Decommissioning project, management and planning aspects for the decommissioning of Research Reactor Ispra1

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Introduction and motivation

The present work illustrates the study conducted for the:

- evaluation of the residual radiological contamination assessed by DA assays
- activation calculations with the Monte Carlo N-Particle Transport Code

in order to obtain

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The Decommissioning Plan of ISPRA1 Research Reactor

and demonstrate the feasibility and reliability of the planned operations in terms of:

- *contamination / activation management for waste minimization*
- *preliminary dose assessments to optimize occupational exposures through the application of the ALARA principle*

ALARA "as low as reasonably achievable“ objectives:

- No work incidents
- No nuclear incidents (no release of radioactive substances into the environment, no on-site cross contamination, no internal human contamination, etc.)
- Minimal collective and individual doses according to the ALARA principle

Introduction and motivation

1) Occupational doses in Decommissioning of a Research Plant

2) Optimization of the operative techniques foreseen in the cutting station

3) Management of materials according to radiological characteristics

are determined by a large number of parameters, including:

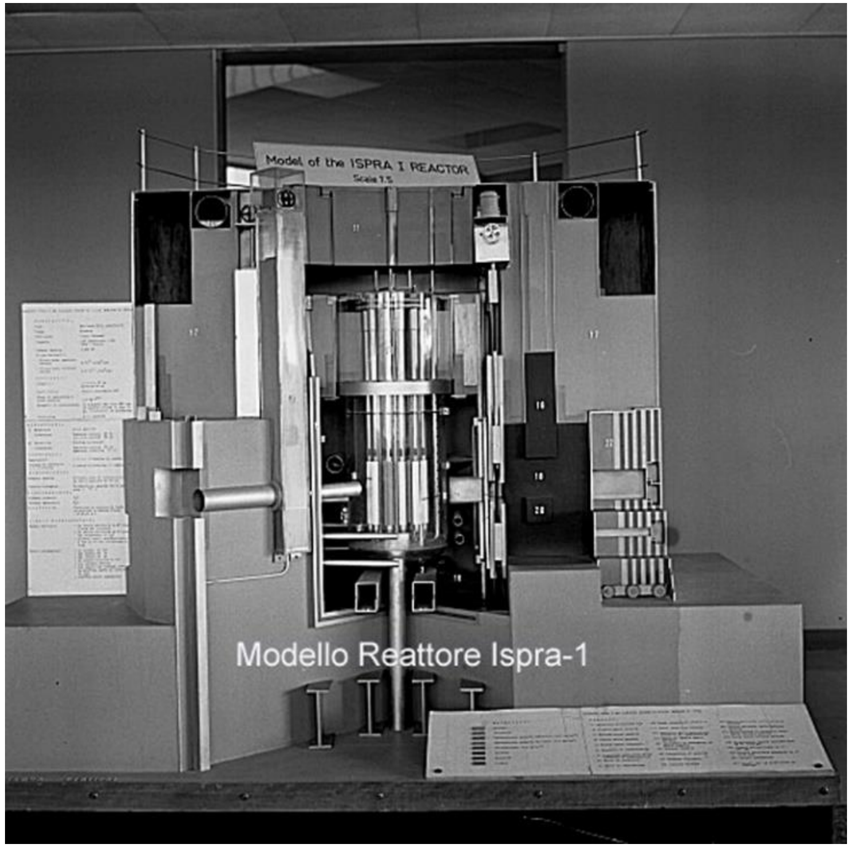
- The study of Experiments in Nuclear Field
- Activation
- Contamination
- Deposits of radionuclides; hot-spots
- Radiometric measurement
- Geometry of shielding
- Self-shielding of components
- Planning of tasks
- Behaviour of workers

