Steam Generator Replacement at Beznau NPP: Radiation Protection Measures for Occupational Dose Reduction

Hartmut Venz, Hubert Schlosser, Nuclear Power Plant Beznau, Switzerland

1 Introduction

The nuclear power plant Beznau consists of two pressurised water reactors. The primary system of the 2-loop-units was designed by Westinghouse, the secondary system by BBC (today ABB).

Unit 1 went into operation in 1969, unit 2 in 1971. Regarding its age, Beznau has to be designated as an old plant. In fact one has to talk of two young, state of the art units, taking into account the numerous back-fittings for which NOK spent approximately 1 billion Swiss francs. One of the most important back-fittings is NANO, an autonomous and protected exceptional emergency system (EES) for save shutdown in case of an external event. This system includes an own heat sink and emergency power supply. Steam generator replacement was very important, too. In 1993 the steam generators of unit 1 were replaced during the annual outage. The replacement of the steam generators of until 2 was realized in 1999.

World-wide a considerable number of steam generators have been replaced during the last years. A good overview concerning realized and projected steam generator replacements has been given in [1]. According to [1] 50 plants replaced their steam generators until 1998, 20 nuclear power plants intend a replacement during the next years. At the end of 1997 the US-PWR-industry started an initiative headed by the Nuclear Energy Institute (NEI) to standardise operation, repair and inspection of steam generators [2].

Publications concerning dose management of steam generator replacement are rare. Some aspects of radiation protection during steam generator replacement are mentioned by H. LOOFT [3] for Ringhals 2 and by B. DIERCKX et. al. [4] for Doel 4. Application of ALARA-principle and dose management during the extensive back-fitting at Borssele are described in detail by C. J. LEURS [5] and F. KAMPING [6]. M. MCGOUGH et.al. gave an overview about the SG-replacement in Tihange 3 [7]. In 1993 U. WEIDMANN [8] reported on know-how and results regarding radiation protection during steam generator replacement at unit 1 of Beznau NPP, which were considered for planning and realisation of steam generator replacement at unit 2, naturally.

2 Radiation protection measures during steam generator replacement at unit 2 in 1999

2.1 Planning and preparation

This work was essentially influenced by international experience and our results and know-how during steam generator replacement at unit 1. This replacement took 44 days. The accumulated collective dose was 1,1 Sievert. Putting the same syndicate in charge of the replacement as in 1993 and having experienced staff being familiar with Beznau NPP had a favourable effect.

Preparation started early. Four months after having decided in December 1995 to use the purchase option and to replace the steam generators of unit 2, the project team has been revived, already. Radiation protection was represented in this DESA-team, which planned, co-ordinated and attended to realization, too.

A collective dose of ≤ 0,9 man Sievert including all jobs connected with steam generator replacement was the general objective defined by radiation protection. This goal was based on slightly lower radiation levels at unit 2 and the possibility to reduce the collective dose by using the know-how resulting from steam generator replacement at unit 1. The development of a dose prediction including all important jobs allowed inspection and settlement of the objective on a reliable and understandable basis. A very detailed schedule of all jobs was the basis for the dose prediction and the course of events.

The original dose prediction of the syndicate, which led to a dose of about 1,2 Sievert, was revised jointly including better shielding, optimised order and detailed course of events and extensive mock-up training. In the planning stage a detailed shielding-plan was developed in co-operation with the radiation protection of Beznau NPP, the syndicate Siemens-CCI and the company putted in charge of the shielding, considering in particular the know-how resulting from the steam generator replacement at unit 1 in 1993. One year before the replacement an inspection with all responsible officials involved was organized while shut down of unit 2 in 1998 to optimize

the shielding-plan once more and to avoid dose-intense adaptation and reconstruction during the exchange as happened in 1993. Based on the expected dose rates at the working places, planned man-hours for the jobs, orders of events and resources and considering the regulations, dose prediction could be specified to 703 man mSv and finally defended successfully against authority.

The steam generator replacement project was divided into 18 single jobs. An individual bar code was created for each job. Entering the controlled area, each employee had to select the right bar code. Once a day the development of the collective dose was checked for each job, to detect differences from the target early.

High-dose steam generator replacement activities have been trained under realistic circumstances at the mock-up. The training included the decontamination of the save ends, processing (cutting off) and welding as well as the installation and removal of the shielding plug of the main coolant pipe. Further the grinding of the weld roots and the non-destructive examination in the main coolant loop was trained, too. During the first training, carried out by the purchaser, all employees involved had the opportunity to practise under realistic circumstances. Just before being brought into action all employees repeated the training on the mock-up at Beznau NPP. At this time authority was involved. This training took six days. The installation of the radiation protection shields at the place being meant for storing the old steam generators in ZWIBEZ was trained, too.

