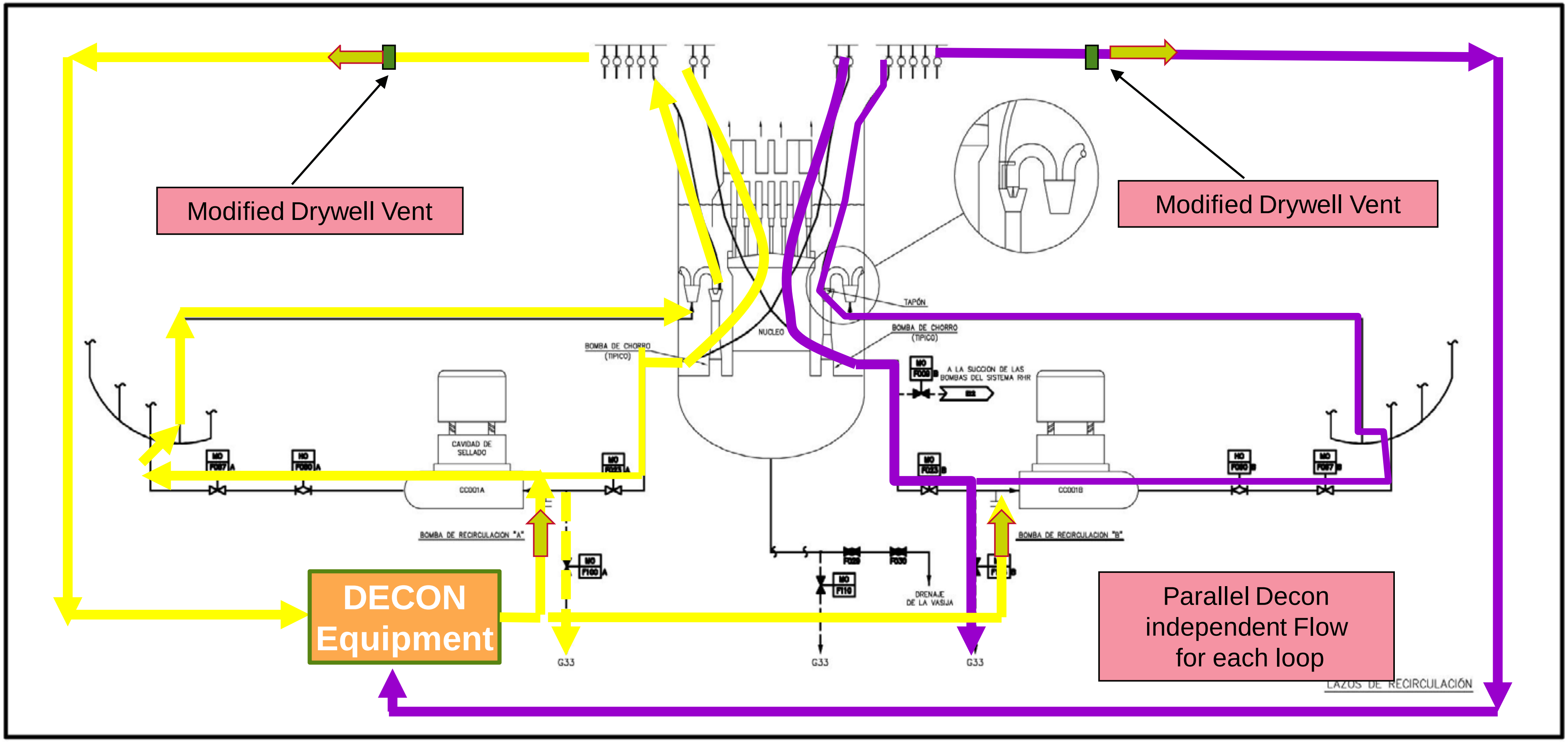
Decontamination of RRS and RWCU internal circuit (within containment)



