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ALARA EFFORTS IN NORDIC BWRs

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ABSTRACT

Some ALARA-related ABB Atom projects are currently under investigation. One of the projects has been ordered by the Swedish Radiation Protection Institute, and two others by the Nordic BWR utilities. The ultimate objective of the projects is to identify and develop methods to significantly decrease the future exposure levels in the Nordic BWRS.

As 85 to 90% of the gamma radiation field in the Nordic BWRs originates from Co-60, the only way to significantly decrease the radiation doses is to effect Co and Co-60. The strategy to do this is to map the Co sources and estimate the source strength of Co from these sources, and to study the possibility to affect the release of Co-60 from the core surfaces and the uptake on system surfaces. Preliminary results indicate that corrosion/erosion of a relatively small number of Stellite-coated valves and/or dust from grinding of Stellite valves may significantly contribute to the Co input to the reactors. This can be seen from a high measured Co/Ni ratio in the feedwater and in the reactor water. If stainless steel is the only source of Co, the Co/Ni ratio would be less than 0.02 as the Co content in the steel is less than 0.2%. The Co/Ni ratio in the reactor water, however, is higher than 0.1, indicating that the major fraction of the Co originates from Stellite-coated valves.

There are also other possible explanations for an increase of the radiation fields. The Co-60 inventory on the core surfaces increases approximately as the square of the burn-up level. If the burn-up is increased from 35 to 50 MWd/kgU, the Co-60 inventory on the core surfaces will be doubled.

Also the effect on the behavior of Co-60 of different water chemistry and materials conditions is being investigated. Examples of areas studied are Fe and Zn injection, pH-control, and different forms of surface pre-treatments.

INTRODUCTION

The annual collective exposures in the Nordic BWRs have traditionally been low, however, showing an increasing trend during the last five years (Figure 1). Significant increases have especially been experienced during 1992 and 1993. In order to counteract this trend, some ALARA-related projects have been initiated by ABB Atom. The first is called DORIS (Dose Reduction in Swedish BWRs), and is ordered by the Swedish Radiation Protection Institute. The second project is called ALARA 2000, and is ordered by the utilities OKG, Ringhals, Barsebäck, and TVO. A related project, an update of the ABB Atom developed computer code BKM CRUD, is separately ordered by Forsmark NPP. The third project, KEMOX 2000, is ordered by the Swedish utilities and Nuclear Inspectorate, and is jointly run by ABB Atom and Studsvik Material. The main purpose of that project is to develop methods to optimize the performance of oxides in the BWR primary system. One method currently being investigated is pH control.

The purpose of this presentation is to report the current status of the DORIS and ALARA 2000 projects.

