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High Level Waste Technical
Development Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Attention: Mr. Naiem Tanious

Subject: Document review of Parsons Brinckerhoff/PB-KBB, "Final Preliminary Design Report, Permian Basin, Texas, March, 1986 (ESF preliminary design, supersedes ONWI-498)

Ladies and Gentlemen:

Please find enclosed the subject document review, which is being sent directly to you for your information and use. We hope you will find this satisfactory.

A copy of this cover letter and document review has been forwarded to our Westmont, IL office and they will complete its distribution.

Should you have any questions or comments, please contact the undersigned.

Sincerely,
ENGINEERS INTERNATIONAL, INC.

Robert Cummings

Robert A. Cummings
Principal Geological Engineer

Enclosure
cc: Dr. M.M. Singh, Engineers International, Inc., Westmont, IL.

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EI DOCUMENT REVIEW

FILE NO.: 1148-07-19-01

DOCUMENT: Parsons Brinckerhoff/PB-KBB, "Final Preliminary Design Report, Permian Basin, Texas", March, 1986 [ESF preliminary design, supersedes ONWI-498]

REVIEWER: Engineers International, Inc. (R. A. Cummings)

DATE REVIEW COMPLETED: 20 October 1987

DATE APPROVED:

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Shafts and boreholes are permanent penetrations into the repository host rock. Past NRC-DOE interactions have identified two broad categories of concern for the exploratory shaft facility (ESF): that the method of construction not result in unacceptable performance of the geologic repository due to the introduction of preferential pathways, and that the method of construction not preclude effective site characterization. These concerns and the many subissues related to them have been articulated in document reviews, meetings, and correspondence involving NRC and its contractors and the DOE.

Through its designs, the DOE wishes to preserve the option to incorporate the ESF in some way into the repository. This has generated additional subissues such as questions of design life, QA requirements, the role of decommissioning seals in the ESF, and the effect of various ESF construction options on repository performance, that add to the importance of the ESF in repository licensing.

The preliminary design report (Title I Design Report) sets out the current design philosophy for the ESF. The construction concept involves two, 12-foot-finished-diameter, conventionally-sunk shafts. This concept was mentioned in the EA but the EA design basis used two different shaft diameters (10 ft and 22 ft). It now appears that the Title I design concept will prevail for the actual ESF. Thus it is very relevant that the preliminary design be understood by the NRC.

SUMMARY OF DOCUMENT CONTENT:

The document describes the engineering intent regarding the Title I ESF design. The design incorporates architectural, structural, mechanical, electrical, and environmental considerations for surface and subsurface facilities, in addition to those related to mining (shaft sinking and the construction of the underground facility). The document is comprehensive, although not detailed on some items owing to the preliminary nature of the subject. Therefore only the topics relevant to the concerns and subissues mentioned above have been reviewed in detail. The major document sections are the Introduction (Chapter 1), Design Basis (Chapter 2), Facility Description (Chapter 3), Environmental and Permitting Considerations (Chapter 4), Schedules (Chapter 5), Cost Estimate (Chapter 6), Impacts of Limited Information on Preliminary Design (Chapter 7), and References and Appendices.

Design Basis

Chapter 2 includes a description of the design basis -- location, physiography and climate, geotechnical data base, design criteria, and QA approaches.

The design basis is largely from the Functional Criteria for Design (FCD), originally dated 17 May 1985 and subsequently modified (18 November 1985). The FCD was issued as ONWI-601 in November 1986. The Title II designs are being prepared according to a requirements document ("RD") that evolved from these. The RD is in the process of being baselined by OGR; it has not been reviewed by NRC but probably differs from the FDC in the language used and perhaps conceptually as well. It is important to recognize that the design is to work from documents like the RD and the FDC, which provide the basic framework for the DOE design review process as well. The exact language of these documents is considered repeatedly during the design and review process. The design and reviews do not draw directly from 10CFR60 or 10CFR960.

