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ALARA AT THE BORSSELE NUCLEAR POWER PLANT.

Summary
The Borssele Nuclear Power Plant is a NPP of KWU-design and was commissioned in 1973.
From the beginning of operation up till today, ALARA has been and is a concern of the radiation protection department as well as of the maintenance and operation departments.
Due to a mishap in the material composition of new loaded fuel elements the dose rates in the primary systems became very high between 1979 and 1982.
Because of this problem the NPP Borssele consequently had also much higher values for the individual and collective doses in these years. This development forced the NPP Borssele to take ALARA very serious.
After discovering the cause of the drastic increase in dose rate and eliminating this, the dose rates declined. Besides a lot of other measures were taken in order to reduce the individual and collective doses.

Today it can be concluded that thanks to a lot of effort in the past years the NPP Borssele, belongs to the best performing NPP's of its kind with respect to dose results.

1 Introduction.

In the late 70's and early 80's the dose rates at the NPP Borssele increased very dramatically in just a few years. Extensive investigations were carried out to find out the cause of this increase.

In one of these investigations it was decided to carry out gamma spectroscopy measurements of samples taken during the wet sipping of the fuel elements. Normally only fission products are measured during wet sipping in order to discover fuel leaks. But for this purpose it was decided to measure also the activated corrosion products like Co-60, Co-58, Cr-51, Sb-122, Sb -124.
Grouping the gamma nuclide-activity results by batches of new loaded elements and trending of these results over the years showed that the new loaded fuel elements caused a cobalt ingress and appeared to be the cause of the increase in dose rate in the primary system.
Then the results were discussed with the supplier of the fuel and in-depth investigations were carried out to find out which part of the fuel element might be the cause of the cobalt-ingress.

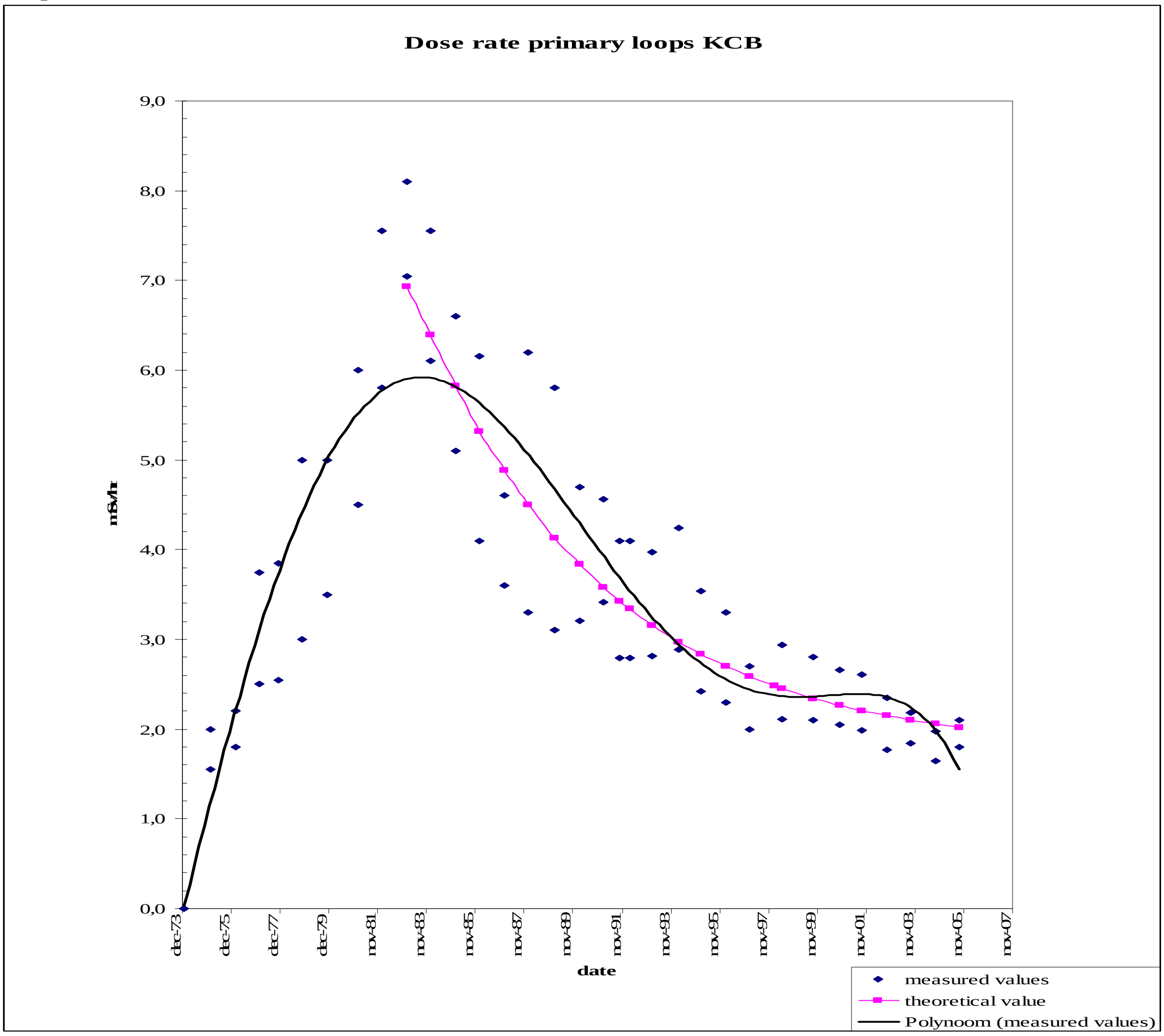
In those days the cobalt content in nickel coating of the spacers in the fuel elements varied.
Especially in the loading of the fifth cycle the cobalt content was very high, much more than 1%.
These fuel elements have been in the core during the cycles 6, 7 and 8, and during these cycles the dose rate increased.
After unloading these elements and other measures taken, the dose rate in the primary system gradually decreased again.
From that time on strict specifications for the cobalt content in material, that is used in the core or in the primary circuit, were defined and verified.
Due to the high dose rates and the work being carried out in the way it was carried out in those days, the cumulative year dose at the Borssele NPP went up as high as 5500 mSv in the years 1982 to 1985.
All the ALARA measures taken in the past years resulted in a substantial decrease of the annual collective year dose. Last year (2005) the collective dose was 199 mSv, which was the lowest value since the start up of the plant.

