Experience in Using MAVRIC for Shielding Analysis at the Nuclear Safety Council

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- Facilities
- Methodology
- Utilities
- Remarks

3 Type of nuclear and radioactive facilities

- Storage and transport casks
- Independent Spent Fuel Storage Installations (ISFSI)
- Waste & Spent Fuel Storage buildings

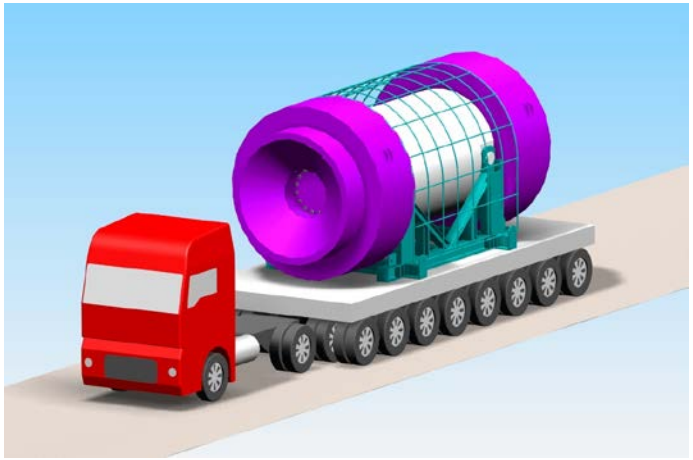
Additionally, shielding analysis of Centers for Emergency Management (CEM) and Filtered Containment Venting Systems (FCVS) at the NPP sites have been made

4 General Methodology

Shielding evaluations are based on independent calculations:

- Modelling based on the original drawings provided by licensees
- Test of geometry using a dummy source and the *voidAllRegions* keyword
- Separate calculations for fuel gammas and neutrons and activation gammas
- Preliminary calculations (*parm=impmap*) to verify the real source representation (*dsim.msm* temporary files) and the adjoint flux distribution
- Flux-to-Dose conversion factors from ICRU Report 57
- Sufficient number of batches and *perBatch* histories

5 Storage & Transport Casks



The casks used in Spain in interim storage are made of metal by Ensa:

- ENSA DPT
- ENUN 32P
- ENUN 52B
- ENUN 24P

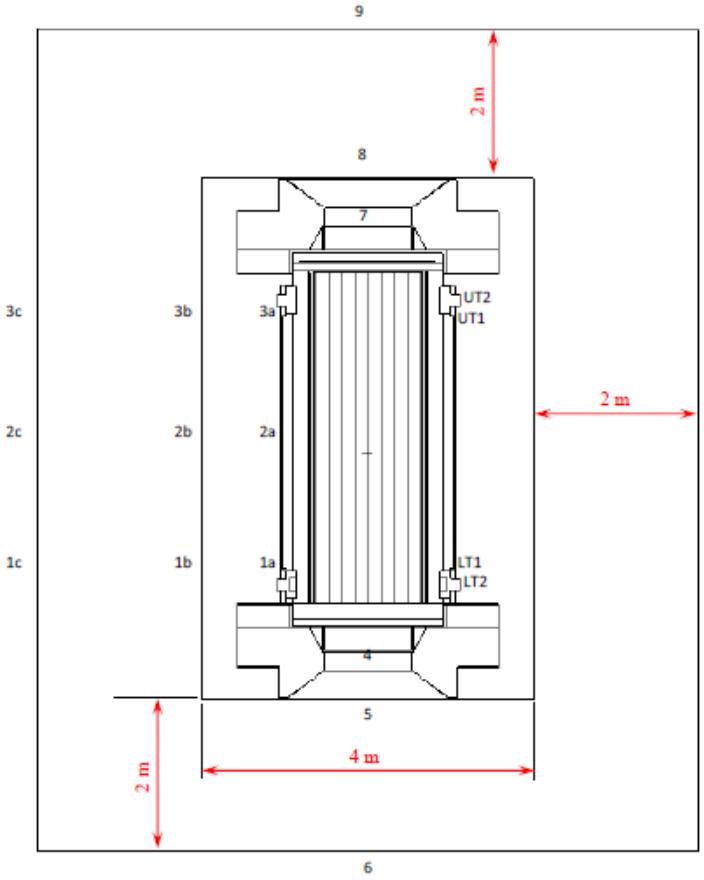
or concrete and metal by Holtec:

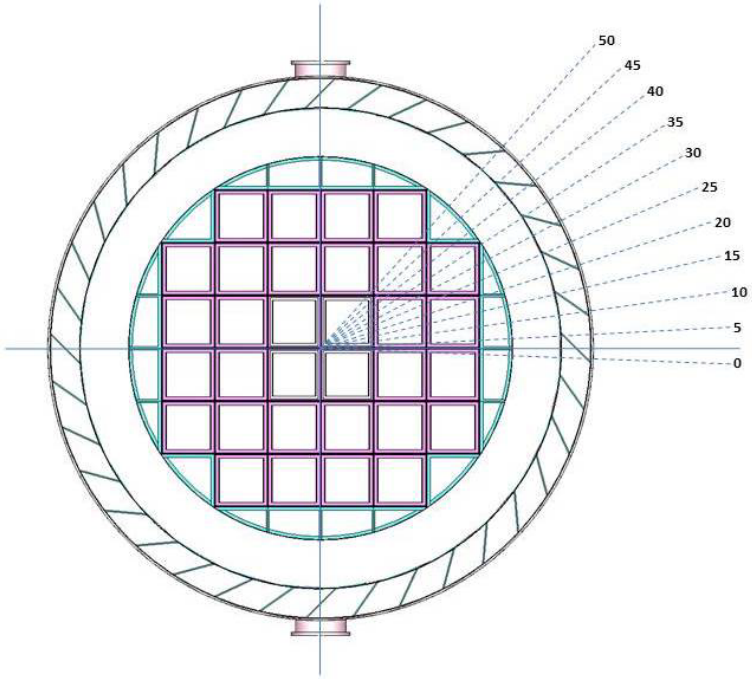
- HI-STORM
- HI-SAFE
- HI-STAR

6 Storage & Transport Casks. Methodology

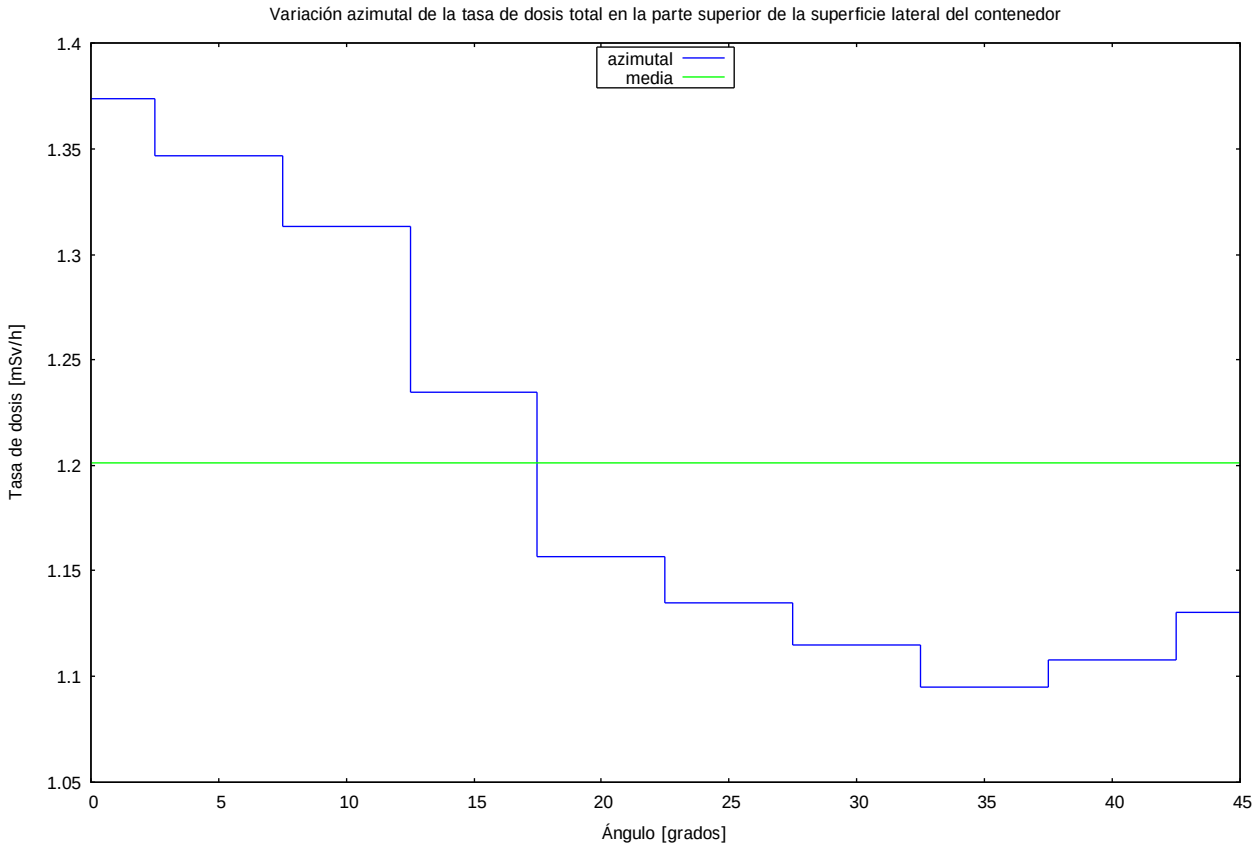
- Fuel rods are represented explicitly. Compositions of fresh fuel to maximize the subcritical multiplication
- The activation source from rod spacers is explicitly defined when its contribution is important
- Mesh tallies are defined at top, bottom and lateral locations. Azimuthal variation on lateral dose rates are taken into account
- Denovo calculations are performed using the MG 27n19g library. Monaco calculations are performed using the CE library
- FW-CADIS
- Utility to process the mesh tally binary files (*mt.3dmap*) and to obtain maximum values