The geotechnical data used are from the baselined synthetic data base developed through ONWI. This data base projects to the site the subsurface information from boreholes that are miles away. The design is carried out as if the synthetic data base represented known site conditions. The document is very clear in not pretending that the actual site conditions are known and in fact devotes an entire chapter (Chapter 7) to the impact of the data uncertainties on the design. Nevertheless, the point of view adopted by the DOE regarding the design is essentially that the synthetic data and the designs based on them are correct until proven wrong. Thus the document in several places indicates that the design will need to be redone if site conditions differ from the design assumptions. The document does not detail what level of difference would prompt a design reconsideration. Some design items are very sensitive to parameters that are not well-known at the site, such as creep rates and rock elasticity. The synthetic data base also appears to be incomplete in some cases; for example the document acknowledges on page 14 that the effects of mud seams on salt mass behavior are largely unknown. Such seams may be prevalent in salt-bearing units at the site that are to be overexcavated during shaft sinking to allow for creep closure.

Facility Description

The description of the facility addresses the surface site arrangement, the types and construction of surface buildings, utilities and fire protection, and construction and outfitting of the shafts and underground Page workings. The aspects of these discussions that are most relevant to the NRC's concerns are discussed later in this review.

The sinking method is conventional, with ground freezing in the Ogallala and Dockum sections. Both preliminary and final linings are specified through these strata. The foundation would be in the Alibates, just below the Dockum. The preliminary lining type may be either block or formed concrete (construction contractor option). Although lining concepts are given for the section down to the LSA-4 Salt, the option to not line below the Dockum exists. The LSA-4 Salt section would be unlined, but would be overexcavated 1 ft on radius and supported with rock bolts and wire mesh. (All shaft sections may be initially supported with rock bolts and mesh.) If any section below the Alibates were to be lined, the installation of the final lining may be delayed until after the start of site characterization, in order to allow testing to begin as soon as possible. All lining concepts are tentative until the EDBH is drilled, at which time the adequacy of the initial design would be assessed and any required changes implemented.

The underground drifting (5,000 ft) is much more extensive than the EA basis. The support to be installed includes 8-ft-long fully-resin-encapsulated bolts. The bases for the bolt designs are the NGI and Geomechanics rock classification system predictions. Surface capacity for excavated salt from drifts is 25% over neat excavation. It is not known if this would permit the potential expansion of the facility should a larger-scale test be needed, such as a retrieval demonstration. As might be expected, retrieval demonstrations are not mentioned anywhere in the document.

The underground test plan is not discussed but the layout does give some indication of the types of tests planned for. The testing in the shafts is targeted for design verification only. The schedule specifically omits time for shaft-wall mapping and says nothing about site characterization testing. The schedule allows one shift per day for in-shaft testing.

Schedules

The schedule includes several ambitious assumptions. Notably, it assumes that the shaft final lining below the Alibates can be omitted and that the LSA-4 Salt will not need to be lined. The schedule gives a 27-month period from the start of construction until the start of Phase II testing. Phase II testing continues for 36 months thereafter.

Impact of Limited Information

This chapter lists and briefly describes the potential impacts from differences between the actual site conditions and the design assumptions, broken down into impacts on the site, surface facilities, shafts, subsurface facilities, and underground service systems. The impacts to the shafts and subsurface facilities are many, and some of them are profound, such as the impact of differing hydrological conditions that could delay the start of testing while the final liner is installed below the Alibates. That this section is included at all is encouraging; however, there are only short discussions of the impacts, and some potential impacts are not identified or are discussed too broadly. For example, significant differences between site-specific physical properties and the assumed values are said to potentially result in re-evaluation of design pressures and possible changes in lining dimensions. While this is true, it very broad, gives little specific guidance, and appears to omit the possibility that in the sections to remain unlined, the discovery of mud seams susceptible to air slacking may result in a decision to line, even though the physical properties of the enclosing salt masses may be nearly as predicted. Since the design has been done on data that reasonably can be expected to change, an uncertainty assessment is appropriate. These uncertainty assessments should be parts of the design process early enough that the full impacts of the assumptions can be assessed systematically, thereby reducing the potential for omissions and overgeneralizations.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS

Shaft and ESF Stability

The liner design is very preliminary and is dependent on synthesized rock properties. The document acknowledges a potential for fracture-dominated inflows, swelling, and sloughing below the Dockum, but does not make clear how these would be handled. The initial support is to be rock bolts and wire mesh. Whether there would be additional protection in the muddy salt zones, such as shotcrete, is not specifically defined, but certainly there is a potential for substantial mud seams in the LSA-4 Salt, which is to remain unlined.

