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RESPONSE TO AN OPEN (ACTION) ITEM FROM THE APRIL 14-15, 1987, MEETING BETWEEN THE NUCLEAR REGULATORY COMMISSION (NRC) AND THE DEPARTMENT OF ENERGY (DOE)

Reference: Summary of Meeting on Proposed Changes to the Nevada Nuclear Waste Storage Investigations Exploratory Shaft Facility, April 14-15, 1987

The subject meeting resulted in seven open (action) items that are listed in the referenced meeting summary.

Action Item 3 states that ". . . the DOE will evaluate the relevance of drift stability and damage control to retrievability and waste isolation." In addition, the meeting summary, Page 2, Item 3, states that "the NRC is of the position that adequate [exploratory drift] construction controls have to be adopted to meet 10 CFR 60 preclosure and postclosure performance requirements." The matter of drift construction controls has been designated "Information Item IIIa" by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project. The NNWSI Project believes that the enclosed response provides the requested evaluation for closure of this action item and provides adequate information on control of blasting to resolve the NRC staff concerns about drift construction controls.

Please address questions on this topic to Dennis H. Irby (FTS 575-8932) or Lester P. Skousen (FTS 575-8929) of my staff.

Carl P. Gertz, Project Manager
Waste Management Project Office

WMPO:DHI-130

Enclosure:
Response to NRC-NNWSI Open Item No. 3
and Information Request IIIa

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RESPONSE TO NRC-NNWSI PROJECT OPEN ITEM NO. 3
AND INFORMATION REQUEST IIIa

Problem Statement

Open Item #3 states: "The DOE will evaluate the relevance of drift stability and damage control to retrievability and waste isolation." Information Request #IIIa states: "Adopt adequate drift construction controls to meet 10 CFR 60 pre/post closure performance requirements." The open item and the information request are closely related and will be discussed together.

Below is the NNWSI Project's evaluation of the relationship of drift stability and control of blasting damage to the performance requirements of 10 CFR 60. The planned approach to drift construction for the repository is outlined in the SCP-CDR , Section 3.3.1. Plans for obtaining the appropriate data for assessment of construction techniques are covered in the Site Characterization Plan (SCP) and associated Study Plans and are beyond the scope of the subject NRC requests.

Drift Construction

Stated very briefly, the planned approach to drift construction, as outlined in the SCP-CDR, is to use a drill-and-blast method to mine the drifts and depending on the quality of the rock encountered, select from a set of planned ground support systems. To control the amount of damage to the surrounding rock, smooth blasting, a type of controlled blasting will be used. The application of controlled blasting methods is a subject covered in numerous textbooks and technical articles. A brief description of the controlled blasting to be used in the mining of the shafts of the ESF is contained in reference 2. A study of controlled blasting , which includes preliminary plans for its application to the entire ESF, was conducted by the NNWSI Project. The NNWSI Project will develop detailed procedures for the drill-and-blast method that are based on this study and other information that has become available. For example, a drift was constructed in welded tuff in G-Tunnel on the Nevada Test Site using controlled (smooth) blasting. The operation was closely monitored and a report that documents the activity will be available shortly. Based on pre- and post-excavation permeability measurements in the G-Tunnel study, damage due to blasting and relaxation around the opening was small and progressed, at most, about two meters into the rock. Instead, most of the measurements, which were made from about one

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meter from the opening outward, showed no significant change in permeability after excavation. Therefore, there is good evidence to believe that the carefully prepared procedures that are planned for ESF construction will lead to small amounts of damage that is located in a small area around the drifts. A detailed discussion of the possible changes in permeability around vertical shafts is contained in reference 5. Monitoring that is planned to be conducted in numerous locations in the ESF (as described in the SCP and Study Plans) will quantify the limited extent of the damage in the shafts and drifts.

