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STATUS REPORT ON ZORITA NPP CONCRETE AGEING PROJECT

CEIDEN
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3 | Plant description (1/2)

- Zorita NPP consists of a PWR reactor, 1 loop, W design. 160 Mwe output
- It was commissioned in 1968, and it operated until 2006
- On february 2010, ENRESA took the responsibility for decommissioning the station



José Cabrera NPP (Zorita)

4 | Organization

Current partners of the project:

- ENRESA (National Company of Nuclear Waste), in charge of the dismantling process of Zorita NPP
- ENDESA (utility)
- IBERDROLA (utility)
- GAS NATURAL FENOSA (utility), licensee during operation of Zorita NPP
- IETcc (Instituto Eduardo Torroja de Ciencias de la Construcción), R&D lab.
- CSN (Consejo de Seguridad Nuclear, Spanish Nuclear Regulator)
- The project is being developed through a Steering Committee and a Technical Committee
- Managing coordination: ENRESA
- Technical coordination: IETcc
- A formal cooperative agreement is in place
- The project will be opened to other national or international organizations

5 | Bibliography review. Irradiation

- GAP analysis on the degradation of concrete structures on NPPs, due to irradiation
 - Literature references on the effect of radiation in concrete properties indicate that values around or above **$1 \times 10^{19} \text{ n/cm}^2$** might be the threshold for concrete degradation (H.K. Hilsdorf & J. Kropp, ACI SP-55, 1978)
 - The majority of the research performed until now was made in laboratory conditions which are different than the real ones in operation → Extrapolation concerns
- Preliminary calculations made by ENRESA (decommissioning project) have given an estimation of neutronic fluence about **$8 \times 10^{18} \text{ n/cm}^2$** on the concrete of the biological shielding of Zorita NPP

7 | Bibliography review. Temperature

- GAP analysis on the degradation of concrete structures on NPPs, due to temperature
 - It is well known the effects of short events, type fire, but not the effects of medium to high temperatures for long periods of time
 - Concerning the effect of temperature in the biological shielding around the reactor it also depends on the interaction of **gamma radiation** with concrete and not only on the temperature of the components
 - The literature related is also scarce (Kontani et al, proceedings of ICAPP Conference, 2011) and indicates that higher doses than **10^{10} rads** might produce effects

8 | Stressors selection

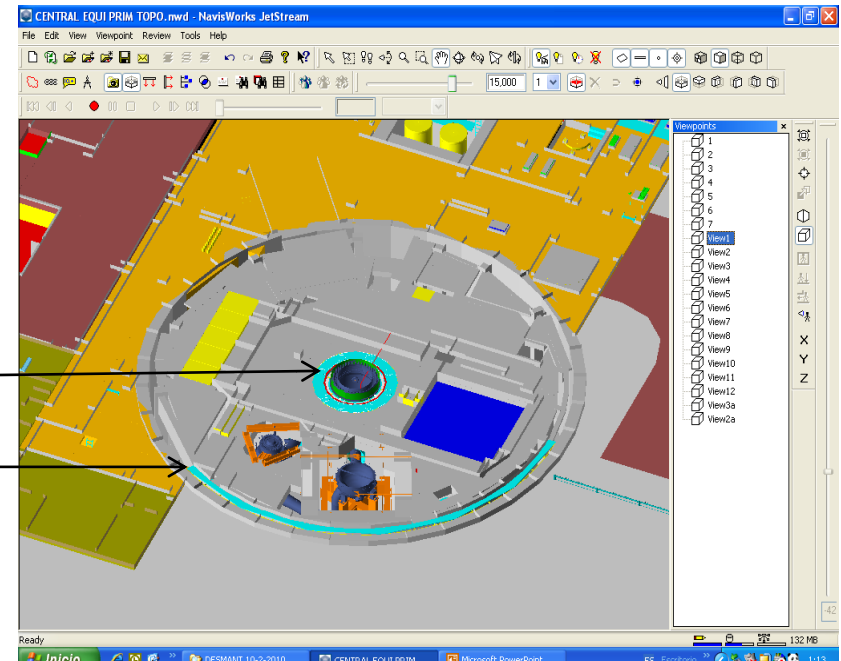
Stressors selection:

- As a consequence of the Gap Analysis, it was agreed that the effects of the following stressors on concrete will be studied:
 - High levels of neutron and gamma radiation
 - High temperature for long periods of time, taking also into account gamma radiation effects
 - Boric acid effects on concrete structures, and
 - NDT on liner under concrete slab
- The objective consists in developing experimental tests and theoretical studies, related to the **aging and degradation of concrete** in the particular service conditions (**radiation, temperature and chemicals**) of **nuclear plants** in operation
- ✓ Only those aspects relevant for the life management of NPPs and also important for other nuclear applications (spent fuel containers, centralized storages,...) will be addressed

9 | Structures

Structures to be considered:

- Biological shielding (radiation and temperature)
- Spent fuel pool/transfer channel (boric acid)
- Containment building (as reference)
- Steel liner under concrete slab (NDT)



10 | Samples. Irradiation (2/5)

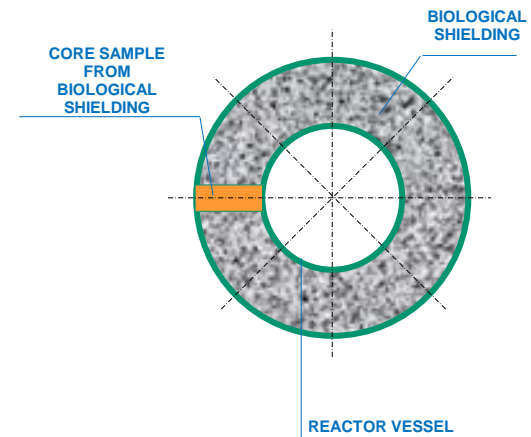
Biological shielding. Core samples identification (irradiation) :

- Symetry of the irradiation level around the fuel elements is 1/8
- This means that 8* core samples with the maximum level of irradiation can be obtained

For their identification, the same methodology of the ZIRP project will be used:

Neutron and Gamma sources calculation

- Compilation of 29 cicles of operation (38 Years ↔ 26.36 EFPY): Load patterns, cicle duration, power and burnup montly history, moderated high and low leaks configuration, upflow-downflow configuration of core bypass



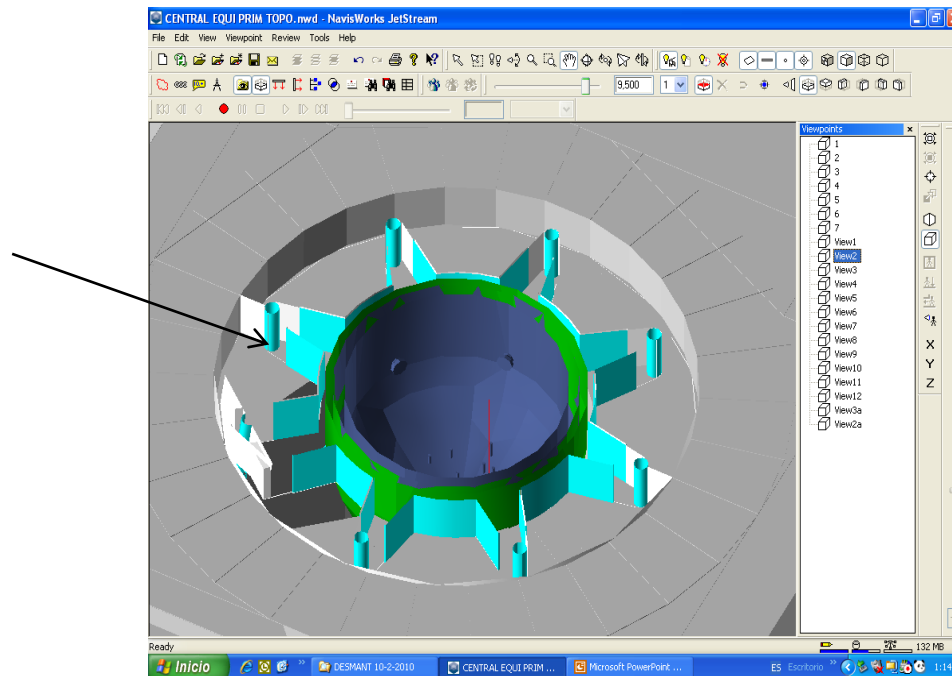
* In fact, due to the irradiation profile, more samples with very similar levels of irradiation could be obtained.