The liner is not designed for lithostatic loads. Overexcavation of "salt" and the provision of a compressible backfill material are supposed to isolate the liner from such loads and this approach has been used for potash and salt shafts elsewhere. However it is unclear how the material properties of the "salt" and the backfill are to be assured in support of a 100-year maintainable design life. The backfill is to exert a uniform 200-psi stress on the preliminary lining; it would have to do so at very large strains with no damaging increase in load transmitted, if the creep of the salt turns out to be more rapid than presently thought. The closure prediction draws from the "baseline creep laws" developed by others; the reliability of some of these "laws" has been questioned by NRC and by ONWI, among others.

It is not clear how "salt" is defined for the overexcavation requirement. Overexcavation may be required for strata that are predominantly nonsalt.

Safety factors for shaft linings are not given. The design lifetime for the shafts is to be 100 years, which exceeds the greatest known lifetime for shafts of comparable construction and depth in other viscous materials.

The ESF openings are to be stable only for the ESF lifetime, which for the nonpermanent surface facilities is 5 years. It is not clear whether the drifts are to be stable for 5 years or 100. The document stresses the importance of maintenance in achieving the design objectives, which may be a way to address the lack of comparable mining and construction experience.

The safety factors are given for the drifts and are said to be at least 1.5 and the design is such that the deviation from the undisturbed stress condition at the "midpoint between drifts" (pillar centers?) is not more than 20%. There are no calculation details presented. The bases for the calculations are said to be the Wilson method of pillar design and the beam analyses in the 1973 SME Mining Engineers Handbook. Neither method was developed for salt. It is doubtful that the safety factor concept has much meaning in a viscous material.

The use of resin-encapsulated bolts is defended on the basis of their performance at WIPP. It is by now fairly well known that the resin bolts at WIPP had a high failure rate and that the concept was changed to a bolt type that tolerates creep more effectively.

The potential deferral of final lining installation until site characterization begins (page 113) means that thawing may begin while only the preliminary liner (if one is used at all) is in place below the Alibates. It would be instructive to know what the criteria would be for such a decision because development of leakage through the shaft key above non-watertight or unprotected sections could adversely affect shaft-wall conditions or testing. The length of time required for thawing to resault in leakage development could be months to years, so that testing may be well under way by the time the potential leakage would begin. It is mentioned in the document that accelerated thawing may be needed to protect the freeze pipes or shaft linings from excessive creep of the ice wall, so that a lining decision may be needed sooner than expected.

According to the document, some permissible unsupported shaft-wall heights are as low as 6 ft, and some moisture-sensitive materials may require protection within 8 hours. The document contains no discussion of how to avoid adverse impacts on the time available for site characterization data collection in materials requiring rapid installation of support. Site characterization data collection is a topic that receives little attention in the document.

Shaft Design/Construction/Sealing

In describing the linings and operational seals, the document uses language like "prevent" vertical migration of water and "watertight" linings. Without defining such performance numerically, these terms are without much meaning.

The document appears to place undue reliance on the ability of future data to resolve design uncertainties. For example, as mentioned previously regarding shaft sections below the Alibates (1,036 ft depth), the shaft may be unlined entirely or the final lining may be deferred. The document states that data from the EDBH is to resolve these questions (and many others regarding the design). While the data from the EDBH will certainly be helpful, they may not completely address all the issues impacting such a decision. Part of the attractiveness of not lining below the Alibates stems from the difficulty and expense of providing a lining in creep-prone materials. However the salt in many places will be interbedded with weak, moisture-susceptible materials for which a lining would be desirable. By the logic of the preliminary design, the EDBH is to yield accurate enough data to evaluate this and yield a decision. However, a testing program that would be supportive of a 100-year design life, incorporating creep behavior, strength of salt and nonsalt components, and degredation, would be time-consuming. There will be many other demands on the EDBH for samples, and it may not be possible to adequately cover the shaft vertical extent to everyone's satisfaction.

One might make similar observations regarding lining thickness, unsupported wall height, creep rate of frozen ground, amount of overexcavation in salt sections, position of the ESF within the LSA-4 Salt, or many other topics. Also, the single EDBH may not sufficiently assure the absence of fracture flow in units not otherwise considered aquifers. The point is that the EDBH data may not be as conclusive as apparently thought in resolving design issues that are presently tentative because of insufficient data. Considering this, it is noteworthy that the schedule assumptions are in many instances nonconservative, such as the assumption that there will be no final lining in the LSA-4 Salt.