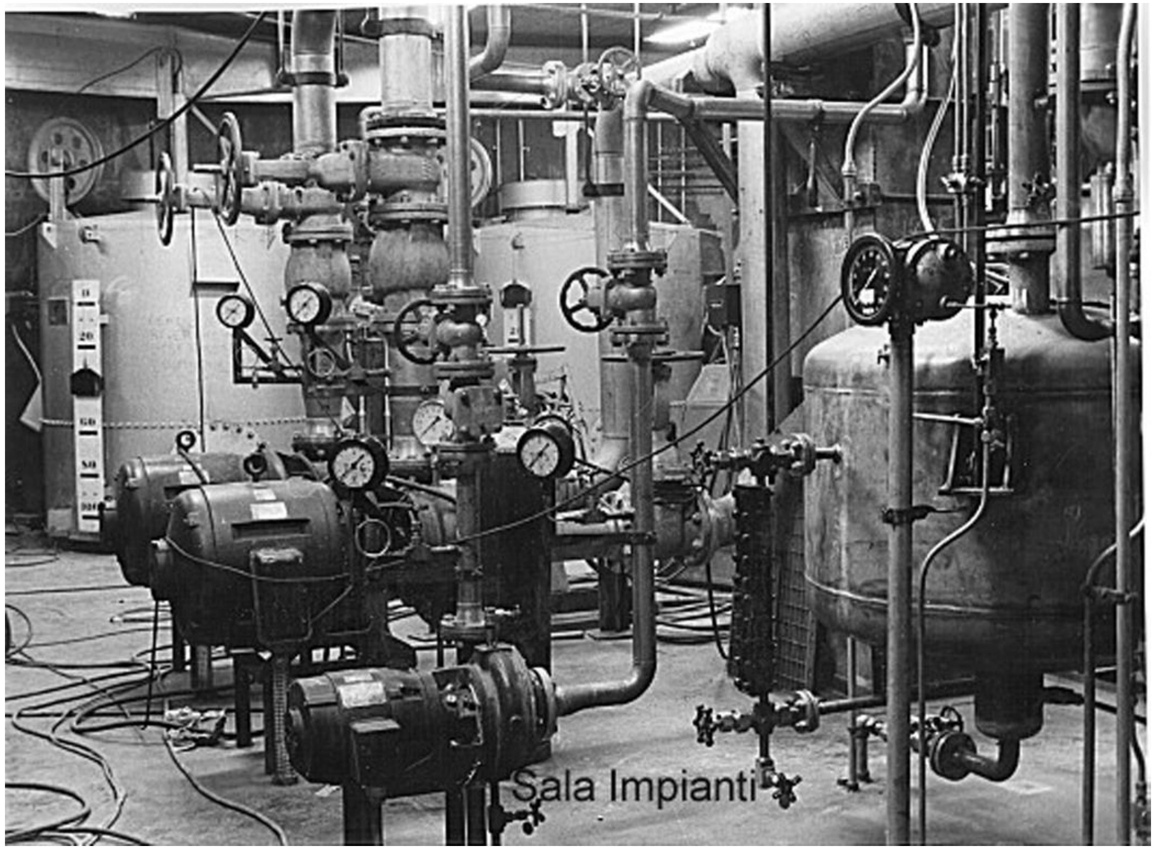
Historical Information

On 26 September 2019 Sogin definitively took charge of the **Ispra1 Reactor** and the ownership of the authorization measures.

Sogin submitted to the Ministry of Economic Development on 29/04/2020 an application for authorization to

<u>**Dismantling the Ispra1 Reactor**</u> pursuant to Article 55 of Legislative Decree 230/95.





Historical Information

The **Ispra-1 Research Reactor** belongs to the **CP5** Argonne type, moderated and cooled with heavy water and with graphite as a neutron reflector.

The fuel used was of the **MTR type** with 19 lamellae per element in U-Al alloy enriched approximately 90% in U-235; the cylindrical core (60 cm high and 84 cm in diameter) was made up of 18 fuel elements and surrounded by heavy water which acted as moderator/reflector.

The heat produced was transferred by means of heat exchangers to a secondary light water circuit with a cooling tower. The reactor could produce a thermal power of **5 MW** and was equipped with a control and safety system consisting of 6 vertical control bars and one for regulating.

Historical Information

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DISMANTLING STRATEGY OF ISPRA1 REASEARCH REACTOR

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Sogin has developed a strategy for decommissioning the Ispra1 Research Reactor, divided into preparatory activities and in three distinct phases

Phase 1

collection of historical information, radiological characterization of the plant, cleanout and possibly clearance of large and small components used in research experiences, dismantling activities of the systems and components of the primary and secondary cooling circuits external to the Reactor Pile, storage pit and hot cell;

Phase 2

validation of the activation calculations and evaluation of the levels of contamination for the design and dismantling of the Reactor Pile, the dacay pool with the hot cell, the channel connecting the two facilities and the horizontal and vertical storage pits

Phase 3

Final Radiological Survey and Final Release.

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PHASE I DISMANTLING SYSTEMS AND COMPONENTS

SYSTEM AND COMPONENTS AFFECTED BY CONTAMINATED PROCESS FLUIDS

The process of dismantling the systems / components of PHASE I present in the radiological impacted areas of the Ispra1 Plant involve the management of quite considerable quantities of materials of different nature, with different characteristics and with different radioactivity content, mainly due to contamination.

Reactor Building I0			
ID Systems	Systems/Component	Weight [kg]	Volume [m3]
1001	Main Coolant D2O System	7404.4	6212.7
1002	D2O Clean-up System	604.2	0.1
1003	Reactor Vessel gage glass System	98.9	0.5
1004	Radiation Monitoring System	167.3	0.0
1010	Helium cover gas System	3203.5	7.4
1011	Recombiner Helium System	829.5	0.3
3001	Secondary Coolant System	7530.8	1.9
1005	Reactor off-gas System	226.3	0.1
2010	Shield cooling water System	1722.6	13.7
2011	Shield cooling clean-up H2O System	118.5	0.0
2030	Graphite Nitrogen System	2295.0	7.1
1012	Rig Helium System	99.3	0.1
2020	Experimental facilities cooling System	1756.4	9.9
2021	Experimental facilities clean-up H2O System	306.7	0.1
2022	Rig cooling System	247.2	0.1
4001	Organic coolant loop System	1646.9	1.3
4010	Organic hot drain system	1912.7	1.3
S001	CECILE main coolant loop system	721.7	1.0
S002	CECILE secondary cooling system	1226.5	0.7
S011	RABBIT Helium system	7157.9	12.5
2040	Active/Dubious effluents System	2116.1	0.9
2100	Decay Pool cooling System	1164.6	0.7
2110	Decay Pool clean-up H2O	141.1	0.1
5002	Ventilation exhaust & Reactor off gas system	4479.3	7.5
Building Annex A 21n (I1)			
2040	Active/Dubious effluents System	3376.5	12.0
Building B (I2)			
0010	Manipolatori cella gamma	801.1	0.3
2110	Gamma Cell components (internal and external)	2853.5	0.1
2040	Decay Pool clean-up H2O	506.7	0.2
5010	Gamma cell Air ventilation System	3725.1	7.3
Total	System 2040	5999.3	13.2
Total	System 2110	2994.5	0.3
Total phase I dismantling Systems- Ispra1		58440.3	6299.9

PHASE I DISMANTLING SYSTEMS AND COMPONENTS

1) Radiometric monitoring campaign with direct measurements of dose rate and total surface contamination aimed at the classification of the areas

2) Radiological characterization and radiochemical analysis campaign

made it possible

- to consolidate the list of reference radionuclides,
- to define in a definitive form the homogeneous groups and the related Correlation Factors,
- to define the distribution of residual radioactivity, update the radiological inventory of the plant and
- Carry out preliminary dose assessments for the subsequent dismantling phases.

