

# PWR Alara / RP Association

## Doel Nuclear Station Benchmark

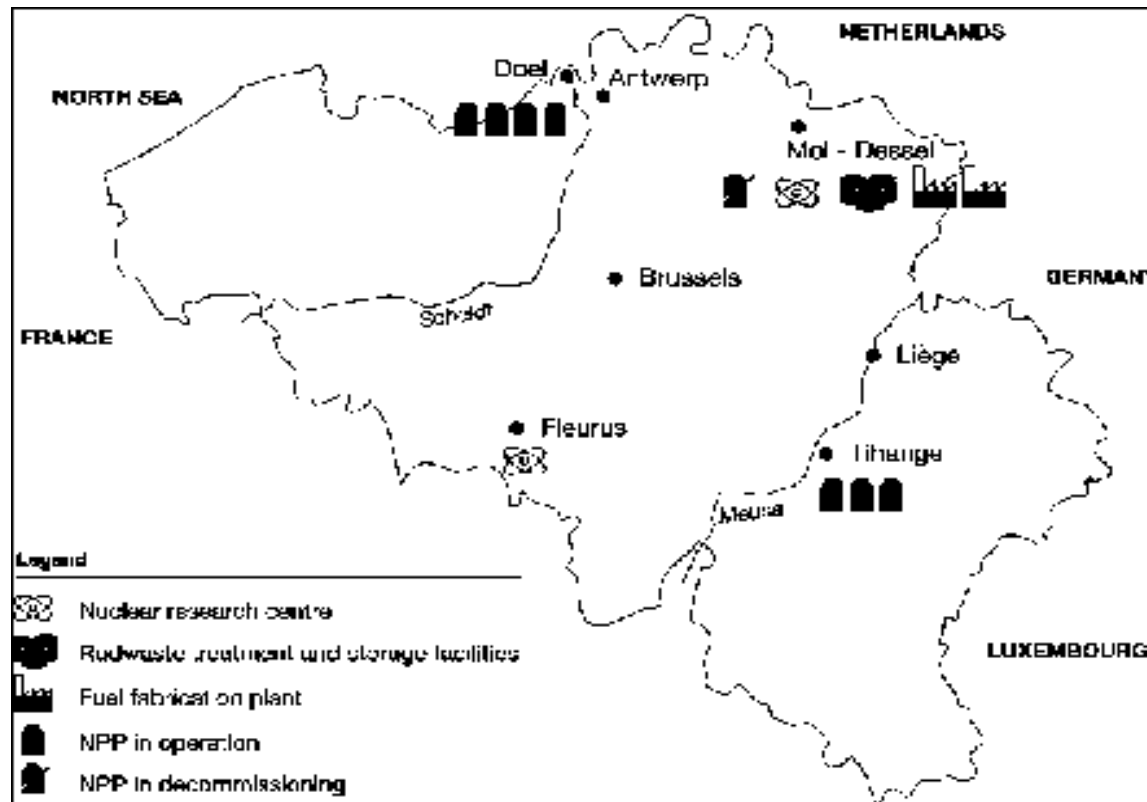
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Willie Harris  
Corporate Radiation Protection Manager  
Exelon Nuclear



# Doel Nuclear Station Benchmark

- The Doel Nuclear Power Station is one of the two nuclear power plants in Belgium.



# Doel Nuclear Station Benchmark

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- The plant lies on the bank of the river Scheldt, near the village of Doel in the Flemish Province of East Flanders.



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- The plant consists of four second-generation PWRs with a total capacity of 2839 MWe.
  - Doel 1 : 392 MWe
  - Doel 2 : 433 MWe
  - Doel 3 : 1006 MWe
  - Doel 4 : 1008 MWe
- Doel 1 and 2 came online in 1975, while Doel 3 and 4 came online in 1982 and 1985, respectively.

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## WANO CRE Data for Worldwide PWRs (3-Yr)

1. Doel U4 = 20.21 person-rem
2. Prairie Island U2 = 25.90 person-rem
3. Cook U1 = 26.60 person-rem
4. Beznau U1 = 27.65 person-rem
5. Doel U1 = 28.23 person-rem
6. Doel U2 = 28.23 person-rem
7. Ringhals U3 = 29.81 person-rem
8. Beznau U2 = 32.49 person-rem
9. Farley U2 = 35.70 person-rem
10. VC Summer = 36.00 person-rem



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- Regulation and safety
  - The Federal Agency for Nuclear Control (FANC) operates under the Minister of Interior. Its focus is on radiation safety, both occupational and public.