Performance Issues

Although the planned approach by the NNWSI project is almost certain to lead to only very limited damage around openings, the question still remains as to whether this limited damage will adversely affect the ability of a repository to meet the pre/post closure performance requirements in 10 CFR 60. The planned approaches to resolving the issues related to the performance objectives are covered in the SCP. Without reviewing the issue-resolution strategies in detail, the parts of the strategy that might be affected by drift damage will be discussed.

(1) Issue 1.4, Waste Package Containment (SCP Section 8.3.5.9). During repository operations, waste will be placed in vertical or horizontal boreholes off of waste emplacement drifts. The ESF drifts that become operational in the repository will become mains or panel access drifts. Therefore, the ESF drifts are removed from the future locations of waste packages (by at least 25 meters according to present plans) and any small damage to these drifts cannot significantly impact waste containment.

(2) Issue 1.5, Engineered Barrier System Release Rates (SCP Section 8.3.5.10). Similar to Issue 1.4, the drifts in the ESF will not be a part of the "engineered barrier system" and are too far removed from that system for localized damage around the drifts to affect releases.

(3) Issue 1.6, Ground-Water Travel Time (SCP Section 8.3.5.12). If the damage to the rock surrounding the drifts were extremely extensive, it might require that the disturbed zone be extended and, hence, reduce slightly the distance over which travel time is calculated. But, none of the definitions that are being considered for the "disturbed zone" would be affected by fracturing due to controlled blasting or even the more extensive damage that might occur with typical blasting that is not controlled. Also, the primary unit of rock that is being relied on for ground water travel time calculations is the Calico Hills Unit which underlies the Topopah Spring unit (the unit in which the waste will be emplaced). Therefore, the resolution of this issue is not dependent on a small amount of localized damage around the drifts.

(4) **Issue 1.1, Total System Performance (SCP Section 8.3.5.13).** The present strategy for limiting releases to the accessible environment via liquid transport relies primarily on the Calico Hills unit, with the Topopah Spring unit as a backup. As described above, the drifts being mined for the ESF do not include any emplacement drifts. Any releases of radioactivity that would be transported via water will be primarily vertically downward from the waste-emplacement areas. Therefore, the effect of a small amount fracturing in the main and panel access drifts is too insignificant to be determined. Even if the fracturing were located a few meters above and below the waste, the models anticipated to be used in the license application will not have the detail to determine this very small effect. Therefore, the impact of the small damage around drifts is negligible for the liquid portion of this performance objective.

The present strategy for gaseous releases relies on the waste packages to prevent significant releases. However, the rock units provide significant backup to this position. A small amount of fracturing in the rock around the ESF drifts will change the local permeability but will not measurably change the global performance. The fracturing around drifts does not provide a path to the accessible environment, only a very short path to rock that has been unaffected by the mining operations. The increase in permeability in the direction of a drift is insignificant compared to the permeability of possible drift backfills. Reference 6 contains a further discussion of gaseous releases through the rock formations and from the ESF.

(5) Issue 2.4, Waste Retrievability (SCP Section 8.3.5.2). The strategy for waste retrieval requires the ability to maintain as useable the openings from the surface to the emplacement boreholes. Because some of the drifts associated with the ESF will become openings for potential waste retrieval, they must be maintained to be useable during repository operations. As discussed under Issue 4.4, Preclosure Design and Technical Feasibility (SCP Section 8.3.2.5), the ground-supported drifts are expected to be generally stable, but maintenance will be required. Experience from G-tunnel mining[4] has been generally favorable. Rock bolts and wire mesh have been adequate ground support for a repository-size drift in welded tuff even though a fault at about 75 degrees to the axis of the drift was encountered.

The type of ground support system that will be necessary to stabilize the underground openings cannot be predicted with confidence prior to actual mining. As noted above, the approach outlined in the SCP-CDR and to be followed in the ESF requires that the rock quality be evaluated during the mining operation. Careless blasting could lead to requirements for more elaborate ground-support systems. However, the controlled blasting to be used in the ESF will, if properly implemented, result in only minor damage to the surrounding rock. Therefore, ensuring that the ESF drifts will not need more complex ground-support systems to meet performance objectives for retrieval requires that well written, but flexible, technical procedures be followed during the mining operations. As discussed above, adequate background information exists for the preparation of such procedures.

