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5 November 1986

David Tiktinsky - SS623
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

"NRC Technical Assistance
for Design Reviews"
Contract No. NRC-02-85-002
FIN D1016

Dear David:

Enclosed are Itasca Reviews No. 001-02-18, "A Preliminary Assessment of Water Inflow into Proposed Excavations in the Cohassett Flow Interior" by F. M. Baker (Rockwell Hanford Operations SD-BWI-TI-274, June 1985) and No. 001-02-19, "Determination of an Upper Temperature Limit for Bentonite as a Backfill Component in a Nuclear Waste Repository in Basalt" by R. A. Palmer, R. G. Johnston, and M. I. Wood (Rockwell Hanford Operations RHO-BW-ST-47P, February 1983). Please call me if you have any questions.

Sincerely,

John S. Whalen for
Roger D. Hart
Program Manager

cc: J. Greeves, Engineering Branch
Office of the Director, NMSS
E. Wiggins, Division of Contracts
DWM Document Control Room

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ITASCA DOCUMENT REVIEW

File No.: 001-02-18

Document: Baker, F. M. "A Preliminary Assessment of Water Inflow into Proposed Excavations in the Cohassett Flow Interior," Rockwell Hanford Operations "SD-BWI-TI-274, June 1985.

Reviewer: Adrian Brown (Nuclear Waste Consultants)

Date Approved:

Date Review Completed: 5 November 1986

1.0 INTRODUCTORY INFORMATION

FILE NO: ITASCA LIBRARY DOCUMENT 728

DOCUMENT: "A PRELIMINARY ASSESSMENT OF WATER INFLOW INTO PROPOSED EXCAVATIONS IN THE COHASSETT FLOW INTERIOR", by F.M. Baker, Rockwell Hanford operations. Copy dated 5/29/86, document number SD-BWI-TI-274.

REVIEWER: Adrian Brown, Nuclear Waste Consultants.

COMPLETED: October 24, 1986

APPROVED:

2.0 SUMMARY OF DOCUMENT AND REVIEW CONCLUSIONS

2.1 SUMMARY OF DOCUMENT

The document presents a number of scenarios for inflow into a repository located in the Cohassett flow interior. Essentially three scenarios for inflow are examined:

1. Inflow through the expected low permeability Cohassett flow interior rock from two essentially infinitely permeable aquifers, located immediately above and below the interior. The resulting flow that is calculated is about 100 gallons per minute, using a average vertical hydraulic conductivity of 10^{-11} meters per second for the flow interior materials.

2. The flow through an exploratory bore hole drilled ahead of workings to the repository. The computed additional flow for this circumstance is a function of time, and drops from about 20 gallons a minute initially to about 10 gallons a minute finally.

3. Flow to a tunnel which intersects a flow top. The computed analysis here depends on which assumption is made about the permeability of the flow top. Values computed ranged from an initial 3400 gallons a minute and lower, depending on the assumptions.

The report goes on to state that the maximum expected flow, even under worse conditions (3400 gallons per minute) can be readily accommodated by normal mining techniques, and therefore does not constitute a threat to the integrity of the repository. It also states that further data would be required to refine the estimate of the maximum flow, and that this data will be forthcoming at the time when the underground exploratory test facility is mined and evaluated.

2.2 SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM

The issue of the inflow to the underground mining system is significant in a number of areas of 10 CFR 60. These include the following:

1. 10 CFR 60.111 (b) - Performance of the geologic repository; retrievability of waste. The NRC requires that the waste must be retrievable for up to 50 years after emplacement operations are completed. If flooding of all or part of the repository presents the possibility that retreival of any of the waste would be prevented, then it would appear that such a finding would jeopardize the licensability of the facility. As a result it is clearly important that retrievability be maintained, and flooding is possibly the major threat to retrievability in a high level nuclear waste repository in Basalt.