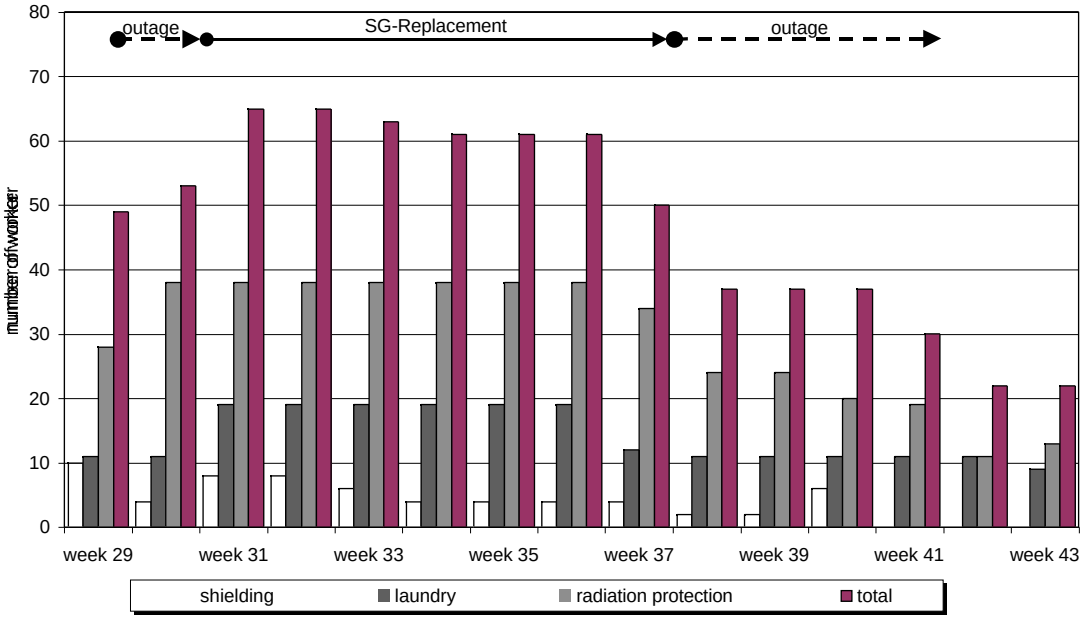
Precautionary a possibly rescue operation in the main coolant pipe was also trained intensively.

2.2 Steam generator replacement actions being relevant to radiation protection

2.2.1 Employment of staff

During steam generator replacement and outage 300 own and up to 830 workers of other companies (220 of them were assigned to the steam generator replacement project) have been deployed. Altogether 51'000 entries into the controlled area have been registered during steam generator replacement and outage, 10'000 for the Beznau staff and 41'000 for employees of other companies. The peak for one single day was 1'089 entrances. On the basis of the expected activities and to make available operational radiation protection, laundry and radiation protection gate around the clock, radiation protection staff had to be completed extensively. 47 experienced radiation protection workers familiar with our plant have been contracted. Figure 1 gives an idea of employment of staff for radiation protection during outage.

Figure 1: Radiation protection staff during outage with steam generator replacement at unit 2 of Beznau NPP in 1999



2.2.2 Focal point of the radiation protection work

The most important jobs during steam generator replacement were:

- Instruction of the employees of other companies concerning the most important rules of job safety and radiation protection. It was carried out by means of verbal instructions, videos, pamphlets and briefings on site before the beginning of the employment. Video and pamphlet are available in four languages (German, English, French and Italian),
- daily co-ordination with project managers (Beznau NPP and syndicate), e.g. concerning the adaptation of shieldings and the regulation of special safety precautions,
- control of shieldings, radiation protection areas, following of radiation protection rules, dose rate, the lack of radioactive contamination,
- care of staff at their working places,
- daily comparison of actual values with the dose prediction for all activities and every single job,
- making available protectants and clothes used in the controlled area,
- organisation of the use of the primary locker room and inspection of the entry of the controlled area (radiation protection gate),
- examination of 1'090 persons on possible incorporations.