Drifts in the ESF that become openings for waste retrieval in the repository will be heated and stressed by the presence of the waste. As discussed in section 7 of the SCP-CDR; interpretations of preliminary analyses of waste emplacement drifts suggest that thermal stresses will not lead to changes in ground-support systems. The main and panel access drifts are further removed from the waste than waste emplacement drifts and temperatures and stresses will be lower. However, if future analyses and experiments indicate that ground supports used in the ESF will not be adequate during repository operations, additional support can be provided readily.

(6) Issues 2.1, 2.2, and 2.3, Radiological Safety (SCP Sections 8.3.5.3, 8.3.5.4, and 8.3.5.5). Some of the drifts in the ESF will be used for the passage of waste from the surface to the emplacement drifts. Therefore, poor performance of these drifts could contribute to potential accident conditions for the repository. Although the present strategy includes the handling of such accidents through engineered systems (e.g. ventilation systems), excessive rock fall should clearly be avoided. Thus, one concern for this performance objective is similar to the concerns for retrievability and the DOE's strategy is described above.

Under some circumstances, the rock in the repository is relied upon to provide shielding against radioactivity. Although careless blasting could result in reduced shielding capabilities, the limited increased fracturing that will occur during controlled blasting will have virtually no impact on shielding requirements. The final design for the repository will be made using data that is gathered from the ESF and, if the effect from the blasting were measureable, it would be included in the design.

Conclusions

As discussed under items (1)-(4) above, no effects of blasting damage to drifts in the ESF on post-closure performance objectives can be identified. For preclosure objectives, damage due to blasting that was not controlled might require more extensive ground support. Controlled blasting will result in very limited damage. Therefore, any impact on preclosure performance objectives is expected to be insignificant. It is worth emphasizing that the planned approach (controlled blasting) is required in the ESF, so that the methods can be evaluated for use in the repository. Without this evaluation, the construction of the repository would not have the necessary assurance that the methods meet all of the requirements of a repository. Some small risk will always exist that the blasting will do more damage than anticipated, but the information on the construction methods is vital. Also, DOE's approach to drift stabilization includes a wide variety of ground support systems. The rock quality in the ESF is expected to be similar to that at G-Tunnel and would require a very minimal ground support system; this will leave a number of much more elaborate systems for backup.

REFERENCES

(1) "Site Characterization Plan - Conceptual Design Report, Comment Resolution Draft," SAND84-2641, Sandia National Laboratories, March 1987. (Will be transmitted to the NRC under separate cover by December, 1987)

(2) Letter, Bullock to Vieth, dated 06/29/87, FS-NNWSI-0239. (Attached)

(3) "ESF Controlled Blasting Study," Fenix & Scisson, Inc., draft dated December 1986. (Reviewed by NRC at the September 1987 Appendix 7 Meeting.)

(4) Zimmerman, R. M., et al., "Final Report: G-Tunnel Welded Tuff Mining Evaluations," SAND87-1433, Sandia National Laboratories, in preparation. (Will be transmitted to the NRC under separate cover by December, 1987.)

(5) Case, J. B. and P. C. Celsall, "Modifications of Rock Mass Permeability in the Zone Surrounding a Shaft in Fractured, Welded Tuff," SAND86-7001. Sandia National Laboratories, September 1987. (Transmitted to the NRC 6/18/87.)

(6) Fernandez, J. A., T. E. Hinkebein, and J. B. Case, "Analyses to Evaluate the Effect of the Exploratory Shaft on Repository Performance of Yucca Mountain," SAND85-0598, Sandia National Laboratories, in preparation. (Will be transmitted to the NRC under separate cover by December, 1987.)

