KBS TEKNISK RAPPORT 120

Some notes in connection with the KBS studies of final disposal of spent fuel

Ivars Neretnieks

Kungl Tekniska Högskolan september 1978

KÄRN - BRÄNSLE - SÄKERHET

POSTADRESS: Kärnbränslesäkerhet, Fack. 102 40 Stockholm. Telefon 08-67 95 40

SOME NOTES IN CONNECTION WITH THE KBS STUDIES OF FINAL DISPOSAL OF SPENT FUEL

Ivars Neretnieks
Kungl Tekniska Högskolan Stockholm september 1978

Denna rapport utgör redovisning av ett arbete som utförts på uppdrag av KBS. Slutsatser och värderingar i rapporten är författarens och behöver inte nödvändigtvis sammanfalla med uppdragsgivarens.

I slutet av rapporten har bifogats en förteckning över av KBS hittills publicerade tekniska rapporter i denna serie.

Some notes in connection with the KBS studies of final disposal of spent fuel

Ivars Neretnieks

Abstract

This report contains four short notes on problems briefly studied in connection with the KBS investigations on final disposal of spent unreprocessed fuel.

The first note discusses the possibility for thermal convection flow of water in the buffer material. It is concluded that thermal convection will not have a noticable effect on the transport of water dissolved species.

The second note reports some experimental data on the sorption of strontium and cesium on granite.

The third note discusses the time required to accumulate a critical mass of uranium in the buffer material. It is concluded that it would take millions of years even if very unlikely series of events are postulated.

The fourth note discusses the consequences of hydrogen production in the repository. It is concluded that no grave consequences are expected if escaping hydrogen opens a channel in the clay and in the rock.

KEMISK APPARATTEKNIK
KTH

Some notes in connection with the KBS project

1 A note on thermal convection.771229

2 A note on sorption of Sr^{2+} and Cs^{+} on granite - some experimental results.780125

3 A note on the time to accumulate a critical mass of uranium.780405

4 A note on the consequence of hydrogen production in the repository. 780411

Ivars Neretnieks

A NOTE ON THERMAL CONVECTION

Contents:

Ivars Neretnieks

1977-12-29

1 Backgrund

The buried capsules evolve heat. This heat will induce thermal convection due to the resulting thermal gradient. It is of some interest to determine if the thermal convection will induce a velocity in the clay barrier which will transport the nuclides and other components faster than other mechanisms.

2 Estimation of the magnitude of the thermal convection

Häggblom (1) investigated this problem. The thermally induced hydraulic gradient i_{th} may be determined from

$$i_{th} = \frac{\alpha \Delta \theta}{k_1(k_2+1)} \qquad 1$$

where α is the thermal expansion coefficient for water. α is between $2 \cdot 10^{-4}$ and $10 \cdot 10^{-4}$ for water in the temperature range 20°C - 140°C. $\Delta\theta$ is the temperature difference over the clay barrier. k_1 is a constant between 1 and 2 depending on the geometry of the induced water movement. k_2 is another constant dependent on the geometry. k_2 can vary from 0 to very large values. Häggblom used $k_1 = 2$ and $k_2 = 2$. Using these values and $\Delta\theta = 20$°C and the temperature at the capsule wall = 80°C we get $\alpha = 5.8 \cdot 10^{-4}$ and $i_{th} = 1.5 \cdot 10^{-3}$ m/m. This is of the same magnitude as the figure often used for the hydraulic gradient.

With this thermally induced hydraulic gradient, a permeability of $K_p = 10^{-10}$ m/s and with a porosity $\epsilon = 0.25$ for the compacted clay it takes 20 000 years for the water to travel a distance equal to the thickness of the clay barrier ($z = 0.38$ m).

This figure should be compared with the time it takes for a species to diffuse the same distance. This may be computed from

$$\frac{Dt}{z^2} = \text{Const} \qquad 2$$

for the instationary case, z is the barrier thickness, D the diffusivity of the species in the compacted clay. For Const = 0.1 the concentration on the other side of the barrier has increased to 0.05 c_o. c_o is the sudden concentration difference at time t = 0. For Const = 1 the concentration has increased to 0.95 c_o.

It takes 13 years to reach 0.05 c_o and 130 years to reach 0.95 c_o for methane. D for methane has been measured in our laboratories. D= $3.9 \cdot 10^{-11}$ m^2/s. Most other species will diffuse slower.

3 Conclusions

Although many of the data used are approximate, it may safely be concluded that thermal convection will not have a serious or even noticable effect on the transport of water solved species to and from the capsule.

References:

1 Häggblom, H. Calculation of nuclide migration in rock and porous media, penetrated by water. KBS teknisk rapport nr 52, 1977-09-14.

KEMISK APPARATTEKNIK
KTH

A note on sorption of Sr^{2+} and Cs^{+} on granite - some experimental results.

Contents:

1978-01-25

Ivars Neretnieks

1 Summary

Sorption experiments were made to determine the equilibrium of Cs^+ and Sr^{2+} in water solutions with granite.