11 | Samples. Irradiation (4/5)

Biological shielding. Core samples identification (irradiation)

- Also a rough estimation of fluence and gamma radiation will be obtained from the instrumentation wells and from operating experience

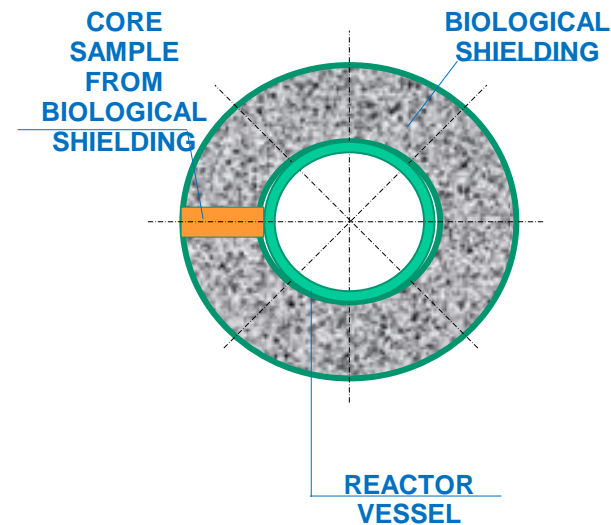
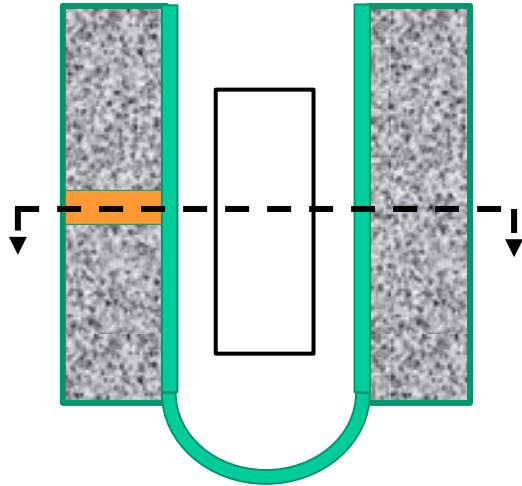
Instrumentation wells



12 | Samples. Irradiation (5/5)

Biological shielding. Core samples (irradiation):

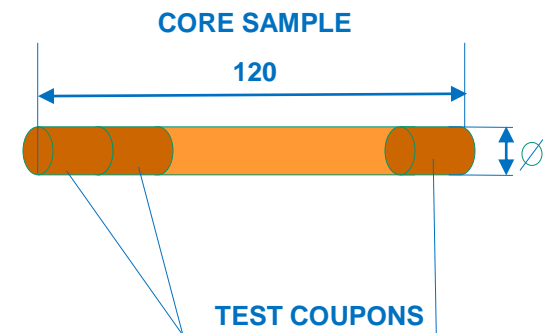
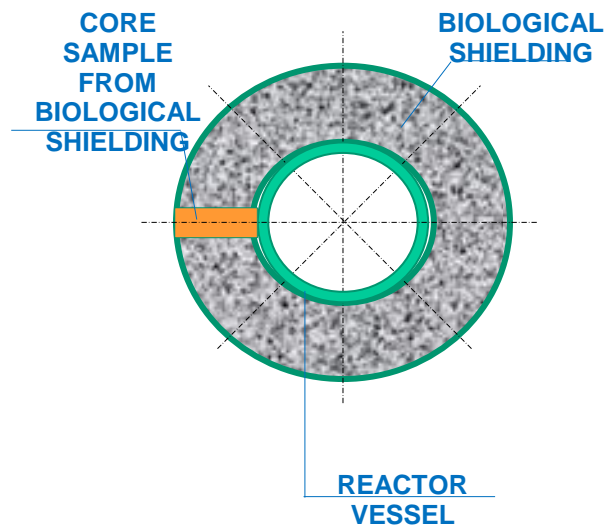
- The biological shielding will be drilled in-situ, in the identified locations, from reactor vessel side or from the opposite side, still to be decided



13 | Test coupons. Irradiation

Test coupons (irradiation):