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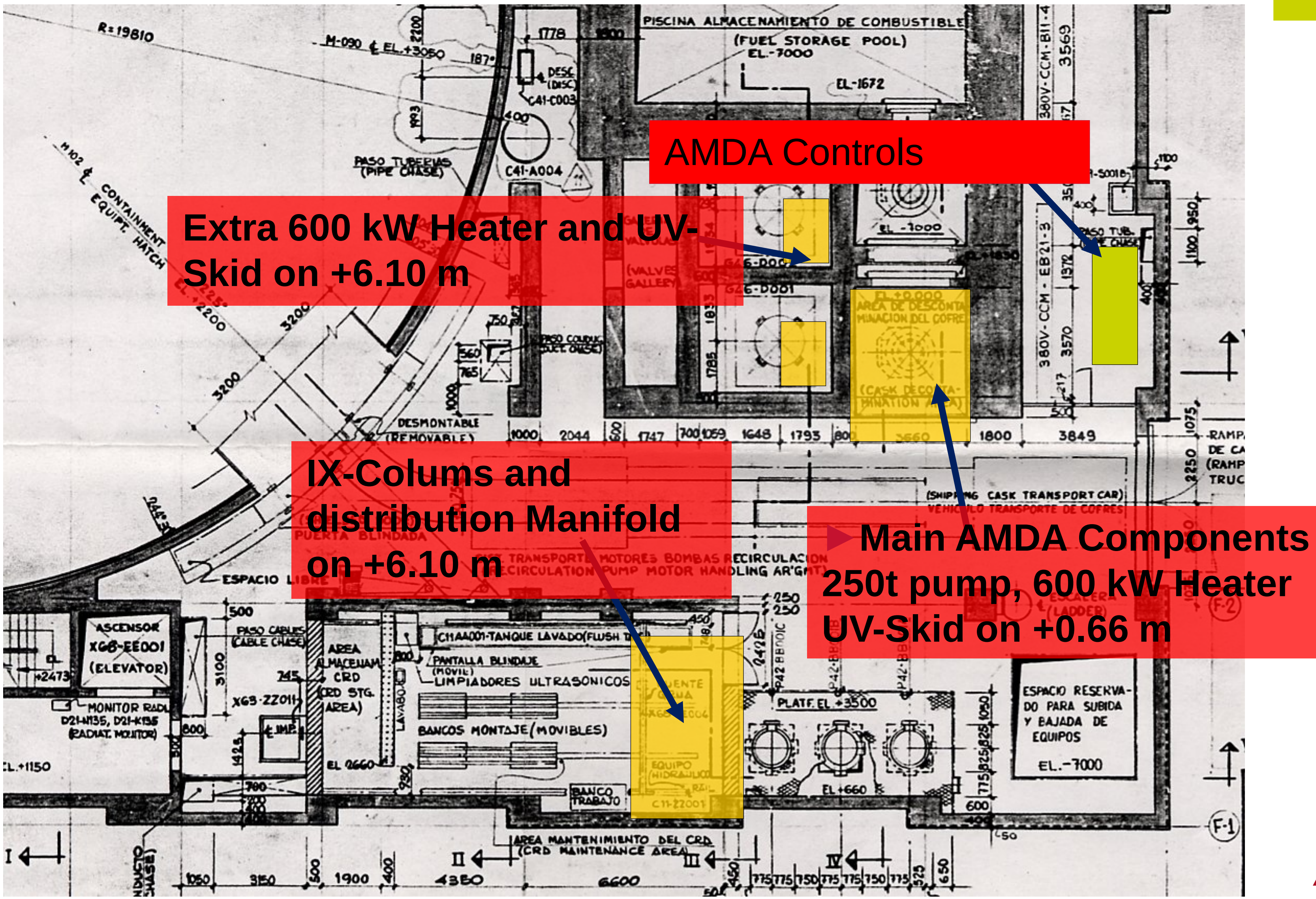
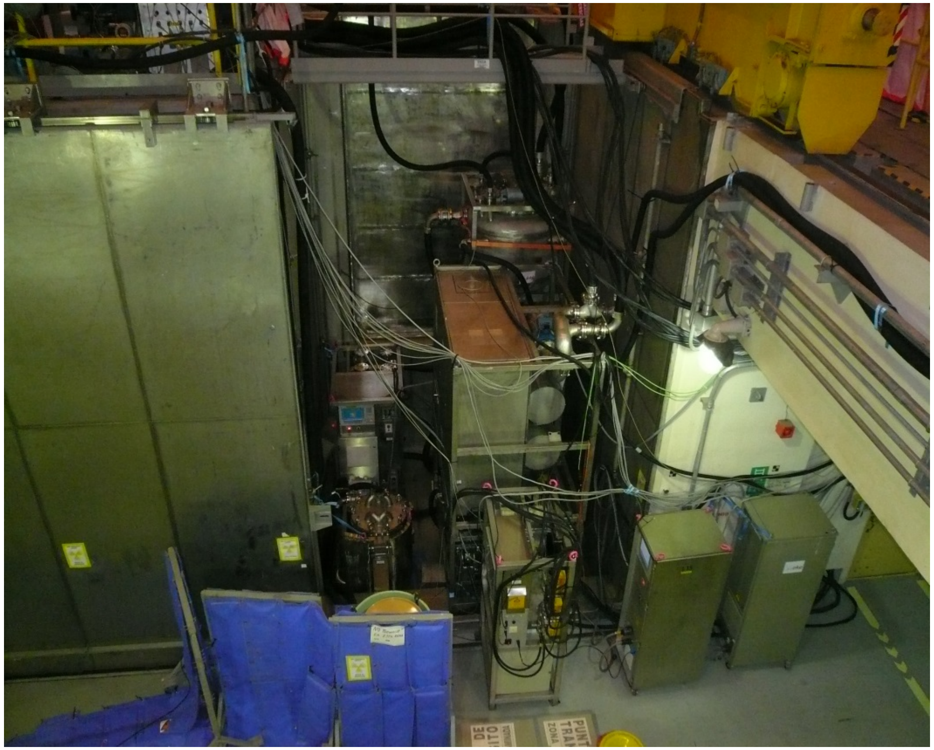
Decontamination of RRS and RWCU internal circuit