Particle sizes between 0.044 and 1 mm were used. The results indicate that the whole volume of the particles is utilized - not only the outer surface. The K_d-values were

Sr^{2+} : K_d = 10 g/g
Cs^+ : K_a = 15 g/g

at 25°C in a synthetic groundwater.

The results are in good agreement with previous investigations.

The results should however not be used for larger particles than 1 mm without further investigations.

2 Backgrund

It is important to have good equilibrium data on ion exchange and adsorption reactions for radionuclides on rock, as ion-exchange and adsorption reactions will retard escaping nuclides from a final repository. It is also important to know if it is a surface reaction or a reaction in depth.

If only the surface of the fissures reacts, there is a limited amount of rock surface which may be utilized. If it is a reaction in depth there is a considerable amount of rock which may be utilized.

In the latter case, however, the time for the ion to diffuse into the rock proper may be considerable.

The literature does not give a clear picture of these phenomena. See 4.2.2 in reference (2).

3 Experimental

Granite was crushed and sieved to various fractions ranging in sizes from less than 0.044 to 1 mm in diameter.

Between 5 and 20 g of granite were contacted in a stirred vessel with 100, 200 and 400 ml of water.

The water had the following composition

Na	288 mg/l	Cl	500 mg/l
K	10 "-	F	1.5 "-
Mg	15 "-	SO_4	15 "-
Ca	75 "-	CO_3	200 "-

Cs^+ and Sr^{2+} concentrations were near 5 mg/l. The temperature in all experiments was 25°C.

The contact time was up to 15 days. Frequent sampling was made during the first day. Thereafter the sampling was done every 2 to 3 days.

4 Results

During the first hour concentration fell rapidly. Thereafter the concentration fell vary slowly. Evaluated K_d-values increased with time, indicating a slow diffusion into the particle. The time used (7 - 14 days) was probably not sufficient to reach a real equilibrium even for the rather small particles d_p = 0.1 - 0.12 mm. Table 1 and 2 give the experimental conditions for the runs.

In diagram 1 K_d and K_a values are plotted versus the particle diameter for Sr^{2+} and Cs^{+} equilibria. There is a considerable scatter in the results. The results indicate that the equilibrium cannot be described by a surface equilibrium constant

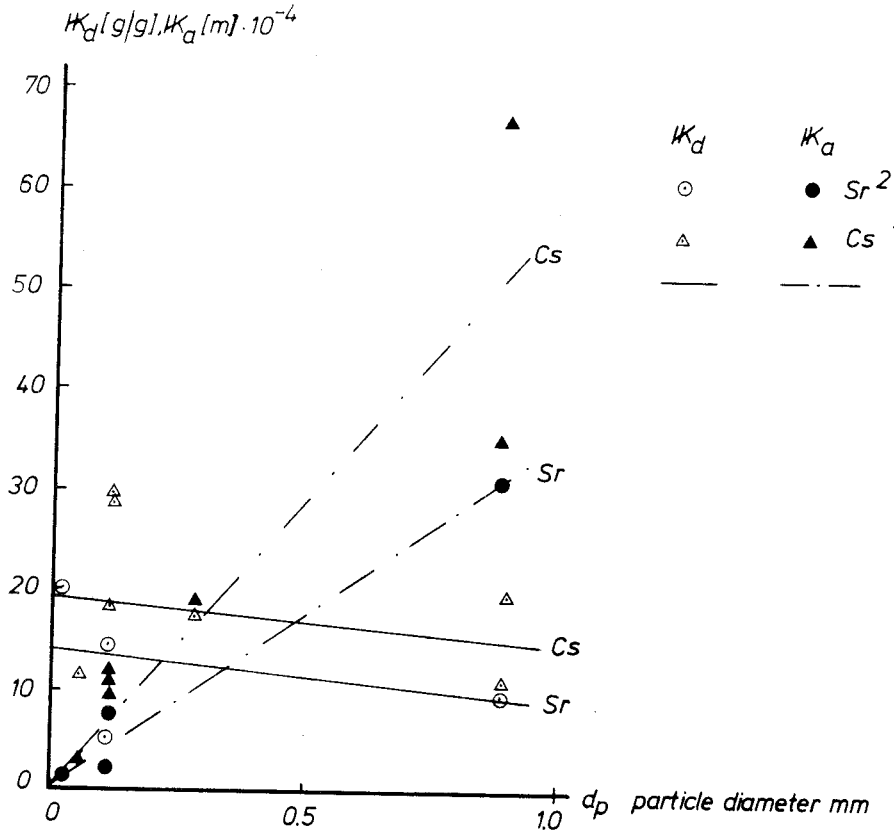
$$K_a = \frac{g/m^2 \text{ solid}}{g/m^3 \text{ liquid}}$$

as K_a is so strongly dependent on the particle size.

There is however some indication that the mass equilibrium constant K_d decreases somewhat with increasing particle size. This would mean that the interior pasts of the particles are not as active as the outer or that thay are less accessible and that equilibrium was not reached.

These results compare well with those of Allard (1).

Diagram 1



5 Conclusions

The ion exchange equilibrium of Cs and Sr with granite is better described by a mass equilibrium constant than a surface equilibrium constant.