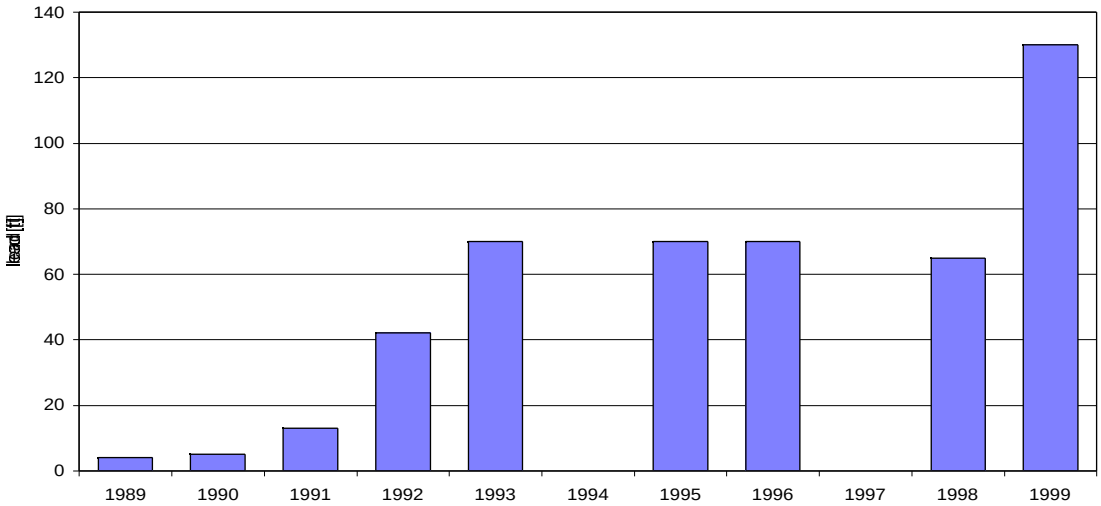
All jobs done in the reactor building were supervised by a co-ordinator of the syndicate. He was assisted by a radiation protection co-ordinator of Beznau NPP. Daily an accurate co-ordination of all jobs intended was made.

The most important jobs from the radiation protection point of view will be described in the following section.

2.2.3 Shielding

Approximately 130 tons of lead have been necessary for shielding the activities that had to be carried out during outage. Thanks to a good organisation and careful planning it could be done with the available 100 tons of lead. Therefore a number of shieldings had to be took down having finished the job and rebuilt elsewhere. Altogether this was the largest quantity of shielding material used at Beznau NPP at all (Figure 2).

Figure 2: Use of temporary shieldings for the outages at unit 2 of Beznau NPP



During outage an extraordinary large number of temporary shielding measures have been done in the reactor building. Apart from standard shieldings specialized shieldings were used for steam generator replacement. Lead was mainly used in the form of sheet metals or shell sections (Figure 3 and 4).

Figure 3: Shielding at the closure leg B from SG to the elbow

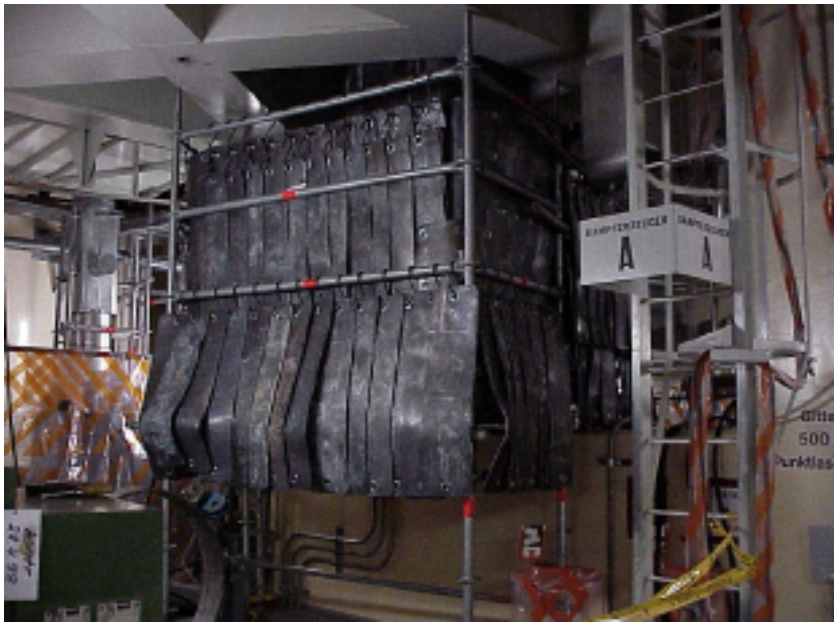
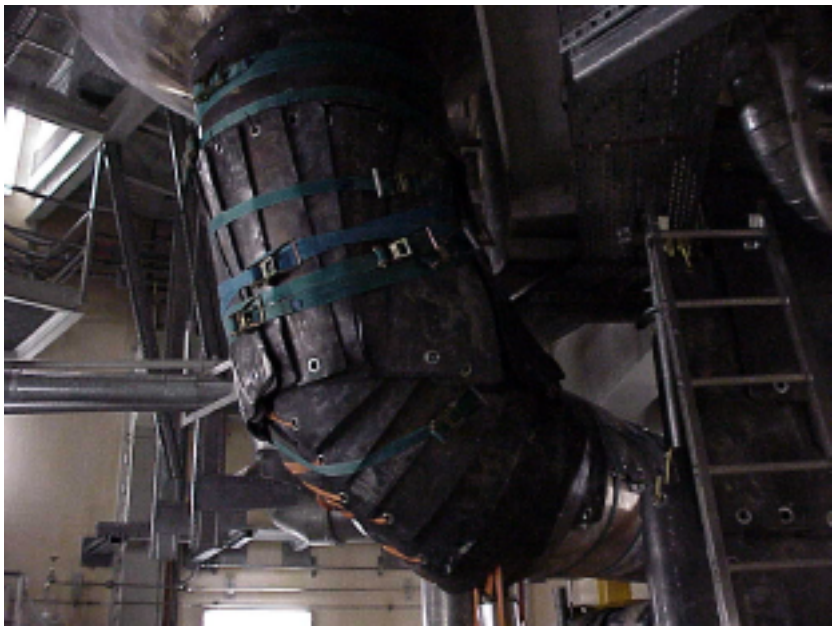