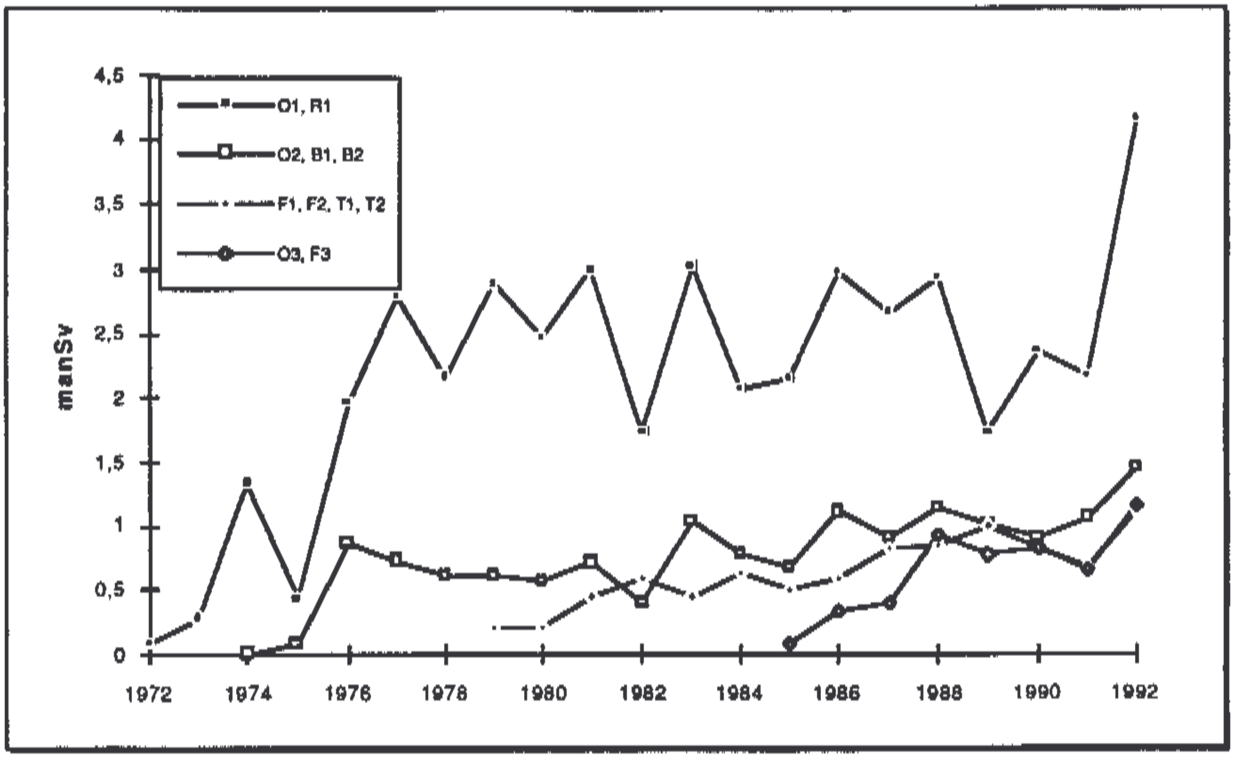

Figure 1. Annual occupational exposure in different ABB Atom reactor generations (manSv per reactor unit)

THE DORIS PROJECT

General Outline

In foreign BWRs, the annual occupational exposures have been gradually decreasing for some years (Figure 2). In Nordic BWRs, the occupational exposures have been low. During the last five years they have increased significantly. This trend is of concern. The DORIS project has been initiated in order to map factors which significantly affects the exposure. Among others the following items will be addressed:

- The effect of increased burn-up of the fuel.
- The effect of HWC-operation.
- Exposure statistics for different types of jobs.
- The possibility to use extra shielding to decrease the exposure. Chemistry control, e. g. ph-control, Fe injection to the feedwater, etc.
- Optimization of inspection programs.
- Optimization of operational procedures, e.g. fuel failure management.

The ABB Atom developed computer code BKM-CRUD2 will be used as a tool to assess the importance of the different items.

