STEAM GENERATOR REPLACEMENT FROM ALARA ASPECTS

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Introduction

This paper is going to consider radiological related parameters important for steam generator replacement (SGR) implementation. These parameters are identified as ALARA related parameters, owner-contractor relationship, planning, health physics with logistic services, and time required for the replacement. ALARA related parameters such as source or initial dose rate and plant system configuration define the initial conditions for the planning.

There is room to optimize work planning, managerial procedures and also the staff during the implementation phase. The overview of these general considerations is based on the following background: using internationally available data and the experience of one of the vendors, i.e. Siemens-Framatome, and management experience of SG replacement which took place at Krško NPP in the spring of 2000.

Generally plant decisions on maintenance or repair procedures under radiation conditions take into account ALARA considerations. But in the main it is difficult to adjudge the results of an ALARA study, usually in the form of a collective dose estimate, because a comparison standard is missing. That is, very often the planned work is of a one-off nature so comparisons are not possible or the scopes are not the same. In such a case the collective doses for other types of work are looked at and a qualitative evaluation is made.

In the case of steam generator replacement this is not the case. Over years of steam generator replacements world-wide a standard has been developed gradually.

The first part of the following displays an overview of SGR and sets the Krško SGR in perspective by applying dose analysis. The second part concentrates on the Krško SGR itself and its ALARA aspects.

Replacement times and doses

During the last ten years there have been more than thirty steam generator replacements performed at PWRs in the world. From the data of ISOE the collective dose per steam generator was in most cases from 0.3 to 0.8 man-Sv. Collective dose is a rough indicator of the project planning and of overall occupational exposure control.

The procedures have become very similar and collective doses and replacement times have tended to reach a plateau around which the replacements fluctuate. Figure 1 illustrates how the replacement times have dropped drastically from the first beginnings down to a near-constant level. The general curve drops to a plateau around 40 days. We will return to this subject later in connection with the theme of ALARA.

Analysis of the data for such steam generator replacements provides a unique opportunity of making a true ALARA judgement. The work scopes have become very much the same and therefore the number of staff required and the number of hours required are very comparable.

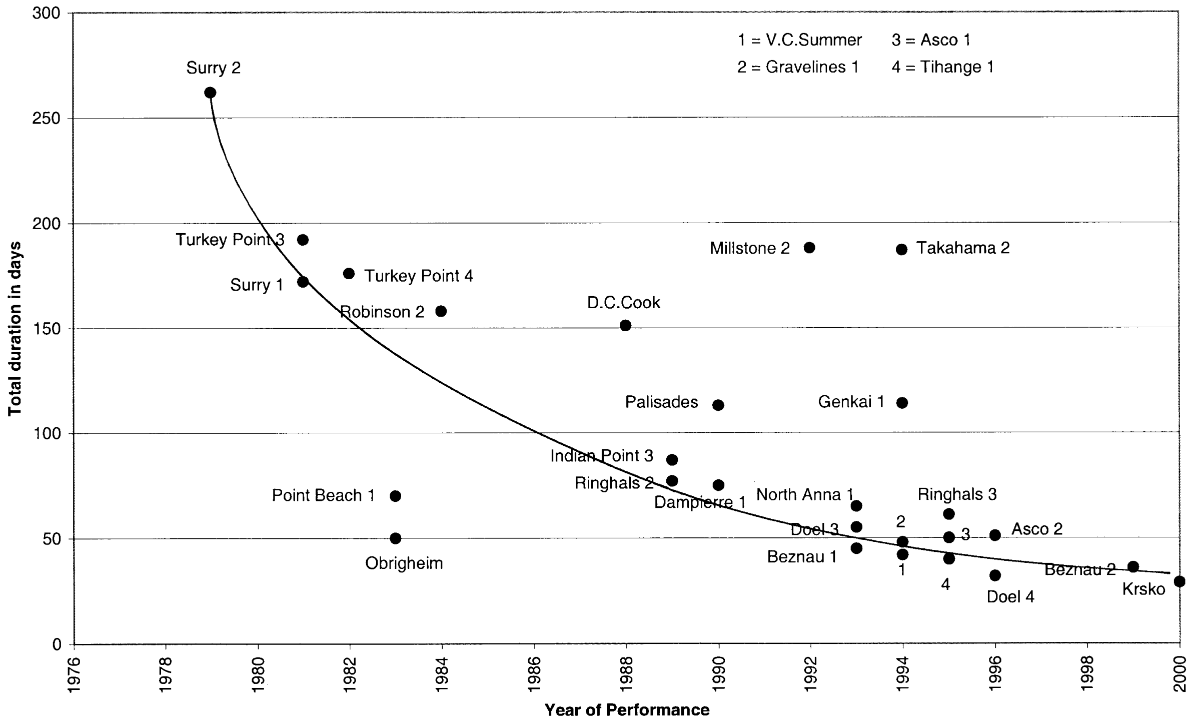

Figure 1

Reduction of SGR times

Let us now look at figure 2 for the case of collective dose in replacements as conducted in the USA and Europe. As can be seen the doses in the last twenty years have dropped , with one or two exceptions, by a great deal. A plateau for the dose can be perceived by eye to lie around 1200 man-mSv.

