“ALARA principal and dosemanagement during large scale backfitting at Borssele nuclear powerplant.”

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This contribution consists of 2 separate articles, which be are joined in 1 presentation.

PRACTICAL APPLICATION OF THE ALARA PRINCIPLE DURING LARGE-SCALE BACKFITTING AT THE BORSSELE NUCLEAR POWER PLANT

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Summary

At the Borssele nuclear power plant an extensive backfitting programme (Modifications Project) has been carried out. It concerned sixteen technical modifications. In connection with the extent of the work and the dose rates at places where work had to be carried out, it was clear from the start that a high collective dose had to be taken into account. For this reason radiation protection was arranged within the project in such a way that in all phases of the project the radiation protection principles were applied.

In respect of radiation protection the Modifications Project could be divided into three phases, namely:

- conceptual phase, in which especially the justification principle applied
- the engineering phase, in which the ALARA principle was carried out and
- the implementation phase, in which besides the ALARA principle attention should also be paid to maintaining the (internal) dose limits.

In all phases of the project the radiation protection considerations and results were documented in so-called ALARA reports and radiation protection checklists.

Maximum attention to radiation protection in all phases of the project eventually resulted into a collective dose of 2,505 mSv, which is a reduction by a factor of 4 compared to the initial estimate.
Considering the extent and complexity of the work and the prevailing radiation levels at the Borssele nuclear power plant, this is an excellent result.

1 Introduction

Over the last decade the attention to the risks involved in older power plants has increased strongly. On an international scale the necessity to minimise these risks led to the implementation of periodical integral safety evaluations. The technical, organisational, administrative and personnel facilities of the power plant are tested according to the standards for power plants newly to be built.
A difference is made between two-yearly and ten-yearly evaluations. The ten-yearly evaluations must be a "more extensive evaluation in which the points of departure themselves must also be compared to the new developments with regard to nuclear safety and radiation protection".
In 1992 the above development resulted in the addition of a requirement to the licence of the Borssele nuclear power plant pursuant to the nuclear energy regulations. This requirement imports such periodical safety evaluations relating to the technical, organisational, administrative and personnel facilities.

The first ten-yearly evaluation took place in the period from 1991 to 1992.
On the basis of this ten-yearly evaluation a number of technical modifications have been introduced at the Borssele nuclear power plant.
It concerned sixteen technical modifications.

In view of the extent of the work and the dose rates at places where work had to be carried out, it was clear from the start that a high collective dose had to be taken into account.
On this basis it was decided to pay special attention to radiation protection at the basic design stage. This article deals with the procedures applied and the measures taken to keep the radiation load as low as was reasonably achievable.

2 Project Modifications

The Borssele NPP is owned by the N.V. Elektriciteits-Produktiemaatschappij Zuid-Nederland and is located at the Westerschelde estuary. The Borssele NPP is a pressurised-water reactor and was built by Siemens/KWU. The power plant was put into operation in 1973. The electricity output is 480 MW.

The ten-yearly integral safety evaluation mentioned in the introduction, has led to sixteen technical modifications aiming to increase the safety of Borssele NPP in such a way that it complies with the latest internationally recognised technical insights in the field of nuclear safety and radiation protection. The evaluation and the realisation of the technical modifications were referred to as Modifications Project [1].

The modifications comprised modifications aiming to
- improve the general operation and reduce the risk of system failure
- increase the redundancy (multiple execution)
- increase the spatial separation of subsystems which are mutually redundant
- increase the diversity of components/systems of which the redundancy applied was considered insufficient, and
- fully automate the execution of safety functions in case of failures

In 1992 the implementation of the modifications was assigned to Siemens/KWU by means of a turnkey contract. The total project budget was NLG 467 m. In 1993/1994 an extensive licensing procedure, comparable to that of the construction of a new power plant, took place.

The implementation of the modifications was largely realised during an extra long overhaul period in 1997. The entire modification and the annual refuelling took from 8th February to 14th July 1997 inclusive.

As stated before, special attention was paid to radiation protection right from the start of the project in view of the high collective dose to be expected. For this purpose a Radiation Protection Co-ordinator was appointed within the project organisation at the start of the project. This co-ordinator's main task was to see to it that in all phases of the project the ruling radiation protection principles were applied.