2 Dose rates.

As the NPP Borssele is a power plant that was built in the late 60's, early 70's it is expected that the dose rate would go up during operation due to the cobalt content of various materials used in the primary system.

From 1979 to 1982 however the dose rate increased dramatically due to the use of fuel elements with high cobalt content.

Graph 1



Before having established that some fuel elements were the cause of the higher dose rate, they had already been in the core for 3 years. Except for one element which had a defect.

After the large update modification of the Borssele NPP, in 1997, this element was again used for one cycle. This was done after ALARA considerations, like the amount of work that had to be carried out in the coming few years and the power this element could produce (economical value).

In graph 1 above, it can be seen that the measured values follow the theoretical values (decay) well, although there are still some materials with cobalt in the primary circuit and a small amount of Co-60 is still being deposited.

The theoretical line is the decay of Co-60 with an (asymptotic?) minimum value of 1.75 mSv/h which is, we suppose, the dose rate caused by other nuclides than Co-60 and the balance between the newly activated and decayed Co-60.

The dose rates decreased during the years because of the decay of Co-60 and the following measures taken:

- Taking enough time for cleaning the primary water before starting the outage.
- Changing ion exchange filters more often than usually, not only because of too high delta P but mainly due to applying the criterion of breakthrough for certain nuclides which are important for avoiding dose rate build-up.
- The water of the spent fuel basin is cleaned through powder resin and a “Balduf” micro filter.
- The pores of mechanical filters in the supporting primary systems were reduced from 3 micrometer to 0.3 micrometer.
- The pH is kept very constant between 6.9 and 7.0, with dosage of LiOH in dependence on boron content of the primary system.