2. 10 CFR 60.131 (b) - General design criteria for the geological repository operations area; structure systems and components for emergency capability. This section of the rule requires that the operations area provide emergency capability for reasonably expected emergencies. Clearly the flooding of the repository is an emergency condition that must be provided for, and if the estimate of flow for that flooding is substantially below a reasonable maximum, recovery may be difficult or impossible.

3. 10 CFR 60.113 (b) - Additional design criteria; close control of water and gas. The rule requires that the underground workings provide for control of water or gas intrusion. Again it is important that reasonable maximum flow needs are considered.

4. 10 CFR 60.131 (9) - General design criteria for geologic repository area. This section indicates that it is required that there be compliance with mining regulations, which would presumably also include safety against flooding and water related events.

In summary the rule clearly requires that the maximum credible mine inflow be known so as emergency operations equipment could be designed, so that water handling equipment can be sized to provide a low probability of loss of all or part of the repository due to flooding, and that the inflow handling equipment be designed so that retrievability can be maintained.

2.3 REVIEW CONCLUSIONS

The reviewer has checked the mathematical integrity of the materials presented, and finds that the computations have been performed correctly. The evaluations which have been performed do seem to reasonably predict the flows under the ranges of scenarios presented. The analytical approach is very simple, which is considered by the reviewer to be appropriate for this kind of evaluation.

The principal concern which the reviewer has is whether the so called 'worst situation' is indeed a reasonable bounding condition. Specifically all of the inflow scenarios considered take water only from the flow top immediately above and below the Cohassett formation. It appears entirely feasible that the repository could be directly connected to many other aquifers higher in the sequence, resulting perhaps from a rock-burst-induced stoping of a blow out zone from the repository horizon upwards into the considerably more permeable units well above the repository. Estimates of flow under similar conditions (flow to an open shaft) have been developed in the past by Rockwell and by the NRC, and produced flows in the order of 100,000 gallons per minute. Accordingly, the reviewer considers that the 3,500 gallon per minute maximum expected inflow ignores far more serious inflow scenarios that are credible in this setting.

The second major concern which the reviewer has about this paper is the assertion that recovery from relatively large inflows can and are routinely made in the mining community. It is true that many mine inflow situations have been successfully reversed in the mining industry. However in many of these cases the reversal is only after heroic efforts, and very frequently involves the abandonment of some significant portion of the mine behind pre-existing high pressure bulkheads. Good examples of this are available in particularly the South African gold mining experience, and in a number of potash and salt mining operations around the world. It is therefore an oversimplication to say that the mining industry can overcome inflow problems. The implications of a major inflow event for a partially completed high level nuclear waste repository would appear to be very significant, and particularly if inflows in the order of 100,000 gallons per minute can be contemplated to the repository, it is the opinion of this reviewer that it would be unlikely that it would be possible to fully recover from such an inflow.

The final conclusion is that the reviewer considers that it is encouraging that the DOE is performing and presenting simple calculations in support of design and other decisions which are being made, or will in the future be made, with respect to the construction program of the underground repository. However in this case it would appear that the "upper bound" computation of inflow is very substantially less than could reasonably be expected to be used for the purpose of protecting the underground work force, and for the purpose of protecting the integrity of the repository itself.

2.4 RECOMMENDATIONS

It is recommended that this evaluation be expanded to include more extreme scenarios than are currently considered in the report. It should be noted that this recommendation and review in no way suggest that the approach taken is inappropriate, as it combines the benefits of a simple understandable analysis, and avoids the difficulties associated with the use of complex and essentially uncheckable computer analyses for such evaluations.

3.0 DETAILED REVIEW (PROBLEMS, DEFICIENCIES AND LIMITATIONS)

The following points are made about the report in order of their appearance in the text. The text location is indicated by page and paragraph number on that page. Part paragraphs at the beginning of the page are considered to be the first paragraph.