With regard to radiation protection the Modifications Project could be divided into three phases, namely:
- conceptual phase, in which especially the justification principle applied
- the engineering phase, in which the ALARA principle was carried out and
- the implementation phase, in which besides the ALARA principle attention should also be paid to maintaining the (internal) dose limits.

In order to guarantee a maximum contribution of the radiation protection when choices and decisions are made during all phases of the project and in order to guarantee the central specific experiences of the Radiation Protection Department of BORSSELE NPP, a procedure with regard to radiation protection was laid down in advance by the general contractor Siemens/KWU and BORSSELE NPP. This procedure is shown in a diagram in appendix 1. For the monetary value of the Sievert NLG 1,000.- per mSv was applied.

In all phases of the project the radiation protection considerations and results were documented in so-called ALARA reports (see section 4.1) and radiation protection checklists. (see section 4.2)

3 Conceptual phase

The integral safety evaluation mentioned in chapter 1, has resulted in a safety concept. In this safety concept it was specified what technical safety requirements BORSSELE NPP would have to comply with after the modifications were made. In addition this safety report gave a broad outline of technical modifications necessary to comply with these requirements.

In this conceptual phase a dose justification was drawn up for the modifications planned. For this purpose a comparison was made between the potential dose for the population as a result of accidents and the anticipated collective dose for the personnel in connection with the execution of the modifications. For the potential exposure of the population the definition “risk x effect” was applied whereby risk and effect were determined by means of a probabilistic safety analysis (PSA) specific for Borssele NPP [2, 3].

On the supposition that the power plant would be in operation for another ten years after the modifications, it was concluded that the decrease of the potential dose for the population justified the anticipated collective dose in connection with the execution of the modifications [4].

The doses for the individual modifications were chiefly considered legitimate on the basis of the purposeful increase of the safety of the installation through prevention or control of accidents and through compliance with the licence requirement that the power plant must periodically be modified according to the latest technical developments. These justifications were recorded in ALARA reports (see section 4.1).

In the conceptual phase an estimate, based on the safety concept, was made of the collective dose to be expected for the entire project.
For this estimate no empirical figures were available, apart from operations on the pressurising system, as a backfitting programme of these proportions had never before been carried out and/or the anticipated operations were to be carried out for the first time.

In this phase the broadly estimated collective dose was 10 person-Sv.
Assumptions for this estimate were:

- estimates on the basis of floor plans of the rooms where work had to be carried out and process diagrams and instrumentation diagrams of systems on which work had to be carried out
- the dose tempi measured
- the installation effort broadly known (number of persons, duration)
- an extra 10% for general work (radiation checks, scaffolding, decontamination, etc.) based on empirical figures of BORSSELE NPP
- only operations in spaces with a dose rate > 10 _Sv/h were included in this rough estimate

In advance it was estimated that by taking general radiation protection measures (distance, time, shielding) the dose could be reduced to approx. 7.5 person-Sv. By taking more specific measures a further reduction would be aimed at.

4 Engineering phase

The engineering phase was subdivided into a basic engineering phase and a phase in which the detail engineering took place.

The detailed preparation with regard to the radiation protection for the individual modifications (sub-projects) took place in both sub-phases. In order to determine the radiation protection measures, the safety standard of the IAEA about design aspects

relating to radiation protection for new nuclear power plants was applied, insofar as it was implementable [5].
In this phase the emphasis of the radiation protection was on the optimisation within the framework of the ALARA principle.

4.1 Basic engineering

In the basic engineering phase the possible technical variants and variants concerning possible set-up locations were examined, insofar as these were applicable. The considerations between the variants and the eventual choice of variants was based on a cost-benefit analysis as described in ICRP 55 [6], a so-called ALARA procedure. This procedure is shown in a diagram in appendix 2.

This analysis was carried out exclusively for the modifications in which:
- the collective dose for the execution of the modification concerned > 10 mSv or
- the annual collective dose of the future operation > 5 mSv as a result of this modification.

The results of the optimisation processes (cost-benefit analysis) were recorded in ALARA reports.
For modifications without variants the motivation was documented.