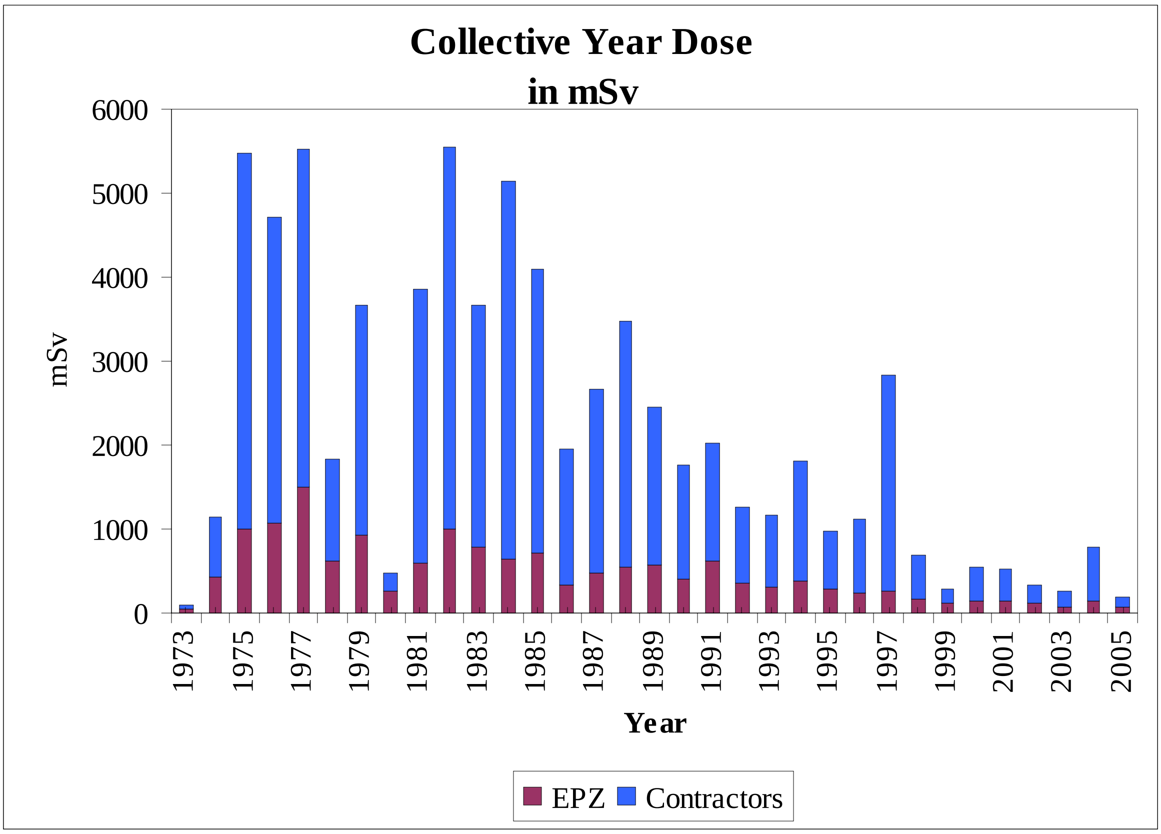
Now, in 2006, the dose rate, on primary loops, is still decreasing and will probably reach, in time, 1.75 mSv/h.
This process can also be influenced by zinc injection for instance.
More about this under “3 collective dose”.

3 Collective dose

As a result of the high dose rates, the collective dose was in the early 80’s so high that the regulator considered dictate a maximum allowable year dose for the Borssele NPP.
Integral primary system decontamination was therefore considered.
Several decontamination processes available at that time were extensively investigated. Numerous corrosion tests were carried out and consequences of the decontamination for operations and waste management were inventoried.
The project for decontamination was already in a very advanced stage when a last test was carried out on some core internals. In this test it became evident that some springs in the core appeared to be not corrosion-resistant for the decontamination fluid, and were more or less crumbled after the test.
As a result of this test the whole decontamination was cancelled, because such a result after all the investigations carried out caused that confidence was lost.

