TO: U.S. Nuclear Regulatory Commission, WMEG 5-09-84
ATTN: Jerome Pearring
FROM: J. Daemen JD
RE: Information considered Necessary Regarding Exploratory Shaft Construction and Sealing. Letter of January 11, 1984 from J. O. Neff, NWTS, to H. Miller, HLW Technical Development Branch.

Review Summary

The letter and its attachment respond to the two main concerns expressed previously by NRC, namely that

- -site characterization activities, including exploratory shaft construction, should not compromise long-term isolation and containment capabilities of the repository
- -construction procedures used for the exploratory shaft will not preclude the acquisition of adequate information for site characterization

The first of these two broad concerns is raised in order to draw attention to the need to comply with 10 CFR Part 60, §60.10.d.(1); §60.11.(a), (6),(iii); §60.31,(a),(1),(iv); §60.134; §60.140,(a),(2),(c), (d),(1),(2).*

The second of these two broad concerns is raised in order to draw attention to the need to comply with site characterization requirements, e.g. 10CFR Part 60, §60.122,(b),(2),(i),(ii),(iii); (c),20; §60.140,(d),(2), §60.141,(a),(b),(c),(d).*

With respect to the first of these two broad concerns, the letter and its attachment heavily rely on references, hence the adequacy of the DOE response can only be assessed on the basis of a detailed assessment of these references. (Some of these are quite long, and a detailed critical review would be very time consuming). The DOE position on sealing presented in the letter and its attachment is that sealing problems essentially have been solved. This is in direct contradiction with conclusions reached and comments made in several of the references. The present review concentrates on identifying some of these contradictions, rather than on identifying remaining problems, because a list of such contradictions between the letter (with attachment) and the references cited in support clarifies many inadequacies in the letter. Of prime concern in this context is that many of the references identify remaining uncertainties, problems, research and testing needs on sealing performance, while the letter appears to take the position that all sealing issues are resolved and require no further feasibility demonstrations.

With regard to the second of the two concerns, the position taken in the letter and its attachment is that the shaft is used only to gain access to the

*All these sections of the rule appear to be relevant, but it would be desirable for NRC staff to confirm or to disavow, as appropriate.

potential repository level, and has no other site characterization function. None of the other site characterization methods that are given can provide geological or geotechnical characterizations equivalent to shaft mapping and instrumentation. Hence not using the exploratory shaft for site characterization will result in an information gap that can not be filled by indirect or borehole methods.

Review of the letter

The subject letter was written in response to the June 15, 1983 NRC letter expressing two broad areas of concern regarding exploratory shaft construction and sealing. No new information or analysis is given in the letter nor in its attachment, which refer extensively to other documents. At first glance this suggests that the letter and its attachment are based on these references. In fact, although the references are listed, they are used only very loosely, leaving it largely to NRC to identify, from a large body of material, those items of direct relevance to the expressed NRC concerns.

Although no new information is given, the letter clarifies the DOE position considerably. Essentially the position appears to be that the references contain the information needed to close both broad concerns. No indication is given that DOE would consider an active in situ seal performance testing program (in direct contradiction with recommendations made in several of the references used in the attachment), and that no site characterization or exploratory functions will be assigned to the so called "exploratory" shaft. It might have been preferable to call these shafts "repository horizon access shafts," or some similar nomenclature avoiding the implication that these shafts would have a major exploratory function during site characterization.

With respect to the first of the broad concerns, the letter stresses short-term failure of the shaft due principally to water inflow. The short-term is strongly emphasized in this context, and the short-term presumably implies the operational phase, i.e. the period up to permanent closure, after which the entire function of preventing water inflow is assigned to the permanent seals.