- Recirculation Loops A and B by recirculation through an in-reactor vessel connection for each loop
- Jet pump Plugs and N2- Nozzle (suction RRS) plugs for each loop connected by hoses to a vented header located at RPV flange elevation
- Each header returns through two hoses to the drywell via a reactor cavity connection (modified drywell vent connection)
- Core completely unloaded
- RWCU piping from both Loops returning to the Bottom Drain Line included in the decontamination circuit
- RPV in-vessel installations performed by CN Cofrentes
- Hardware for the In vessel connections designed by Cofrentes

AMDA Layout in Fuel Building on Elevations +0.66 and +6.10 m



Decon Equipment AMDA



AMDA Equipment set-up in Fuel Building

AMDA control centre

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System connections

Bottom Drain line connection RWCU

connection at 4“ Decon Nozzle RRS

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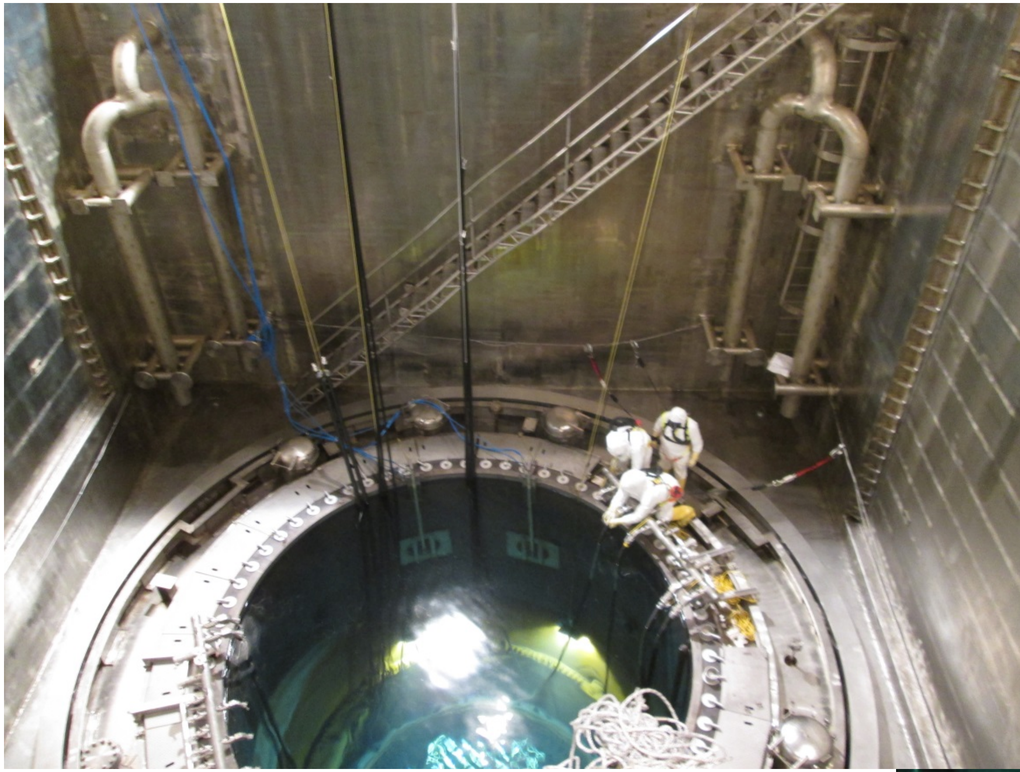
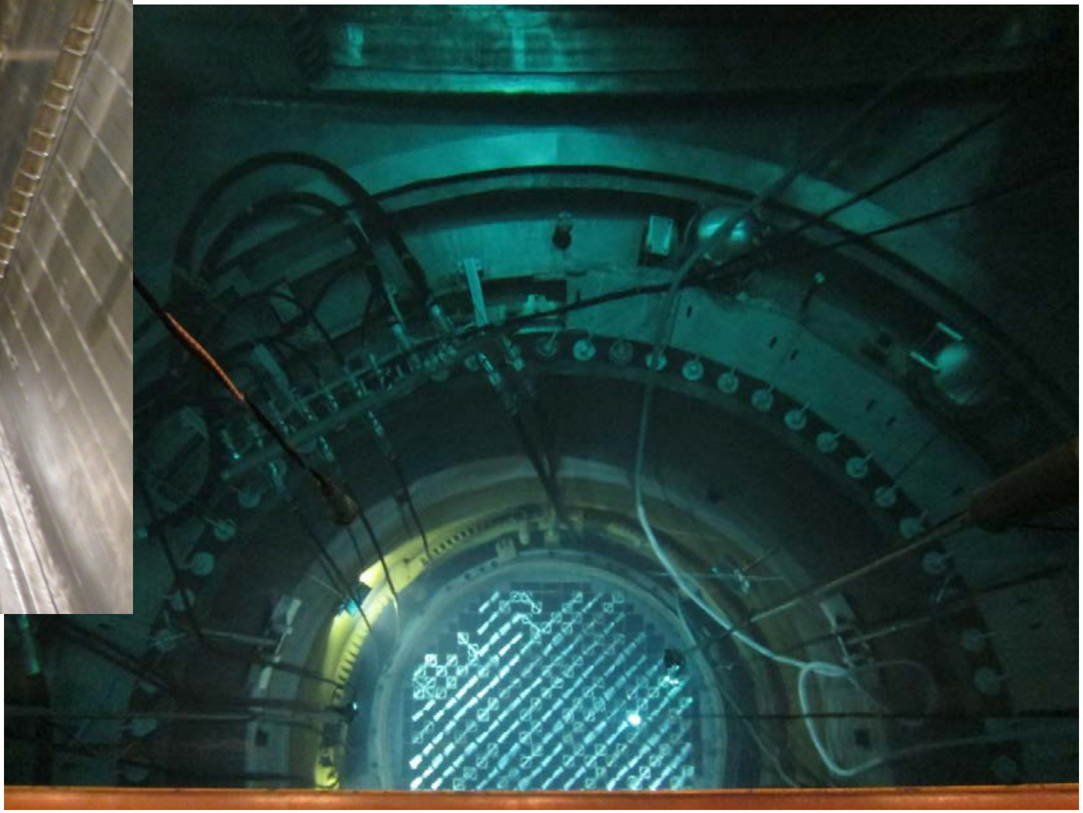
RPV Installations





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Decontamination Results

- Final average DF of 34 for RWCU external circuit
- Final average DF of 27 for RRS and RWCU internal circuit
  - Average DF of 8 on the RRS Loops
  - Average DF of 68 on the RWCU internal circuit
- 1000 liters of Resin waste produced (compared to 2600 liters estimated)
- Chemical Application Duration
  - 2 cycles CORD in RWCU external system applied in 4.5 days (3.5 days planned)
  - 3 cycles HP/CORD UV in RRS and RWCU internal system applied in 5.5 days (6.5 days planned) due to time reduction by Outage Management of the plant