June 29, 1987

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DRILLING AND BLASTING CONSTRUCTION METHODS THAT WILL BE USED IN ES-1 AND ES-2 OF THE ESF THAT WILL LIMIT THE DAMAGE TO THE WALL ROCK (WMPO ACTION ITEM: 87-1753)

References: (1) "Proposed Changes to the NNWSI Project Exploratory Shaft Facility: Background Paper for the U. S. Nuclear Regulatory Commission (NRC) and the State of Nevada Agency for Nuclear Project", dated 03/87.

(2) Letter, Vieth to Knight, dated 04/27/87.

(3) Letter, Vieth to Bullock, dated 06/10/87, WMPO:JSS-1992.

This letter is in response to your request to describe the construction methods which will limit the shaft wall damage during the drilling and blasting of ES-1 and ES-2. So that the readers of this letter may fully understand the significance of the controlled blasting procedure recommended and understand how and why it will limit the damage to the wall rock, a discussion is first given of normal blasting and how it affects the wall rock. Then a discussion is presented on the recommended controlled blasting procedure, and how and why it works to limit the damage to the wall rock.

1. <u>Normal Blasting</u> (1) (2) (3)
   The detonation of an explosive contained in a blasthole (drill hole) initiates several actions which can contribute to the breakage of rock. The gases generated by the normally charged and detonated explosion produce intense pressures that can reach 1,500,000 pounds per square inch (psi). In the immediate vicinity of such a normal detonation, the rock stresses on the blasthole wall due to the gas pressure, usually exceed the strength of the rock and a zone of rock surrounding the blasthole shatters. The impact of the high pressure gasses against the blasthole wall produces a compressive shock wave which travels radially outward into the rock mass at a velocity of 6,000 to 14,000 feet per second (fps), depending upon acoustical coupling, rock density and other rock and explosive characteristics.

Outside the shattered zone, a zone of new radial fractures can be created, due to the large tangential tensile component of the stress field induced by the shock wave. The magnitude of the stress field varies primarily with and is proportional to the detonation velocity and the associated acoustical coupling between the explosive and the rock. The shock wave in the rock attenuates rapidly in magnitude with distance from the blasthole. However, if a free face (surface) exists that is normal to the direction of propagation of the shock wave, the compressive shock wave will be reflected from the free face, as a tensile shock wave. The resulting tensile stresses can create new fractures that are generally parallel to the free face. The reflecting tensile shock wave if of large enough magnitude can also alter the stress field and the resulting fracture pattern around the blasthole.

The most effective action produced by the explosion in normal blasting is not related directly to the shock wave but rather to the relief of the expanding gases produced by the explosion. The high pressure gases from such a blast, wedge apart both the previously existing fractures and the newly created fractures, causing them to grow much larger than the rock stress conditions alone would cause. In addition, the gas pressure moves the broken rock away from the blasthole, and thereby provides an adequate space for expansion of the rock during any subsequent detonations occurring in the same blast round.

The depth of the fractures developed in the wall rock from normal blasting have been estimated to be 15 to 20 times the borehole diameter(4). In instances where attempts have been made to measure these fracture depths, the fractures were found to vary from 1 m to 2.5 m. However, the fractures measured were in fact the results of both blasting induced fracturing and in situ stress relief fracturing.

2. <u>Controlled Blasting</u>
When a drilling and blasting procedure is used to limit the extent of the damage to the wall rock compared to normal blasting and at the same time control the overbreak, the practice is referred to as controlled blasting. While there are several different methods of controlled blasting(3)(5) the method which appears to be most applicable and is planned for the construction of ES-1 and ES-2 is smooth blasting. Smooth blasting is sometimes referred to as smooth wall blasting or perimeter blasting. In any case the desired effects of limiting the damage caused by the perimeter holes is achieved by:

- Decreasing the burden on the boreholes.
- Decreasing the spacing between the boreholes.
- Decreasing the acoustical coupling between the explosive and the boreholes.
- Decreasing the charge density per foot of borehole.