By usual salt mining standards the period up to permanent closure would not be considered short-term. There is considerable evidence that over such a period of time mine shafts have leaked, occasionally with disastrous consequences (e.g. Reference 7, Section 3.2.2). Conversely, shafts of 80 years old, obviously without the CSR seal, are known that have remained dry. Twenty years of experience, as cited here, clearly is short even in terms of the construction, operation and retrieval life of a repository. No indication is given here that sealing studies will be made or are even considered in order to provide the information needed to make adequate predictions of short-term (i.e. until permanent closure) sealing performance. This is regrettable because these operational seals, especially liners and grout, could make a substantial contribution to permanent closure sealing as well as to operational sealing. The contribution of the operational seals is more valuable in direct

proportion to the uncertainties associated with the permanent seals, to which DOE apparently intends to assign the exclusive burden of permanent closure sealing.

At present, considerable uncertainty remains about the permanent closure seals as designed in reference 9, quoted in the attachment as figures 4 and 5. Reference 8 addresses decommissioning seals on p. 33, and states "methods for decommissioning underground chambers and the shaft have not yet been determined." In situ testing goals listed in pp. 1-2 include (last bullet): "Demonstration of the capability to adequately seal penetrations into the salt. This would include confirmation of the placement equipment and sealing materials." On p. 8 Reference 8 refers to reference 7 in stating "Prevention of ground-water inflow by the shaft liner and seals is of critical importance to the exploratory shaft. ONWI-255 (D'Appolonia, 1981) should be utilized for guidance. The exploratory shaft shall be essentially watertight." This complete citation of the full extent to which reference 8 addresses long-term decommissioning seals makes clear that this document states unambiguously the importance of sealing, but does not go beyond a broad statement of intent. Reference 6 makes it clear that some data needs for permanent closure seal design will remain unsatisfied due to time pressure, pp. A-4/5 in particular: "The Exploratory Shaft will be designed and constructed with licensability provisions to be used during the repository operation, but selection of horizons for final repository closure seals was not considered to carry sufficient weight to justify missing of the legislatively-mandated shaft completion milestone." Of serious concern in reference 6 are the first two sentences of section 2.2 of the Appendix, p. A-6: "The confidence based upon the sealing design and past performance of similar seals is such that special testing is not considered requisite. Proof of performance will be immediately provided when the base of the shaft liner is drilled out, and the shaft does not fill with water." Obviously, if the shaft were to fill with water immediately this would be a serious problem. If the shaft does not immediately fill with water, the opposite does not necessarily follow, i.e. this would not prove satisfactory sealing. Specific counter-examples are give in reference 7, especially section 3.2.3.2. In particular, it is highly probable that inflows would result from gradual dissolution of salt, and would develop slowly. Although it is true that considerable evidence of satsifactory performance exists, there also is significant evidence of unsatisfacotry performance, and reference 7 provides extensive summaries of both types of situations. The gas testing described would be a valuable test for the bottom seal, although only a short-term one, i.e. not providing any information about slow water ingress to the salt horizon. The main conclusion from reference 6, with regard to the effect of the particular shaft construction method (i.e. blind boring) on post-closure sealing is that several major information needs can not be satisfied because of the use of this method.

It almost certainly is true that the prime function of the shaft permanent closure seals is to prevent ingress of water to the repository salt horizon. It might be true that these seals can be placed regardless of the shaft construction method, but it is highly improbable that the sealing performance

that can be achieved will be independent of the shaft construction method. First and foremost, the shaft construction method selected (i.e. blind boring) might not allow an optimum selection of the seal position (as explicitly recognized in reference 6, section 1.3, p. A-4; reference 7, p. 98, top paragraph: " . . . there would be no direct inspection of the host rock in the shaft walls, in key areas in the aquifers above the salt and in the top of the salt section, . . . ", second paragraph: "It is not advisable that all shafts at a site be drilled and lined blind," (similar comments in many other places).

It is highly unlikely that the proposed over-excavation of the shaft will mitigate the effects of rock damage caused by liner removal. Such over-excavation will, with some shaft sinking methods (e.g. boring with mud-filled shaft) for the first time, relieve the stress on the newly exposed surfaces, precisely at those locations where permanent seals are to be installed. This would at least partially negate one of the principal advantages of blind boring with a mud-filled hole, namely that the shaft walls are never entirely stress relieved (and therefore maintain maximum possible integrity). This might affect not only the rock adjacent to the seal, but also the liner-grout-rock system directly above and below the seal as well.