Decontamination Results

- **Metallic shining surfaces after chemical decon and passivation treatments**
- **Considerable dose rate reduction in the lower elevation of the drywell**
- **Total collective dose for Decontamination works during the outage : 105 mSv (compared to the 110 mSv estimated)**
- **Total Net Personnel Dose savings in RFO20: 650 mSv·p**

RRS valve housing after chemical decontamination in 2015 (above) as compared to after high pressure water cleaning in 2011 (to the right)

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Post-decon Passivation Treatments Objectives

- Elaborate surface treatment methods for prevention of quick recontamination of Carbon Steel of BWR reactor coolant systems after decontamination applications
- 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 (Oct-2015)
- The work was performed in a joint R&D program of IBERDROLA and AREVA
  - The work was started in 2013
  - Results of research done up to date are provided in the following
- <u>Details and first results of the project were already presented at the ISOE conference in Apr-2014 in Bern.</u>

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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 NobleChem Technology™ 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**

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

2) **A total of SIX sets of test specimens were prepared for the In-plant exposure test**

In-plant exposure tests Approach

- **Use the Mitigation Monitoring System for the in-plant exposure tests (MMS panel)**
  - **The test samples were machined from ¾“ carbon steel tube**
  - **The selected carbon steel grade ASME SA179 is representative of the steel grade used at NPP Cofrentes**
  - **Oct. 2013: A total of 6 sets of test samples were installed during the 19th refueling outage of the plant**
    - End of Jan. 2014: First set removed and replaced three months after start of the 20th fuel cycle
    - End of April 2014 to end of January 2015: Replacement of another 4 sets, exposure time meanwhile covers fifteen months.
  - **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)**

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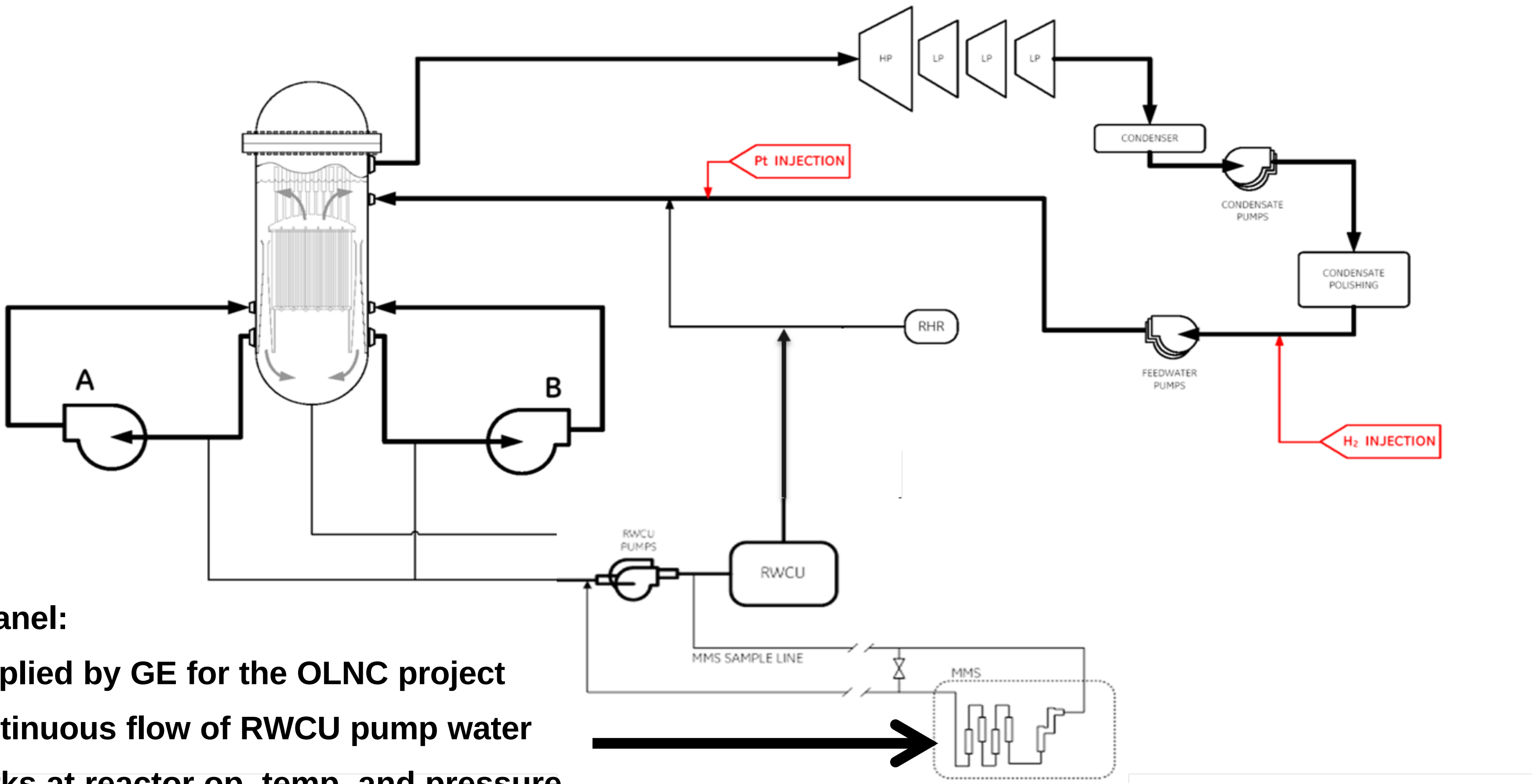
Location of the MMS panel