Due to the rather large scatter in the results and the very small particles used this result should not be used to extrapolate to large particles such as the rock itself.

A further investigation must be made on larger particles.

6 Literature

1 Allard, B., Kipatsi, H., Rydberg, J.,
Sorption av långlivade radionuklider i lera och berg.
KBS teknisk rapport 55 1977-10-10

2 Neretnieks, I., Retardation of escaping nuclides from a final depository.
KBS teknisk rapport 30 1977-09-14

Table 1. Experimental conditions and results for Sr^{2+}

Experiment	Initial concentration C_o (ppm)	Final concentration C_s (ppm)	Particle diameter d_p (mm)	Mass of granite L (g)	Volume of liquid V (ml)	Temperature (°C)	Mass equilibrium constant K_d (g/g)	Surface equilibrium constant K_a m
1	5,025	3,5	0,0 -0,044	5.76	200	25	20	$1,7 \cdot 10^{-4}$
2	5.025	3.9	0.105-0.149	5.76	200	25	14.6	$7.3 \cdot 10^{-4}$
5	4,66	4.2	0.1 -0.120	11,40	400	25	4.7	$2,0 \cdot 10^{-4}$
6	4,66	3,78	0.75 -1.00	11,40	400	25	9.4	$31,5 \cdot 10^{-4}$

Table 2. Experimental conditions and results for Cs^+

Experiment	Initial concentration C_o (ppm)	Final concentration C_s (ppm)	Particle diameter d_p (mm)	Mass of granite L (g)	Volume of liquid V (ml)	Temperature (°C)	Mass equilibrium constant K_d (g/g)	Surface equilibrium constant K_a m
3	5.11	4.17	0.105-0.149	5.74	400	25	18	9.10^{-4}
4	5.11	4.44	0.044-0.063	5.79	400	25	13	$2.7 \cdot 10^{-4}$
7	5.14	3.28	0.1 -0.12	11.40	400	25	28.2	$11.9 \cdot 10^{-4}$
8	5.14	3.28	0.75 -1.00	11.40	400	25	10.5	$35.2 \cdot 10^{-4}$
9	10.91	1.553	0.1 -0.120	20.93	100	25	29	$12.8 \cdot 10^{-4}$
10	10.91	2.193	0.75 -1.00	20.93	100	25	20.1	$67.4 \cdot 10^{-4}$
11	10.91	2.45	0.25 -0.3	20.93	100	25	17.3	$18.2 \cdot 10^{-4}$

KEMISK APPARATTEKNIK
KTH

A note on the time to accumulate a critical mass of uranium

19780405

Ivars Neretnieks

Time to accumulate a critical mass of uranium

The minimum critical mass is some 4-7 tons if it is arranged in a sphere with a radius of 1 m. Other geometries are also possible but then considerably more uranium is needed. If the uranium from all capsules is distributed evenly over the tunnel no criticality is achieved. The uranium from at least 3 capsules is needed to get one critical mass. There are various ways to achieve this mass. Three capsules in a row may give up their uranium content simultaneously, in which case the transport distances are short, or many capsules (there are 160 in a tunnel at 6 m intervals) contribute to achieve the necessary mass. In the latter case the transport distances are very large for the capsules furthest away from the point where the mass is accumulating.

The transport velocity for uranium from one capsule is determined by a series fo resistances. The first (after the penetration of the copper) is the gradual dissolution and diffusion of uranium in the penetrated capsule. The second is the transport in the clay in the hole up to the tunnel bottom and the third is the transport in the clay/sand mixture in the tunnel.

The first and second mechanisms have been treated in (1,2). If the capsule is chopped off at the top and the transport resistance in the tunnel is neglected, the time to transport a given amount of uranium from the capsule to the tunnel botton may be computed. The results are given in table 1 for oxidizing conditions when the uranium oxide solubility is high.

It will take 35 million years for one capsule to give up its entire uranium content by the very improbable mechanisms assumed here. That will also be the minimum time for three capsules

to simultaneously contribute to the necessary minimum critical mass. The other possibility when many capsules contribute may be somewhat faster, provided the transport resistance in the tunnel may be neglected and the copper in many of the capsules is seriously degraded at about the same time. A little hole does not suffice. The top portion of the copper capsule must be degraded. If this happens to some 30 capsules at about the same time it will take about 2 million years for the neces sary amount (4-7 tons) of uranium to escape. The time for it to gather again is not included in this figure.

The mechanisms necessary for the reconcentration of the uraniu to a critical configuration are known in principle. This may be achieved by a solution of the uraniumoxide in oxidizing water and precipitation of the solved species at some spot where the uranium (VI) is again reduced to uranium (IV).

The series of events leading to this are not easy to imagine. The copper capsules must be not only penetrated but seriously degraded to achieve a hole large enough for the transport of the solved species. The uranium must be oxidized to U(VI) by some mechanism. It should be pointed out that the water at these depths in the rock is reducing. The water must contain large amounts of carbonates or other complexing agents to achieve a high solubility of the uranium. A small spot must be available where all the uranium can be again reduced to uranium (IV).

If all these events occur it will take many millions of years to reach critical mass. Furthermore the gathering will be very slow which eliminates the possibility of a quick blow up.