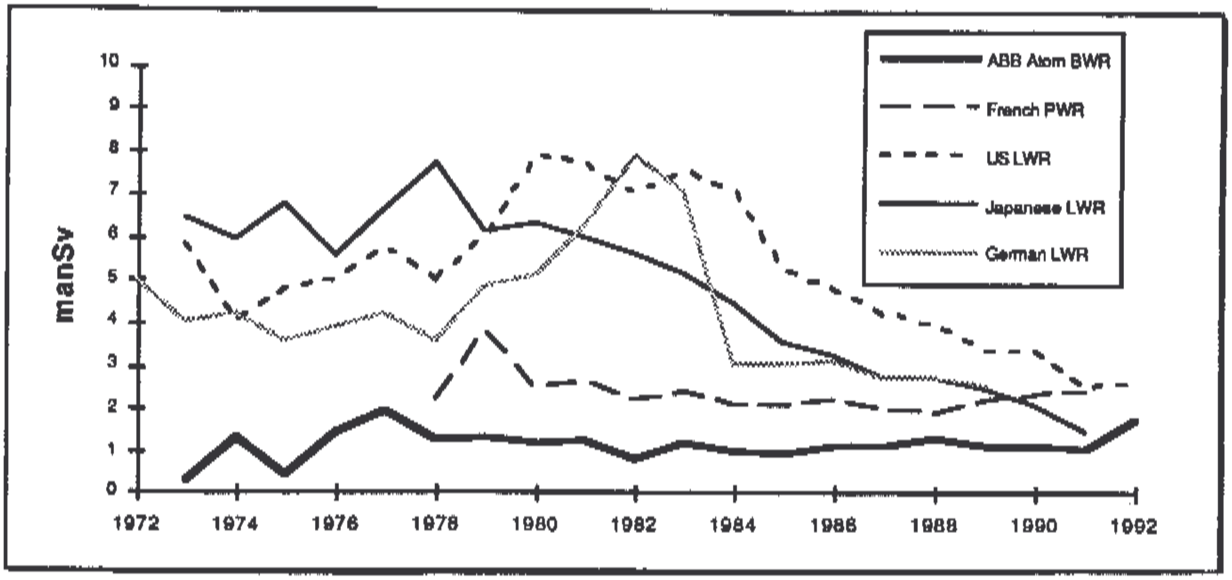

Figure 2. Annual occupational exposure per unit of ABB Atom BWRs compared to international LWR standard

Some Results

Increased burn-up levels of the fuel will increase the fuel crud Co-60 activity. The combined effect of a with time linear build-up of Co and increasing specific activity of Co-60 means, that the Co-60 inventory increases proportional to the square of the burn-up level (Figure 3).

An increase of the burn-up level from 35 to 50 MWd/kgU increases the amount of Co-60 on the fuel by a factor of two. The potential for release of Co-60 from the fuel will increase correspondingly.

Another fuel related problem affecting the radiological conditions is operation with defected and degrading fuel. Then the core will be contaminated by tramp uranium, causing a significant background activity level of fission products. The dose rates in the turbine system will increase because of the presence of Ba- and La-140. Ba-140 (Tl/2 = 12.8 d) is a daughter product of Cs-140 (65.5 s), which is a daughter product of the noble gas isotope Xe-140 (13.6 s). La-140 (40.3 h) is a daughter product of Ba-140. The high gamma energies emitted from Ba- and La-140 significantly increase the dose rates especially in the high pressure part of the turbine. Another important result of contamination of the core with tramp uranium is an increased release rate of fuel crud (e.g. Co-60) because of knock-out reactions.

Models for estimation of the radiological impact because of dispersion of fuel during operation with defected rods will be assessed. Models for estimations of the dissolution rate of U02 and the uptake of uranium on core surfaces have earlier been discussed.[1]