MMS panel:

- **Supplied by GE for the OLNC project**
- **Continuous flow of RWCU pump water**
- **Works at reactor op. temp. and pressure**
- **Provided with six sets of tube samples**
- **Program for extraction every 3 months in principle**

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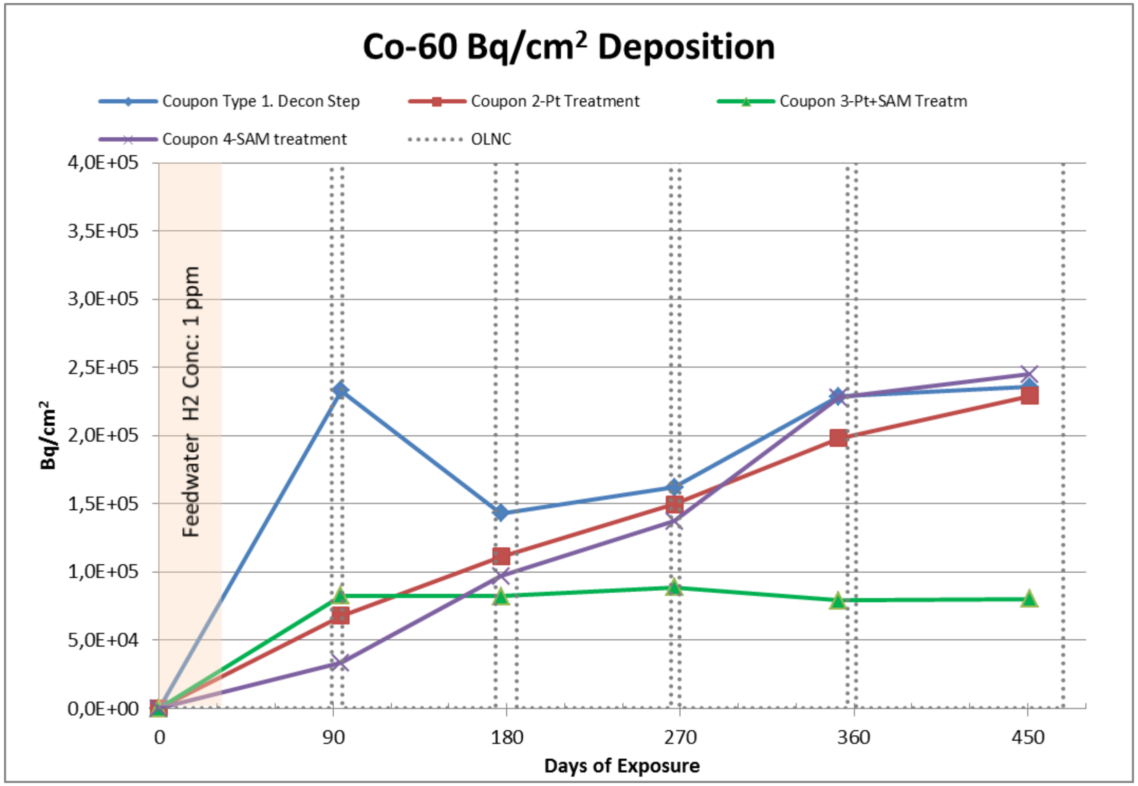
Surface Co-60 activities as a function of exposure time