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## ○ Goals

- 20 mSv/yr (2 Rem/yr) is legal limit in Belgium
- Doel has Admin limit of 10 mSv/yr (1 Rem/yr)
  - When a worker reaches 7 mSv (700 mrem), more thorough checking at the entrance to the controlled area is implemented.
  - At 9 mSv (900 mrem), the worker can no longer freely enter
    - Required to report to the radiation protection office for authorization to enter the controlled area.
    - If the worker cannot be replaced (a point that is checked with its management), they are accompanied by a radiation protection specialist throughout its controlled area work
- Every six months, the head of the radiation protection department submits a self-assessment of radiation protection

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## ○ Design Features

- Doel has a permanent design feature that includes concrete shield walls around their RCPs and S/Gs
- Letdown Demin size: 1500 Liters (53ft<sup>3</sup>) and 500 Liters (17.6ft<sup>3</sup>)
- Reactor Head design at Doel does not have Cono-Seals
- Doel station has a high number of permanent platforms located at components requiring frequent maintenance
- Permanent anchor points for installing temp shielding



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## ○ Chemistry

- Doel uses Amberlite for the Letdown (HOH) mixed bed
- Doel uses an Amberlite Macro-porous resin over their HOH mixed bed.
- Doel Primary system chemistry uses a constant regime with a pH of 7.2
- Doel has in-line plant monitoring system to determine radio-isotopic liquid composition.



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## ○ Source Term

- Gamma Scans performed each refuel outage.
- Piping film layer rates are comprised of 45% Cobalt-60 and 45% Cobalt-58.
- Steam Generators at Doel have been through a passivation process using a Hot Thermal Soak

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## ○ Fuel

- Doel is a low duty core that uses a second layer loading pattern
- Doel uses Gadolinium (Gad) burnable absorbers mixed in with their fuel
- Doel U4 Fuel design is 17 X 17 and 14'.
- They have 157 bundles in their core
- Doel recycles their boron

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- Permanent shielding paneling





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## ○ Training

- According to Station Management the good results at the Doel plant can be ascribed to the substantial investment in staff training
- Doel has Alara Training for all station personnel
- Doel has extensive Alara Training for their work planning organization. The additional training provides opportunities for personnel to identify dose reduction techniques that may go unnoticed or unrecognized.



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- Outage Implementation
  - Doel shuts down at  $\sim 2\%$  power and does a manual insertion (Soft Shutdown)
  - Doel has a 24 hour holdout limitation while post peroxide clean-up is in progress
  - Doel's most recent outage was  $\sim 24$  Rem.
  - Doel uses about 50 Tons (100,000 lbs) of temporary shielding

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## ○ Outage Implementation

- The purification rate is 25 m<sup>3</sup>/h (110 gpm) in operation, and 35 m<sup>3</sup>/h (154 gpm) during outages.
- Technical specifications for status at the end of purification are the following: <sup>58</sup>Co < 20,000 MBq/m<sup>3</sup> (0.05 mCi/ml) (however, 700 MBq/m<sup>3</sup> (0.0018 mCi/ml) is attained in practice),
- Doel uses dilution to deborate.
- During restoration of RC from system maintenance injects 80% hydrazine.

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## ○ Outage Planning

- 4000 to 6000 work permits are issued during each unit outage
- All steam generator secondary side work is carried out with the tube bundle filled with water.
- The maintenance program for the steam generators adheres strictly to the American ASME rules, with no additions by the Belgian safety authorities.
- S/G Maintenance is performed every third cycle.
- Major efforts made concerning the maintenance of the special tools, which has substantially reduced the number of contingencies and hence the time taken to complete tasks



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## ○ Outage Planning

- In most cases, the planner for the profession involved makes the first dose prediction.
- After a work request has been issued, the planner for the profession must make an application for a work permit.
- It is up to the radiation protection planner to determine whether the dossiers should be combined and treated as a single ALARA dossier



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## ○ Outage Planning

- Dosimetry hold points have been included in the operating procedures.
- Depending on the collective dose and the dose rates predicted, an ALARA dossier is prepared

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## ○ Outage Planning

- Requirements for an ALARA dossier:

- If the ambient dose rate is less than 0.1 mSv/h (10 mrem/hr) (and the maximum contact dose rate is less than 5 mSv/h (500 mrem/hr)) and/or if the predicted collective dose is less than 0.5 man.mSv (50 mrem), the planner for the profession is not required to go any further with the procedure.
- If the ambient dose rate is greater than 0.1 mSv/h (or the maximum contact dose rate is greater than 5 mSv/h) and/or if the predicted collective dose is between 0.5 and 5 mSv (50-500 mrem), an ALARA dossier is opened.