By means of a cost-benefit analysis it has been examined for both modifications whether decontamination was an optimisation possibility in view of the anticipated high doses for the work on the pressurising system and the residual heat removal system. On the basis of the dose factor of NLG 1,000.- per mSv it was established that only decontamination of the residual heat removal system was eligible for implementation. For this reason chemical decontamination of part of the residual heat removal system was carried out at the start of the implementation phase. For the procedure and results of this decontamination please refer to [7].

4.2 Detail engineering

In the detail engineering phase the radiation protection measures to be taken for the variants chosen during the basic engineering phase are determined at detail level. In this respect the requirements set in the safety standard of the IAEA Safety Series No. 50-SG-D9 were of importance [5].

After a concept detail engineering plan had been drawn up, this plan was assessed and, insofar as applicable, optimised from a radiation protection angle. The aim was to keep the dose for the implementation of the modification and for the operation of the modified installation as low as was reasonably possible.

Important optimisation aspects were:
- set-up locations
- accessibility for maintenance
- simplification of maintenance work

- use of tried maintenance-friendly components
- correct choice of material (e.g. Co content basically _ 2000 ppm)
- prevention of leakage
- prevention of deposition (hot spots)
- shielding against other radiating components
- determining radiation protection measures for the implementation of the modifications.

The results of above optimisations were documented in so-called radiation protection checklists. These checklists were drawn up by the designer of the modification together with the radiation specialist of the supplier. In appendix 3 a model of such a checklist is shown.

5 Implementation phase

During the implementation phase radiation checks were conducted by the Radiation Protection Department of BORSSELE NPP. This department also checked whether the radiation protection measures proposed in the engineering phase were actually taken and applied.
Naturally this department could demand additional radiation protection measures, if desired.

The planning of the use of personnel was based on the internal annual limit of BORSSELE NPP of 10 mSv including the dose sustained before. In exceptional cases this individual dose could be raised to 15 mSv with the permission of the Radiation Protection Department of BORSSELE NPP. In a few isolated cases this exception measure was applied.
At the end of the project the collective dose was 2,505 mSv (2.5 Sv).

It may be concluded that maximum attention to radiation protection during all phases of the project has in fact resulted in a collective dose of 2,505 mSv, which is a reduction by a factor of 4 compared to the initial estimate. Considering the extent and complexity of the operations and the prevailing radiation levels at the Borssele nuclear power plant this is an excellent result.

6 References

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DOSE MANAGEMENT AT BORSSELE NUCLEAR POWER PLANT DURING MODIFICATION OPERATIONS IN 1997

Summary

It is customary that, prior to overhaul periods at nuclear power plants, an estimate of the dose of ionising radiation to be received is made in conjunction with the executive departments. During these overhauls the dose received is recorded and evaluated afterwards.

In 1997 a large-scale backfitting operation was executed at the Borssele nuclear power plant. This operation took approximately four months. The extent of the collective dose to be expected dictated a different approach towards its assessment as well as the registration and the constant interim evaluation.
The procedure of detailed planning of the dose and the daily monitoring and consulting with the operational staff of the estimated dose and the dose realised, appeared to be very useful and contributed to the fact that the dose received remained within the limits of the estimated dose.

1. Introduction

In connection with the ten-yearly evaluation a modification project was executed at the Borssele nuclear power plant between 1994 and 1997. The aim of this project was to modify the power plant in such a way that it would comply with the latest internationally recognised insights in the field of nuclear safety and radiation protection [**1**].

These modifications have resulted in a ten times smaller risk of a melting accident and a better control of the situation if such an accident should nonetheless occur.

This modification comprised 16 sub-projects which largely had to be conducted in the “controlled area”.

In 1994 a start was made with the implementation of the project.

The most extensive part was conducted in 1997 and took approximately four months.

It was clear right from the start that a relatively high collective and individual doses would be received during these operations and that it was of utmost importance to monitor these doses carefully in order to be able to react in time in case of deviations.

2. Preparation for the modifications relating to radiation protection.

In 1993 a first dose estimate was made which yielded **10 person-Sv**.

At BORSSELE NPP the ALARA principle is applied to try to keep the doses as low as is reasonably achievable.

The monetary value for the Sievert, i.e. the value in Dutch guilders which may be spent on measures to limit the dose, is between NLG 1,000.- and NLG 2,000.- per mSv saved.

