BWR System Surface Contamination

Comparison of three similar units with different development

2018 ISOE European Symposium, Mattias Olsson – Forsmarks Kraftgrupp AB

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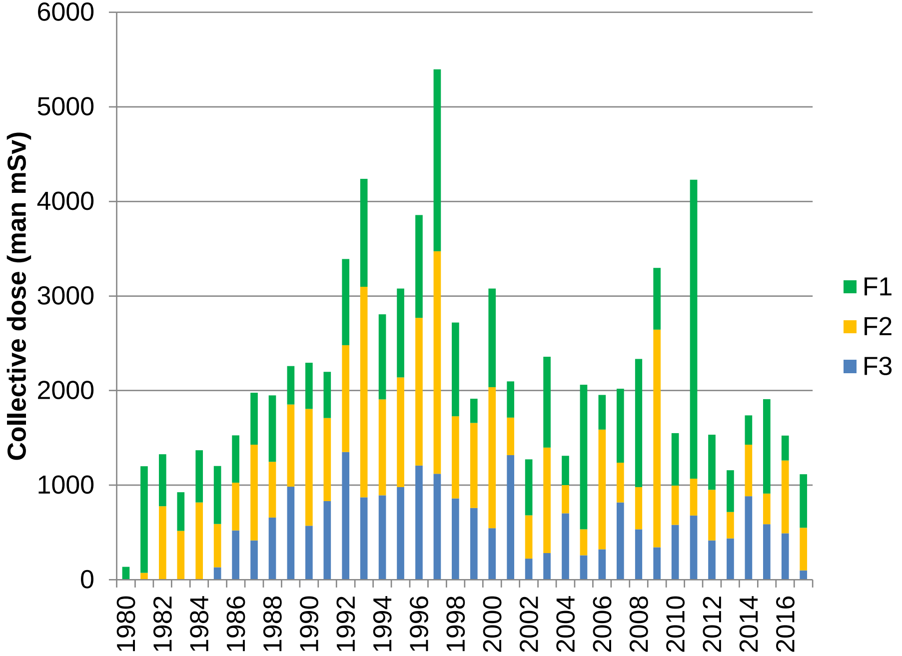
Forsmark – Three BWR units

- Forsmark 1, op 1980
  - Asea Atom BWR 69
  - 984/2928 $MW_{e/t}$
- Forsmark 2, op 1981
  - Asea Atom BWR 69
  - 1120/3253 $MW_{e/t}$
- Forsmark 3, op 1985
  - Asea Atom BWR 75
  - 1190/3300 $MW_{e/t}$
- Other Swedish units:
  - R1–R4, O3

Annual collective doses

- The annual collective doses to personnel are at a reasonable level
- No increasing trend
- The dose depends on the work done and on the state of the radioactive source term
- Poor source term control makes dose increases more likely