- o Decreasing the detonation velocity of the explosive within the boreholes.

- o Detonating the boreholes after the last line of reliever holes have detonated.

These variables are further discussed below.

You must have a lower burden* compared to normal blasting for the rock to break successfully, since by design the compressive shock wave from the detonation within a smooth blasthole is lower and the impact of the expanding gases is lower than for normal blasting. Also, the spacing* between the perimeter holes must be reduced. The resultant shock waves from adjacent perimeter holes is believed to cause localized stress concentration in the rock and at the blasthole surface, and influence the direction and magnitude of a propagating fracture plane. Ideally, the end result is a plane of weakness which develops into a fracture between holes that outlines and limits the extent of the broken rock. The relationship of perimeter hole spacing to burden is critical to establishing a fracture plane between holes. The burden must be greater than the spacing between the holes. A burden/spacing ratio of 1.25 or greater is recommended. See Figure 1 for a typical smooth blasting pattern.

For best results, the explosive that is used for smooth blasting should be of a small diameter and left untamped. This will leave an air gap between the explosive and most of the borehole wall. In turn, this will lessen the acoustical coupling of the explosive, decrease the charge density within the borehole, and will also result in lower detonation velocity compared to an explosive tamped to the diameter of the borehole. Special explosives will be used for these applications.

The perimeter holes should be delayed to detonate last in the blast round, and are initiated with detonators with at least a half-second delay following the detonation of the last row of reliever holes.

Compared to normal blasting, the desired effects of the above is to lower the velocity of the detonation wave and the impact of the high pressure gases against the blasthole, which will produce a lower compressive shock wave traveling into the rock mass. Thus, a lower stress field will be induced compared to normal blasting and radial fracturing will be limited.

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* Burden: the perpendicular distance from the blasthole to the closest free face.

Spacing: the distance between blastholes in a row, measured perpendicular to burden and parallel to the free face of expected rock movement.

The depth of the fractures developed in the wall rock from smooth blasting have been estimated to be 5 to 10 borehole diameters[4]. In the instances where attempts have been made to measure these fracture depths, the fractures were found to vary from 0.3 m to 0.5 m . However, the fractures measured were in fact the results of both blast induced fracturing and in situ stress stress relief fracturing.

Another factor besides the explosive variables that affect the success of smooth blasting to limit the damage to the wall rock, is drilling precision. To attain satisfactory blast results, it is important that care be taken to drill blastholes in the correct position and with the correct alignment. This is particularly true for the perimeter holes. Errors in hole collaring and alignment become more pronounced with depth. For smooth blasting to be most effective, perimeter holes should be equally spaced and parallel with the minimum constant burden maintained.

To assure that the best possible results are continuously achieved to limit the damage to the wall rock with smooth blasting, comprehensive quality control procedure will be developed and closely monitored by inspectors. They will assure the quality of the drilling and blasting cycle. Also, blast vibration monitoring will be performed to assure that peak particle velocity of the ground waves from the blasts will be held to an allowable factor.

Regardless of the techniques used, the visual success of the smooth blasting will be strongly dependent upon the geology and rock characteristics. Smooth blasting will be most successful in hard, homogeneous, and isotropic rock where there are few planes of weakness. Smooth blasting, however when properly executed will cause less damage to the rock surrounding the borehole than conventional blasting in almost any rock type and condition. The procedural technique usually must be refined for particular rock conditions over several blast rounds. Because of the variability of rock characteristics, the optimization of the smooth blasting technique to limit damage to the wall rock can only be done through field trials at the ESF site and as the shaft is sunk.

If you have any questions or comments regarding this response please contact me at 295-2220.