Even the title of reference 9 emphasizes the preliminary nature of this study, which unquestionably is a significnat step in the right direction, but is probably more important in terms of the procedures it outlines for future studies and site-specific designs rather than for specific applications and conclusions. Many examples of uncertainty can be found in this document, e.g., p. 121, first sentence of last paragraph: "Additional study is required to determine the effectiveness of bulk-heads for reducing disturbed zone permeabilities." Of particular concern in this context is that neither reference 9, nor, to the best of my knowledge, any of the other references addresses the potentially serious sealing problems associated with extensive shaft sloughing in the weak rocks above the salt formations. The high probability of such sloughing is indicated by the borehole stability problems encountered in the Permian Basin, as noted in the attachment (p. 7, II. B) and in reference 6(p. A-8).

None of the alternative site characterization methods that are given can provide the type of information and certainly not the detail and quality of information that would be available through direct physical access to the shaft wall. This is stated unambiguously in reference 6, Section 1, especially pp. A-4/5, in reference 7 in several places, e.g., p. 98, p. 104: "Disturbed zone and host rock-seal interface characteristics which are critical to adequate seal performance, are not routinely obtained from site characterization," p. 120, next to last paragraph: "An associated disadvantage is that . . . there is no possibility for direct visual inspection of the host rock or placement of water seals."

It might well be that the method of exploratory shaft construction can accommodate the techniques being considered for shaft decommissioning sealing. No indication is given that the acceptability of the techniques being considered will be tested. Given the considerable uncertainty about the performance

of the permanent closure seals, to which the full responsibility for long term repository sealing is assigned, it must be considered a serious deficiency that no more effort is made to assess the performance of the operational seals. It appears probable that a significant long-term sealing function could be assigned to operational "seals" (especially grout), and that uncertainty about the effectiveness of the rock surrounding the shaft in reducing or preventing water flow towards repository formation salt could be reduced, if an adequate in situ testing program could be incorporated into the Exploratory Shaft functions. This in turn would reduce the need for making assumptions when making performance assessments.

Review of Attachment

Time does not permit a very detailed assessment of this document, which relies heavily on references, some of which have only recently become available to me. Emphasized below are some very clear contradictions between positions taken in this attachment and conclusions or recommendations reached in the reference documents. Such contradictions are stressed because it appears that the technical references make recommendations that would come much closer to meeting the NRC information needs than does the DOE letter and attachment. The main point of contention might well be when, as much as whether, sealing information is needed, the DOE position being that ES construction has no impact, hence should not presently be of concern.

I.A. The conclusion that the seals can be designed to overcome these disturbances can not be drawn from ref nces 7, 9, and 10, all of which identify signficant remaining uncertain ies in seal design. Reading of several sections should make this obvious. Chapter 5 of reference 7 identifies numerous parameters that are essentially unknown, and recommends generic and site-specific testing. (Particularly section 5.2, lists on p. 105, 106; p. 106: " . . . very little is known regarding the nature or extent of the disturbed zone for a given combination of rock type and excavation process"). Reference 9, p. 82: " . . . there is probably no practical means for restoring the permeability throughout the disturbed zone to that of the undisturbed rock." Reference 10, p. 4: "Preliminary designs will incorporate site and penetration characteristics obtained from shafts and tunnels at the candidate repository site and will be supported by in situ testing of seals or seal components. Preliminary designs will be sufficiently complete and detailed to be submitted to the regulatory authority as part of a license application for repository construction."

The emphasis in the attachment is distinctly different from that in the reference it quotes. The latter clearly expresses the need for further study and demonstration, including site specific in situ testing (as well as generic work), and specifically acknowledge areas of uncertainty not recognized in either the letter or the attachment.