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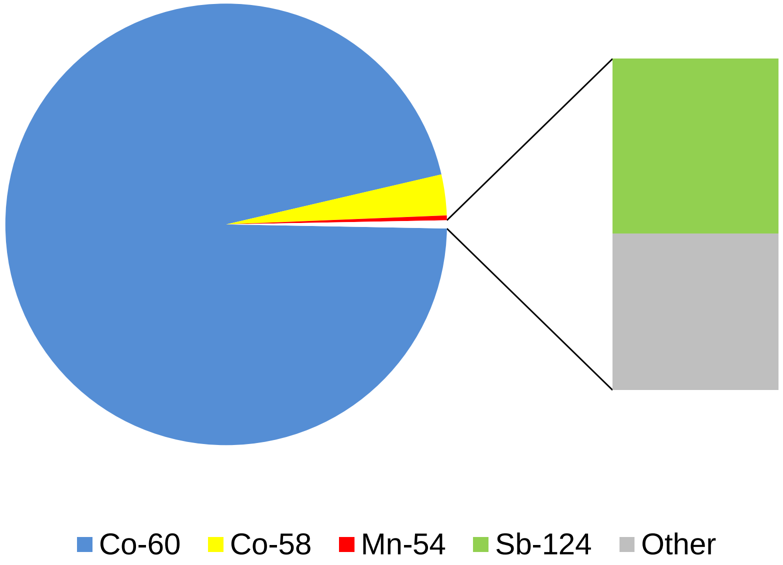
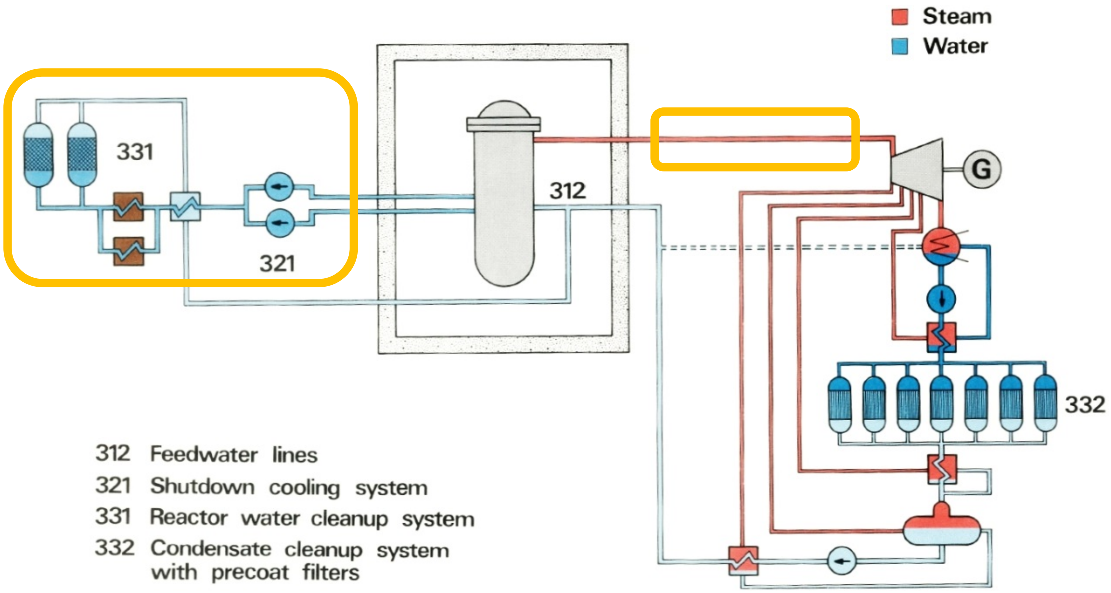
System surface dose rate contributors

- Surface activity measurements on reactor and turbine systems show Co-60 as the biggest contributor by far, during outage
- Colder systems have had periods with Ag-110m as the biggest contributor
- Figure: Shares of surface dose rate contributions for a shutdown cooling system pipe at Forsmark 1 (2017)
  - The pipe carries hot reactor water from the reactor pressure vessel



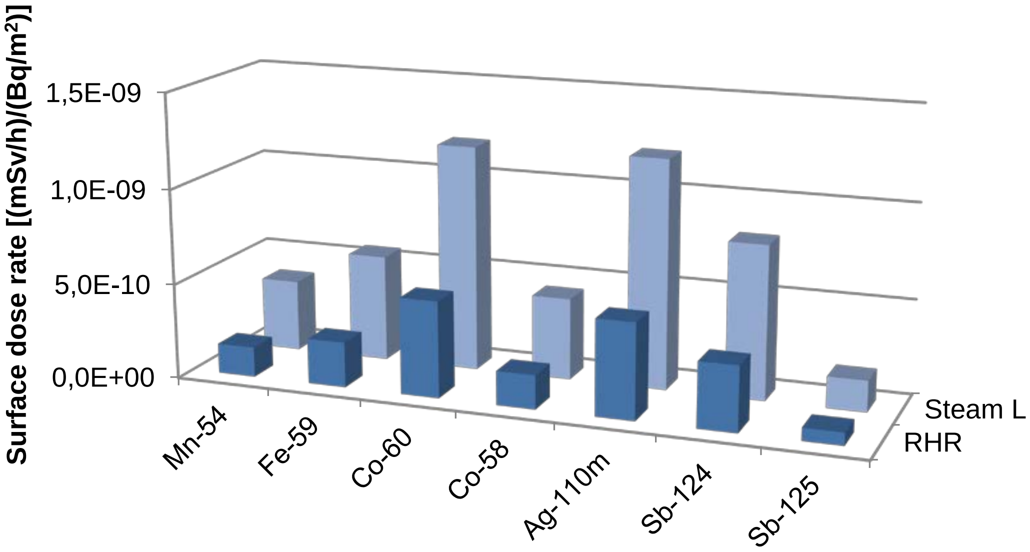
Surface activity measurements

- Nuclide specific gamma measurement campaign every outage – reactor and steam systems
- Mobile HPGe detector
- Done at all Swedish plants and Olkiluoto (Finland)
- Long term trends available, development analyzed every year