Figure 4: Shielding at the closure leg B from the pipe elbow to the main circulation pump



Dose rates in the cavity and at frequently populated localities on the valve floor could be lowered generally by a factor of 2 to 4 by various shielding measures. Weakening coefficients larger than 10 could be reached near shielded radiation sources.

After separation both endings of the hot-legs have been closed with water-filled shielding plugs until decontamination. After mechanical decontamination the four endings of the main coolant pipe have been sealed with shielding plugs made from steel. They were removed after installation of the new steam generators and the grinding of the welding seams in the main coolant pipe.

2.2.4 Installation of radiation protection areas and regions with minimal dose rate

During steam generator replacement the usual radiation protection area plan was applied. The radiation protection area in the reactor building was generally designated as type II-S. This type dictates apart from special underwear, overalls and shoes (type II), headgear, gloves and shoe-covers. Radiation protection area III supplementary requires a change of overalls and wearing of dust masks. In the radiation protection area of type IV the protective clothing is completed by a mask and rubber gloves. Wearing of a protective suit may be directed by the radiation protection depending on the radiological situation.

To avoid the spreading of contamination radiation protection areas of type III and IV separated by tapes and polythene-films have been installed at places with potentially enhanced contamination. This was the reason for lining and forced ventilation of the area around the cut off sector of the main coolant pipe and the decontamination facility by polythene-films, too.

To remove contamination instantly and prevent a spreading of contamination cleaning personnel was in operation in the reactor building, in particular in areas with open radiation sources, around the clock.

To keep the floor with the temporary steam generator transportation opening free of contamination, the cavity, where contamination is at a higher level by technical reasons, was sealed for the period of steam generator replacement. The region taken up by the conveyer was declared as radiation protection area of type 0 (access with dose meters but no rules for clothing). Disturbances of work flow and time-consuming changing procedures passing the transportation opening have been avoided this way.

In the reactor building three regions with minimal dose rate (< 10 µSv/h) have been marked as "radiation safe islands" (Figure 5). This well-experienced measure led to smaller doses while breaks dependent on organisation.

Figure 5: Example of a region with minimal dose rate

2.2.5 Contamination

Prophylactically the old steam generators have been painted with a fixative after the dismantling of the insulation to prevent contamination during transport and at the intermediate storage site definitely.

Airborne contamination of valve and operating floor in the reactor building was constantly inspected by several aerosol-monitors and air-collectors. Additional air-samples have been taken periodically at working-places with open radiation sources. The area of the steam generator transportation opening was supervised very intensively. We never discovered airborne contamination.

2.2.6 Decontamination

The four endings of the main coolant pipe have been sandblasted to a depth of 50 centimetres to get acceptable operating conditions for the activities which had to be carried out at the open endings of the main coolant pipe. By this method dose rate could be lowered by a factor of 20 to 40. Loose contamination was removed as far as further jobs could be carried out without respiratory protection and protection suit, which led to a lower occupational dose.

Figure 6: Decontaminated and sealed part of the loop (closure leg)

The two parts (elbows) of the hot leg dismantled have been decontaminated for the future use as a test piece, too. Decontamination factors up to around 1'000 have been reached.

