



Svensk Kärnbränslehantering AB  
Box 250  
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**Vår referens:** SSM2011-2426-236  
**Er referens:** KTL - Kärnbränsleförvaret

## Begäran om förtydligande information avseende krypmodellering för kopparhöjet

Strålsäkerhetsmyndigheten (SSM) har vid granskningen av Svensk Kärnbränslehantering AB:s (SKB) ansökan om tillstånd enligt lagen (1984:3) om kärnteknisk verksamhet för ett slutförvar för använt kärnbränsle och kärnavfall, funnit behov av nedanstående förtydliganden.

SSM önskar att förtydligandena är myndigheten tillhanda senast den 23 oktober 2015.

Om SKB önskar ytterligare förklaringar eller förtydliganden av de frågor som omfattas av denna begäran, och som inte avser enklare klargöranden av praktisk eller administrativ karaktär, ska detta ske vid protokollförra möten mellan berörda personer på SSM och SKB.

### Förtydliganden

SSM har anlitat en konsult (Inspecta) för att göra en djupgående kvalitetsgranskning av SKB:s tillämpning av modellen för kryp i fosfor-legerad koppar utarbetad av Sandström och Andersson (2008). Det kvantitativa modelleringsarbetet gjordes på uppdrag av SKB av en konsult (Hernelind) med hjälp av finit element modelleringsprogramvaran ABAQUS.

SSM har tidigare (SSM2011-2426-233) begärt förtydligande både förståelse för den ursprungliga modellen och de antaganden som görs för att implementera modellen i ABAQUS. Som följd av myndighetens vidare granskning av hur modellen har tillämpats av SKB för att utreda särskilda fall har några ytterligare frågeställningar uppkommit.

Dessa frågor berör två studier som gjorts av SKB för att besvara kompletteringsbegäranden av SSM. Studierna redovisas i SKBdoc 1419643 (Analysis of canister with unfavourable pressure load) och SKBdoc 1399768, version 2 (Analysis of creep in the KBS-3 copper canister due to internal and external loads).



SSM:s konsult har uttryckt detaljerade frågor (på engelska) enligt nedan.

1. "Questions to SKB regarding report 1419643 rev 1.0" (Bilaga 1)
2. "Questions to SKB regarding report 1399768 rev 2.0" (Bilaga 2).

SSM anser att svar på dessa frågor är viktiga för att bygga förståelse för SKB:s rapporterade resultat och ge underlag komma fram till en bedömning av hur koppars krypegenskaper har hanterats av SKB i samband med analys av strålsäkerhet efter förslutning av slutförvaret.

### **Skälen för begäran om förtynliganden**

SSM granskar för närvarande SKB:s ansökan om tillstånd enligt lagen (1984:3) om kärnteknisk verksamhet för ett slutförvar för använt kärnbränsle och kärnavfall. För att underlätta SSM:s bedömning av om SKB:s ansökan uppfyller tillämpliga krav önskar SSM ovanstående förtynliganden.

### **STRÅLSÄKERHETSMYNDIGHETEN**

Ansi Gerhardsson

Chef, enheten för slutförvaring av radioaktivt avfall

### **Referenser**

Rolf Sandström and Henrik C.M. Andersson, Creep in phosphorus alloyed copper during powerlaw breakdown, *J. Nuc. Mat.*, 372 (2008) 76-88.

SKBdoc 1399768, ver 2.0. Hernelind J., Analysis of creep in the KBS-3 copper canister due to internal and external load, mars 2015.

SKBdoc 1419643, ver 1.0. Hernelind J. Analysis of canister with unfavourable pressure load, februari 2014.



## Bilaga 1

### Questions to SKB regarding report 1419643 rev 1.0

1. In section 1, it can be read that the copper shell material model is based on a creep model developed by Rolf Sandström.

According to section 4.3, the material model for the short duration analysis (neglecting creep) is based on a simplified elastic-plastic model using data from the creep model assuming a strain rate of  $5 \cdot 10^{-3} \text{ 1/s}$ . This model is consistent with contour plots showing equivalent plastic strain PEEQ in the report. The model is also consistent with the “\*static”-procedure that is used in the analyses according to section 2 in the report.

According to Appendix 3, each analysis is started by *abaqus job=input-file (w/o .inp) user=creep\_rs\_march2009*. This means that the user subroutine CREEP is used for the copper material in the analyses. However, no contour plot shows equivalent creep strain CEEQ in the report.