PHASE I DISMANTLING SYSTEMS AND COMPONENTS

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1) Preliminary dose assessments for Phase I SC dismantling

The estimate of the **doses to personnel for Phase I activities** was prepared on the basis of a preliminary assessment of the required manpower effort

Working time →	calculated starting from the weight of the metal material subjected to cutting considering a productivity cutting of about 20 kg / h
Team →	3 operators and 2 technicians (for 10% of the total time)
Activities →	1 Preliminary and preparation activities; 2 Dismantling of systems and components included in Phase I.
The algorithm applied →	• E_{est} = Te × (Rav × 0.97 + Rmax × 0.03) [mSv]

PHASE I DISMANTLING SYSTEMS AND COMPONENTS

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1) Preliminary dose assessments for Phase I SC dismantling

The table shows the estimates of the **effective annual doses** for the operator (maximum value) and the **annual collective doses** as a function of the dismantling macro-activities.

Team	Activity description		Effective dose operator (mSv/year)				mSv tot
			Year 1°	Year 2°	Year 3°	Year 4°	TOTAL
Team 1 (3 operators, 2 technicians)	Preliminary Activities	System revamping	0.42				0.61
		Facility preparation					
		Free articles management	0.13	0.06			
	Dismantling System and Components Reactor Building	Dismantling SC (q.ta -2.40 m)		0.13			1.01
		Dismantling SC (q.ta +0.00 m)		0.37	0.45		
		Dismantling (q.ta +4.40 m)			0.07		
	Dismantling System and Components external Reactor Building	Dismantling SC Building B (pond and gamma cell)			0.13	0.25	0.82
Team 2 (3 operators, 2 technicians)		Removal of radioactive effluent storage tanks(21f)	0.10	0.17	0.07		
		Removal of active liquid collection tanks Annesso A (ed 21n)			0.10		
Collective Dose	Total Dismantling Phase I		I anno (man*mSv/y)	II anno (man*mSv/y)	III anno (man*mSv/y)	IV anno (man*mSv/y)	TOT (man*mSv)
			2.09	2.31	2.62	0.79	7.81

PHASE I DISMANTLING SYSTEMS AND COMPONENTS

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2) Analysis of the results of DA measurements on SC

Between 2007 and 2010, a radiological characterization campaign of the systems and components was conducted by JRC through NDA and DA measurements

Subsequently, a radiological characterization and radiochemical analysis campaign was designed and carried out by Sogin in 2021 to integrate the previous radiological data,

In total, considering both characterization campaigns, 97 DA samples were taken from the SSCs object of Phase I of dismantling

Results

Gamma emitters: Co-60, Cs-137, Ag-108m, Eu-152; Eu-154

Beta e x emitters: Fe-55, Ni-59/63, Sr-90, Pu-241, H-3; C-14;

Alfa emitters: Am-241, Pu-238, Pu-239/240.