REFERENCES

1) Andersson, K., Neretnieks, I.,
Utdiffusion av svårlösliga nuklider ur kapsel efter kapselgenombrott. KBS TR 80 1978-03-07.

2) Neretnieks, I., Transport of oxidants and radionuclides through a clay barrier. KBS TR 79 1978-02-20

Table 1

Time for a given amount of uranium in one capsule to dissolve and diffuse up to the tunnel bottom.

Length of UO_2 matrix dissolved m	Amount of U dissolved tons	Time after copper penetration Myers
0.1	0.035	0.36
0.2	0.07	0.75
0.5	0.175	2.1
1	0.35	4.8
2	0.7	12.3
4	1.4	35.3

Diffusivity in clay $2 \cdot 10^{-11}$ m^2/s (2), in UO_2 matrix $10^{-10} m^2/s$ solubility in water 1073 gU/m^3, compacted clay above the capsule 2 m.

A note on the consequence of hydrogen production in the repository

Background

Hydrogen may be produced in the copper capsule by zircalloy-corrosion and by radiolysis. Hydrogen diffuses slowly in compacted bentonite (1). If the production of hydrogen is fast it will not have time to escape by diffusion at the same rate at which it is produced. A gas bubble may form.

Treatment of the problem

Pusch (2) has treated this case. He concludes that the 4.5 m^3 of hydrogen at 50 bar pressure will be confined in a stable bubble, the space beeing created by the displacement of the tunnel fill.

The question has been posed of what would be the consequences if the bubble escapes. For this to happen a channel must be formed in the compacted clay and in the rock. A local expansion of the rock might be concieved if the pressure of the hydrogen rises to 130-140 bar or more. This is the pressure of the overlying rock. A widening of the fissures in the nearby rock will facilitate the extrusion of bentonite in the fissures This is further facilitated by the increased pressure differenc If a channel is formed, some clay will probably escape. As the clay will keep its swelling properties even at very low clay densities (2), a minor loss of clay does not leave a void. The permeability decreases but will still be much less thant that of the rock (10^{-9} m/s) even after a major loss (> 80 %) of clay (2).

After the escape of the bubble the locally expanded rock will settle down again. The fissures that were opened will probably not settle to their original width. This is partly because other points on the surfaces will touch after resettling and partly because clay has crept out into the fissures. Any widened fissure which is blown free of clay will fill very quickly if the fissure width is larger than about 0.2 mm. Pusch (3) has investigated the extrusion velocity of bentonite in fissures experimentally, as well as theoretically. In two months the clay creeps about 6 mm in a 0.5 mm fissures. Larger fissures will fill faster and smaller are of no importance as the water flow and its transport capacity of radionuclides is low in such fissures (4). A 6 mm deep layer of clay in a fissures has about the same resistance to diffusion as the clay surrounding the capsule in the hole. This is mainly because the fissure area is very small in comparison to the area of the wall in the hole with the capsule.

The clay will continue to extrude in the fissure but at a continually decreasing rate. The resistance to diffusion will thus continually increase.

If the fissure(s) become very large 1-3 mm, the clay will fill these fissures much quicker and the resistance to diffusion will increase proportionally.

In the part of the fissure which has not yet been filled with clay the retention time of the water will increase compared to the undisturbed rock. There is at present no method to describe in detail the fissures in the disturbed rock. The following example will however give an indication of the consequences to be expected if all fissures increase from 0.1 mm to 0.5 mm after the escape of the gas. Originally we have the following

relative resistances for escaping nuclides (from table 5 ref 4).

	fissure width mm	relative resistances clay in hole	clay in fissure	"film" resistance
original case	0.1	1	0	7.1
after H_2 escape	0.5	0	1 (6 mm clay)	3.2

After the event, clay has extruded 6 mm into the fissure and restored the resistance which may have been lost in the hole. The film resistance has decreased to less than half. In total the resistance has decreased to half the original.

Conclusion

No grave consequences are expected if the escaping hydrogen opens a channel in the clay and in the rock. This is because:

- If a limited amount of clay is lost the clay still retains strong swelling properties and will quickly fill the channe in the clay mass.
- A large (> 0.5 mm) fissure will quickly fill with clay and considerably decrease the escape of diffusing species.
- The escape of a limited amount of clay from the hole does not increase the permeability of the clay above that of the rock.
- The"filmresistance" will decrease with increasing fissure widths. Even very large fissures (3 mm) will not decrease the total resistance to mass transfer to more than half the original.