Which model has been used for the copper material in the analyses? If a simplified elastic-plastic model is used for the copper material, does this mean that no creep strain will develop in the two analyses?

2. Load cases analysed in the report are more or less load controlled. How is it justified that creep in the copper canister is not taken into account in the analyses? (Assuming creep is not considered in the analyses)
3. According to section 7, short term analysis is based on static response but the results will depend on the time used for the simulation since rate-dependent material data is used. According to section 4.1, the strain rate dependence is not needed in this study since the swelling pressure process is very slow. How should the analysis approach be understood?
4. Is the swelling pressure/shear stress applied as a ramp on the copper canister in the analyses? If yes, how does the ramp look like?
5. Is the temperature evolution, in one or another way, considered in the analyses?
6. According to section 1 and with reference to the SKB report TR-10-31, the highest swelling pressure occurs for bentonite with density



2050 kg/m<sup>3</sup> with a magnitude of 12.3 MPa. How has the swelling pressure 12.3 MPa been derived based on TR-10-31? Why is not the swelling pressure 15 MPa given in TR-09-22 (design premises) used?

7. According to section 1 and with reference to the SKB report TR-10-31, the shear stress in the bentonite limited to 1.75 MPa in the report. How has the shear stress 1.75 MPa been derived based on TR-10-31?
8. Is the copper cylinder in contact with the insert when the shear stress and the swelling pressure are applied on the copper cylinder in the second load case? If not, 1) what is the initial gap between the copper cylinder and the insert and 2) is the gap closed during the analysis?
9. According to section 9, strain rate effects in the copper and iron will affect the results. According to section 4.1, the strain rate dependence is not needed in this study since the swelling pressure process is very slow. How should this contradiction be understood?
10. Are there any contour plots of the copper lid region and the copper bottom region showing plastic strains at a component level?



## Bilaga 2

### Questions to SKB regarding report 1399768 rev 2.0

1. In figure 2-2, the swelling pressure between 10 and 20000 years is 15 MPa. Is the additional hydraulic pressure of 5 MPa only considered in the design case?
2. Figure 2-5 shows internal pressure as a function of time. For how many years is the canister analysed with an internal pressure of 0.5 MPa?
3. In the four different analyses, is the internal pressure load in figure 2-5 combined with the external pressure load shown in figure 2-2 or 2-3?
4. In figure 4-2 and 4-3, the insert is placed up-side-down with respect to the copper canister. Is the model shown in the figures used in the analyses?
5. Figure 10-2 and figure 10-3 are difficult to compare as they show results from different analyses, i.e. *isostat\_JLH\_creep\_red\_dim* and *isostat\_JLH\_creep\_blue\_dim*. Is it a mistake that results from the latter analysis is shown in figure 10-3? Is a contour plot of minimum principal stress available from the analysis *isostat\_JLH\_creep\_red\_dim*?
6. In figure 10-12 and 10-31, does the x-axis show time from  $10^4$  to  $10^5$  years?
7. What explains the sudden increase in creep strain for the *isostat\_JLH\_creep\_red\_dim* analysis in figure 10-12? At what time does it happen?
8. Creep strain development over time is shown in specific elements, see for example figure 10-16. This gives an idea of local effects. Regarding global effects it would be of interest to compare creep strain development just before the onset of the glacial period at time 20000 years with that at time  $10^5$  years. Are contour plots of CEEQ at time 20000 years available for comparison with results presented in the report? If yes, the same scale as for the contours plots at  $10^5$  years is preferred.



9. What are the biggest differences between the 2D and the 3D mesh?  
Major impact on the results caused by these differences?
10. In section 13 it is stated that "*The creep from the internal processes, before external loads are applied, case c) and d), is very small and of minor importance.*" Are there any contour plots available on creep strains caused by this load for case d), i.e. at time 10 years?
11. In section 13 it is written that "*The creep from the internal processes, before external loads are applied, case c) and d), is very small and of minor importance.*" Isn't internal pressure also applied in load case a) and b)?
12. According to figure A1-5 (and the following figures showing results for the time 10 years), gas pressure is applied. Does "gas pressure" correspond to the load described in figure 2-5?
13. Are contour plots with creep strain at a component level available from the *isostat\_JLH\_creep\_red\_dim* analysis?