R L Bullock

R. L. Bullock
Project Manager

Attachments (2)

cc: J. A. Cross
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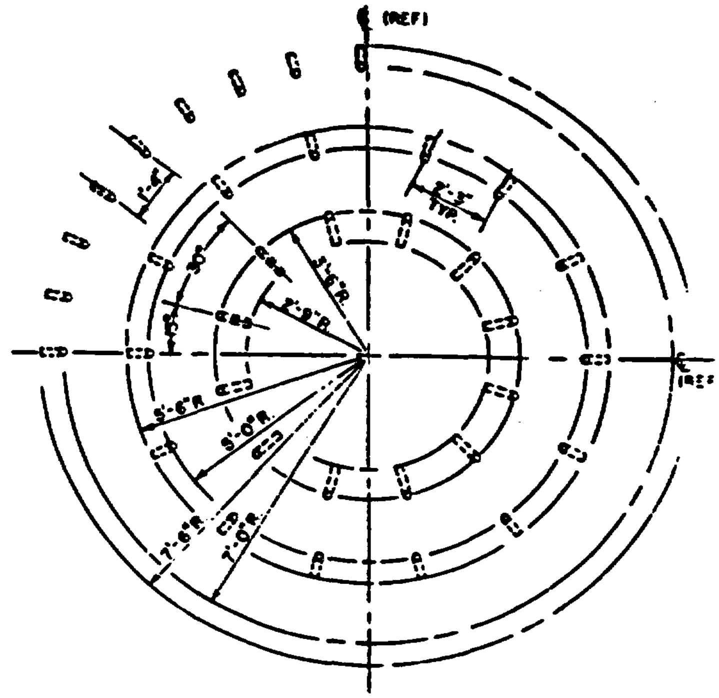
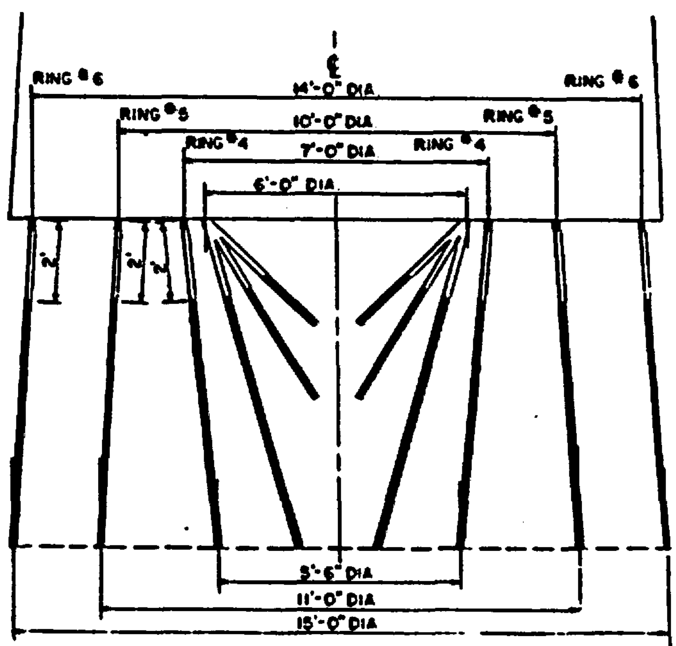
Central Files

Attachment 1



PLAN



SECTION

TYPICAL SMOOTH BLASTING PATTERN

FIGURE 1

Attachment 2

Bibliography

1. Dick, R. A., "Explosive and Borehole Loading", SME Mining Engineering Handbook, Vol. I, Section 11, pp 78-111, Society of Mining Engineers, New York, 1973.

2. Gregory, C. E., Explosive for North American Engineers, Trans Tech Publications, Clausthal, Germany, 1973.

3. Longefors, U. & B. Kihlstrom, Rock Blasting, John Wiley & Sons, New York, 1973.

4. Case, J. B., and P. C. Kelsall, Modification of Rock Mass Permeability in the Zone Surrounding a Shaft in Fractured, Welded Tuff, SAND86-7001, NNWSI Project, Sandia National Laboratories, Albuquerque, NM, 1987.

5. Blaster's Handbook, E. I. duPont de Nemours, Wilmington, DE, 1980.