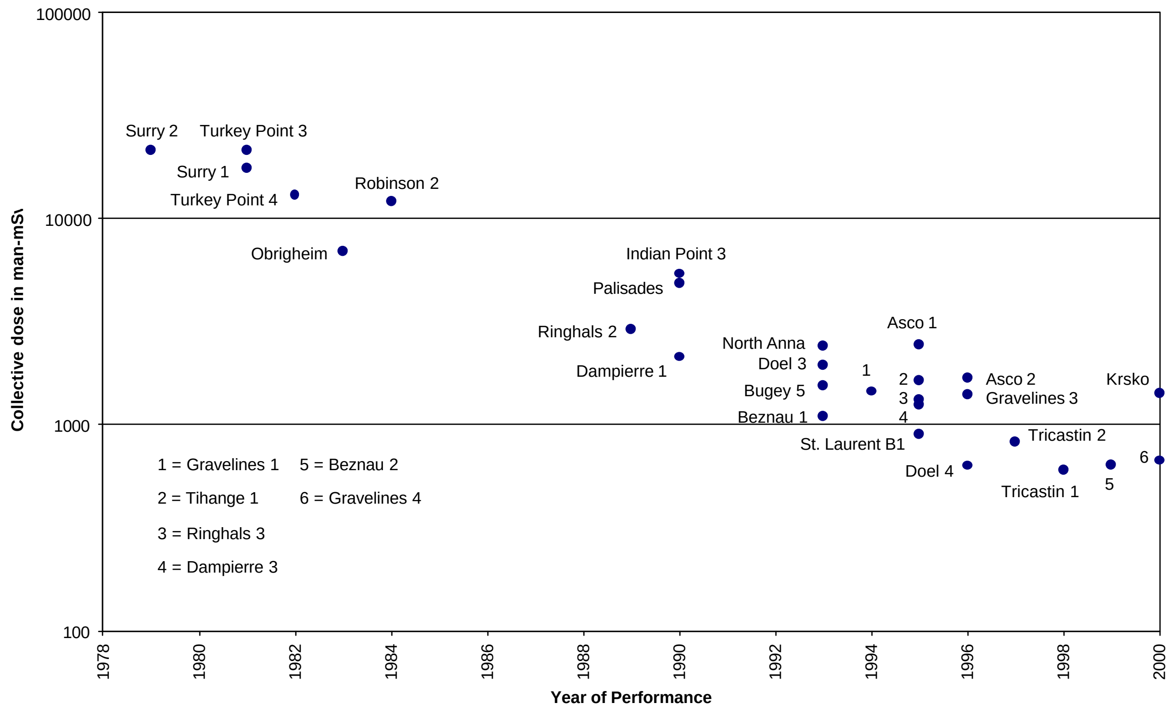

Figure 2

Collective dose trend with time

Assessment of management procedures

The data, as displayed in figure 2, are used to make various comparisons on the world market where competition is rife. But is it adequate? It is certainly not a correct comparison from an ALARA stand-point. Why not , since the scopes are assessed to be the same ?
There are three important factors which control the collective dose that have little to do with direct ALARA management procedures. These are

- the primary circuit dose rate
- the number of steam generators
- the amount of shielding

The last item can be misunderstood. This is indeed a very important ALARA measure. But ALARA management procedures are required only to install and to remove it. In other words a great deal of lead reduces the need for management. Once it is installed its very material mass influences the collective dose but this has nothing to do with management procedures.

In order to make an ALARA assessment of managerial procedures these three factors have to be filtered out of the collective dose to enable proper ALARA management comparison.

We have decided to define a quantity called Figure of Merit or FOM for short, borrowed from a method related to Monte-Carlo calculations. Turning to our case the FOM also becomes an artificial factor which includes the three previously named factors independent of ALARA managerial work procedures. Thus we have defined a FOM for filtering the published collective dose that we have seen in figure 2. The resultant dose is then weighted with the FOM to produce a new weighted dose, a dose FOM or D_{FOM}, which reflects more the managerial ALARA aspects rather than physical conditions over which no control has been exerted. To make this more clear:

$$D_{FOM} = \frac{\text{Total collective dose} \times \text{Amount of lead}}{\text{Number of SG} \times \text{Primary dose rate}} = \text{Total collective dose} \times \text{FOM}$$

For example , if the primary circuit dose rate is small and massive shielding is installed then the FOM will become very large and the D_{FOM} also becomes larger. This presents then a slightly different picture of the collective doses by producing a proper comparison of efforts made from the managerial side. If the D_{FOM} is small than this reflects good management practices.