7 Storage & Transport Casks. Mesh Tallies





8 Storage & Transport Casks. Dose Rate Azimuthal Variation



9 Storage & Transport Casks. Utility to obtain maximum dose rates

ENUN 47,5G - 3,4a
Factores de escalado de las tallies: 1.010 1.000 1.170

		f.comb.	f.est.	f.ng.	fotones	neutrones	total
Side surface							
	1a	0.0776 ± 5.35	0.0014 ± 4.72	0.0072 ± 6.13	0.0862 ± 4.84	1.3600 ± 0.81	1.4462 ± 0.81
	2a	0.2169 ± 2.63	0.0003 ± 5.19	0.0196 ± 2.67	0.2369 ± 2.42	0.0293 ±10.57	0.2662 ± 2.45
	3a	0.0082 ± 9.79	0.0009 ± 4.06	0.0028 ± 7.38	0.0118 ± 6.99	0.4872 ± 1.11	0.4990 ± 1.09
Side railcar							
	1a	0.0423 ± 4.39	0.0004 ± 4.44	0.0049 ± 3.49	0.0476 ± 3.92	0.2913 ± 1.07	0.3389 ± 1.07
	2a	0.1432 ± 1.29	0.0002 ± 3.62	0.0129 ± 2.10	0.1563 ± 1.20	0.0251 ± 3.40	0.1814 ± 1.13
	3a	0.1090 ± 1.40	0.0003 ± 2.52	0.0069 ± 2.94	0.1163 ± 1.32	0.0293 ± 2.92	0.1456 ± 1.21
Side 2 m							
	1a	0.0432 ± 1.17	0.0001 ± 3.94	0.0034 ± 2.52	0.0467 ± 1.10	0.0171 ± 2.24	0.0638 ± 1.00
	2a	0.0464 ± 1.19	0.0001 ± 2.53	0.0037 ± 2.52	0.0502 ± 1.11	0.0154 ± 2.31	0.0656 ± 1.01
	3a	0.0333 ± 1.33	0.0001 ± 2.37	0.0027 ± 2.87	0.0361 ± 1.24	0.0121 ± 2.52	0.0482 ± 1.13
Bottom							
Surface	4	0.0192 ± 3.51	0.0015 ± 3.51	0.0193 ± 2.18	0.0401 ± 1.99	1.1535 ± 0.78	1.1936 ± 0.76
Railcar	5	0.0028 ± 6.83	0.0002 ± 7.84	0.0026 ± 3.31	0.0056 ± 3.80	0.0863 ± 1.81	0.0919 ± 1.71
2 m	6	0.0009 ±10.64	0.0001 ±10.81	0.0006 ± 5.89	0.0016 ± 6.59	0.0242 ± 3.93	0.0258 ± 3.71
Top							
Surface	7	0.0014 ± 4.66	0.0004 ± 3.16	0.0076 ± 2.83	0.0094 ± 2.39	0.3766 ± 0.86	0.3860 ± 0.84
Railcar	8	0.0003 ± 7.61	0.0001 ± 5.02	0.0009 ± 3.42	0.0013 ± 3.02	0.0286 ± 2.38	0.0299 ± 2.28
2 m	9	0.0001 ±11.65	0.0000 ± 9.09	0.0003 ± 6.51	0.0004 ± 5.39	0.0084 ± 4.38	0.0088 ± 4.19