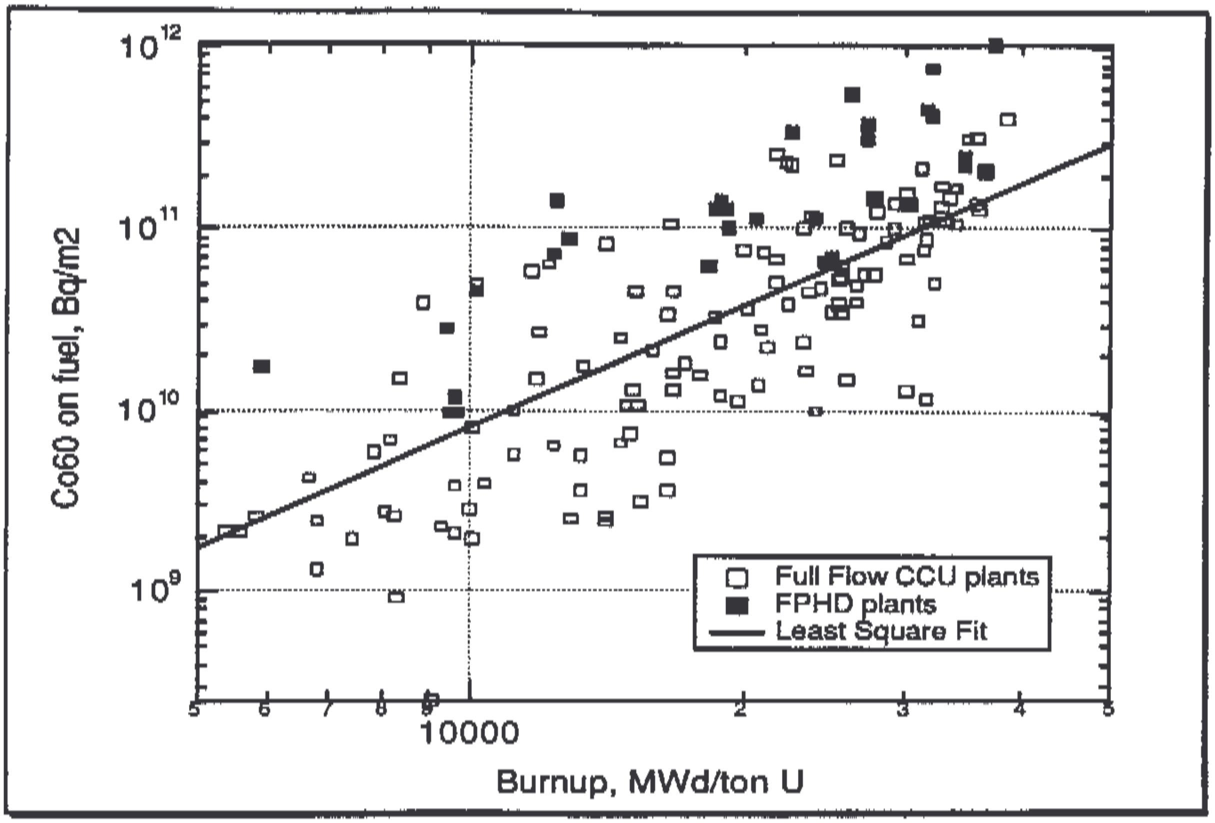

Figure 3. Co-60 in fuel crud as a function of fuel burnup level.

THE ALARA 2000 PROJECT

General Outline

The ALARA 2000 project is divided into three sub projects:

1. Estimation of the future radiological conditions for each of the participating plants by use of the BKM-CRUD code.[2] This estimation shall be carried out with the current measured feedwater concentrations extrapolated to the year of 2010 as input to the code. Three to five parameters dominating the effect on the radiological conditions shall be identified plant specifically.

2. Corrosion product balances. The objective is to assess the mass balances for Fe, Ni, Cr, Co, Zn and Cu for the plants. As discussed above, the mass balance and source strength study for Co is especially important.

3. Within the third ALARA 2000 sub project a correlation study between measured dose rates and gamma scan data and operational data from the plants will be performed. The objective of this task is to identify specific operational practices at the plants that have significantly affected the radiation levels.

Some Results

Figure 4 shows measured shut-down radiation levels on a vertical RWCU pipe in the different ABB Atom BWRS. The data clearly indicate, that significantly increasing levels are still experienced after 15-20 years of operations.