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## ○ Outage Planning

- Requirements for an ALARA dossier is prepared:

- If the predicted collective dose is between 5 and 25 man.mSv (500-2500 mrem),
  - a meeting between the planner for the profession and the planner for radiation protection is mandatory
  - Together they draw develop ALARA dossier
  - Final approval by the radiation protection planner
- If the predicted collective dose is greater than 25 man.mSv (2.5 Rem)
  - ALARA committee is called in for investigation of methods of reducing the collective dose for the job planned.



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## ○ Outage Planning

- The plant planner for the professions meets those in charge of the contractor work during a kick-off meeting during which they are informed of the radiation protection goals.

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## ○ Outage Dose Monitoring

- Dose predictions for jobs that are covered by an ALARA dossier are posted at the entrance to the controlled area or the workplace, as are the current dose results
- There is an RP office (table and chair) on each level of the reactor building during the unit outage. The role of the RP specialist is to check that the work effectively corresponds to the work permit and that the conditions recommended in it are correctly established.



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- Outage Dose Monitoring
  - The radiation protection technicians regularly patrol the controlled areas to measure the dose rates.
  - The dose rate readings are entered into the SARA computer application installed on the Electrabel intranet of the Doel site
  - Some 25 measurements of the ambient dose rate are continuously (these are visible on the screens in the radiation protection room and in the control room).

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- Zoning criteria are as follows:
  - Free-access controlled area (green): dose rate < 7.5  $\mu\text{Sv/h}$ . (<.75 mr/hr)
  - Limited-access controlled area (yellow trefoil): 7.5  $\mu\text{Sv/h} \leq$  dose rate < 20  $\mu\text{Sv/h}$ . (.75 - 2 mr/hr)
  - Regulated-access controlled area (orange trefoil): 0.02 mSv/h  $\leq$  dose rate < 0.2 mSv/h. (2 - 20 mr/hr)
  - Regulated-access controlled area (purple trefoil): 0.2 mSv/h  $\leq$  dose rate < 1 mSv/h. (20 - 100 mr/hr)
  - Forbidden-access controlled area (red trefoil): dose rate  $\geq$  1 mSv/h. (100 mr/hr)
  - Closed Areas  $\geq$  100 mSv/h are padlocked with two keys (one of the keys is held by the radiation protection foreman and the other by the operations team shift manager). (>10 R/hr)



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- Contamination Control:
  - In the areas where surface contamination is between 0.4 and 4 Bq/cm<sup>2</sup> (24 -240 dpm), wearing of gloves and overboots is mandatory.
  - A physical barrier is installed if the contamination in the area exceeds 0.4 Bq/cm<sup>2</sup> or if the work can cause contamination (use of grinders for example)
  - In 4 to 40 Bq/cm<sup>2</sup> areas
    - wearing of leaktight washable gloves is mandatory (as well as a second pair of rubber gloves on top in the presence of wetness)
    - pair of plastic overboots (or leggings)
    - mandatory to wear a white suit with a red collar; in the presence of wetness, a tear-resistant leaktight flexotane® suit must be worn.
    - A ventilated visor is worn if there is a risk of atmospheric contamination

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- Contamination Control
  - In zones of a contamination greater than 40 Bq/cm<sup>2</sup>,
    - The gloves worn are yellow
    - The overboots are red.
    - A suit with a red collar must be worn.
    - A mask is also mandatory, as well as a leaktight flexotane® oversuit (in which case the full-face filtering mask is taped to the hood of the suit).
  - A complete ventilated suit is recommended for lengthy operations

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- What leads to success
  - Doel plant has benefited, from the start, from major efforts concerning the chemistry of the primary coolant.
  - Radiation Protection has long been highly regarded by the other workers / departments
  - Regulatory dose limit reduced to 2 person-rem/yr



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- What leads to success
  - Efforts made to install standardized biological shielding at the start of unit outages
  - Excellent collaboration between the departments responsible for the chemistry and the radiation protection department
  - The ALARA approach has been formally established and has become a second nature for the different planners (for all professions alike).