Figure 3 takes some of the more recent SGR operations shown in figure 2. The SGR operations have been taken for which the authors have been directly or indirectly involved and therefore for which exact data are known. The collective doses have been modified by the non-physical FOM factor. The number is an index of the application of the ALARA principle by managerial processes. This is a first-time comparison showing true managerial skill in controlling dose in the spirit of ALARA. As can be seen the position of Krsko has changed in the assessment. Indeed in this comparison Krško has risen to the top of the ALARA management table. For the higher D_{FOM} plants conditions were such that not so much management was required.

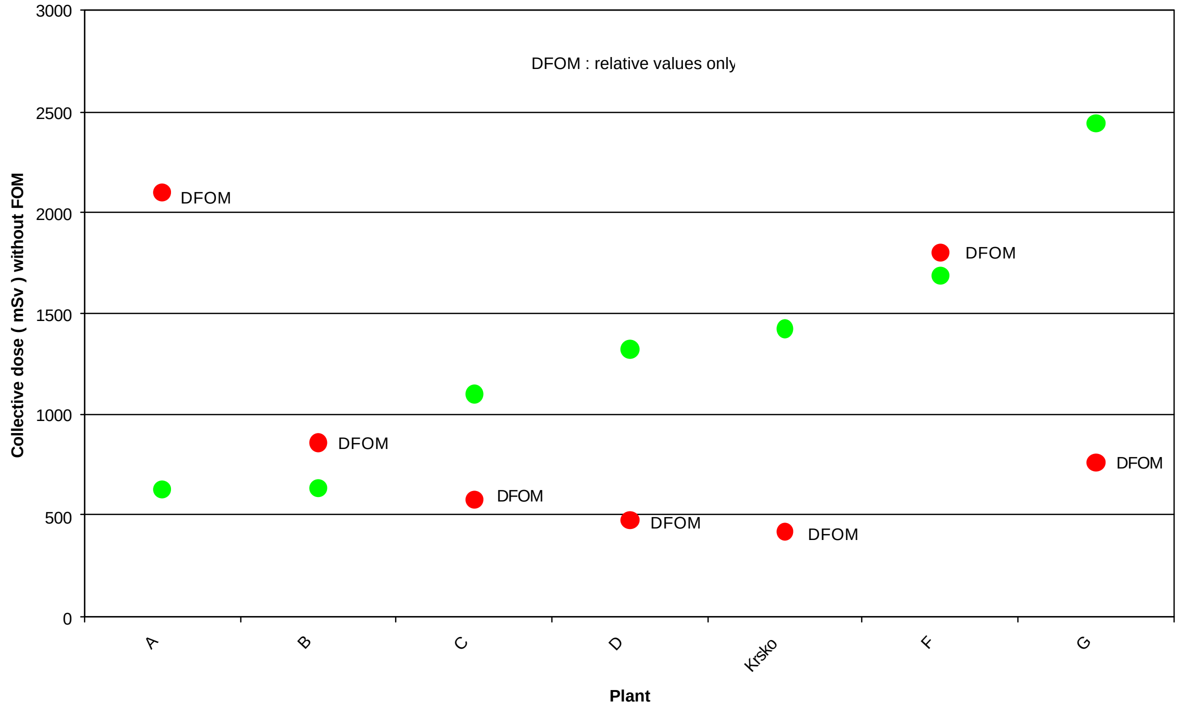

Figure 3
Collective dose analysis illustrating ALARA management

Let us now turn our attention to the Krško Steam Generator Replacement itself and examine some of the management aspects which produced this successful replacement.

Perhaps we should first see what SGR involves with regard to radiation exposure. The main activities with regard to radiation are:

- construction of scaffolding next to the primary loops
- removal of thermal insulation from primary loops and SG
- installation of shielding
- clamping of primary piping to hold it in place
- cutting of primary piping
- decontamination of remaining pipe ends
- machining the new weld lips on the pipe ends
- welding of new SG to pipe ends
- general pipe works for auxiliary systems in the loop rooms
- cleaning activities
- health physics

All in all over a thousand single work activities had to be co-ordinated and the doses of more than 400 persons controlled daily. This was a difficult task which required close collaboration.