Literature

1 Neretnieks, I., Skagius, C. Diffusivitetsmätningar av metan och väte i våt lera. KBS TR 86 1978-01-09.

2 Pusch, R. Highly compacted Na-bentonite as buffer substance. KBS TR 74 1978-02-25.

3 Pusch, R. Self injection of highly compacted bentonite into rock joints. KBS TR 73 1978-02-25.

4 Neretnieks, I. Transport of oxidants and radionuclides through a clay barrier. KBS TR 79 1978-02-20.

FÖRTECKNING ÖVER KBS TEKNISKA RAPPORTER

01 Källstyrkor i utbränt bränsle och högaktivt avfall från en PWR beräknade med ORIGEN
Nils Kjellbert
AB Atomenergi 77-04-05

02 PM angående värmeledningstal hos jordmaterial
Sven Knutsson
Roland Pusch
Högskolan i Luleå 77-04-15

03 Deponering av högaktivt avfall i borrhål med buffertsubstans
Arvid Jacobsson
Roland Pusch
Högskolan i Luleå 77-05-27

04 Deponering av högaktivt avfall i tunnlar med buffertsubstans
Arvid Jacobsson
Roland Pusch
Högskolan i Luleå 77-06-01

05 Orienterande temperaturberäkningar för slutförvaring i berg av radioaktivt avfall, Rapport 1
Roland Blomqvist
AB Atomenergi 77-03-17

06 Groundwater movements around a repository, Phase 1, State of the art and detailed study plan
Ulf Lindblom
Hagconsult AB 77-02-28

07 Resteffekt studier för KBS
Del 1 Litteraturgenomgång
Del 2 Beräkningar
Kim Ekberg
Nils Kjellbert
Göran Olsson
AB Atomenergi 77-04-19

08 Utlakning av franskt, engelskt och kanadensiskt glas med högaktivt avfall
Göran Blomqvist
AB Atomenergi 77-05-20

09 Diffusion of soluble materials in a fluid filling a porous medium
Hans Häggblom
AB Atomenergi 77-03-24

10 Translation and development of the BNWL-Geosphere Model
Bertil Grundfelt
Kemakta Konsult AB 77-02-05

11 Utredning rörande titans lämplighet som korrosionshärdig kapsling för kärnbränsleavfall
Sture Henriksson
AB Atomenergi 77-04-18

12 Bedömning av egenskaper och funktion hos betong i samband med slutlig förvaring av kärnbränsleavfall i berg
Sven G Bergström
Göran Fagerlund
Lars Rombén
Cement- och Betonginstitutet 77-06-22

13 Urlakning av använt kärnbränsle (bestrålad uranoxid) vid direktdeponering
Ragnar Gelin
AB Atomenergi 77-06-08

14 Influence of cementation on the deformation properties of bentonite/quartz buffer substance
Roland Pusch
Högskolan i Luleå 77-06-20

15 Orienterande temperaturberäkningar för slutförvaring i berg av radioaktivt avfall
Rapport 2
Roland Blomquist
AB Atomenergi 77-05-17

16 Översikt av utländska riskanalyser samt planer och projekt rörande slutförvaring
Åke Hultgren
AB Atomenergi augusti 1977

17 The gravity field in Fennoscandia and postglacial crustal movements
Arne Bjerhammar
Stockholm augusti 1977

18 Rörelser och instabilitet i den svenska berggrunden
Nils-Axel Mörner
Stockholms Universitet augusti 1977

19 Studier av neotektonisk aktivitet i mellersta och norra Sverige, flygbildsgenomgång och geofysisk tolkning av recenta förkastningar
Robert Lagerbäck
Herbert Henkel
Sveriges Geologiska Undersökning september 1977

20 Tektonisk analys av södra Sverige, Vättern - Norra Skåne
Kennert Röshoff
Erik Lagerlund
Lunds Universitet och Högskolan Luleå september 1977

21 Earthquakes of Sweden 1891 - 1957, 1963 - 1972
Ota Kulhánek
Rutger Wahlström
Uppsala Universitet september 1977

22 The influence of rock movement on the stress/strain situation in tunnels or bore holes with radioactive consisters embedded in a bentonite/quartz buffer mass
Roland Pusch
Högskolan i Luleå 1977-08-22

23 Water uptake in a bentonite buffer mass
A model study
Roland Pusch
Högskolan i Luleå 1977-08-22

24 Beräkning av utlakning av vissa fissionsprodukter och aktinider från en cylinder av frånskt glas
Göran Blomqvist
AB Atomenergi 1977-07-27

25 Blekinge kustgnejs, Geologi och hydrogeologi
Ingemar Larsson KTH
Tom Lundgren SGI
Ulf Wiklander SGU
Stockholm, augusti 1977

26 Bedömning av risken för fördröjt brott i titan
Kjell Pettersson
AB Atomenergi 1977-08-25

27 A short review of the formation, stability and cementing properties of natural zeolites
Arvid Jacobsson
Högskolan i Luleå 1977-10-03

28 Värmeledningsförsök på buffertsubstans av bentonit/pitesilt
Sven Knutsson
Högskolan i Luleå 1977-09-20

29 Deformationer i sprickigt berg
Ove Stephansson
Högskolan i Luleå 1977-09-28

30 Retardation of escaping nuclides from a final depository
Ivars Neretnieks
Kungliga Tekniska Högskolan Stockholm 1977-09-14

31 Bedömning av korrosionsbeständigheten hos material avsedda för kapsling av kärnbränsleavfall. Lägesrapport 1977-09-27 samt kompletterande yttranden.
Korrosionsinstitutet och dess referensgrupp