SITUATION AFTER 15 MONTHS IN-PLANT EXPOSURE



- **Stable Co-60 trends after fifteen months of exposure**
- **Pronounced decrease in Co-60 activity of the Post Decon samples after 3 months of exposure can be explained by the conversion of the oxide layer induced by the OLNC treatment (particle release)**
- **Examination of the microstructure of the oxide layers after exposure has been done.**

►SAM treatment showed a benefit after 3 months (see ISOE 2014) but it has not kept the initial positive trend.

►Positive results obtained after 15 months lead to the choice of Pt+SAM as the surface treatment for the coming RFO20 decontamination

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Next steps and actions since March 2015

- **Microstructural examination of the oxide layers in the tubes after in-plant exposure; initiated in April 2015**
- **The in-plant exposure program was continued with the last set of coupons exposed for the whole 24 months cycle and extracted at the end of RFO20 (Nov-2015)**
- **Adaptation of Pt and SAM treatment steps to Cofrentes-specific conditions was accomplished ("process engineering") with regard to:**
  - **Time availibility for application**
  - **Dosing equipment and parameters**
  - **Process monitoring and control program**
- **RWCU System decontamination was applied in the RFO20 and a 24 hours surface treatment (Pt+SAM) was applied right after decontamination and the system returned into service**

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Coupon Microstructural Examination

- **A total of 12 shell plates (20x10 mm) cut from the CS coupons exposed to RWCU water at MMS panel in Cofrentes were sent to AREVA laboratories in Erlangen.**
- **<u>5</u> samples of Pt+SAM, <u>3</u> Decon reference (3, 9, 15 m exposed) samples of and <u>2</u> samples for each SAM and Pt treatment (3 and 15 months exposed).**
- **Microstructural examination consisted of:**
  - **Visual appearance of the oxide layers in the tubes and comparison of surface layer color after in plant exposure**
  - **Surface morphology (micro sections through the tube walls)**
  - **Oxide layers Composition and Pt content (SEM pictures, EDS analysis data)**

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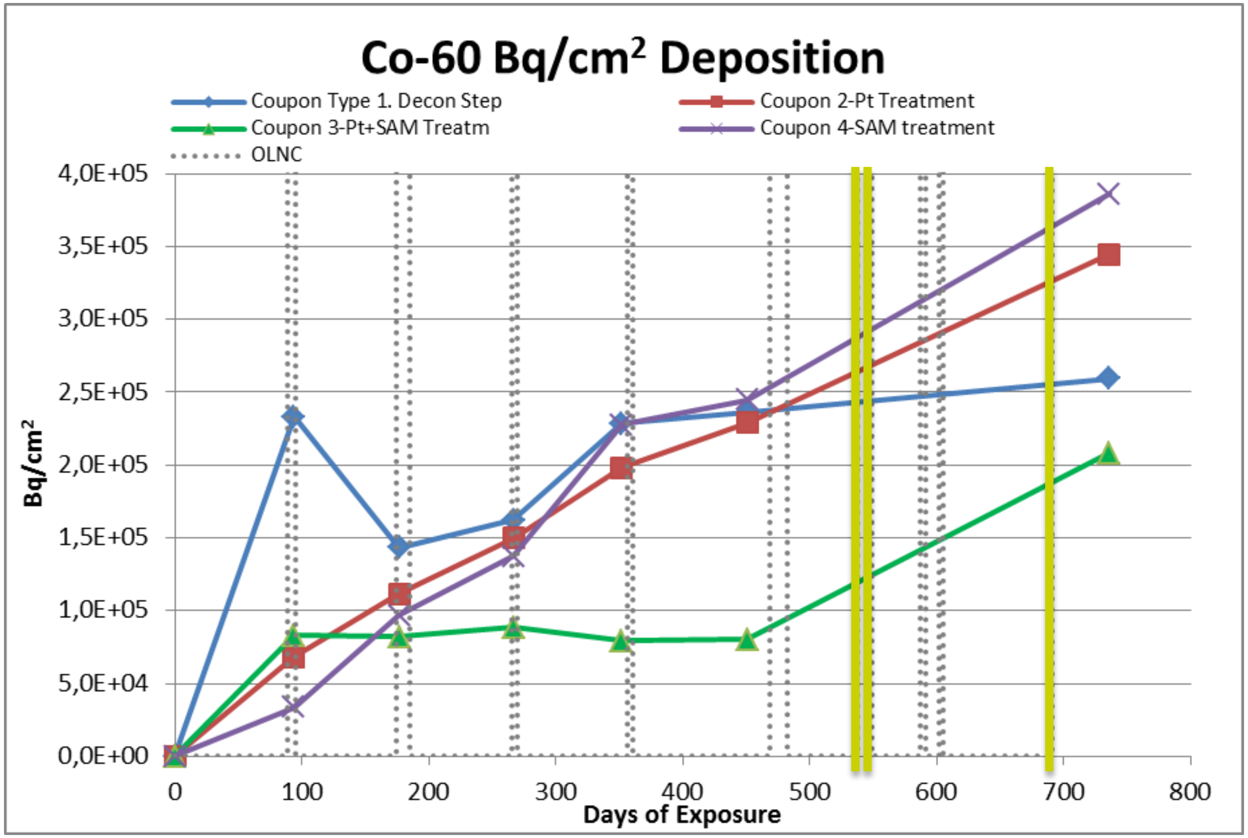
Oxide layers Composition & Pt content