Owner-contractor Collaboration

A good example of owner-contractor collaboration can be presented in the case of the Krško steam generator replacement project (SGRP). Owner-contractor relationship was based on the technical specifications of SG replacement prepared by Krško plant. These had included requirements for the total collective dose of the replacement from one to two man-Sv for two loop plants and preparation of the radiation protection plan, ALARA plan, shielding plan, lay-down area and waste management plan. The contractor was requested to provide radiation protection laisons in each shift to be an interface between the contractor's technical staff and plant radiation protection organization. Each organization had its own SGRP Supervisor who had been responsible also for preparation work.

The plans mentioned above were prepared by the Consortium Siemens-Framatome, and then reviewed and approved by the Krško plant. The ALARA plan included brief descriptions of each activities with the appropriate flow diagrams, if necessary. All radiation protection related plans were then presented to the plant ALARA Committee, for feedback if necessary.

For specific tasks, such as for measurements, scaffolding, insulation removal, clamping, cutting, pipe decontamination, cleaning and shielding, detailed RP instructions were prepared by the planning team, also composed of task managers, and included in the ALARA work planning forms following plant procedures.

SGR ALARA Review

Unlike other SGR projects, Krško SGRP had an extremely short replacement time. This was 29 days to Operational Delivery. In other earlier SGR projects, depending on scope, the replacement times lay more by 40 days, as mentioned at the beginning. This short SGR time , which although contractually arranged, had negative effects on ALARA towards the project end. This indicates, too, that further efforts to reduce replacement times could lead to higher doses. An example of this is if more activities have to be performed in parallel towards the end of the SGR. At this stage shielding is being removed prior to hand-over. Thus more dose is generated than would be case with shielding still in place.

One boundary condition for the Krsko SGR was the primary circuit dose rate, which was very high. In the unshielded state the contact dose rate was 3.4 mSv/h and 8.6 mSv/h when drained. In view of this fact the collective dose was held to an acceptable level which was only approx. 30 % above another SGR (also two loop) where the dose rates were half these values. But we have already seen this comparison.

The collective dose estimate itself was obtained using the Dosiana software which requires large amounts of input for manpower and dose rates. These data are weighted by occupancy factors, which are based on experience, and decide the actual time spent in radiation fields. A repeat run on-site, using the actual dose rates measured after shutdown, showed no major deviation from the prediction, as based on previous years measurements.

SGR doses were analysed according to job codes used during performing the jobs. Because exact planning of work is not always possible and also corrective actions can not be predicted, then an estimate accuracy in a band of around ± 10 % can be regarded as exact and around ± 20 % as acceptable.

Some Examples of Good ALARA Practice

Experienced personnel were engaged for the shielding. Training for auxiliary personnel on inactive piping in the water processing plant took place in order to ensure that installation and securing of shielding was almost routine.

Scaffolding work was speedily carried out to avoid dose. This resulted in smaller man-power needs, by a factor of at least three, than that expected. It shows the advantage of using a trained team with good planning for the required scaffolds in advance.

To prevent cross contamination of large items special clean areas were introduced in which no shoe covers were required. As radioactive items were removed this good practice was extended by issuing instructions in the form of ALARA Cleaning Regulations. Thus these clean areas were extended to the operation deck in the containment and then to the Auxiliary Building.

Dose-following was on a daily basis in order to compare actual doses with the predictions. This enabled timely intervention to modify procedures if it was shown that conditions had changed and would be producing unexpected doses if the work was continued unmodified.

Health Physics Management- Krško SGRP

Health physics team of Krško plant conducted operational radiation protection. In each shift there were five health physics (HP) technicians, in the morning shift in addition two technicians and two engineers most of the time. On comparison to other similar replacement projects the number of technicians and engineers was optimised to a very minimum. HP shift leaders and engineers attended training sessions for a few SGR activities. The plant contracted some HP technicians from abroad already experienced in SGR, others were taken from the local Institute for Occupational Health.

The responsibilities and cooperation between NEK and the Consortium were defined in a Project Radiation Protection Plan, as mentioned before. Health physics activities were planned daily by the Radiation Protection Lead Engineer (who acted also as NEK's SGR Supervisor) and by the Consortium Radiation Protection Supervisor. Both supervisors participated in the daily project management meetings.

The use of experienced health physics liasons from the local Institute made a positive contribution to ALARA. These people had been trained for SGR by the Consortium and were fully familiar with the Krško plant and procedures. They ensured that the needs of the teams (protective clothing, measurement services) were fulfilled well in advance.

Conclusion

In conclusion, this paper has provided a method of evaluating ALARA management in SGR operations and named those managerial aspects which lead to keeping occupational exposure low.