# APPLYING ALARA FOR REPLACEMENTS OF STEAM GENERATOR FEEDWATER DISTRIBUTION PIPES AT PAKS NPP

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## 1. Introduction

The Paks Nuclear Power Plant Ltd. operates four VVER-440 type reactors. Unit 1 has been operating since 1982 and the fourth Unit connected to the grid in 1987. The role of Paks Nuclear Power Plant is decisive in the domestic electric power generation. The share of the nuclear energy in the electric power production of Hungary during the period from 1988, once the Unit 4 was put into operation, is constantly more than 40%.

Similarly to other VVER-440 type NPPs erosion corrosion damages of feedwater distribution pipes were observed at Paks NPP in 2000. An extensive steam generator feedwater distribution pipes replacement programme was started at Paks NPP in 2001. In the frame of this programme the replacement of feedwater distribution pipes was carried out on 14 steam generators in 2001.

The steam generators that are used at VVER-440 type NPPs are horizontal shapes. Each VVER-440 unit has six steam generators. The feedwater distribution pipes are inside the steam generator. The erosion corrosion damages are observed especially on so-called T-connection. The dose rates inside the steam generators, that we measured during outages in 2000, were 5-8 mSv/h on Unit 1, 9-16 mSv/h on Unit 2 and 8-20 mSv/h on Unit 3. A significant part of the replacement work can be only performed inside the steam generator. Based on our own experience the workers all together should spend 50 hours inside steam generator during the replacement.

In the view of the extent of the work and the dose rates at places where work was to be carried out, it was clear from the start that a relatively high collective dose had to be taken into account. The ALARA approach played important role in preparation phase as well as in implementation phase.

Applying ALARA principle means that a work management approach must be adopted that considers all the factors contributing to radiation dose, identifies and co-ordinates the actions which can be implemented and analyses their dose reduction effectiveness in relation to their respective cost. At Paks NPP we followed this approach as much as possible during the replacement of feed water distribution pipes.

## 2. Preparation of replacement of feedwater distribution pipes

### *2.1. First phase*

The preparation of replacement work has been started approximately 8 months before when the first replacement was performed in 2001.

In the frame of first phase of preparation we collected and analysed our own and some other VVER-440 type NPPs' experience in connection with replacement of feedwater distribution pipes. We considered the procedure of replacement and all aspects of work (protective options, schedule of work, working environment, tools and training) in order to optimise the duration of exposure, the number of people exposed as well as the dose rates. In this phase of preparation decision aiding technique was also used. As per the authority approved Plant Radiation Protection Code of Paks NPP differential cost-benefit analyses was used and a monetary value of 25000 HUF (~ 100 USD) per man mSv saved was applied.

At the end of the first phase of preparation the radiation protection experts in co-operation with experts of maintenance, technical support and chemistry completed an ALARA report. This report among others included the results of cost-benefit analyses and the preliminary dose plan of the replacements. Based on the cost-benefit analyses the report suggested the following measures to optimise the dose rates inside the steam generators:

1. one or two cycle decontamination (the number of cycle is depending on the dose rate in steam generator)
2. use of self-shielding effect of water which is in primary and secondary side of steam generator
3. shielding of hot and cold leg collectors and top layer of heat exchanger tubes inside the steam generator

The dose rate reduction factors of the above measures were mainly determined by use of earlier measured data. In some cases the factor was assumed by computer code. In the cost-benefit analyses the dose rate reduction factor of one and two cycle decontamination was 2.5 and 6-8 respectively, which figures are based on measured data. The dose rate inside the steam generator will reduce by factor 1.3 if the steam generator secondary side is filled with water to the top of heat exchanger tubes. Filling of primary side of steam generator with water results in 6 % dose rate reduction. The suggested 5 tonnes shielding can reduce the dose rate by factor 2, which was calculated by computer code.

### *2.2 Second phase*

In the second phase a multidisciplinary team continued the preparation and co-ordinated the preparation activity between all workgroups involved in replacement of feedwater distribution pipes by organisation of regular meetings. During the second phase all aspects of work considered in order to optimise the radiation exposure.

*Scheduling*

The proper work scheduling is important in maintaining doses ALARA. In case of replacement of feedwater distribution pipes the proper work scheduling and the harmonisation of dose rate reduction measures (water in the primary and secondary side of steam generator) with the conditions of other outage works was very important.

As a result of compromise between the dose rate reduction and prolongation of outage there was no water in primary side of some steam generator during the replacement work that resulted in higher dose rate by 6 % than it was planned.

*Manpower*

The qualified and specially trained manpower availability was also important for that work because of the relatively high number of steam generators where the replacement was planned in 2001. In Paks NPP the plant level monthly dose limit is 6 mSv and the plant level yearly dose limit is 20 mSv. The goal was that none of the workers reach the monthly or yearly plant level dose limits. When we determined the number of workers we took into account this goal.

*Working environment*

The working condition factors were taken into account during the preparation. The proper light, the convenient temperature and ventilation of secondary side of steam generator were prepared.

Another important subject of preparation that is linked to working environment was to optimise the workload in relatively high dose rate area. We minimised the work inside the steam generator, as much as possible we transferred the steps of replacement work to a low dose rate area.

*Training of workers*

The Paks NPP has a Maintenance Training Centre at site, which is among others equipped with full size steam generator. The workers received training on that steam generator where the working environment, except the ionisation radiation, is totally same than in the field.

Completing ALARA reports separately for each Unit where the replacement of feedwater distribution pipes was planned during the outage closed the second phase of preparation. These ALARA reports among others included the results of repeated cost-benefit analyses and the detailed dose plan for the replacement works.  The dose rate reduction measures practically were not changed. The reports suggested decontamination, use of self-shielding and shielding for decreasing the dose rate inside the steam generators.

## 3. Work implementation

The replacement of feedwater distribution pipes started on Unit 2 where the feedwater distribution pipes were replaced in 5 steam generators. The implementation of earlier mentioned dose rate reduction measures was usually enough effective, however we had to perform three cycles of decontamination on two steam generators.

After the dose reduction measures the dose rate level inside the steam generators varied between 0.4 and 0.5 mSv/h and it was not higher than 1-2 mSv/h when the workers partly pulled off the shielding.

The multidisciplinary team continued its work and co-ordinated the activity between all workgroups involved in replacement work. The radiation protection personnel provided assistance and advice to workers. The individual and collective dose of workers was controlled continuously by electronic dosimeters. The dose rate were followed and analyzed by supervisors as well as radiation protection personnel.

The collection of feedback data was performed during implementation phase. This collection had two interests:

1. to provide timely feed back and allowing to implement rapid corrective actions
2. to support the preparation of replacement feedwater distribution pipes on the next Units

As a result of collection and analyses of feedback data we modified the shaping of shielding inside the steam generator and put slip-way to help access to steam generator and exit.  The modifications and the more skills of workers resulted in lower working time in the steam generator and lower individual and collective dose on Unit 1 and Unit 3.

Table 1: Dose results of replacement

| Unit | Number of SGs (where the replacement was performed) | Planned collective dose per SG (man mSv) | Actual collective dose per SG (man mSv) |
|---|---|---|---|
| Unit 2 | 5 | 40.7 | 41.5 |
| Unit 1 | 3 | 53.4 | 28.8 |
| Unit 3 | 6 | 59.8 | 23.2 |

## 4. Conclusion

The work management approach which was used during the replacement of feedwater distribution pipes helped to consider all the factors contributing to radiation dose and to identify and co-ordinate the actions which can be implemented to optimize the radiation exposure.