After separation of the main coolant pipes each opening of the steam generators have been welded tightly with shielding caps. The old steam generators and removed parts of the main coolant pipes have been tested for superficial contamination and if necessary cleaned. To be on the safe side the external surfaces have been painted with a fixative before taking the steam generators out of the reactor building. Figure 7 shows the transportation of an old steam generator.

Figure 7: Transportation of an old SG

3 Assessment of the activities from the radiation protection point of view

The collective dose for the outage including the steam generator replacement was 1,102 Sievert. 18 % of it is allocated to our own staff, 82 % to employees of other companies. For the steam generator replacement work 640 mSv was accumulated during barely 57'000 man-hours. Figure 8 shows the development of the collective dose in comparison with the dose prediction. Figures 9 to 11 show the quite good agreement of prediction and actual values in all and for single jobs for the work done by the syndicate and by NOK, respectively.

Figure 12 gives an overview of the percentage portion of all jobs relative to the total collective dose counted during outage and steam generator replacement.

The very good record of collective dose as a whole was based on good planning of the project and operations scheduling, the existence of a person to turn to of the syndicate for solving unclearnesses and problems concerning steam generator replacement work, the exceptional large number of shieldings, the really good discipline and highly motivated staff concerning personal radiation protection, dropping dose rates on the components for the last years [9] and the shortening of the jobs compared with planning by 2 to totally 42 days.

The success of the reduction of the collective dose by consistent ALARA-work can be classified and seen correctly only when comparing the dose accumulated during outage 1999, which includes the steam generator replacement, to that for the previous years (Figure 13).

Figure 8: Collective dose and comparison with dose prediction

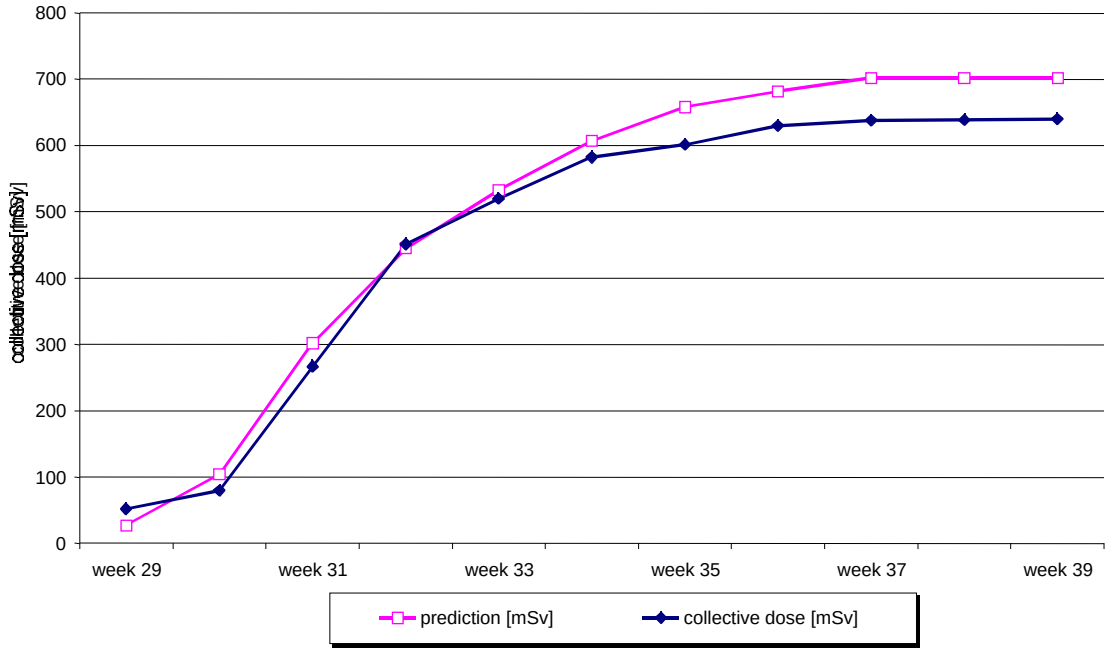


Figure 9: Comparison of effective collective doses for the most important activities with planned values during steam generator replacement and outage of unit 2 in 1999