32 Egenskaper hos bentonitbaserat buffertmaterial
Arvid Jacobsson
Roland Pusch
Högskolan i Luleå 1978-06-10

33 Required physical and mechanical properties of buffer masses
Roland Pusch
Högskolan i Luleå 1977-10-19

34 Tillverkning av bly-titan kapsel
Folke Sandelin AB
VBB
ASEA-Kabel
Institutet för metallforskning
Stockholm november 1977

35 Project for the handling and storage of vitrified high-level waste
Saint Gobain Techniques Nouvelles October, 1977

36 Sammansättning av grundvatten på större djup i granitisk berggrund
Jan Rennerfelt
Orrje & Co, Stockholm 1977-11-07

37 Hantering av buffertmaterial av bentonit och kvarts
Hans Fagerström, VBB
Björn Lundahl, Stabilator
Stockholm oktober 1977

38 Utformning av bergrumsanläggningar
Alf Engelbrektson, VBB
Arne Finné, KBS
Stockholm december 1977

39 Konstruktionsstudier, direktdeponering
ASEA-ATOM
Västerås

40 Ekologisk transport och stråldoser från grundvattenburna radioaktiva ämnen
Ronny Bergman
Ulla Bergström
Sverker Evans
AB Atomenergi 1977-12-20

41 Säkerhet och strålskydd inom kärnkraftområdet.
Lagar, normer och bedömningsgrunder
Christina Gyllander
Siegfried F Johnson
Stig Rolandson
AB Atomenergi och ASEA-ATOM 1977-10-13

42 Säkerhet vid hantering, lagring och transport av använt kärnbränsle och förglasat högaktivt avfall
Ann-Margret Ericsson
Kemakta november 1977

43 Transport av radioaktiva ämnen med grundvatten från ett bergförvar
Bertil Grundfelt
Kemakta november 1977

44 Beständighet hos borsilikatglas
Tibor Lakatos
Glasteknisk Utveckling AB

45 Beräkning av temperaturer i ett envånings slutförvar i berg för förglasat radioaktivt avfall Rapport 3
Roland Blomquist
AB Atomenergi 1977-10-19

46 Temperaturberäkningar för slutförvar för använt bränsle
Taivo Tarandi
Vattenbyggnadsbyrån Stockholm 1978

47 Teoretiska studier av grundvattenrörelser
John Stokes
Roger Thunvik
Inst för kulturteknik KTH maj 1978

48 The mechanical properties of the rocks in Stripa, Kråkemåla,Finnsjön and Blekinge
Graham Swan
Högskolan i Luleå 1977-09-14

49 Bergspänningsmätningar i Stripa gruva
Hans Carlsson
Högskolan i Luleå 1977-08-29

50 Lakningsförsök med högaktivt franskt glas i Studsvik
Göran Blomqvist
AB Atomenergi november 1977

51 Seismotechtonic risk modelling for nuclear waste disposal in the Swedish bedrock
F Ringdal
H Gjöystdal
E S Husebye
Royal Norwegian Council for scientific and industrial research

52 Calculations of nuclide migration in rock and porous media, penetrated by water
H Häggblom
AB Atomenergi 1977-09-14

53 Mätning av dissusionshastighet för silver i lera-sand-blandning
Bert Allard
Heino Kipatsi
Chalmers tekniska högskola 1977-10-15

54 Groundwater movements around a repository

54:01 Geological and geotechnical conditions
Håkan Stille
Anthony Burgess
Ulf E Lindblom
Hagconsult AB september 1977

54:02 Thermal analyses
Part 1 Conduction heat transfer
Part 2 Advective heat transfer
Joe L Ratigan
Hagconsult AB september 1977

54:03 Regional groundwater flow analyses
Part 1 Initial conditions
Part 2 Long term residual conditions
Anthony Burgess
Hagconsult AB oktober 1977

54:04 Rock mechanics analyses
Joe L Ratigan
Hagconsult AB september 1977

54:05 Repository domain groundwater flow analyses
Part 1 Permeability perturbations
Part 2 Inflow to repository
Part 3 Thermally induced flow
Joe L Ratigan
Anthony S Burgess
Edward L Skiba
Robin Charlwood

54:06 Final report
Ulf Lindblom et al
Hagconsult AB oktober 1977

55 Sorption av långlivade radionuklider i lera och berg,
Del 1
Bert Allard
Heino Kipatsi
Jan Rydberg
Chalmers tekniska högskola 1977-10-10

56 Radiolys av utfyllnadsmaterial
Bert Allard
Heino Kipatsi
Jan Rydberg
Chalmers tekniska högskola 1977-10-15

57 Stråldoser vid haveri under sjötransport av kärnbränsle
Anders Appelgren
Ulla Bergström
Lennart Devell
AB Atomenergi 1978-01-09

58 Strålrisker och högsta tillåtliga stråldoser för människan
Gunnar Walinder
FOA 4 november 1977

59 Tectonic Lineaments in the Baltic from Gävle to Simrishamn
Tom Flodén
Stockholms Universitet 1977-12-15

60 Förarbeten för platsval, berggrundsundersökningar
Sören Scherman

Berggrundvattenförhållande i Finnsjöområdets nordöstra del
Carl-Erik Klockars
Ove Persson
Sveriges Geologiska Undersökning januari 1978