We performed in those days some partial decontaminations, for instance of the primary circuit pumps, when they were taken out of the system.
It was only in 1997 that a partial decontamination of a primary supporting system was carried out.
In connection with a big modification project a lot of work had to be carried out in the vicinity of the residual heat removing system.
For this project an ALARA report was made in which the decontamination of the system was compared with the option of extra shielding. For ALARA reasons decontamination appeared to be the best option.
This decontamination was carried out very well, with very good decont factors up to 17.
The benefit of this decontamination was mainly in this one year. After half a year the recontamination factor was about 5.
Besides the reduction of the dose rates, the collective dose has been reduced as a result of the following measures taken:

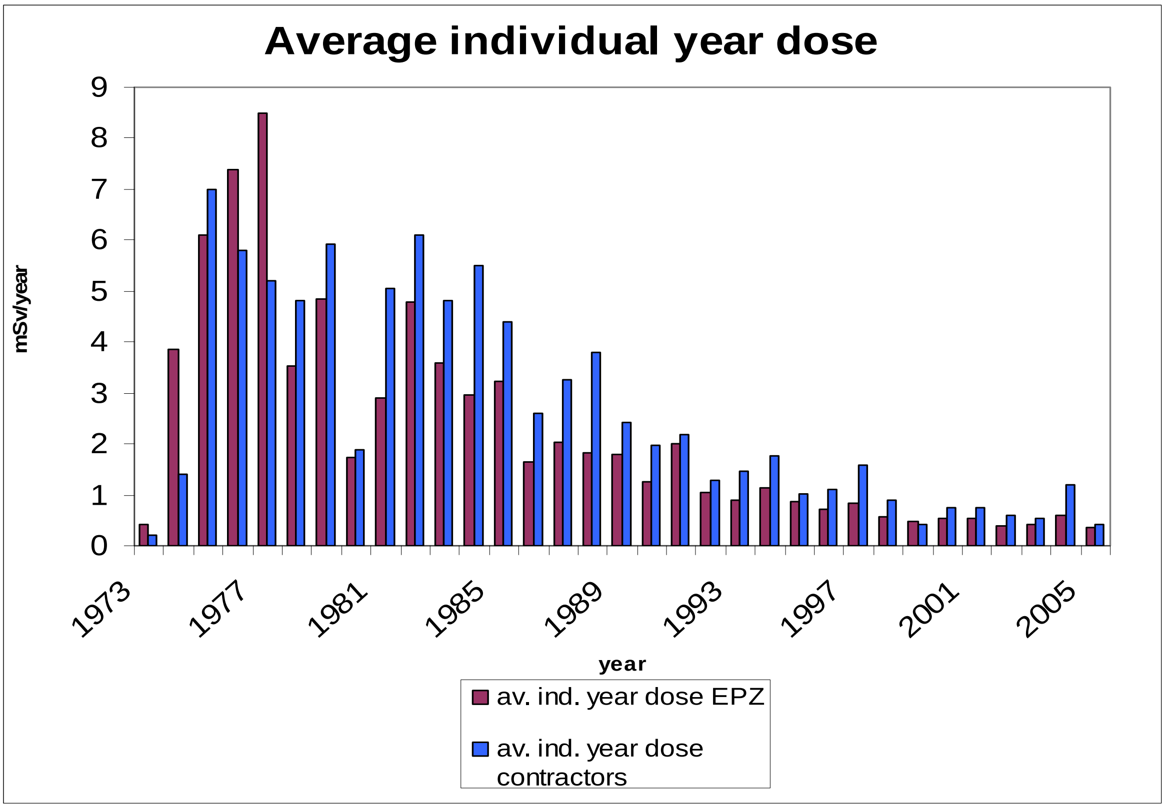
- Improving local shielding where useful
- Many different maintenance activities that were carried out separately in the past were combined.
- The amount and intervals of periodical maintenance and periodic inspections were, in consultation with our regulators, reduced, where possible.
- Commitment of the maintenance department to reduce dose.
- Better planning and preparation of the work being carried out in normal operation
- Careful outage planning and detailed yearly evaluation and feedback of results
- Mockup training
- More consequent RP supervision
- Lowering the threshold for working without a proper dose estimate and dose reduction plan.
- Shortening the yearly outages.