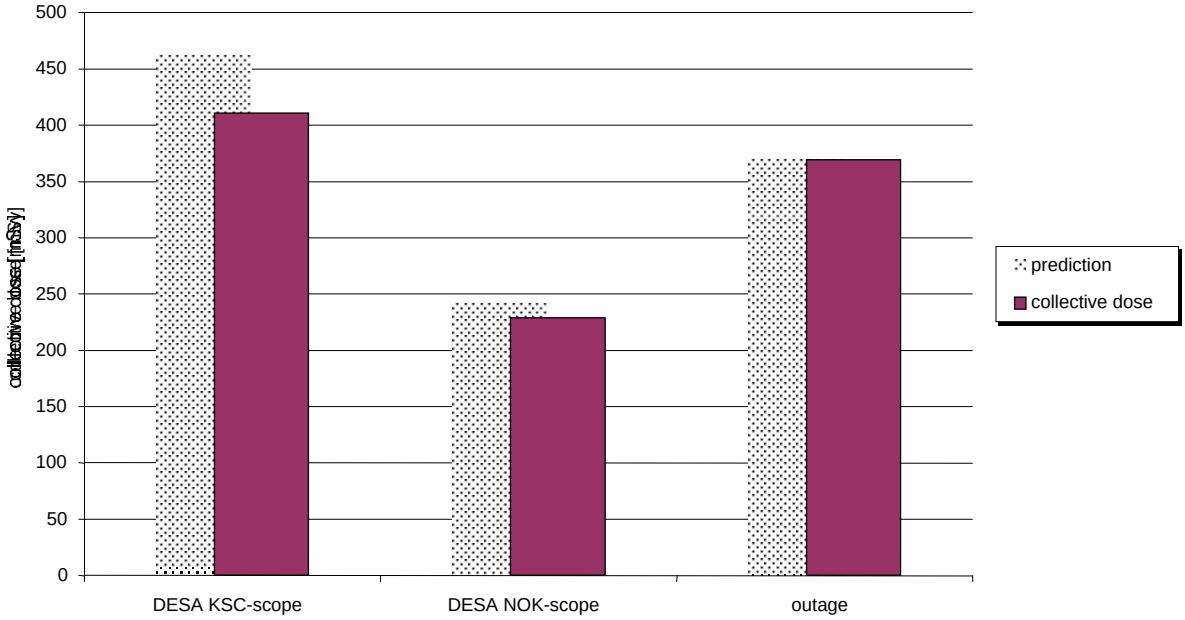


Figure 10: Comparison of effective collective doses for the work of the syndicate with planned values

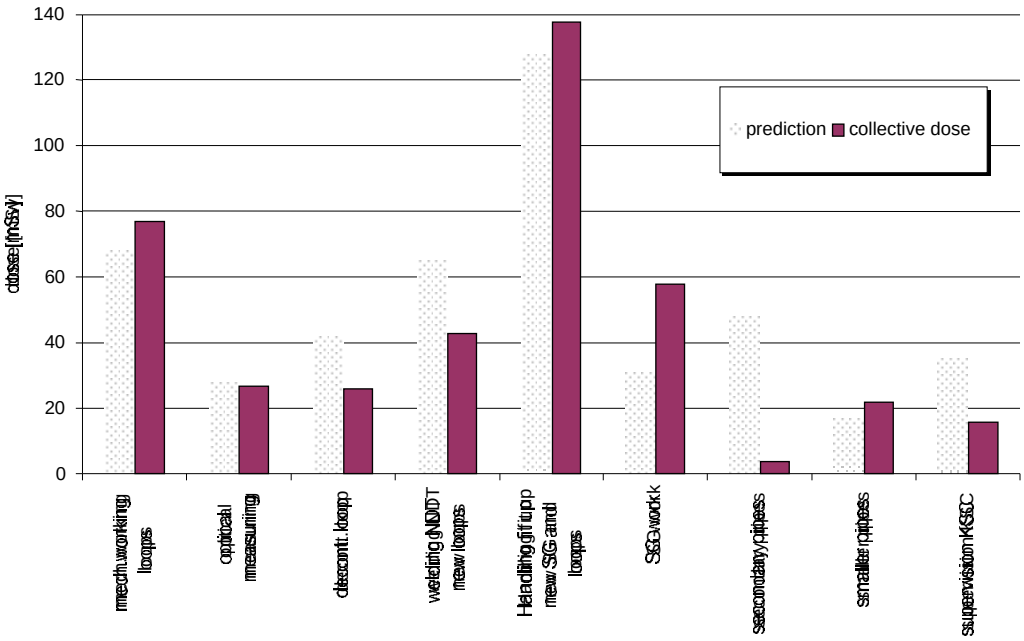


Figure 11: Comparison of effective collective doses for the work of NOK with planned values