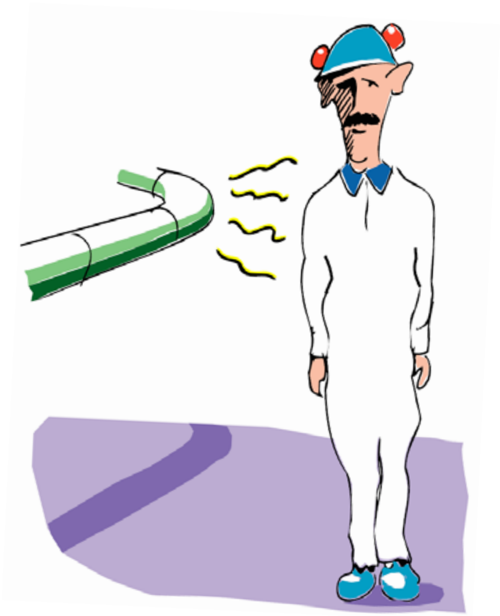
System surface dose rate contributors

- Surface contamination inside pipes contributes to the surface dose rate on the outside of the pipe
- Figure: Nuclide specific factors that convert internal surface contamination to external surface dose rate for two types of pipes
- Co-60 and Ag-110m are among the least wanted contaminants



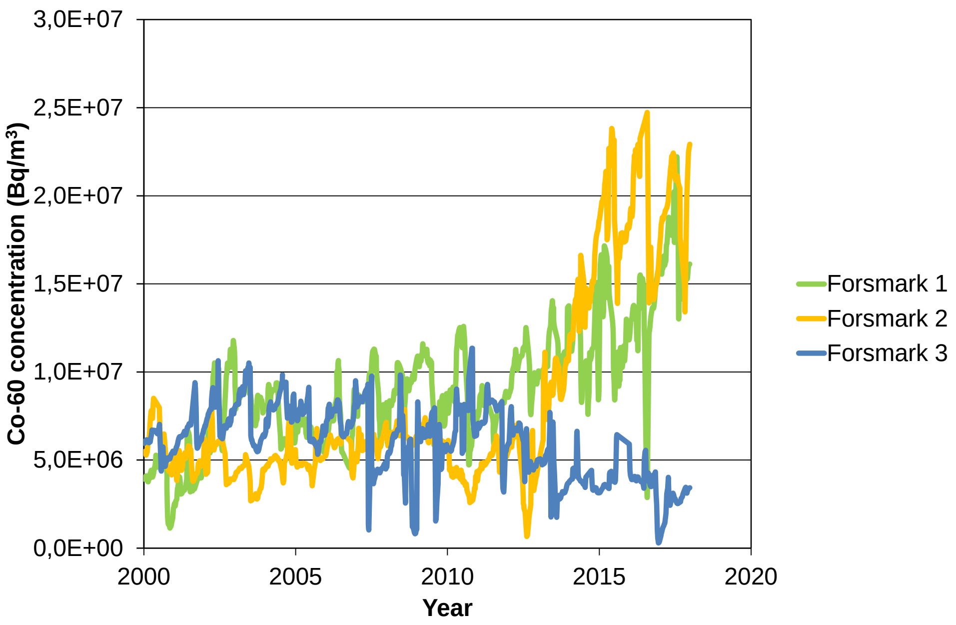
Three units – three Co-60 source term developments

- Forsmark 1
  - Increased reactor water concentration
  - Constant contamination and dose rates for reactor systems
- Forsmark 2
  - Increased reactor water concentration
  - Severely increased contamination and dose rates for reactor systems
- Forsmark 3
  - Decreased reactor water concentration
  - Decreased contamination and dose rates for reactor systems