6/2 The report states that "General mining experience shows that inflow rates inflow rates even greater than those estimated by these calculations can be controlled using available mining techniques." In the opinion of the reviewer this statement, and several others like it mentioned below, over-simplify the difficulty of controlling water inflows, particularly under several thousand pounds per square inch pressure. The track record of water inflows on mines in general is mixed. While it is true that some major inflows have been prevented or controlled using a variety of techniques including grouting, diversion, bulkheading, and the like, it is also true that a number of mines have lost part or all of their operating area as a result of unstoppable inflows. In general the response time available to overcome flooding is short, and remediation requires great flexibility and initiative on the part of the operators. At least in the opinion of this reviewer the opportunity to operate freely and flexibly is much constrained in a highly regulated nuclear waste repository setting. As a result this and all statements about the ease with which groundwater inflow control can be achieved in conventional mines would appear to provide poor guidance for the ease with which similar control could be achieved in a high level nuclear waste repository.

6/4 The report states that "additional data must be collected ... to assure that this assessment of inflow is adequate". (Emphasis added). While it seems to this reviewer that it would be prudent to collect additional data to enhance the confidence with which inflow calculations can be performed, it does not seem that the report as presented demonstrates that this is an imperative, as suggested in this sentence. The reviewer is very sensitive to the expansion of the mandated data requirements for the high level nuclear waste program as a result of statements of this kind embedded in the middle of secondary or tertiary reports in the program.

6/5 The report assumes that water flowing from the overlying or underlying flow top into a repository in the Cohassett has no effect on the pressures in the aquifers at those locations, and is therefore a conservative estimate. While this may be true for that particular analysis, it is the opinion of this reviewer that the inflow estimates that have been performed are far from conservative in that they consider flow only from those two flow tops, and ignore the far more prolific and similarly highly pressured aquifers further away from the repository, which may well be capable of being connected to the repository as a result of failure of parts of the rock system surrounding the repository opening. That is while the reviewer agrees with in principle with the statement, the level of conservatism achieved by making this assumption is small compared to the unconservatism of only considering the aquifers immediately above and below the repository.

9/3 The report states that "During tunnel construction bore holes will be drilled into the mine faced probe ahead..." (emphasis added). Again while the reviewer considers that it would be entirely prudent to do this, the provision of this as an undertaking in a report of this kind seems inappropriate. It would seem more appropriate for this to be couched in terms of a recommendation, and for the design documents themselves to indicate whatever undertakings the DOE is committing to.

9/3 The report states that "high conductivity zones are routinely sealed using existing mine technology". Again the reviewer has the same comment as made above: while it is true that high conductivity areas are plugged routinely, it is also true that not infrequently this plugging fails, and the areas remain a problem which quite often has to be either sealed off or in some other way abandoned. This would not appear to be a viable option in general with respect to a high level nuclear waste repository.

10/4 The report quotes in this paragraph that "in many cases large water inflows were encountered (in existing mines). It is not an unusual occurrence. Mining experts are expert in handling water (sic).". While again this is reasonably true of mining experience, it does not seem entirely appropriate to contrast a normal mining operation with the more stringent requirements of a high level nuclear waste repository. It is difficult for this reviewer to believe that a repository will be likely to easily to be licensed in which significant flows of water are coming in at unpredictable locations. The general concept to which which the NRC appears to have written the rule is that the underground repository will be essentially dry, and that all of the difficult and remote activities associated with lowering, emplacing, and possibly subsequently retrieving canisters will be done under relatively favorable conditions. This would not appear to this reviewer to include emplacement, etc., under conditions of significant inflow.

11/1 The examples given of successful recovery operations again ignore the significant track record of unsuccessful recovery operations, and losses of entire mines and significant numbers of working personnel due to inrushes in deep underground mines. Accordingly this review seems extremely biased in favor of a view of underground mine water problems which is that they are easily overcome. This is not by any means the uniform experience of the industry.

11/2 To suggest as the report does "significant fault zones mud and water filled cavities and high permeability rock are not likely to exist in the Cohassett basalt at the RRL and the basalt rock is generally structurally very good" seems to be at odds with the very substantial discussion and anticipated problems with respect to cooling features, discontinuities, vertical features, and rock bursts which have consumed a good deal of the discussion about geotechnical and geological conditions in the Cohassett formation.