The executive firm was committed to plan dose limiting measures in accordance with the ALARA directives applicable at BORSSELE NPP, and to apply the monetary value for Sievert.

One sub-project was cancelled on the basis of the justification principle. It concerned the relocation of the branching of the emergency core cooling system in the primary system. The safety gain (reduction of the melting frequency) calculated by means of the probabilistic safety assessment (PSA) specific for Borssele NPP, was deemed insufficient to justify the collective dose necessary for the relocation of this branching.

After ALARA reports were drawn up for all eligible sub-projects and the procedures were determined, the dose estimate was **5 person-Sv**.

The ALARA procedure applied is described in detail in [2]. In brief the procedure amounted to the following. By means of a first ALARA report the best solution was selected from several technical solutions, partly on the basis of ALARA considerations (ALARA part 1). After this a second ALARA report was drawn up for the solution selected in order to optimise the procedure with regard to the dose even further through a closer examination of procedures, elapsed time, shielding concept and possible decontamination (ALARA part 2).

After several optimisation rounds on the basis of the above-mentioned ALARA reports, the dose estimate for the part of the modifications which was executed in 1997, was **1.85 person-Sv**.

Together with the 0.725 person-Sv received in the period from 1994 to 1996 this led to an expected collective dose of **2.575 person-Sv** for the entire project.

The most important modifications in respect of radiation load for the operations in 1997:

- The modification of the piping and the primary safety valves of the pressuriser (YP) (dose estimate: 0.54 person-Sv)
- The separation of the emergency core cooling system TJ into two fully separate systems. (dose estimate: 0.27 person-Sv)
- Initially the dose estimate was 1.00 person-Sv, but after an optimisation by means of ALARA considerations it was decided to decontaminate the subsystem, which resulted in a much lower estimate [**3**].
- Renewal of the feed water and the main steam pipes (RL and RA) (dose estimate: 0.15 person-Sv)
- Making the shielding walls, cable trays and pipe suspensions earthquake-resistant. (dose estimate: 0.12 person-Sv)

3. Dose management.

The dose management tools applied

For the individual dose:

- Dosimetry with TLD badges (official dosemeters) and electronic alarm dosemeters (RAD 80/90, operating dosemeters).
- Daily dose lists, a possible two-weekly adjustment of the operating dose on the basis of results of the TLD reading.
- For EPZ personnel: the life dose.

Internal dose limits:

Daily dose: a maximum of 1 mSv. If necessary, daily consultation between the management of the Radiation Protection Department and the executive department took place about a possible higher limit of maximum 4 mSv/day.

Annual dose: guideline _ 7 mSv. After consultation with the Radiation Protection Department this limit could be raised to 10 mSv. In exceptional cases, e.g. for specialists, an increase up to 14 mSv was possible.

For the collective dose:

- A very detailed planning of the work sequence and a dose estimate which was worked out in minute detail and of which the variations in the course of time were related to the detailed work planning.
- An electronic dose measuring system with directly readable alarm dosemeters.
- A read out unit for the dosemeters close to the operation to be performed in order to obtain a correct registration of the job dose without distortion by the dose of possible other operations.
- Daily dose lists for each operation to be inspected.
- A proper daily comparison of the dose estimate and the dose sustained in the form of graphs.
- Daily consultation between the Radiation Protection Department and the executive departments.

An example: the primary safety valves modification sub-project (YP)

The YP sub-project comprised the removal of the old piping and the safety valves and the fitting of the new installation.
For the whole sub-project a total of 1,790 man hours were estimated.
For the removal 444 hours were projected and for the fitting of the new piping and valves 1,000 hours. The other hours projected were anticipated to solve so-called “obstacles” (e.g. the re-routing of pipes from another system which were blocking the way).

In order to limit the dose received as much as possible the first operation was the removal of the radiating pipes and valves. These components were sawed out of the system and instantly carried off as waste.

The average dose rate in the work space during the removal of the old pipes and valves was approx. 0.40 mSv/h. During the fitting of the new pipes and valves the average dose rate in the work space was approx. 0.25 mSv/h with some local peaks of 1 mSv/h.
These dose rates applied even though an optimum lead shielding (approx. 23 tons) was fitted.