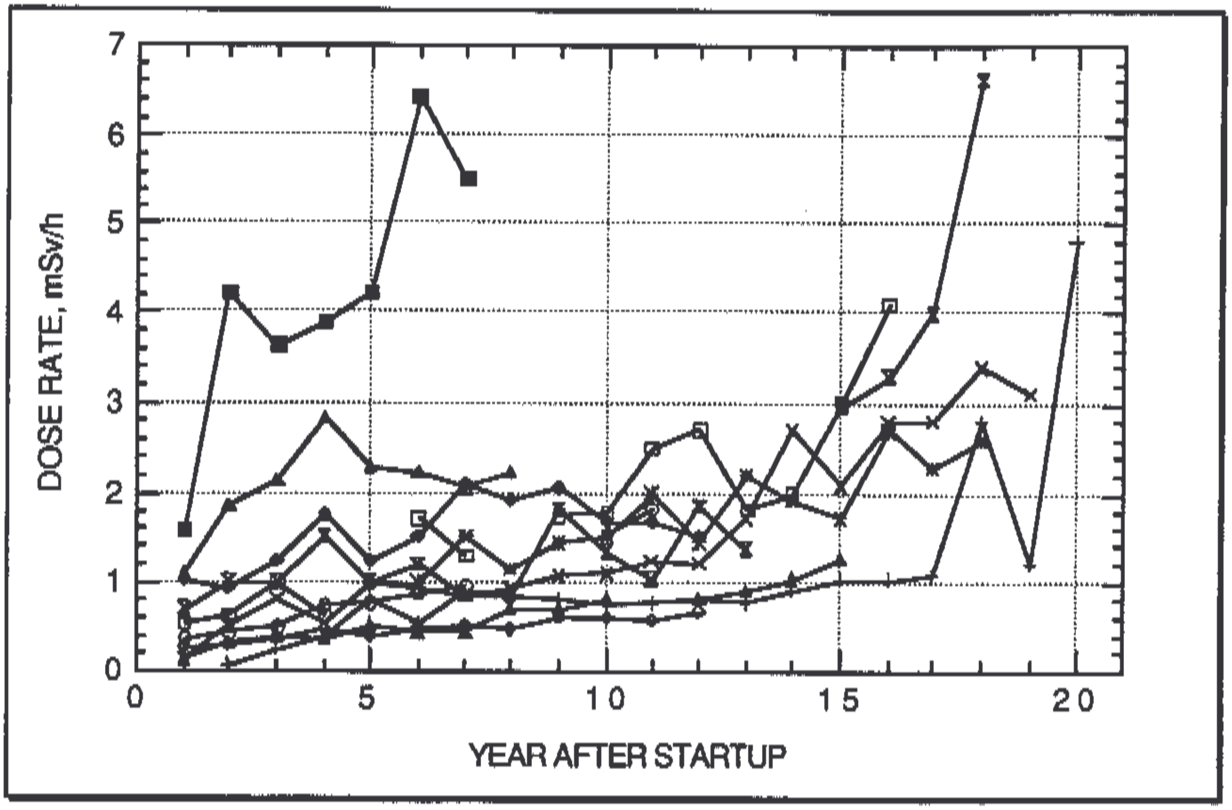

Figure 4. Shut-down radiation levels on a vertical RWCU pipe in different ABB Atom BWRs

Gamma scan data show that Co-60 contributes with about 70-90% of the total dose rate from the pipe.

The currently adopted strategies for the ALARA 2000 project are:

1. To reduce the input of Co to the reactor.

2. To minimize the release of Co-60 from the core surfaces.

3. To minimize the uptake on system surfaces.

4. To shield components which significantly contribute to the gamma radiation fields.

The stainless steel surfaces, approximately 7000-14000 m^2, in the feedwater train contains less than 0.2% Co in the Nordic reactors. This means that the Co/Ni ratio in this steel is less than 0.02. In Figure 5 the measured Co/Ni ratio in the feedwater in one Nordic BWR is presented, and in Figure 6 the corresponding ratio in the reactor water.

The Figures 5 and 6 show that the Co/Ni ratios are significantly higher than 0.03, indicating that there are other Co sources than corrosion of stainless steel.

A preliminary study has indicated that there are two possible sources for this additional Co: corrosion/erosion of specific valves containing Stellite, and Stellite dust produced during valve grinding. Both this sources have earlier been recognized.[3,4,5]