61 Permeabilitetsbestämningar
Anders Hult
Gunnar Gidlund
Ulf Thoregren

Geofysisk borrhålsmätning
Kurt-Åke Magnusson
Oscar Duran
Sveriges Geologiska Undersökning januari 1978

62 Analyser och åldersbestämningar av grundvatten på stora djup
Gunnar Gidlund
Sveriges Geologiska Undersökning 1978-02-14

63 Geologisk och hydrogeologisk grunddokumentation av Stripa försöksstation
Andrei Olkiewicz
Kenth Hansson
Karl-Erik Almén
Gunnar Gidlund
Sveriges Geologiska Undersökning februari 1978

64 Spänningsmätningar i Skandinavisk berggrund - förutsättningar resultat och tolkning
Sven G A Bergman
Stockholm november 1977

65 Säkerhetsanalys av inkapslingsprocesser
Göran Carleson
AB Atomenergi 1978-01-27

66 Några synpunkter på mekanisk säkerhet hos kapsel för kärnbränsleavfall
Fred Nilsson
Kungl Tekniska Högskolan Stockholm februari 1978

67 Mätning av galvanisk korrosion mellan titan och bly samt mätning av titans korrosionspotential under γ-bestrålning
3 st tekniska PM
Sture Henrikson
Stefan Poturaj
Maths Åsberg
Derek Lewis
AB Atomenergi januari-februari 1978

68 Degraderingsmekanismer vid bassänglagring och hantering av utbränt kraftreaktorbränsle
Gunnar Vesterlund
Torsten Olsson
ASEA-ATOM 1978-01-18

69 A three-dimensional method for calculating the hydraulic gradient in porous and cracked media
Hans Häggblom
AB Atomenergi 1978-01-26

70 Lakning av bestrålat UO_2-bränsle
Ulla-Britt Eklund
Roland Forsyth
AB Atomenergi 1978-02-24

71 Bergspricktätning med bentonit
Roland Pusch
Högskolan i Luleå 1977-11-16

72 Värmeledningsförsök på buffertsubstans av kompakterad bentonit
Sven Knutsson
Högskolan i Luleå 1977-11-18

73 Self-injection of highly compacted bentonite into rock joints
Roland Pusch
Högskolan i Luleå 1978-02-25

74 Highly compacted Na bentonite as buffer substance
Roland Pusch
Högskolan i Luleå 1978-02-25

75 Small-scale bentonite injection test on rock
Roland Pusch
Högskolan i Luleå 1978-03-02

76 Experimental determination of the stress/strain situation in a sheared tunnel model with canister
Roland Pusch
Högskolan i Luleå 1978-03-02

77 Nuklidvandring från ett bergförvar för utbränt bränsle
Bertil Grundfelt
Kemakta konsult AB, Stockholm 1978-08-31

78 Bedömning av radiolys i grundvatten
Hilbert Christenssen
AB Atomenergi 1978-02-17

79 Transport of oxidants and radionuclides through a clay barrier
Ivar Neretnieks
Kungl Tekniska Högskolan Stockholm 1978-02-20

80 Utdiffusion av svårlösliga nuklider ur kapsel efter kapselgenombrott
Karin Andersson
Ivars Neretnieks
Kungl Tekniska Högskolan Stockholm 1978-03-07

81 Tillverkning av kopparkapsel för slutförvaring av använt bränsle
Jan Bergström
Lennart Gillander
Kåre Hannerz
Liberth Karlsson
Bengt Lönnerberg
Gunnar Nilsson
Sven Olsson
Stefan Sehlstedt
ASEA, ASEA-ATOM juni 1978

82 Hantering och slutförvaring av aktiva metalldelar
Bengt Lönnerberg
Alf Engelbrektsson
Ivars Neretnieks
ASEA-ATOM, VBB, KTH Juni 1978

83 Hantering av kapslar med använt bränsle i slutförvaret
Alf Engelbrektsson
VBB Stockholm april 1978

84 Tillverkning och hantering av bentonitblock
VBB
ASEA
ASEA-ATOM
Gränges Mineralprocesser
Juni 1978

85 Beräkning av kryphastigheten hos ett blyhölje innehållande en glaskropp under inverkan av tyngdkraften
Anders Samuelsson

Förändring av krypegenskaperna hos ett blyhölje som följd av en mekanisk skada
Göran Eklund
Institutet för Metallforskning september 1977 - april 1978

86 Diffusivitetsmätningar av metan och väte i våt lera
Ivars Neretnieks
Christina Skagius
Kungl Tekniska Högskolan Stockholm 1978-01-09

87 Diffusivitetsmätningar i våt lera Na-lignosulfonat, Sr^{2+}, Cs^{+}
Ivars Neretnieks
Christina Skagius
Kungl Tekniska Högskolan Stockholm 1978-03-16

88 Ground water chemistry at depth in granites and gneisses
Gunnar Jacks
Kungl Tekniska Högskolan Stockholm april 1978

89 Inverkan av glaciation på en deponeringsanläggning belägen i urberg 500 m under markytan
Roland Pusch
Högskolan i Luleå 1978-03-16