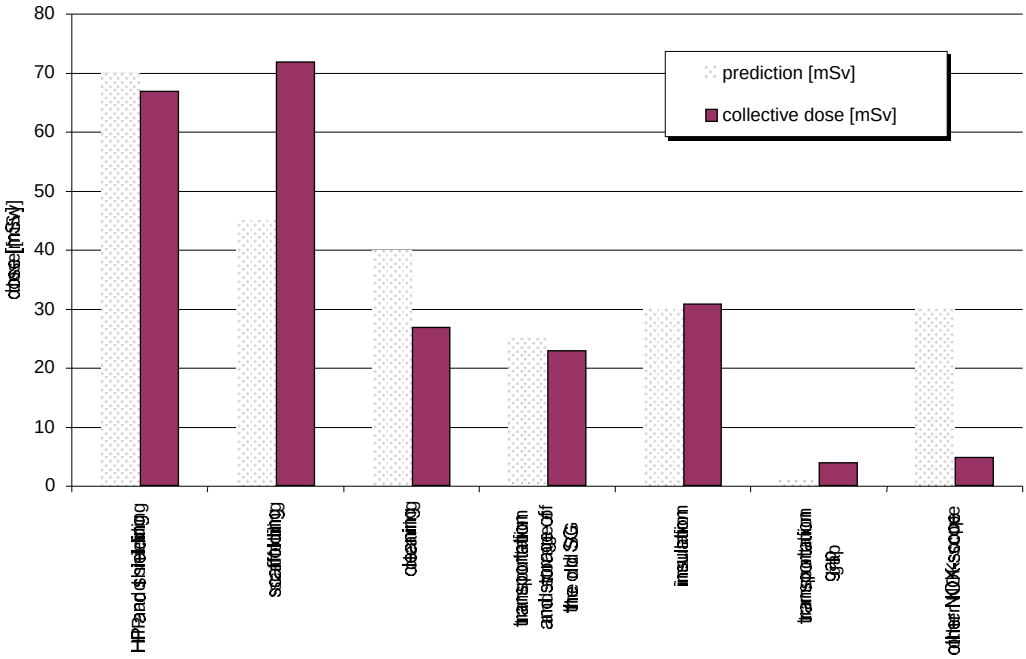


Figure 12: Distribution of the collective dose for steam generator replacement at unit 2 of Beznau NPP in 1999

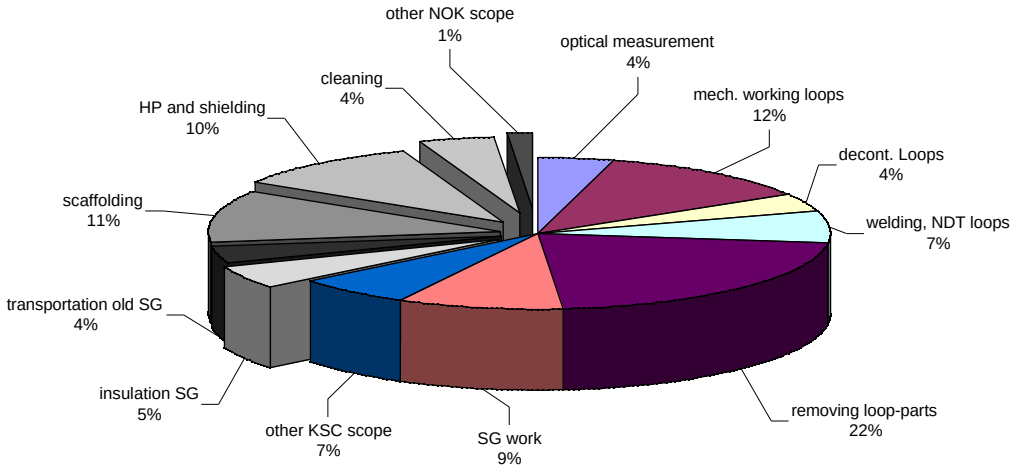
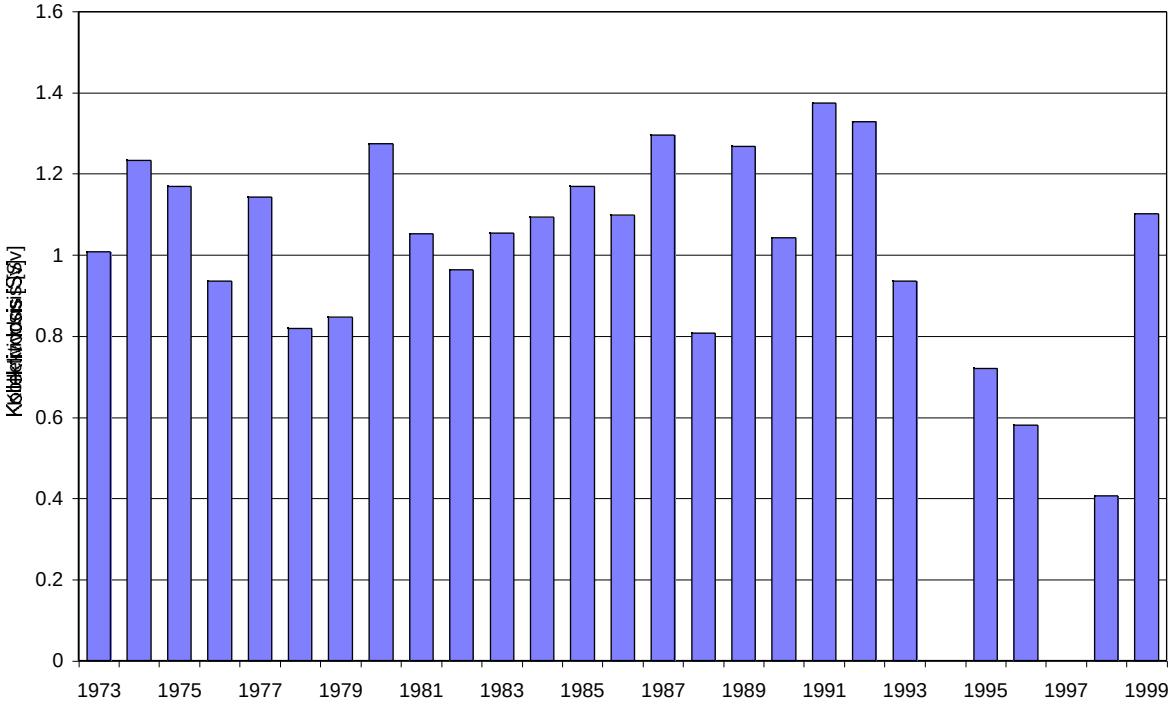