The initial estimate of the dose for the modification described above was 0.54 person-Sv. The anticipated dose variations in the course of time corresponded with what is shown in figure 1.

During the implementation of the sub-project the daily dose sustained was compared to the dose estimated for that day.
Possible changes in the planning were immediately processed in the estimate.
On account of the extremely detailed planning of the dose and the detailed monitoring of the dose received, deviations of the actual dose compared to the estimate were detected immediately.
When deviations were detected, these were immediately discussed with the executive departments, after which the necessary corrective steps were taken.

Right at the start of the implementation of the operations it appeared that the removal of the old piping cost more dose than had been estimated in advance.
As soon as this was detected, the Radiation Protection Department consulted with the executive firm to find the cause and consider a change in the procedure.

In this case the procedure appeared to be optimised sufficiently, however, and the dose estimate was adapted on the basis of experiences acquired.

The new dose estimate was 0.595 Sv; eventually the dose was 0.586 Sv.

During the whole project daily consultations were conducted with the executive firms on the basis of the dose estimated and the dose received.

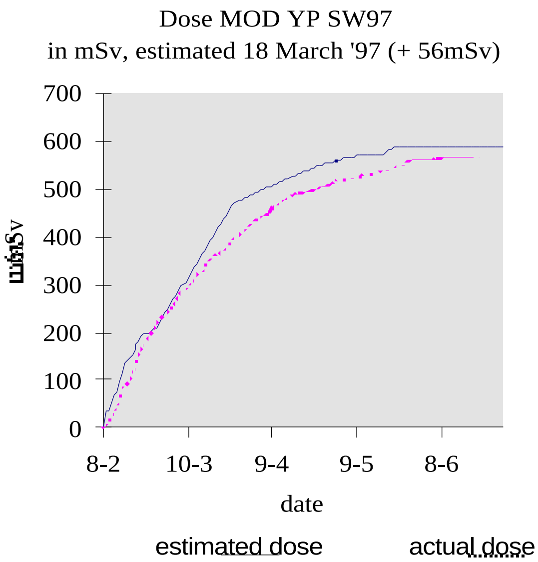

Figure 1: The dose planned and the dose realised as a function of the time allocated to the operations relating to the modification of the primary safety valves.

4. Results.

Dose estimates:

First estimate	1993:	10 person-Sievert
Estimate	1995:	5 person-Sievert

(the non-implementation of the relocation of the branching of the emergency core cooling system yielded a saving of 1 person-Sv)

Dose estimate for operations in 1997: 1.85 person-Sievert

Results:

Dose received in 1997: 1.78 person-Sievert

Dose received from 1994 to 1997 inclusive (total project): 2.58 person-Sievert

DOSE DISTRIBUTION FOR THE OPERATIONS IN 1997

Dose interval in mSv	%
0.01 - 0.50	53
0.51 - 1.00	12
1.01 - 2.50	15
2.51 - 5.00	12
5.51 - 10.00	7.4
10.01 - 15.00	0.6

Total dose received for the operations in 1997 (person-Sv)	:	1,777
Highest individual dose (mSv)	:	14
Number of radiological workers	:	1,905
Number of entries into the “controlled area”	:	130,000
Total number of man hours in the “controlled area”	:	241,500

5. Conclusions

As a result of the detailed planning of the dose, in a technical respect and with regard to the variations in the course of time and the daily monitoring and discussing of the dose estimated and realised with the executive departments, there was at all times a good overview of the state of affairs relating to the variations of the dose. Hence the deviations detected could be discussed with the executive departments immediately once and corrective measures could be taken.

This way of working has contributed strongly to the fact that the dose received in connection with the Modifications Project remained within the estimated dose.

A positive side-effect of the intensive consultations described above, is that a good relationship developed between the Radiation Protection Department and the executive departments. The result was that the executive departments started to regard dose reduction as an essential part of their daily task even more than before.

Estimating and monitoring the dose in such an intensive way is only useful if it concerns a relatively long-term project from which a significant dose is expected, seeing that the preparations and the monitoring of the project involve a considerable amount of work.

During the Modifications Project the procedure with regard to the monitoring of the dose appeared to be very useful. In the future other eligible projects will be approached in the same way.

6 References

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