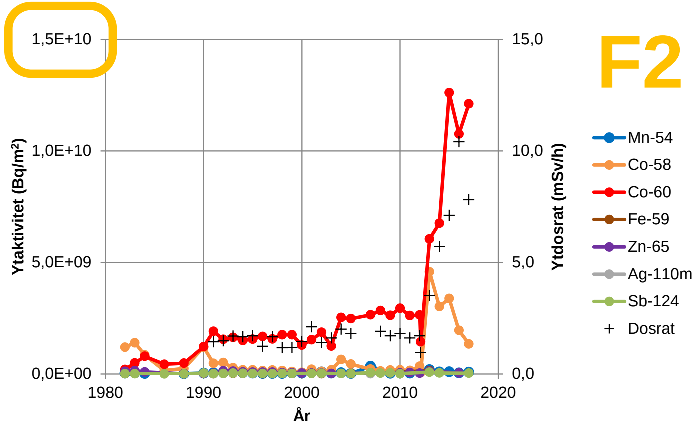
Co-60 in reactor water

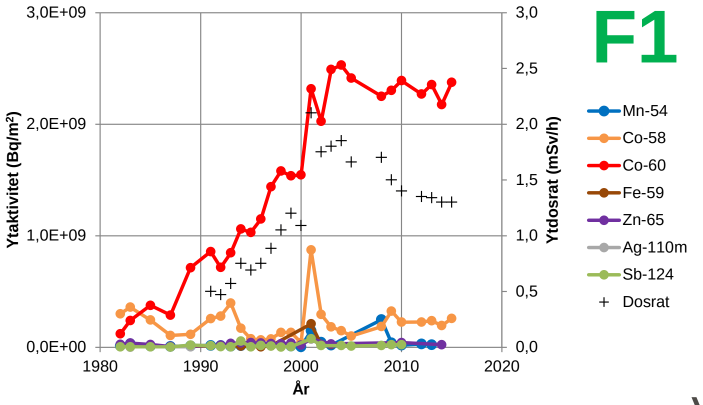
- Forsmark 3 has a very good development for Co-60 in reactor water for several reasons
- Forsmark 1 and 2 have increased significantly and are at record high levels
- All units have reasonably stable cobalt trends for the feed water
- The increases at units 1 and 2 likely have a common cause
  - Corrosion of activated nickel base alloy in the reactor

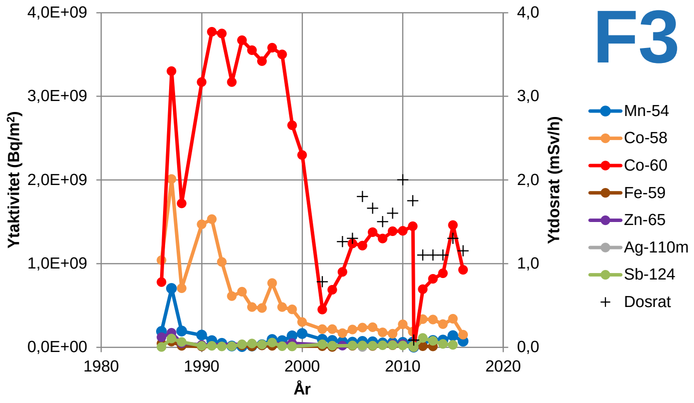


System surface contamination

- Surface contamination trends inside shutdown cooling system pipes (Bq/m^2)
- Three very different sets of trends







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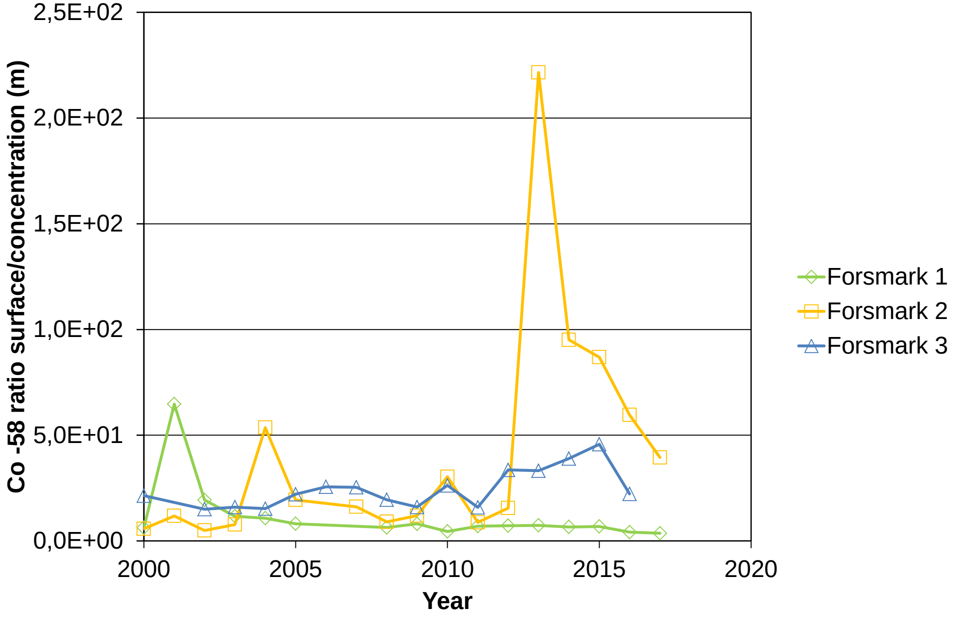
Hungry surface at Forsmark 2

- Forsmark 2 did a system decontamination of shutdown cooling and reactor water cleanup systems in 2012
- Subsequent high uptake of cobalt on some system surfaces
- The same thing did *not* happen after decontaminations at Forsmark 3 in 2001 and 2011
- Figure: Co-58 ratio surface/water for shutdown cooling systems