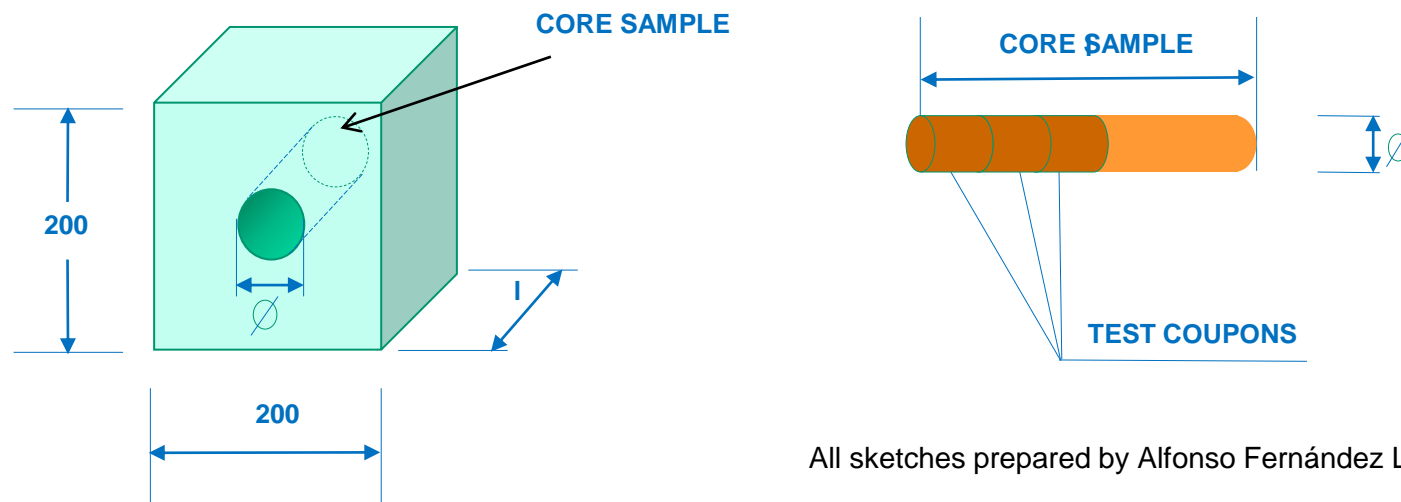
- From each core sample several test coupons will be obtained:
 - The closest to the reactor vessel
 - One from the opposite side
 - Some intermediate ones
- This approach will also allowed to determine the attenuation effects
- Dimensions of test coupons still to be decided



14 | Samples. Boric acid

Spent fuel pool/transfer channel. Core samples (boric acid):

- The core samples of the spent fuel pool/transfer channel will be identified through analysis of operating experience:
 - Boric acid leaks during operation or refuelling outages
- Blocks of 2x2 meters will be cut
- As in the previous stage, core samples will be drilled from the blocks and from these cores tests coupons will be cut



15 | Test coupons matrix(1/2)

STRUCTURE	No. CORES	SPECIMENS BY CORE	TESTS	EXPOSURE
Biological shielding wall of high density	$4 + 1^{**} + 2^{***} = 7 \text{ T}$	$(1\text{T} \times 3\text{P}/\text{T}) + (3\text{T} \times 2\text{P}/\text{T}) = 9 \text{ P}$	Table 2. Issue 1, 2	Maximum radiation
	$2 + 1^{**} = 3 \text{ T}$	$(1\text{T} \times 3\text{P}/\text{T}) + (1\text{T} \times 2\text{P}/\text{T}) = 5 \text{ P}$		Maximum temperature (with or without radiation)
	$2 + 1^{**} = 3 \text{ T}$	$(1\text{T} \times 3\text{P}/\text{T}) + (1\text{T} \times 2\text{P}/\text{T}) = 5 \text{ P}$		Combination of radiation and temperature
	$2^{****} = 2 \text{ T}$	$(2\text{T} \times 2\text{P}/\text{T}) = 4 \text{ P}$		Maximum temperature without radiation
Spent fuel pool ¹	$2^* = 2 \text{ T}$	$2 \text{ T} \times 1\text{P}/\text{T} = 2 \text{ P}$	Table 2. issues 1, 2	Without contact to boric acid. To be used as reference
	$2^* = 2 \text{ T}$	$2 \text{ T} \times 1\text{P}/\text{T} = 2 \text{ P}$		Seldom contact to boric acid
	$2 = 2 \text{ T}$	$2 \text{ T} \times 1\text{P}/\text{T} = 2 \text{ P}$		Leaking places to the exterior and the collector of leaks
Mobile pieces in the transference channel ¹	$2^* = 2 \text{ T}$	$2 \text{ T} \times 1\text{P}/\text{T} = 2 \text{ P}$	Table 2. issue 1, 2	Without contact to boric acid. To be used as reference
	$2^* = 2 \text{ T}$	$2 \text{ T} \times 1\text{P}/\text{T} = 2 \text{ P}$		Seldom contact to boric acid

* These cores are located in already cut concrete pieces.