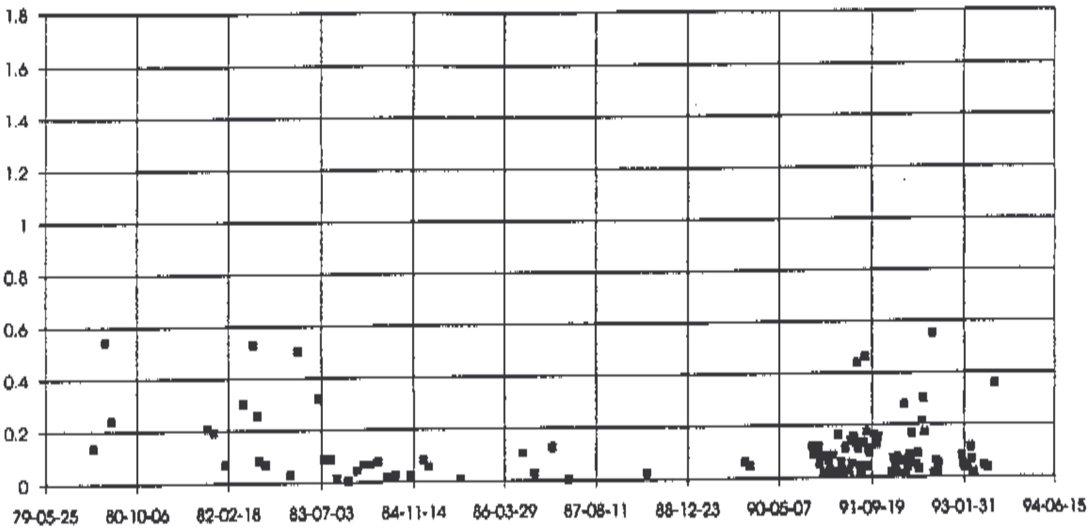

Figure 5. The Co/Ni ratio in the feedwater in one Nordic BWR

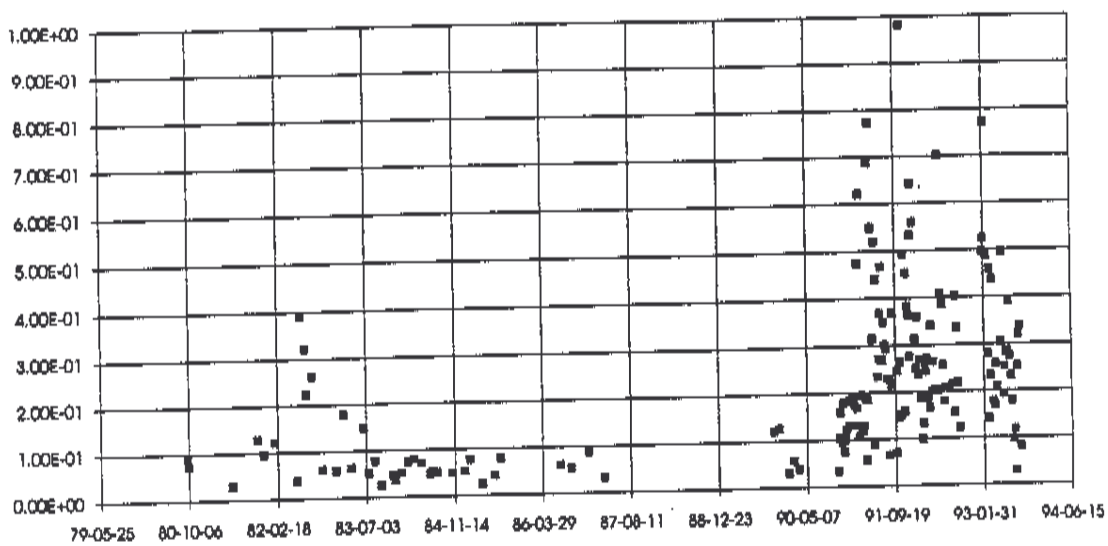

Figure 6. The Co/Ni ratio in the reactor water in one Nordic BWR

For the proceeding discussions, valves containing Stellite will be separated in three categories depending on technical function and radiological impact:

- <u>Red valves.</u> These are characterized by such high corrosion/erosion rates, up to 900 mdm (mg/dm2 and month) has been recorded,[6] that their technical function will be affected. Of course, these valves are significant sources for Co to the reactor. These valves are not acceptable for future use. It is recommended for the outage -94 that as many as possible of these red valves are to be identified and the Stellite exchanged. All red valves should be exchanged at latest during the outages 1995.

- <u>Yellow valves.</u> These are characterized by a high corrosion/erosion rate which significantly contribute to Co inflow to the reactor. However, technically the valves can be accepted. These valves should be identified during the outage -94. Corrosion/erosion rates for individual valves should be estimated. Some of these valves will be exchanged and made Stellite free. A cost-benefit study of the exchange of yellow valves will be carried out plant and valve specifically.

- <u>**Green valves.**</u> These are characterized by low or very low corrosion rates and thus do not have any significant radiological impact. There are no reasons to make any changes of the green valves.

The total input of Co to a 1000 MWel reactor of ABB Atom design can be estimated to 50 to 100 g per 8,000 EFPH (Effective Full Power Hours) and the total number of valves are about 12,000. There are, however, only a very limited amount of valves which causes radiological problems.

Also the chemical behavior of Co and Co-60 will be studied. The release of Co-60 from the fuel surfaces and uptake on system surfaces will be treated statistically to try to find parameters which govern the behavior of Co-60. This will be done by comparisons between fuel scraping data, reactor water concentrations, and system deposits of metals and activated corrosion products. Also sampling and measuring procedures will be examined.

The Nordic BWRs have very low Fe concentrations in the feedwater. The effects on the behavior of Co-60 of Fe injection to the reactor are therefore addressed.

As the DORIS and ALARA 2000 projects are running at the same time, the results produced within one of the projects will be used in the other.

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Author Biography

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