Comments on the draft version of "Quality Assurance Review of SKB's Copper Corrosion Experiments"

By Ola Karnland on behalf of the LOT project

Executive summary (Page 1 to 3)

Items 1 to 3 do not concern the two copper corrosion experiments in question.

Item 4 is surprising in that sense that it is:

a) generalizing,
b) speculative in using phrases like "may be conditioned to..." "there may be large errors ..."
c) offending since it implies that SKB researchers should neglect correctly measured values, i.e. to act unscientifically. The statement is especially odd in relation to the LOT experiment since the stated objective for the copper corrosion part is to determine the validity of the calculated mean corrosion rate of 7E-6 m/year.

Item 6. Oxic-anoxic conditions
This is really one of the key points within the LOT Cu corrosion tests. By measuring the mean corrosion rate for different time of exposure one can get a simple indication of the corrosion rate evolution, which likely is closely related to the redox evolution. The LOT Cu corrosion tests do consequently not aim to directly correlate the redox conditions to corrosion rates, since the redox evolution likely is far too complex in time and space to keep track of. However, we do know for sure that we start with a massive amount of trapped oxygen in the system. We also have indications from the subsequent water analyses that the final condition is reducing. The evaluated mean corrosion rates consequently include both oxic and anoxic corrosion. The distribution of the two types of corrosion is not a primary goal of the tests, but the mean corrosion rates are. The statistics are at present not very good with only 2 values representing long term conditions, but considering the remaining coupons in the ongoing field tests, the potential information is substantial.
Since the work by Szakálos et al. are brought up in the review, it is motivated to point out that the present results from the LOT tests are of decisive value. Regardless of the prevailing redox conditions the results contradict the statements made by the KTH group concerning high corrosion rates under reducing conditions.

Item 7. The reporting in the LOT experiment is in no way unclear and the reasons for the reporting status was described at the review meeting in Äspö, 1 December 2009.

a) The LOT A0 parcel is an additional test which was not planned for in the original test program. The ambition with this test was to complete the results from the A1 parcel since part of this experiment was lost in the retrieval. The ambition was to write a separate report concerning this test, but due to priority reasons the results were only presented at various meetings, e.g. with the Swedish authorities, and placed in the database. The delay of a separate report for this extra test is due to low priority which is unfortunate, but not unclear.

b) The real-time corrosion measurements placed in the LOT A2 parcel is formally not a part of the LOT experiment and consequently there are no objectives descried in the LOT test plan concerning these tests. There are several report levels within the SKB documentation system, and it is certainly not all tests and analyses financed by SKB that are reported as "Technical Reports". The choice of what reporting level that should be used for a specific work has to be the responsibility of SKB. As acknowledged by the reviewers, the results of these measurements have been published in scientific journals.

c) The reviewers write:
"This QA review acknowledges the time required to analyse and understand the data obtained, but timely publications of results are important."
Comment from the LOT project:
Concerning the LOT A2 test, the experimental work rather starts than ends at the time of retrieval of the test parcel. I.e. it is not a question of analyzing and understanding obtained data, but of time consuming laboratory work. In the objectives for the LOT tests it is stated in the project plan that one of the main objectives is to ".. facilitate the realization of the full scale test series with respect to preparation, instrumentation, retrieval, subsequent analyses, evaluation and data handling." Much of the work performed accordingly concerned development of analyzing techniques. The LOT A2 post exposure tests and analyses involved 9 laboratories in 5 countries, and the last results were delivered from an external laboratory in August 2009. A full Technical Report published in November 2009 therefore may be considered quite reasonable. As been recognized by the reviewers, the progression of the work was presented to the scientific society and the authorities at various meetings. The time used for the work leading to the previous LOT Technical Report (2000) was only slightly shorter and was not criticized in the previous review of the LOT experiment (2007).

Item 8 concerns the SKB reporting strategy and not the test in questions of this review.

Comments on specific points in the review draft.

Page 11
Bentonite mineralogy and physical properties have been analyzed by Clay Technology AB but also by the BGR laboratory in Germany, the University of Bern in Switzerland, the GR2 and LEM laboratories in France.

Page 13
The review states:
"If the same environmental conditions prevail in all retrieved LOT parcels then, based on SKB's experimental results, the corrosion rate varies by a factor of ten, which displays significant experimental scatter and should be discussed."
Comment:
We do not see the point in speculating concerning a constant environmental conditions and discuss scatter in the calculated mean corrosion, especially since large amount of oxygen is initially present in the system, and the final condition is reducing.
What we do have are two sets of measured masses, one representing short term experiments and the other representing medium term experiments. The statistics at present are poor but the

following applies regardless of the geochemical conditions. The lowest mass loss is 27 and the highest is 86 mg. The variation cannot be explained by the difference in exposure time since the lowest value represents a medium term test. The precision in measured data may thereby be expressed as a variation by a factor of 3.2, or e.g. as a standard deviation of 23.4.

Page 14
The review states:
"The water analysis by VTT indicates that reducing conditions are present in the A2 parcel but the estimated corrosion rate is approximately a factor of ten greater than the theoretically calculated corrosion rate of 2E-8m/year for anoxic conditions."
Comment:
Knowing that the experiment starts with huge amounts of trapped oxygen in the system, it is not relevant to compare the evaluated mean corrosion rate with the expected corrosion rate for anoxic conditions. More relevant comments are that the evaluated corrosion rate is one order of magnitude lower than the calculate corrosion rates for oxic conditions, and two orders of magnitude lower than what has been stated by Szakálos at KTH.

Page 14-15
The review states:
"It would appear a lost opportunity not to carry out more detailed analysis of the copper tube itself. "
Comment:
The relevance of such a corrosion study of the copper tube is most questionable due to a number of identified reasons, such as copper quality, contact with open air in tunnel and most of all metallic contact with sensor tubing. This was the rationale for using copper coupons instead of the copper tube in the corrosion study. The rationale for still using a central copper tube was to study the uptake of copper in the bentonite and its possible effects on the bentonite mineralogy.

Page 22
The review states:
"However, the copper corrosion tests that form part of the LOT and MiniCan experiments suffer from being add-ons to already planned experiments to investigate other processes. "
Comment:
The objectives of the performed copper corrosion tests in the LOT experiment were adjusted to the add-on condition. The specific copper corrosion test in the LOT project does therefore not suffer from being add-ons, but the add-on condition limits possible outcome and thereby the level of ambition.

Page 24
The review states:
"Understanding when conditions are oxic and when they are anoxic is of key importance in copper corrosion tests. It will be difficult to interpret corrosion measurements unless the evolution of geochemical conditions is understood. It is possible that conditions vary spatially in each experiment. However, if anoxic conditions developed in the vicinity of the corrosion coupons as anticipated, then the measured corrosion rates are higher than would be expected."
Comment:

We do not understand the meaning of the expression ".. as anticipated ..". What is anticipated, where and by whom?
The results from the LOT experiments give valuable information, well in line with the project objectives, concerning mean corrosion rates. All measured results include a certain amount of corrosion due to oxic conditions, small or large. The ratio between oxic and anoxic corrosion will decrease with exposure time, and the evaluated mean corrosion rates will ultimately approach the anoxic corrosion rates.

E.g. page 19
We do not understand the reason for the repeated references to the LOT project within the MiniCan sections. E.g "Similar to the LOT copper corrosion analysis, SKB (2009b) does not quantify data uncertainties or ..."