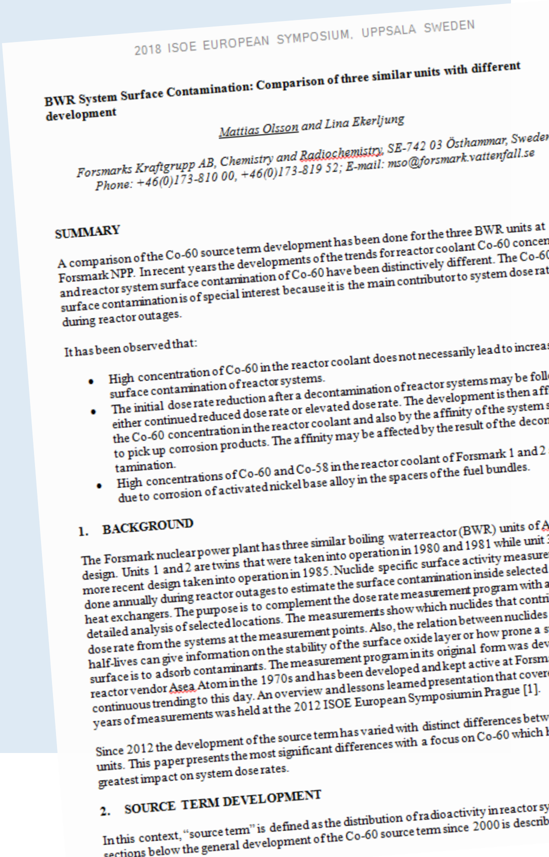


Conclusions and forward

- High concentration of Co-60 in the reacor water can transfer to surfaces but does not have to
- Hungry surface after decon-tamination in combination with high reactor water concentration is a poor combination
- The source of the Co-60 increase at units 1 and 2 is likely the corrosion of the nickel base alloy of fuel spacers – contains cobalt impurities

- Confirm the additional Co-60 source!
- Evaluate possibilities to reduce spacer corrosion: Fe addition to feed water!
  - Forsmark 1 and 2 have ultra-low Fe in feed-water – possible increase in nickel base alloy corrosion rate
- Evaluate the situation carefully before the next system decontamination!

Time for questions



2018 ISOE EUROPEAN SYMPOSIUM, UPPSALA SWEDEN

BWR System Surface Contamination: Comparison of three similar units with different development

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SUMMARY

A comparison of the Co-60 source term development has been done for the three BWR units at Forsmark NPP. In recent years the developments of the trends for reactor coolant Co-60 concen… and reactor system surface contamination of Co-60 have been distinctively different. The Co-60 surface contamination is of special interest because it is the main contributor to system dose rat… during reactor outages.

It has been observed that:

- High concentration of Co-60 in the reactor coolant does not necessarily lead to increas… surface contamination of reactor systems.
- The initial dose rate reduction after a decontamination of reactor systems may be foll… either continued reduced dose rate or elevated dose rate. The development is then aff… the Co-60 concentration in the reactor coolant and also by the affinity of the system s… to pick up corrosion products. The affinity may be affected by the result of the decon… tamination.
- High concentrations of Co-60 and Co-58 in the reactor coolant of Forsmark 1 and 2 … due to corrosion of activated nickel base alloy in the spacers of the fuel bundles.

1. BACKGROUND

The Forsmark nuclear power plant has three similar boiling water reactor (BWR) units of A… design. Units 1 and 2 are twins that were taken into operation in 1980 and 1981 while unit 3… more recent design taken into operation in 1985. Nuclide specific surface activity measure… done annually during reactor outages to estimate the surface contamination inside selected… heat exchangers. The purpose is to complement the dose rate measurement program with a… detailed analysis of selected locations. The measurements show which nuclides that contri… dose rate from the systems at the measurement points. Also, the relation between nuclides… half-lives can give information on the stability of the surface oxide layer or how prone a s… surface is to adsorb contaminants. The measurement program in its original form was dev… reactor vendor Asea Atom in the 1970s and has been developed and kept active at Forsm… continuous trending to this day. An overview and lessons learned presentation that cover… years of measurements was held at the 2012 ISOE European Symposium in Prague [1].

Since 2012 the development of the source term has varied with distinct differences betw… units. This paper presents the most significant differences with a focus on Co-60 which h… greatest impact on system dose rates.

2. SOURCE TERM DEVELOPMENT

In this context, "source term" is defined as the distribution of radioactivity in reactor sy… sections below the general development of the Co-60 source term since 2000 is describ…