I.B. The statement that the selected excavation technique does not in itself limit uncertainties in the consideration for long-term sealing certainly is true. It is more difficult to accept the last sentence, that shaft design

does not preclude the effectiveness of decommissioning seals to reduce the associated uncertainties, in light of several statements in reference 7, e.g. p. 98, first three paragraphs, p. 120, A.1.2, second paragraph: "An associated disadvantage, however, is that . . .", p. 53, 2.6, last sentence of first paragraph, p. 92, last sentence of first bullet, in reference 6, e.g. pp. A-4/5.

The long term post closure seals described here appear to include the backfill inbetween the bulkheads. A major uncertainty remains in this area, namely whether or not the liner will be removed. This remains unclear, especially for backfill sections inbetween bulkheads. The design figures, especially figure 3, emphasize backfill compatible with the surrounding rock, as does reference 10, yet the emphasis that the liner will removed at bulkhead locations sometimes appear to imply that these are the only locations where the liner will be removed. The performance assessments (references 13, 14) clearly imply that the liner (and grout) will be removed over the entire length. A clarification of this issue is needed.

Particularly for a steel liner in a salt (brine) environment leaving it in place could have significant implications, that need to be addressed.

I.E. No characterization of disturbed zone.

No seal testing data for License Application.

II.A. Reference 8 does address the 10CFR60 Subpart B §60.10 d(1) requirements "to limit adverse effects on the long-term performance of the geologic repository" only to the extent of very broad recommendations.

II.B. Response addresses two (important) aspects: preventing collapse and preventing hydraulic fracturing. Does not deal with damage due to stress relief if it is not severe enough to cause collapse.

What remedial action will be taken if localized or substantial shaft collapse does take place during drilling, and how would it affect operational or permanent sealing?

How will the mud engineer know that the mud pressure never exceeded the minimum principal stress? (i.e. how does the mud engineer know the minimum principal stress?)

II.C. Problem of mud contamination on walls and in cement, widely recognized as a serious difficulty in oil well cementing, is not addressed at all.

III.A. Except for a vague test program on CSR material, no reference made to extensive further research needs identified in references. No indication of further test plans.

III.B. A more detailed analysis is needed of the probability of successful void detection by means of cement bond logs only, given the complex arrangement of pipes through the cement grout.

How will adjacent stratigraphy be determined? Problems with over-excavation have been discussed earlier, in comments on letter.

III.C. How will seepage along liner-grout, pipe-grout, rock-grout interfaces be detected, especially between the lowest aquifer above the salt formation and the top of the repository salt horizon?

It might well be that a sudden major inundation of the shaft is not a credible event, according to reference 6, but it must be recognized that inundations of salt shafts have happened (reference 7).

IV.A. What will be the remedial action if shaft diameter is not maintained?

It is somewhat surprising that no water inflow limits are included under the acceptance criteria.

IV.B. It clearly is not true that the mechanical properties (strength) of the cement grout are not significant. Some structural loads (primarily rock pressure) must be transmitted through the cement to the shaft liner casing. If the cement fractures during this load transmittal, the resulting (almost certrainly vertical) fractures could become a high permeability water flow path. This problem could become particularly severe for those shaft liner designs that call for multiple utility pipes outside the liner, embedded in the grout. Each pipe could act as a stress raiser. If high stresses are thus generated (e.g. due to salt creep) it is easily visualized that grout cracking could result: (Detailed discussions of such problems are given in the topical report by Jeffrey, University of Arizona, 1980, to NRC).

IV.C. Is any remedial action planned if bond logs reveal low density cement?

V.A. It would be desirable to obtain very specific information as to what other sources will be used to obtain this information, for example:

-rock characterization of shaft walls (e.g. disturbed zone permeability, vertical joint spacing, frequency, continuity, aperature.
-groundwater inflow
-shaft shape

It would seem desirable to try to run a comprehensive suite of logs prior to lining.

Excellent summaries of the gap in knowledge resulting from the decision to drill are given in reference 6 (pp. A-4/5) and in reference 7 (e.g. p. 98, 103-105).

References

All references refer to references in the attachment to the subject letter.