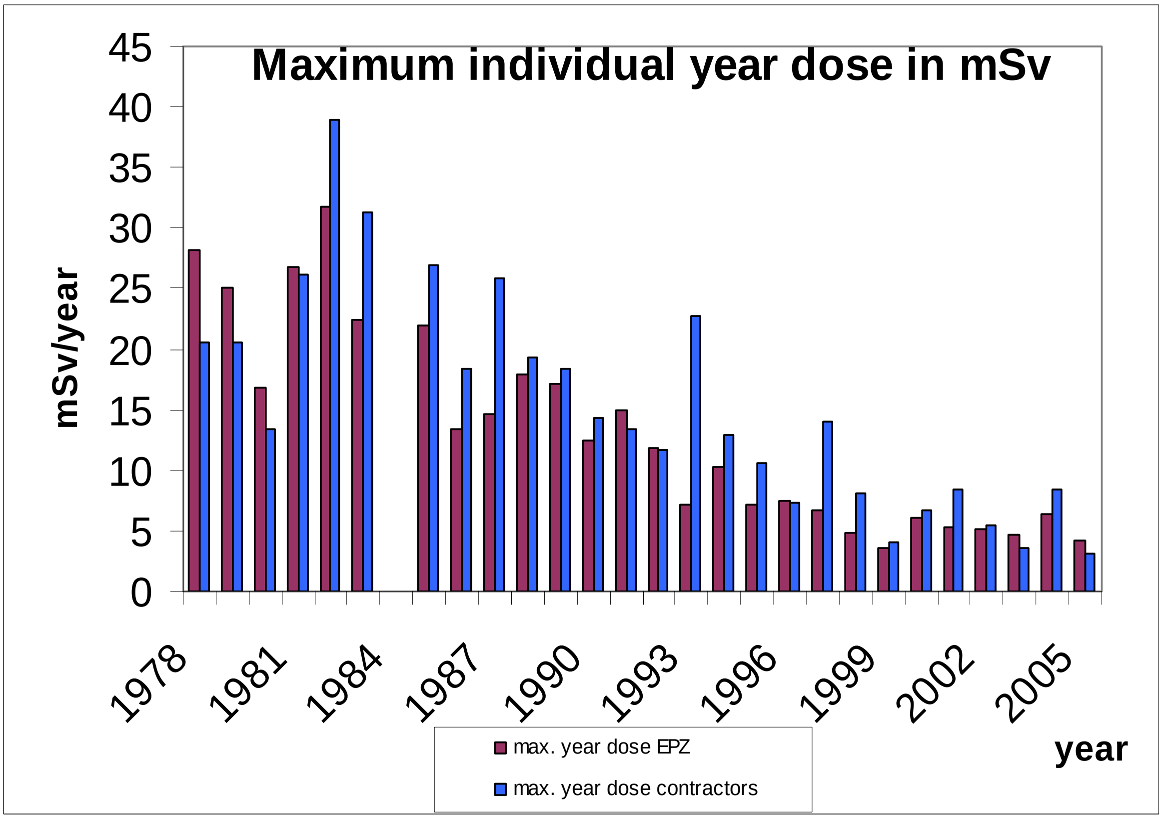


4 Individual dose

With the high dose rates, the individual dose became a great concern to KCB, already in the beginning of the 80's. As we had a dose rate of 500 to 600 mSv/h in the primary chambers of the steam generators, it became virtually impossible to let people work in this area. The "jumpers" were lined up in a queue to do their work for only one minute, and than they had their permissible dose.
Because of these high dose rates KCB was in fact one of the first of the German built plants to use a manipulator to perform work in the steam generators.

From the beginning of operations KCB had the policy to keep the dose results well under the statutory limits for the individual dose.
When the statutory limit was 50 mSv/y, KCB maintained an internal limit of 10 mSv/y as a 5 year average. When the limit became 20 mSv/y, KCB maintained a 5 year average limit of 7 mSv/y as internal limit.
From 2006 this 5 year average limit is lowered to 3 mSv/y.
Very helpful for lowering the individual dose was the permissible individual day dose.
In the 80s this was set on 1 mSv per day, later this was lowered to 0.5 mSv/day and from this year we will maintain a permissible individual day dose of 0.2 mSv/day. This forces the maintenance group to be even more committed to lowering the dose. It also minimizes the "unplanned dose".
To ensure that the individual dose was kept under the internal limits several ALARA measures were taken. Of course the measures mentioned under **par. 3** were also very effective to reduce the individual dose.