Appendix B: The examples included in the appendix do not seem to include perhaps the most significant high inflow scenario which might be considered. This is a scenario where the mine encounters a relatively weak zone of rock, which through rock bursting and high driving water pressures, fails. It is conceivable that this failure would be progressive, stoping up from the underground opening through the overlying rock layers including a number of flow tops. As each flow top would be encounter flow would be increased to the chimney which would be so formed, which in turn would enhance the likelihood of further hydraulically-aided rock bursting. There is a track record of this kind of stoping behavior in brittle rock mines, and it is not at all clear that this phenomena could not occur in a BWIP repository setting. Independent calculations by the Department of Energy's contractors (Parsons Brinkerhoff) and by the NRC's then consultants (Golder Associates) produced results that suggested that inflow to a completely unlined shaft from the top of the basalt section to the repository would be in the order of 100,000 gallons per minute. A significant portion of this flow comes from reasonably deep in the system. If stoping were to continue significantly through the Grand Ronde to the overlying materials, it is entirely conceivable that a flow of this order might occur to the underground mine. As a result, it would seem prudent that the extreme contingency planning should at the least consider flows in this order. While it is true that flows of about that magnitude have on one or two occasions occurred and ultimately been recovered, it is also true that the recovery was only achieved with abandonment of substantial portions of the effected mine, and truly heroic efforts involving multiple mines and very long periods of time. As a result it is this reviewer's conclusion that the cases considered in Appendix B by no means constitute the bounding situations which a repository operation might be required to accomodate as part of an inflow prevention program.

ITASCA DOCUMENT REVIEW

File No.: 001-02-19

Document: "Determination of an Upper Temperature Limit for Bentonite as a Backfill Component in a Nuclear Waste Repository in Basalt" by R. A. Palmer, R. G. Johnston, and M. I. Wood. Rockwell Hanford Operations RHO-BW-ST-47P, February 1983.

Reviewer: Adrian Brown (Nuclear Waste Consultants)

Date Approved:

Date Review Completed: 5 November 1986

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1.0 INTRODUCTORY INFORMATION

FILE NO: ITASCA LIBRARY DOCUMENT 729

DOCUMENT: "DETERMINATION OF AN UPPER TEMPERATURE LIMIT FOR BENTONITE AS A BACKFILL COMPONENT IN A NUCLEAR WATE REPOSITORY IN BASALT", by R.A. Palmer, R.G. Johnston, and M.I. Wood, Waste Package Department, Basalt Waste Isolation Project, Rockwell Hanford Operations. Copy dated February, 1983, Document number RHO-BW-ST-47P.

REVIEWER: Adrian Brown, Nuclear Waste Consultants.

COMPLETED: October 29, 1986

APPROVED:

2.0 SUMMARY OF DOCUMENT AND REVIEW CONCLUSIONS

2.1 SUMMARY OF DOCUMENT

This report examines the effect of temperature on the effectiveness of bentonite to act as a low permeability barrier for radionuclide escape from a high level nuclear waste repository. The objective of the study is stated to be to evaluate "...the temperature at which the structural water (of sodium montmorillonite) is irreversibly lost." (page 4).

The experiment subjected commercial bentonite to a range of temperatures (370, 440, and 550 degrees Celcius) for times up to one year, and examined the effects using differential scanning calorimetry (DSC) and X-ray diffraction (XRD).

The results of the testing indicate that there are "...three reactions that are of interest: (1) loss if interlayer water starting at about 50°C; (2) loss of structural water (hydroxyls) near 500°C; and (3) structural collapse (forming anhydrous montmorillonite) near 650°C." (page 6). The authors consider that the loss of interlayer water is reversible, while the other two changes are considered by the authors to cause a destruction of the swelling property of the montmorillonite, which is responsible for its low permeability.