** Cores to be drilled in case on unforeseen incidences.

*** Recommendation from EPRI for accelerated radiation tests.

**** for discriminating effects of temperature and radiation.

¹ If the concretes are the same, the cores will be drilled only in one of the structures.

16 | Test coupons matrix (2/2)

STRUCTURE	No. CORES	SPECIMENS BY CORE	TESTS	EXPOSURE
Liner in the containment building below the basic floor slab	2= 2 T	2Tx1P/T= 2P	Table 2. issue 4	Humidity of condensation. The cores will be drilled in the contact phase with the liner.
Containment Building	4= 4 T	4Tx1P/T= 4P	Table 2. issue 1, 2 y 3 (except carbonation)	Outdoor ambient: two orientations at two heights above ground level. One (30 cm) should detect capillary rise effect
Material submitted only to indoors ambient in the containment building; to be used as reference	2= 2 T	2Tx1P/T= 2P	Table 2. issue 1, 2	Indoor ambient
Spent fuel pool	N/A	N/A	Visual Inspection	Effects of boric acid. Inspection to be made after removal of liner in the tank of spent fuel pool.

17 | Testing

Testing

- Test coupons coming from the biological shielding, the spent fuel pool/transfer channel and containment will be tested in IETcc research lab or in ENRESAS's facilities, in case they are contaminated
- The envisaged tests to be carried out are those that the international community has already identified as necessary to determine the temperature and radiation damage in concrete structures
- This tests will include:
 - Mechanical
 - Microestructural
 - Others
- Two sets of tests have also been defined for characterization of concrete and liner corrosion

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Testing matrix

TESTS TO BE PERFORMED		
LOCATIONS	CONCEPT	OBSERVATIONS
1	Tests on specimens: <ul style="list-style-type: none"> Mechanical strength Electrical resistivity Ultrasound velocity 	Either for the resistivity or the UT pulses, the technique to be used is with face-to face electrodes.
2	Microstructural analysis on the concrete: <ul style="list-style-type: none"> Porosity Microscopical analysis including elemental composition, cracks and damages Carbonation depth Identification of concrete phases: Differential and thermogravimetric Thermal Analysis (DTA-TG) and XR diffraction (XRD). 	
3	<ul style="list-style-type: none"> In situ non destructive testing (corrosion, resistivity, ultrasound velocity) Carbonation 	These methods are taken in different samples others than in location 1. The resistivity will be measured through 1 and through 4 electrodes. (Disc method and four points method). The corrosion will be measured through the modulated confinement of the current with a guard ring in the probe containing the counter electrode. The UT velocity will be measured with the electrodes in coplanar position.
4	Corrosion measurement in the liner by means of the Polarization resistance technique.	The same corrosion technique will be used than in location 3.

19 | Next Steps

The following activities are foreseen:

- Fluence calculations (same methodology as in ZIRP). All data already available
- Temperature calculations (same as in ZIRP+operating experience)
- Identification of the exact locations of cores to be removed (synergy with ZIRP)
- Protocols/procedures for:
 - Removal of cores
 - Labelling of cores
- Storage
- Shipping to testing facility
- Testing performance
- ✓ Quality Assurance system of each organization will be applied

20 | Committees

Technical Committee (TC) members:

- Carmen Andrade (Chairperson), IETcc
- Eduardo Más (secretary), CSN
- Manuel Ordoñez, ENRESA
- Eduardo Serra, ENDESA
- Pedro Ortega, GAS NATURAL FENOSA
- Félix Pascual, IBERDROLA
- Carlos Castelao, CSN

GAS NATURAL FENOSA Engineering is supporting the TC work in recovering data and documentation from Zorita NPP

- A Steering Committee with a representative from each participating organization is also in place

21 | Actualización de actividades a octubre 2015

- Caracterización química del hormigón.
- Cálculo detallado de flujo neutrónico y perfil de temperaturas
- Plan de segmentación del hormigón de blindaje
- Correlación testigos de hormigón –bloques de segmentación.
- Elaboración de procedimientos
- Adquisición de nuevo equipamiento de laboratorio.

Gracias por su atención