90 Koppar som kapslingsmaterial för icke upparbetat kärnbränsleavfall - bedömning ur korrosionssynpunkt
Lägesrapport 1978-03-31
Korrosionsinstitutet och dess referensgrupp

91 Korttidsvariationer i grundvattnets trycknivå
Lars Y Nilsson
Kungliga Tekniska Högskolan Stockholm september 1977

92 Termisk utvidgning hos granitoida bergarter
Ove Stephansson
Högskolan i Luleå april 1978

93 Preliminary corrosion studies of glass ceramic code 9617 and a sealing frit for nuclear waste canisters
I D Sundquist
Corning Glass Works 78-03-14

94 Avfallsströmmar i upparbetningsprocessen
Birgitta Andersson
Ann-Margret Ericsson
Kemakta mars 1978

95 Separering av C-14 vid upparbetningsprocessen
Sven Brandberg
Ann-Margret Ericsson
Kemakta mars 1978

96 Korrosionsprovning av olegerat titan i simulerade deponeringsmiljöer för upparbetat kärnbränsleeavfall
Sture Henrikson
Marian de Pourbaix
AB Atomenergi 1978-04-24

97 Colloid chemical aspects of the "confined bentonite concept"
Jean C Le Bell
Ytkemiska Institutet 1978-05-07

98 Sorption av långlivade radionuklider i lera och berg
Del 2
Bert Allard
Heino Kipatsi
Börje Torstenfelt
Chalmers Tekniska Högskola 1978-04-20

99 Lakning av högaktivt franskt glas
Lägesrapport 1978-06-01
Göran Blomqvist
AB Atomenergi 1978-06-19

100 Dos och dosinteckning från grundvattenburna radioaktiva ämnen vid slutförvaring av använt kärnbränsle
Ronny Bergman
Ulla Bergström
Sverker Evans
AB Atomenergi

101 Utläckning av Ni-59 från ett bergförvar
Ivars Neretnieks
Karin Andersson
Kungl Tekniska Högskolan Stockholm 1978-04-24

102 Metod att bocka bestrålade bränslestavar
Torsten Olsson
ASEA-ATOM 1978-03-29

103 Some aspects on colloids as a means for transporting radio nuclides
Ivars Neretnieks
Kungl Tekniska Högskolan Stockholm 1978-08-08

104 Finit elementanalys av bentonitfyllt bergförvar
Ove Stephansson
Kenneth Mäki
Tommy Groth
Per Johansson
Högskolan i Luleå

105 Neutroninducerad aktivitet i bränsleelementdetaljer
Nils Kjellbert
AB Atomenergi 1978-03-30

106 Strålningsnivå och till vatten deponerad strålningsenergi utanför kapslar i slutförvaret
Klas Lundgren
ASEA-ATOM 1978-05-29

107 Blyinfodrad titankapsel för upparbetat och glasat kärnbränsleavfall - Bedömning ur korrosionssynpunkt
Korrosionsinstitutet och dess referensgrupp. Slutrapport 1978-05-25

108 Criticality in a spent fuel repository in wet crystalline rock
Peter Behrenz
Kåre Hannerz
ASEA-ATOM 1978-05-30

109 Lakningsbar spaltaktivitet
Lennart Devell
Rolf Hesböl
AB Atomenergi

110 In situ experiments on nuclide migration in fractured crystalline rocks
Ove Landström
Carl-Erik Klockars
Karl-Erik Holmberg
Stefan Westerberg
Studsvik Energiteknik and
The Geological Survey of Sweden juli 1978

111 Nuklidhalter i använt LWR-bränsle och i högaktivt avfall från återcykling av plutonium i PWR
Nils Kjellbert
Studsvik Energiteknik AB 1978-07-26

112 Säkerhetsanalys av hanteringsförfarandet vid inkapsling av utbränt bränsle i kopparkapsel
Erik Nordesjö
ASEA-ATOM 1978-03-20

113 Studier av keramiska material för inkapsling av högaktivt avfall
Lennart Hydén et al
ASEA-ATOM september 1978

114 γ-radiolysis of organic compounds and α-radiolysis of water
Hilbert Christensen
Studsvik Energiteknik AB 1978-09-07

115 Accelererad utlösning av uran från α-aktivt UO_2
Gösta Nilsson
Studsvik Energiteknik AB 1978-04-27

116 Lakning av Al_2O_3 under simulerande deponeringsbetingelser
Britt-Marie Svensson
Lennart Dahl
Studsvik Energiteknik AB 1978-06-02

117 Lakning av Al_2O_3 i dubbeldestillerat vatten
Britt-Marie Svensson
Göran Blomqvist
Studsvik Energiteknik AB 1978-05-29

118 Slutrapport Al_2O_3 kapsel
Korrosionsinstitutet och dess referensgrupp

119 Slutförvaring av aktiverade ståldetaljer
Lars Rombén
Kyösti Tuutti
Cement- och Betonginstitutet 1978-07-14

120 Some notes in connection with the KBS studies of final disposal of spent fuel
Ivars Neretnieks
Kungl Tekniska Högskolan september 1978