10 Independent Spent Fuel Storage Installations (ISFSI)

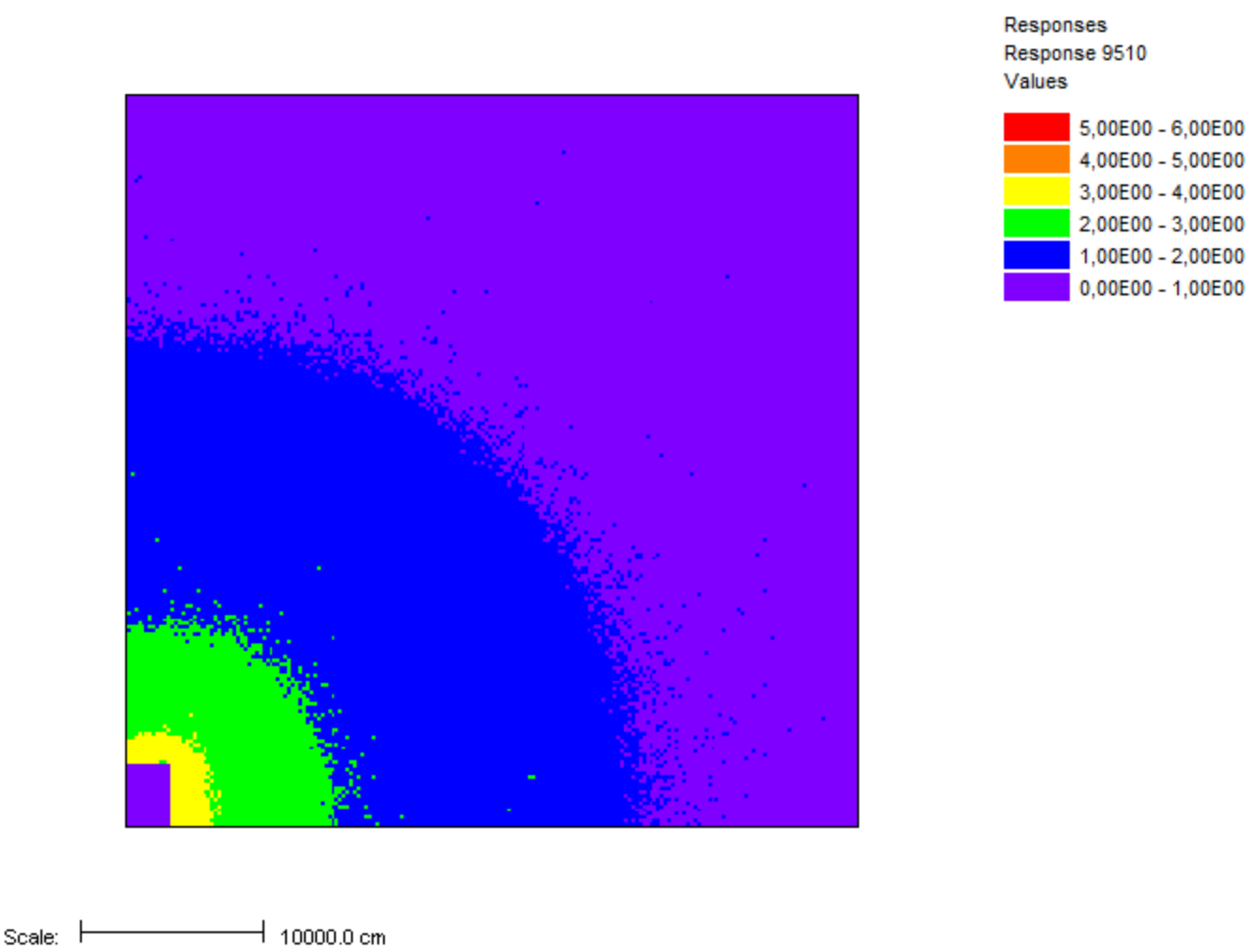
There are six ISFSI at the following NPPs:

- José Cabrera (already dismantled)
- Trillo
- Ascó
- Almaraz
- Sta. Mª de Garoña (under construction)
- Cofrentes (under construction)

11 Independent Spent Fuel Storage Installations. Methodology

- Enough air surrounding the installation and points of interest to take into account sky-shine
- Attention to the modelling of berms. Ground-shine contribution is important
- Tallies are based on point detectors at the limits of the controlled and supervised zones and controlled area
- FW-CADIS, CADIS
- Utility to obtain a graphical representation of the radiological zones using Meshview/Fulcrum a post-processing of *mt.3dmap* files
- Poor man's parallel technique. Utility to collect and combine dose rates and uncertainties

12 Independent Spent Fuel Storage Installations. Utility to obtain radiological zones



13 ISFSI. Poor Man's Parallel. Utility to collect & combine point detector dose rates

1. Adjoint calculations for fuel gamma, activation gamma and neutron sources

2. Independent Monaco calculations with the corresponding adjoint flux and different random seeds

```
./fuel_gamma
   /part1  -> inp.pd1.chart
   /part2  -> inp.pd1.chart
   /part3  -> inp.pd1.chart
      .
      .
   /part10 -> inp.pd1.chart
```

```
./activation_gamma
   /part1 -> inp.pd1.chart
   /part2 -> inp.pd1.chart
   /part3 -> inp.pd1.chart
      .
      .
   /part10 -> inp.pd1.chart
```

```
./neutrons
   /part1 -> inp.pd1.chart
             inp.pd2.chart
   /part2 -> inp.pd1.chart
             inp.pd2.chart
   /part3 -> inp.pd1.chart
             inp.pd2.chart
      .
      .
   /part10 -> inp.pd1.chart
              inp.pd2.chart
```

14 ISFSI. Poor Man's Parallel. Utility to collect & combine point detector dose rates

ISFSI Garoña, controlled area (microSv/h)

Punto	fuel_gamma	activation_gamma	secondary_gamma	neutrons	Total
controlled_area	1.322E-02 (1.38)	1.142E-02 (1.16)	6.127E-04 (2.05)	1.247E-02 (1.73)	3.773E-02 (0.83)

fichero	valor	incer.abs.	rel.%	batch	controlled_area
./fuel_gamma/part1/inp.pd1.chart	1.352300E-02	4.742700E-04	3.51	17	
./fuel_gamma/part2/inp.pd1.chart	1.312800E-02	4.759500E-04	3.63	17	
./fuel_gamma/part3/inp.pd1.chart	1.319200E-02	5.867700E-04	4.45	17	
./fuel_gamma/part4/inp.pd1.chart	1.263800E-02	4.344400E-04	3.44	17	
./fuel_gamma/part5/inp.pd1.chart	1.299300E-02	5.363400E-04	4.13	17	
./fuel_gamma/part6/inp.pd1.chart	1.306600E-02	4.344200E-04	3.32	17	
./fuel_gamma/part7/inp.pd1.chart	1.305400E-02	4.315600E-04	3.31	17	
./fuel_gamma/part8/inp.pd1.chart	1.307600E-02	4.847300E-04	3.71	17	
./fuel_gamma/part9/inp.pd1.chart	1.417700E-02	1.076400E-03	7.59	17	
./fuel_gamma/part10/inp.pd1.chart	1.337200E-02	4.576900E-04	3.42	17	
fuel_gamma ..... media:	1.322190E-02	1.827175E-04	1.38		
activation_gamma ..... media:	1.142481E-02	1.321750E-04	1.16		
secondary_gamma ..... media:	6.127114E-04	1.254095E-05	2.05		
./neutrons/part1/temp/inp.pd2.chart	1.302500E-02	6.926800E-04	5.32	78	
./neutrons/part2/temp/inp.pd2.chart	1.209900E-02	5.651000E-04	4.67	79	
./neutrons/part3/temp/inp.pd2.chart	1.275200E-02	6.655800E-04	5.22	81	
./neutrons/part4/temp/inp.pd2.chart	1.309600E-02	7.086800E-04	5.41	79	
./neutrons/part5/temp/inp.pd2.chart	1.208900E-02	6.547900E-04	5.42	78	
./neutrons/part6/temp/inp.pd2.chart	1.241700E-02	7.303800E-04	5.88	78	
./neutrons/part7/temp/inp.pd2.chart	1.231000E-02	7.850400E-04	6.38	82	
./neutrons/part8/temp/inp.pd2.chart	1.279300E-02	5.915400E-04	4.62	80	
./neutrons/part9/temp/inp.pd2.chart	1.239100E-02	6.216900E-04	5.02	75	
./neutrons/part10/temp/inp.pd2.chart	1.177200E-02	7.428300E-04	6.31	80	
neutrons ..... media:	1.247428E-02	2.156724E-04	1.73		

15 Centralized Temporary Storage (CTS)

The CTS is an industrial facility designed to accommodate the spent fuel from Spanish nuclear power plants and other high level waste in a single location.