Figure 13: Collective dose for the outages at Beznau NPP unit 2 since 1973



Compared with similar projects in other countries the obtained collective dose of 640 mSv for steam generator replacement reaches a top position (Doel 4: 633 mSv [7], Tihange 3: 624 mSv [10]). It is not clear if the figures are comparable with each other directly. In [7] a dose for the outage is given in addition to the dose for the steam generator replacement, too. The 640 mSv reached at unit 2 of Beznau NPP contain the work for the whole steam generator replacement. 229 mSv of it is allocated to our own staff, 411 mSv to employees of the syndicate. The outage led to a dose of 462 mSv. The whole dose for outage and steam generator replacement was 1'102 mSv. This number can be compared to the total reached at Doel 4 (1'864 mSv) and Tihange 3 (1'709 mSv), directly. Considering the fact that Doel and Tihange replaced three steam generators in contrast to Beznau NPP where only two steam generators have been replaced one recognises, that the results are equally and represent the best values reached so far world-wide.

4 Literature

[1] Steam generator replacement and plans, Nucl. Eng. Int., August 1996, S.19

[2] P. Millet; JAIF Int. Conf. Water Chemistry 98, 13.-16.10.1998, Kashiwazaki, Japan

[3] H. Looft; Planing and Realisation of the SG-Replacement at the NPP Ringhals, VGB Kraftwerkstechnik 71 (1991), Heft 4, S. 328 (in German)

[4] B. Dierckx et. al.; Doel-4 SG replacement: facts & figures, Nucl. Europe Worldscan 1-2/1997, S. 56

[5] C. J. Leurs; Applying ALARA for large-scale backfit at Borssele, Nucl. Eng. Int., November 1998, S. 29

[6] F. Kamping; Dose management during the Borssele modifications, Nucl. Eng. Int., November 1998, S. 31

[7] M. Mcgough et.al.; Steam generator replacements get better all the time, Nucl. Eng. Int. , Oct. 1998 p. 67

[8] U. Weidmann; SG Replacement at Beznau 1; Experience and Results in Radiological Protection, 15th Annual Radiation Exposure Management Seminar, 12.-15.09.1993, Pittsburg, USA

[9] H. Venz et.al.; Effect of Primary Water Chemistry on Activity Transport at Unit 2 of Beznau PWR Plant, JAIF Water Chemistry 1998, 13. - 18.10.1998, Kashiwazaki, Japan

[10] E. Brückner et.al.; Replacement of large components with routine - example: Steam Generators, Siemens Power Journal 4/99, S. 34 (in German)