The document repeatedly refers to the data to be gained on site as being design verification data. It states that the EDBH data will be compared with the design data base to determine the need for design changes. As mentioned previously, it is not clear from the document what the level of difference would prompt such changes. Furthermore, as indicated above, the EDBH data may be insufficient to establish the design choice.

The issue of freeze pipe sealing remains unclear. The effectiveness of abandonment of any cased hole is strongly dependent on the details of the method. All the document really says about this is that the sealing will be effected by perforation and cement injection. It does not describe measures that will assure the effectiveness of the method.

The frozen section will undergo considerable disturbance adjacent to the shaft wall. It is doubtful that this can be controlled so that permeability enhancement will not occur. In assessing performance of the ES, the DOE may attempt to show that satisfactory overall performance is obtained regardless of the condition of the formations in these sections.

Page 123 mentions specifications for repair of the shaft wall disturbed zone but does not describe how this is to be done. Elsewhere, the document states that seismic and thermal stresses are responsible for interrupting the rock-liner bond and that this damage is repaired by grouting.

The final lining through the Ogallala and Dockum sections is a steel-concrete composite. A bitumen annulus between the preliminary and final linings is provided as a seal. This type of final lining is fairly heavy and will be free-standing. The design calls for the foundation to be constructed in the Alibates anhydrite, because of its expected strength. The Alibates is projected to be 45 ft thick. The drawings appear show that the foundation and seal systems, which include the bitumen-sand mixtures, chemical seal systems, the support ring, and the foundation itself, will extend from near the top of the Alibates at elevation 1015 to approximate elevation 1052, a distance of 37 ft or so. This leaves only 8 ft of excess thickness, and the Alibates is not known to be uniformly strong nor 45 ft thick at the site. The foundation is designed to accommodate the weight of the bitumen column and the final liner, but nothing is said of how the chipboard-and-block preliminary lining is to be supported. Presumably at least some of its weight will be exerted on the foundation. If the Alibates anhydrite is thinner than expected or contains zones of weaker rock, the flexibility to change the foundation dimensions or the dimensions of the seal system may be reduced.

The manner of placement of the bitumen is not described. It normally is tremmied or pumped into place from the surface. Replenishment is normally by adding bitumen at the surface. The drawings show bitumen placement pipes, but it is not clear what their final disposition is to be.

Two designs for the preliminary lining in the frozen section are provided: chipboard-and-block, or cast-in-place concrete. The block lining approach was developed in Germany for shafts having to tolerate bending strains arising from extraction of shaft pillars. Its relevance here is not described; perhaps the designers are concerned about icewall creep. The cast-in-place preliminary lining is the conventional practice in the U.S., which may be the rationale for its inclusion as an option. The contractor is allowed to choose his preferred option. The two approaches differ fundamentally in their design basis and in their implications for shaft performance; they are therefore not equivalent. It seems that the designer should be making the choice of lining on the basis of engineering need and performance.

The cost summaries include a contingency of only 7%, and clearly state that there is no built-in conservatism in the incremental costs. This contingency seems rather low in view of the preliminary nature of the data, but is a common value for other major construction projects. As was pointed out earlier, the data base is synthetic but is being treated as if it were site-specific for this design. Also, cost totals are given with and without an increment for final lining of both shafts.

Effects on Site Characterization

As stated earlier, the schedule omits allowances for shaft-wall mapping (page 179). The bullet items on page 2 list the purposes of the ESF but do not identify characterization of the intervening strata as one of them.

The final lining below the Alibates may be deferred until the start of site characterization. If conditions differ, site characterization could be delayed pending final lining. On page 192, the document asserts that deferral of final lining until some future time is against the ESF shaft criteria.

The shaft inspection speed is intended to be 120 ft per minute. This seems rather fast to document the performance of the shafts to the quality levels involved.

On page 43, the coordination of the shaft construction with in-shaft testing is deferred to Title II design.

The document states that all salt-contaminated materials will be sent to the salt stockpile. Since some of the salt-bearing materials will be more nonsalt than salt, it seems possible that controlling the makeup of backfills drawn from the stockpile will be very difficult. Salt for room-scale backfill tests should be neither less nor more pure than that which will be used in the repository.