PHASE I DISMANTLING SYSTEMS AND COMPONENTS

2) Analysis of the results of DA measurements on SC

System Distribution Samples

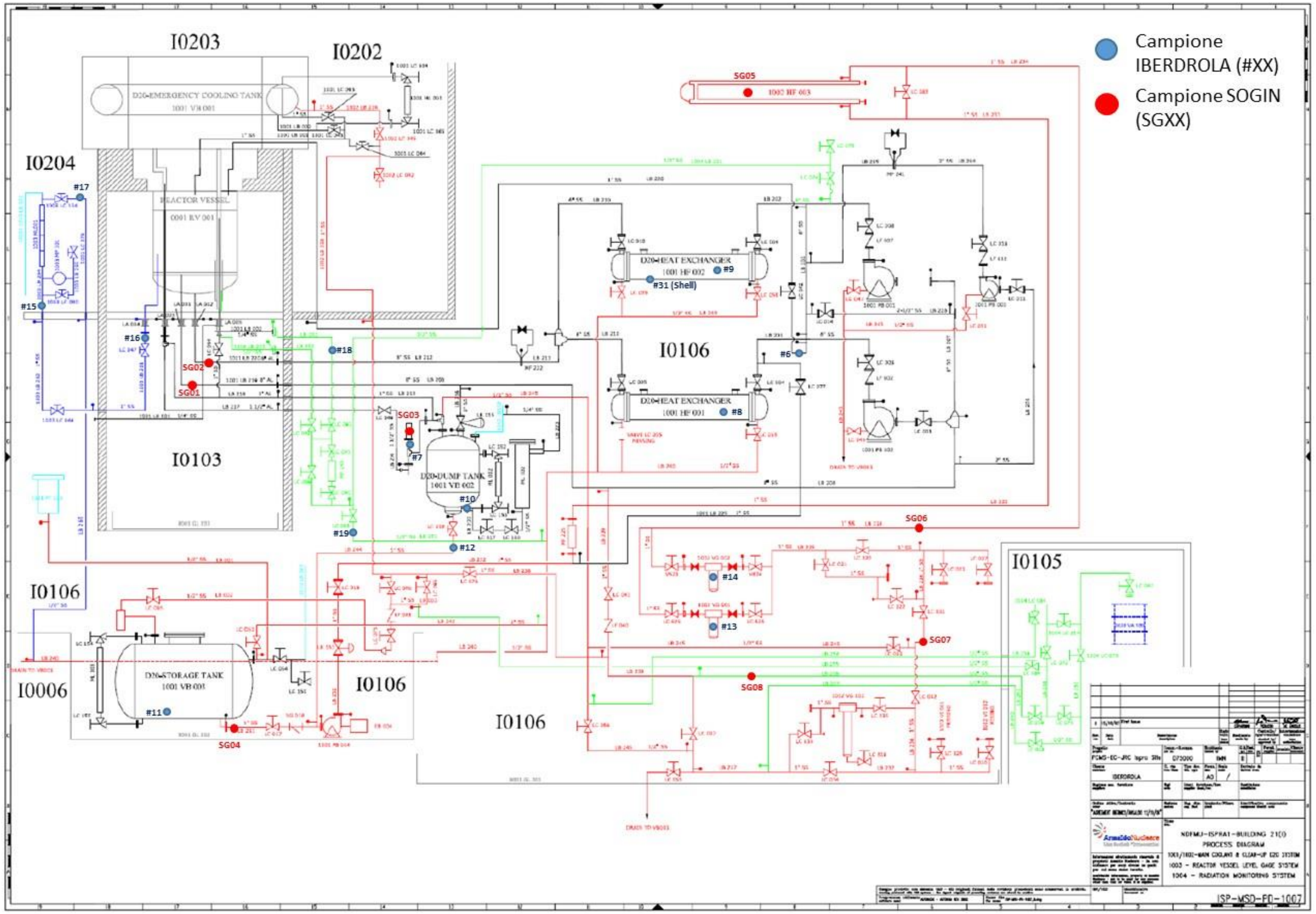
Reactor Building (I0)						
ID Systems	Systems/Components	Internal surface [m²]	N° samples IBERDROLA	N° samples SOGIN	N° samples TOT	TOT m²/samples
1001	Main Coolant D2O System	125.799	7	3	10	13
3001	Secondary Coolant System	66.963	1	1	2	33
1002	D2O Clean-up System	9.037	3	4	7	1
1003	Reactor Vessel gage glass System	6.579	3	-	3	2
1004	Radiation Monitoring System	2.597	2	1	3	1
1005	Reactor off-gas System	2.458	1	-	1	2
1010	Helium cover gas System	28.396	-	2	2	14
1011	Recombiner Helium System	8.484	3	-	3	3
1012	Rig Helium System	2.896	-	1	1	3
2010	Shield cooling water System	93.297	1	1	2	47
2011	Shield cooling clean-up H2O System	2.168	-	1	1	2
2020	Experimental facilities cooling System	67.281	-	4	4	17
2021	Experimental facilities clean-up H2O System	5.276	1	-	1	5
2022	Rig cooling System	5.707	1	-	1	6
2030	Graphite Nitrogen System	13.385	-	2	2	7
4001	Organic coolant loop System	35.128	1	1	2	18
4010	Organic hot drain system	24.703	2	2	4	6
S001	CECILE main coolant loop system	14.432	1	1	2	7
S002	CECILE secondary cooling system	15.235	1	1	2	8
S011	RABBIT Helium system	96.275	2	5	7	14
2040	Active/Dubious effluents System	41.663	1	-	1	42
2100	Decay Pool cooling System	15.580	1	5	6	3
2110	Decay Pool clean-up H2O	2.692	1	-	1	3
5002	Ventilation exhaust & Reactor off gas system	90.436	2	-	2	45
TOTALE		776.468	39		70	11
Building Annex A 21n (I1)						
2040	Active/Dubious effluents System	51.570	4	3	7	4
TOTAL		51.570	4		7	4
Building B (I2)						
2040	Active/Dubious effluents System	12.447	1	1	2	6
10	Gamma Cell components (internal and external)	3.473	1	-	1	3
2110	Decay Pool clean-up H2O	40.307	2	4	6	7
5010	Gamma cell Air ventilation System	112.307	4	-	4	28
TOTAL		168.535	10		13	13
Building 21f (I5)						
2040	Active/Dubious effluents System	322.474	3	4	5	46
TOTAL		322.474	3		5	46

PHASE I DISMANTLING SYSTEMS AND COMPONENTS

2) Analysis of the results of DA measurements on SC

i.e. System Distribution Samples in P&ID for:

- Main Coolant D2O System (black)
- D2O Clean up System (red)
- Rdiation monitoring System (green)



PHASE I DISMANTLING SYSTEMS AND COMPONENTS

2) Analysis of the results of DA measurements on SC

From the elaboration of the totality of the radioanalytical determinations carried out in the context of both characterization campaigns the **scaling factors** of the plant

Not Acivated Materials			
Scaling Factors		Standard Deviation 2σ	n° valid measures
$^{3}H/^{60}Co$	4.6E-01	$D_{FC}^2 = 5.6$	15
$^{55}Fe/^{60}Co$	1.2E-02	$D_{FC}^2 = 3.4$	4
$^{14}C/^{60}Co$	1.7E+00	$D_{FC}^2 = 5.5$	17
$^{63+59}Ni/^{60}Co$	3.0E+01	$D_{FC}^2 = 5.5$	31
$^{90}Sr/^{137}Cs$	7.1E-01	$D_{FC}^2 = 5.2$	21
^{241}Pu/ α-emitters	5.0E-01	N.A.	/
α-emitters/^{137}Cs	4.8E-03	$D_{FC}^2 = 6.0$	10

*(the set of measures used is understood to be updated as of 31/12 2021).

PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

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ACTIVATED MATERIALS

The materials covered by Phase II of dismantling are

- The materials of the **Reactor Pile** which, having been subjected to neutron flux, are *activated materials*
- **vessel,**
- **graphite reflector**
- **thermal shield**
- **biological shield**

There is currently no real characterization for these materials. An exception is the biological shield from which two samples ("coring") were taken and subjected to destructive tests.

- the activated materials that were extracted from the reactor during the exercise which are found in the so-called "horizontal pit" and "vertical pit“:
- **plugs,**
- **irradiated components deriving from pile experiments,**
- **control rods**

There is currently no real characterization for these materials but only dose rate measurements on the basis of which the radioactivity content of gamma emitters has been estimated.

PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

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1) Activation evaluation using MCNP5 code

As part of the characterization investigations neutron activation calculations were performed using the **Monte Carlo N-Particle Transport Code**

The main features of the model, included in the input file are:

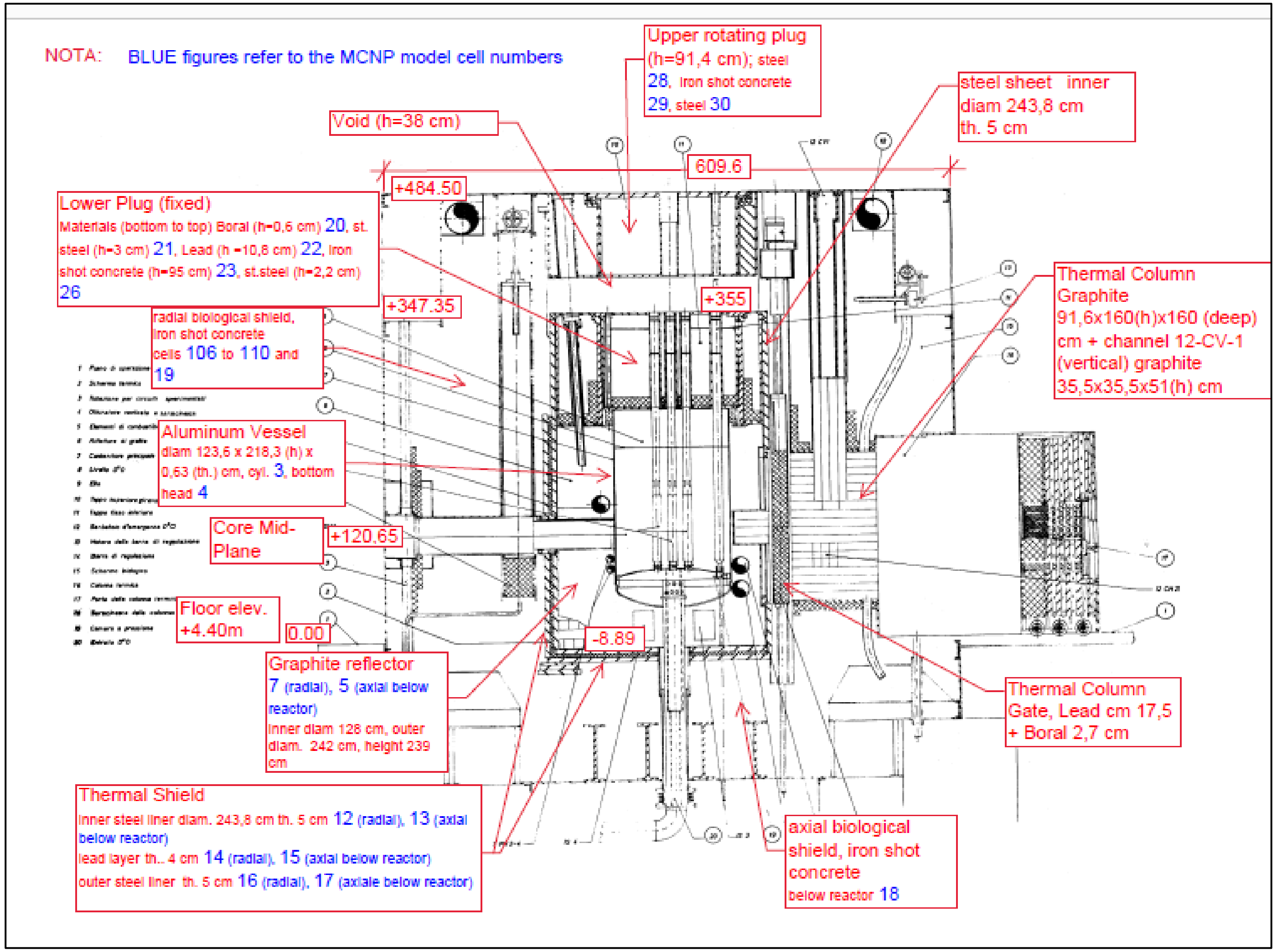
Geometrical information → The main components and structures of the Reactor Pile have been implemented in the geometric model, such as: the **Vessel**, the **reflector**, the **thermal shield**, the biological shield and a generic experimental channel