The testing indicated that structural water was not driven off for at least a year at 250°C. There appeared to be a slight loss of structural water at 370°C, but no formation of anhydrous montmorillonite. Interlayer water is lost at 440°C and above. The report states that "Once the montmorillonite structure has collapsed, the material will no longer swell when in contact with water and probably loses much of its original sorptive capacity. Such changes render the altered bentonite unsuitable as a backfill component." (page 22).

As a result of the above findings, the report concludes that "Therefore, for backfill design purposes, an upper temperature limit of 370°C may now be assigned. This is an increase from the previous limit of 300°C..." (page 26).

2.2 SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM

The backfill materials form a significant barrier to radionuclide transport from the cannisters to the accessible environment. The performance of the engineered barriers, some of which are to involve bentonitic materials, are covered in 10 CFR 60.113, and require (inter alia) that the containment be complete for not less than 300 years (60.113(a)(ii)(A)) and that the release rate be less than 0.1% of the 1,000 year inventory of radionuclides (60.113(a)(ii)(B)). Both of these requirements require a high level of containment for times in the order of centuries to millenia.

2.3 REVIEW CONCLUSIONS

The report adequately presents the study. The approach is clearly described, and the results are comprehensively presented.

The approach that was taken was to evaluate the physical changes that occur as a result of sustained exposure to elevated temperatures. However, the evaluation was confined largely to examination of the structure and the thermodynamic behavior of the material on subsequent heating. This choice of evaluation of the effects of temperature on the properties of bentonite seems inappropriate to the reviewer. The bentonite properties of importance to radionuclide containment are its low permeability, and its sorptive properties. Neither were directly or indirectly tested in this program, which leaves the evaluation of the effect of the heating to inference. It seems entirely possible to the reviewer that the removal of the interstitial water may have a permanent effect on the important properties of the bentonite, and that this effect might not be evident from inspection of the DSC and XRD testing. As both the important properties can be readily tested using standard approaches, and such testing has been performed in the past by Rockwell, the failure to directly test the properties of the heated bentonite is difficult to understand. The failure to perform such direct tests leaves the reviewer unable to agree that the testing described in the report allows the conclusion that "...bentonite can be subjected to a relatively long-term thermal pulse at up to 370°C and still be able to perform its design function in the backfill in the event of subsequent water intrusion." (page 25).

A second criticism of the evaluation is the extension of a one year test to performance over thousands of years. The information presented in the report strongly suggests that the behavior of (particularly) the 370°C material is still changing significantly at the final reading (340 days - see Figure 6, page 17). In addition, the XRD analysis "...indicates some collapse of the structure at this point..." (page 23). Both of these results suggest that the properties may continue to change later at this temperature. As the report notes: "...it is difficult to predict whether bentonite would survive a thermal pulse of 50 years at 370°C." (page 23). While the report advances additional factors that could enhance the performance of the bentonite under repository conditions, it is considered that the testing on which the report is based does not support the contention that bentonite will retain its properties for repository life time periods.

Accordingly, it would appear to the reviewer to be unwise for the NRC to concur in the proposal to raise the "limit" temperature for retaining the performance of bentonite to 370°C based on the testing reported in the reviewed paper.

2.4 RECOMMENDATIONS

Based on the above observations, it is recommended that the DOE retain the previous (presumably supported) temperature limit for bentonite (300°C).

If it were considered important for the limit to be raised, it is considered by this reviewer that the testing to support such a move should include:

1. Longer testing periods. Satisfactory evidence that the temperature effect had been evaluated would, in the opinion of this reviewer require presentation of evidence that the changes in the bentonite performance caused by the heating have essentially ceased by the end of the test period.

2. More temperature steps in the test sequence. The gaps between 250°C, 370°C, and 440°C would appear to be too great if the proposal is to raise the temperature from 300°C (it would seem particularly important to test the material at 300°C to provide a "benchmark" against which to evaluate the results at the more elevated temperatures).

3. Direct testing of the performance characteristics of interest. These include permeability, swelling capacity, and sorptive capacity.

4. Testing under a wider range of conditions, including those more closely approximating those expected in the repository (high humidity, high pressure, reducing conditions, high radiation, possible gaseous products).