The design states that it "minimizes" adverse environmental impacts and site damage in view of the possibility that the site could be selected as a repository; it should describe what features of the design support this claim.

The extent of drifting and the exact layout are to be to the requirements of the In Situ Test Plan. The excavation is to be to a constant roof line, with a roadheader or continuous miner capable of a 12-ft vertical reach. Where rooms higher than 12 ft are required (since the repository will have 20- or 24-ft-high rooms, the interface with the repository dictates that most of the ESF rooms be driven to similar heights) the floor will be taken up by benching. Thus there will be many ramps to access simulated repository rooms, which equipment and personnel will have to negotiate. The depressed floor sections raise the possibility for accumulations of brines, oil, drill water, and so on. Care will need to be taken that tests where floor behavior is involved do not intercept different strata. The facility may have to be moved up or down to avoid including anomalous layers in key tests. The selected approach does have many advantages: roof support will involve the same stratigraphy throughout, and the heading-and-bench approach is more-easily constructed and is favorable for roof stability.

The schedule includes allowances for collecting information from the shafts for "design verification testing"; it says nothing about collecting site characterization data from the shafts. The schedule omits time allowances for geotechnical performance monitoring of the shafts.

Repository Integration

This topic is omitted from Table 2.4-1, which portrays the functional criteria for design. However, repository incorporation of the ESF is stated elsewhere to be a criterion for design. The components considered influential to the design and construction of the repository are to be identified later.

As mentioned above, the ESF room dimensions will reflect those of the repository. All rooms will be 20 ft wide for this reason; variation in room height requirements will be achieved by benching and removal of the floor, as described above.

ES Performance and Performance Analysis

There is no performance analysis mentioned that establishes the suitability of this ESF design. There is no detailed analysis of the construction effects on the rock, long-term liner performance, or the role of the linings in system performance. As pointed out earlier, the freeze interval will be highly disturbed and may not be assigned credit for performance in future analyses.

Table 2.4-1 gives the functional design criteria; this is the design basis. The design is not directly to 10CFR60 and the conformance of the design to 10CFR60 performance requirements will be through the FDC.

The discussion on page 131 identifies the importance of the bitumen. Among other things, the bitumen is important in protecting the liner system from damaging constituents of goundwater, such as chlorides and sulfates. Some bitumens contain volatile components that can escape over the long term, with attendant shrinkage and possible embrittlement of the bitumen. In addition, the satisfactory performance of the operational (chemical) seals is not demonstrated for the 100-year shaft life. The design should either provide assurance of the longevity of these systems or make provisions for the correction of problems with them. It is not at all clear how the polymer seals are to be monitored.

Table 2.4-1 mentions a requirement for shaft linings and seals to prevent aquifer communication and states that this is in conflict with the option to not line "below the Dockum" (actually, the Alibates is effectively lined because it hosts the foundation and seal system), but to provide suitable water control in lieu of such lining. This could suggest that the designers expect inflows below the Dockum.

An entire section is devoted to the importance of maintenance and monitoring to the achievement of a 100-year design life. Instrumentation systems for this purpose (and for site characterization purposes as well) will have a short life in a saline environment, and some, such as embedded concrete load cells and piezometer casings behind the composite liner, will be difficult to maintain or replace. Also, the long-term performance of muddy seams within the salt in unlined sections subjected to the passage of ventilation air, and the effect of variability in materials and their installation will mitigate the expected life as well.

The measures listed on page 153 include no monitoring of groundwater movement behind shaft linings.

RECOMMENDATIONS

The preliminary design will be updated and changed during the Title II design process. It is likely that the designers appreciate many of the problems with the design that have been identified in this review. The NRC needs to stay as current as possible on the evolution of the design. The design is complex and, in many ways, unprecedented. It makes use of techniques such as ground freezing, the placement of chemical seals, rock bolts in salt, and other systems. NRC should endeavor to become very familiar with the advantages, implementation, and limitations of these techniques.

Also, the NRC should recognize that the design documents and Specifications will govern the shaft construction and are therefore the direct controls by which the final system will or will not meet the regulatory criteria. The emphasis in future reviews should be on the implications of these documents. These documents will make extensive use of standard specifications for the fabrication and installation of many items, for example pipe, concrete, and structural steel. NRC should be in a position to assess the appropriateness of such standard specifications in its reviews.

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