SUMMARY OF SEM AND EDS RESULTS

- **Post Decon: High (Cr+Zn) values confirmed the incorporation of high amounts of corrosion products by the oxide layer especially within the first three months of exposure. Consistent with the fast activity buildup of this sample for the first period**
- **Pt : Steady increase in (Cr+Zn) values confirmed continuous incorporation of corrosion products by the oxide layer with exposure. No Pt detected by EDS**
- **SAM: (Cr+Zn) pickup is rather low during the first 3 months of exposure; consistent with very low activity incorporation, probably caused by the protective film. However, after 15 months the (Cr+Zn) values are similar to the Pt treatment sample**
- **Pt+SAM: The low (Cr+Zn) values along the 15 months can be taken as an indicator for a <u>stable oxide layer without significant pickup of corrosion products</u> during in-plant exposure. Contrary to the Pt only sample, the oxide layer in the Pt + FFA treated tube still contained measurable amounts of Pt after 3 and 6 months of exposure.**

In-Plant Exposure Update

SITUATION AFTER 24 MONTHS IN-PLANT EXPOSURE



- **Last set of samples extracted and analyzed at the end of the RFO-20**
- **The plant had a shutdown at the end of April-15 for replacing a fuel leaker and the outage started on Sept 27.**
- **Co-60 and other isotopes point out that the steady trend has moved and activity incorporation on surface has activated.**
- **The two shutdown operations and the activity released may have played some role on the drift of the trend.**

► A new examination campaign for the last extracted coupons is on going to find out the cause for the change

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Process Engineering and Plant Application

- **After the positive results obtained after 15 months exposure, another search was done in order to optimize the Pt+SAM application process.**
- **Challenge was to achieve similar surface condition in a process with total length of maximum 24 hours which was the time granted by the plant for this step in the outage critical path.**
- **A set of laboratory experiments lead to a proposed procedure that was finally applied in the outage, after the RWCU decontamination**
- **The decontamination process and the Pt+SAM treatment was applied successfully and with no delays or were any secondary effects observed after the Pt+SAM treatment.**
- **Final results of the effectiveness of the applied "conditioning" can be confirmed only in the next plant shutdown**

Conclusions

- Decontamination performed at Cofrentes in the RFO20 by the CORD - UV process fulfilled the goals in all the aspects
- Recontamination reduction of carbon steel piping is a very ambitious task
- A set of proposed surface conditioning treatments have been proposed and applied to a set of probes that have been exposed for a full 24 months cycle at the plant
- 15 months In-plant exposure tests yielded positive results for one of the treatments; 70% reduction in activity build-up for the Pt+SAM
- Morphology exams and microscopic analysis of the exposed surfaces showed an stable Fe_2O_3 layer responsible for the minimized uptake of corrosion products
- Engineering of process application has been done and the Pt+SAM treatment has been applied after the system decontamination in October-15

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THANK YOU!

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