Average individual year dose
mSv/year
0
1
2
3
4
5
6
7
8
9
1973
1977
1981
1985
1989
1993
1997
2001
2005
year
av. ind. year dose EPZ
av. ind. year dose contractors


Maximum individual year dose in mSv
mSv/year
0
5
10
15
20
25
30
35
40
45
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
year
max. year dose EPZ
max. year dose contractors

5 ALARA considerations

The NPP Borssele has an ALARA procedure in which is stated which RP documents are needed when a job is planned.
When a job costs more than 10 mSv, an extensive ALARA report has to be made.
If a job will cost > 1 mSv collective or > 0,5 mSv individual dose only a written dose estimate is required.
All ALARA-reports are approved by the site responsible health physicist and discussed in the ALARA commission. The ALARA commission is the internal commission where all important RP-issues are discussed between the RP department and all other relevant departments.
In the ALARA procedure of the Borssele NPP an Alpha value of 500 – 1000 Euro/mSv reduced dose is applied.
If the individual dose is likely to become higher than 10 mSv the 1000 Euro value is applied.

For the decontamination of the residual heat removing system in 1997 (mentioned earlier) an extensive ALARA report was made. The total dose involved in this project was estimated to be over 1000 mSv. In this report it was concluded that decontamination was preferred above only shielding.
The ALARA decision between shielding and decontamination was easy to make, as in the shielding version the dose would be 950 mSv and in the decontamination version the dose would be 200 mSv. The saving of 750 mSv was estimated to cost 105,000 Euro. This was well below our Alfa value of 500 Euro per mSv?
Because of the fact that the decontamination factor that was calculated as 8, became 17, the real received job dose was only 77 mSv.
This is an example of an ALARA consideration with a positive outcome for the intended measure.

An example of an intended ALARA measure that was not implemented is the Zinc injection.
Borssele was under the impression that Zinc injection, as an ALARA measure, was implemented in several NPP without extensive research for cost benefit.
We asked a physics student to make his thesis about the feasibility of Zinc injection at the Borssele NPP.
The following facts were taken into consideration:

- The influence of Zinc on the installation
- The dose rates of the primary loops that are still falling
- The investment costs (once-only)
- The yearly enriched zinc costs
- Yearly implementation costs, for instance due to extra work for NPP personnel
- The extra waste costs and dose
- The planned maintenance work in the next years
- A calculation period of 10 years.

Taking the above into consideration a dose saving of 750 mSv +/- 100 mSv appeared to be achievable in a period of 10 years.
Taken into account the most conservative Alfa value of 1000 Euro per mSv, it appeared not to be ALARA to start zinc injection at the Borssele NPP. (The potential costs of radwaste were not even accounted for. Assuming an increase of 10 % of resin waste, these costs would amount about 330,000 Euro.)

As result of a thorough investigation and a careful and conservative cost-benefit analysis the Borssele NPP decided not to implement the injection of Zinc as a feasible dose reduction measure. The Dutch regulator agreed on this decision.

6 Conclusions

As a consequence of the materials used in its construction at the time, NPP Borssele is a NPP with potential higher dose rates. After a mishap however the dose rates became unexpectedly high in the early eighties. Numerous measures were taken to reduce both the collective and the individual dose. Nowadays Borssele is in the forefront of achieving low dose results, especially taking into account the age of the plant.

From the history of Borssele one can also see that ALARA is not always a matter of spending big money. Small measures like combining maintenance, canceling of “unnecessary” inspections, good preparation, optimal commitment of the maintenance departments, good chemical household etc. can result in a substantial lower collective and individual dose.

The shortening of the yearly outages also provided a large contribution to the dose reduction of the last years

As money is a scarce commodity and it can be spent only once, it is very important to consider ALARA measures very thoroughly.