It is an Enresa project.

http://www.enresa.es/eng/index/activities-and-projects/cts

16 Centralized Temporary Storage (CTS)

Radiological analysis performed:

- Doses to public (Environmental Impact Statement, 2015)
- Radiological classification of zones and dose to workers (Preliminary Safety Analysis, in progress, 2015-2018) in:
  - Cask Holding Facility
  - Reception Building
  - Process Building
  - Storage Vaults
  - Special Waste Storage Module
  - Laboratory for Spent Fuel and Radioactive Waste
  - Cask Maintenance Workshop

17 After Fukushima Accident ...

A coordinated response within the European Union (EU) emerged, in order to ensure that all the nuclear power plants in all European countries were sufficiently robust to address situations similar to those that occurred at Fukushima Daiichi NPP.

CSN required each plant:

- To construct a Center for Emergency Management (CEM) to provide support to the management of an emergency in case of extreme severe accident
- To implement a Filtered Containment Venting System (FCVS) to provide adequate protection against the risk of failure of the containment as a result of overpressure

18 Trillo NPP

19 Center for Emergency Management (CEM) at Trillo NPP [1/3]

20 Center for Emergency Management (CEM) at Trillo NPP [2/3]

21 Center for Emergency Management (CEM) at Trillo NPP [3/3]

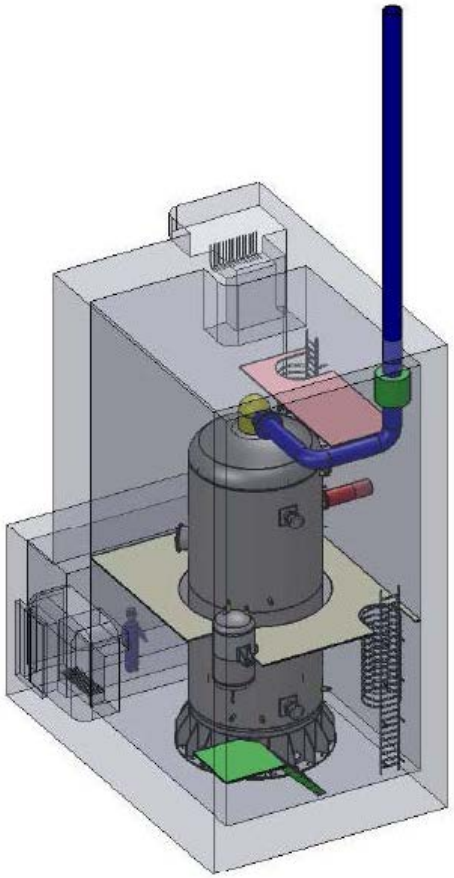
Main radiological characteristics of this building:

- Capacity to accommodate 70 people
- Habitability: Effective dose less than 50 mSv in 30 days of occupation
- Design to avoid contamination

Sources: Accumulated activity of radionuclides in filters and cloud

22 Filtered Containment Venting System (FCVS) at Trillo NPP [1/3]

23 Filtered Containment Venting System (FCVS) at Trillo NPP [2/3]



24 Filtered Containment Venting System (FCVS) at Trillo NPP [3/3]

Teams must be set up and operations must be defined so total effective dose by worker be less than 500 mSv.

Sources: Accumulated activity of radionuclides in filters, pipes and cloud

Scenarios to be analyzed:

- Dose received in the path between the CEM and outside locations
- Dose received at the time of opening the containment isolation valves
- FCVS local control room and surroundings, when monitoring parameters of the system

25 Remarks

- The experience using MAVRIC has been very positive. CADIS and FW-CADIS have worked correctly
- The dose rates obtained with MAVRIC were similar to those calculated with MCNP
- The SCALE help service has given support in a very reasonable period of time and has been very helpful
- Several utilities were developed to process results
- A complete version of Fulcrum is expected