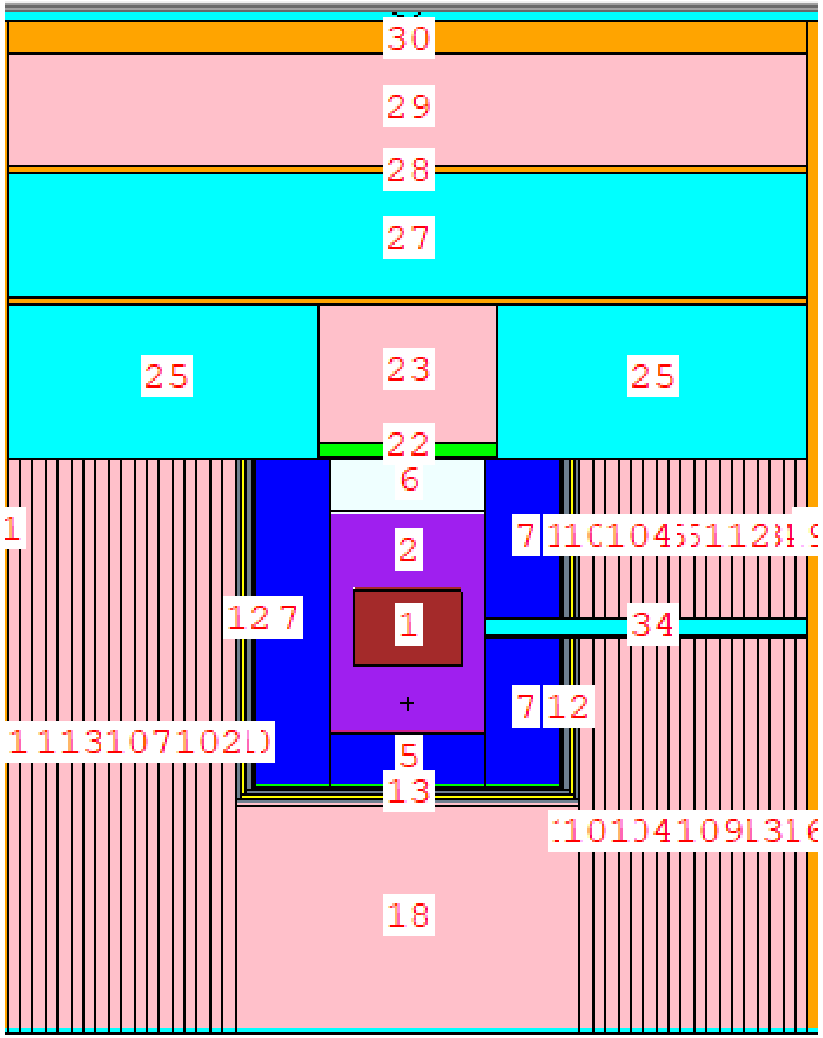
Material information → The **isotopic composition of the materials** relative to the impurities derived to historical infomation, in the absence of specific information, was obtained from international standards (i.e. ASTM and NUREG).

Radiological information → The initial neutron flux and the intensity of the source was calculated assuming the reactor power equivalent to 5 MWt.

PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

1) Activation evaluation using MCNP5 code – Reactor Pile Volume section





PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

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1) Activation evaluation using MCNP5 code

Activation Calculation Results – 31/12/2021

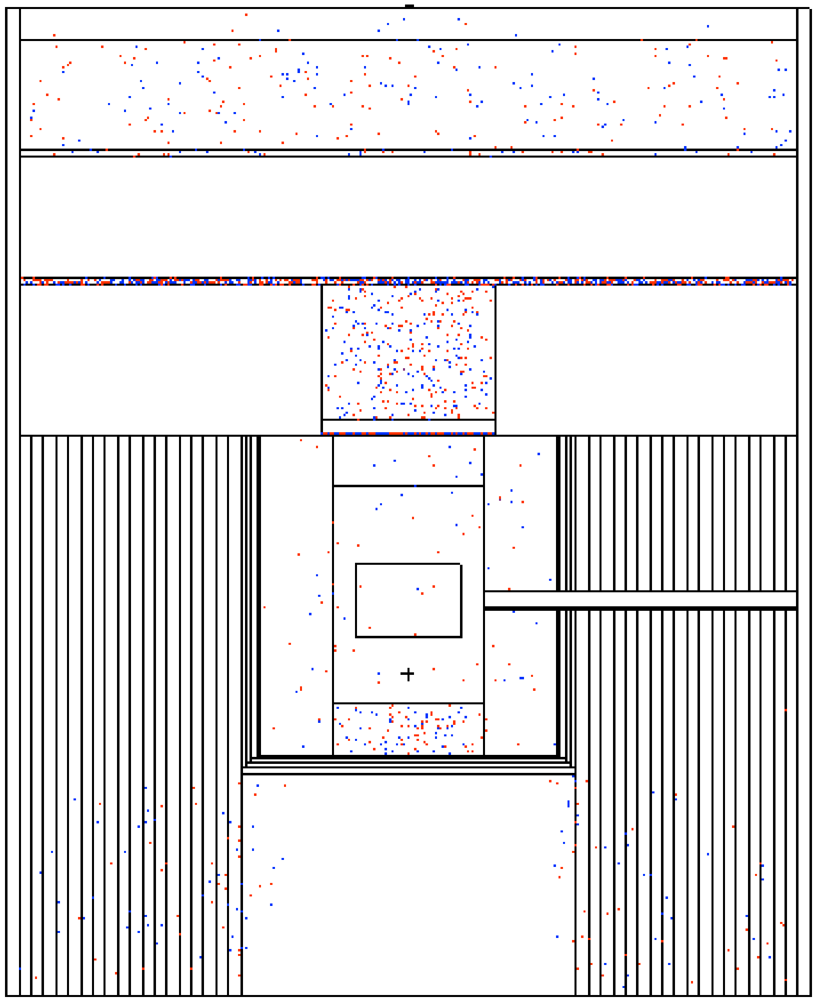
Component	Reflecor	Thermal Shield	Biological Shield	Upper Plug+steel plug	Experimental Channel	Total
Celle MCNP	5, 7	10 ÷ 17	100 ÷116, 18, 19	20÷ 23, 26, 28÷30	32, 33	
Material	Graphite	Lead,Carbon Steel	Baritic Concrete	Lead,Carbon Steel	Alluminium	[Bq]
C-14	2.51E+11	3.01E+08	5.95E+08	1.89E+09	3.06E+07	2.54E+11
Eu-152	6.41E+08		3.95E+08	8.13E+08		1.85E+09
Eu-154	9.04E+06		6.09E+06	1.28E+07		2.79E+07
Co-60	9.73E+08(	3.99E+04	6.84E+09	1.48E+11	6.21E+09	1.61E+11
Ba-133	1.06E+09(1)		2.68E+10		6.57E+09	3.34E+10
Ni-63		2.34E+11	1.87E+10	2.28E+12	1.03E+05	2.54E+12
Ni-59		2.34E+09	1.86E+08	2.27E+10	2.29E+03	2.52E+10
Pb-205		2.68E+05				2.68E+05
Fe-55		3.00E+09	2.68E+07	3.85E+08	3.35E+08	3.75E+09
Mo-93		1.48E+10			6.19E+05	1.48E+10
Ca-41			1.02E+08	2.37E+08		3.39E+08
Total	2.52E+11	2.55E+11	5.36E+10	2.46E+12	1.31E+10	3.03E+12

PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

2) Co-60 Source distribution

Calculated Co-60 activity have been imported into the model

The figure shows the distribution of the Co-60 source in the Reactor Pile.



PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

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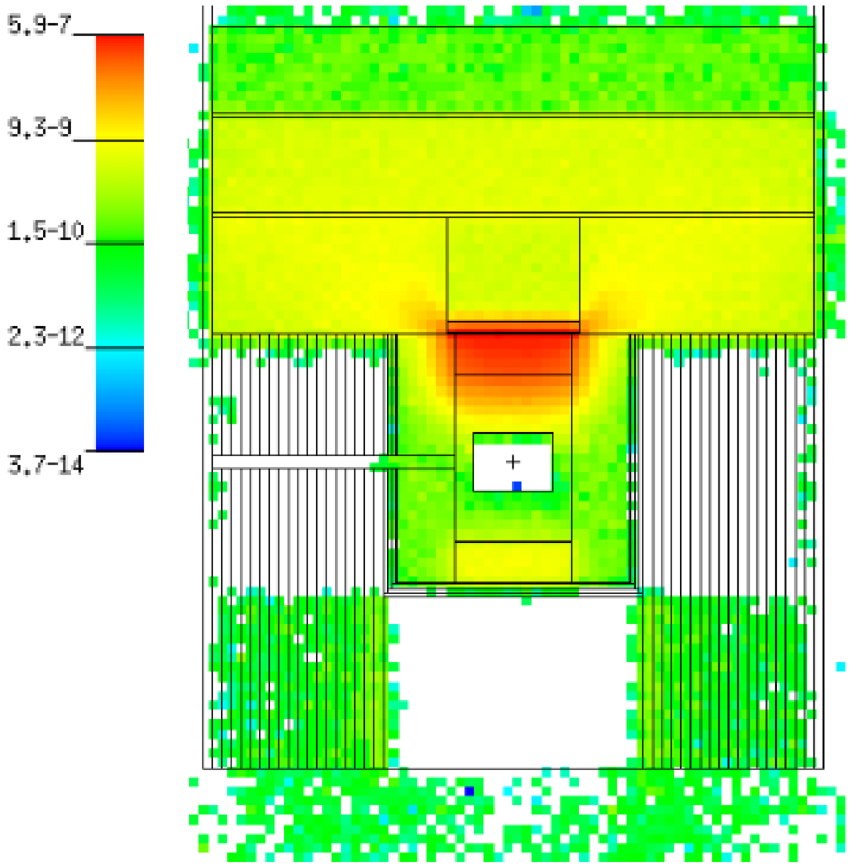
2) Dose Rate Evaluations using MCNP5 Code

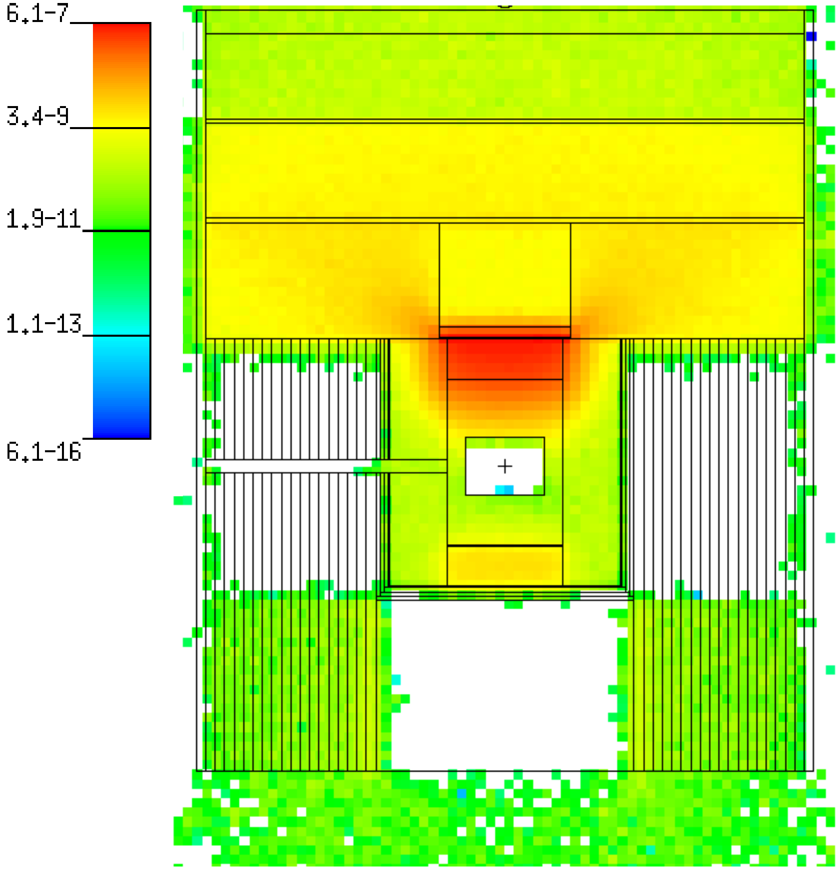
The figures show the evaluated of *Dose Rate distribution* in the Reactor Pile in two considered configuration:

- with upper plug
- without upper plug

WITH UPPER PLUG



WITHOUT UPPER PLUG



*[p/(cm2*nps]*[microSv/h*cm2s] to be multiplied *1.45+E11 γ/s

PHASE 2 DISMANTLING SYSTEMS AND COMPONENTS

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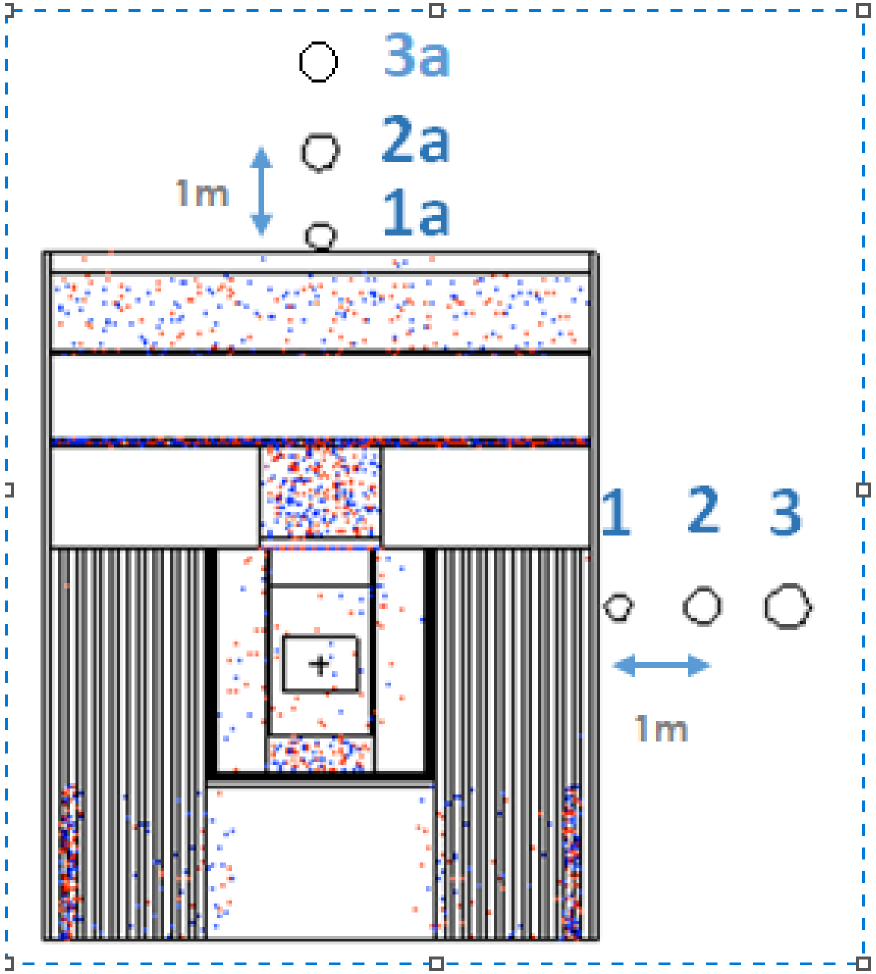
2) Dose Rate Evaluations using MCNP5 Code

- Dose Rates were calculated at **the pile mid-plane** (in contact with biological shield) and in contact **with the upper plug** center line.
- The same simulation was carried out in the same points but **without the upper plug** to evaluate the dose rate at the moment of opening the Reactor Pile. The result are shown in the folowing grid.



Calculation Point	With Upper Plug	Without Upper Plug
	Dose Rate µSv/h	
1 (In contact)	1.40E-01	1.35E-01
2 (at a distance of 1m)	1.48E+00	1.52E+00
3 (at a distance of 2m)	1.45E+00	1.46E+00
1° (In contact)	4.38E+00	1.29E+02
2° (at a distance of 1m)	3.34E+00	9.37E+01
3° (at a distance of 2m)	2.30E+00	6.70E+01

Conclusions

- This paper will describe the activities carried out by Sogin through the characterization of the Plant and the activation calculations made it possible to determine the levels of residual radioactivity in Ispra1 in order to obtain the design of the dismantling interventions and optimize the associated radiation protection activities by refining the preliminary dose assessments.

- The use of MCNP Nuclear Codes is a suitable tool for optimizing dose assessments according to the ALARA principle, defined in the ICRP guidelines and the Directive 2013/59/Euratom on protection against dangers arising from exposure to ionizing radiation.

- Sogin strategy divided in 3 operational phases were carried out in order not only to manage the waste materials but above all to guarantee an adequate level of safety of the operations carried out in terms of radiation protection of workers in dismantling activities.

Thank you for your attention!