M. L. Cramer
RHO-BW-SA-286 P

THE DESIGN AND CONSTRUCTION OF A BLOCK TEST IN CLOSELY JOINTED ROCK

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Basalt Waste Isolation Project

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ABSTRACT

The Basalt Waste Isolation Project developed a large-scale block test to investigate the in situ deformational response of a basalt rock mass. The test was designed and installed into the vertical rib (wall) of a tunnel to examine the response of basalt both in a parallel and perpendicular mode to the basalt columns. The salient challenge confronting the design and development of the test was a lack of documented experience for testing into a vertical wall. Information was available for testing in a horizontal surface.

The major tasks involved in the implementation of this test included flat-jack slot drilling, instrumentation hole drilling, cable anchor hole drilling, flat-jack installation, monitoring instrumentation installation, and cable anchor installation. Drilling in the closely jointed and fractured rock mass required extreme care to prevent unraveling of the columnar structure and to minimize the disturbance of the section to be tested. The adaptation of a high-strength cable anchor system to the space limitations of the test configuration and the design and implementation of an optical deformation monitoring device capable of achieving a measurement precision of 30 μm required equal innovation. Construction of the test facility was successfully completed on schedule in ∿25 wk.

INTRODUCTION

The Basalt Waste Isolation Project, conducted by Rockwell Hanford Operations for the U.S. Department of Energy, is currently evaluating the Columbia River basalts as a potential site for a commercial high-level nuclear waste repository. A field-testing program has been instituted in a basalt flow at the Near-Surface Test Facility on the Hanford Site as a part of this project. The overall purpose of this program is to develop and demonstrate the testing and analytical techniques that will allow characterization. The characterization of the temperature- and pressure-dependent deformational and thermal properties of the closely jointed basalt rock mass is in support of the design and construction of a repository. A major component of this testing program is a large-scale block test that has three specific objectives:

- Determine actual rock mass values, as a function of confining stress and temperature, for deformation moduli, Poisson's ratio, coefficient of thermal expansion, and thermal conductivity.
- Evaluate experimental techniques and instrumentation with regard to their suitability for at-depth testing in support of the repository design and construction.
- Evaluate the effect of structural discontinuities on the rock mass response.

Based on these requirements, test development consisted of a 2-m cube of basalt stressed in two perpendicular directions by an arrangement of flat jacks and in the third orthogonal direction by cable anchors that extend through the test section. The deformational response and stress field produced within the block are monitored by a variety of borehole instrumentation positioned throughout the test section. The temperature of the rock mass is controlled by a series of 29 electric heaters internal and external to the isolated block.

The actual implementation of this arrangement was difficult because of the highly discontinuous nature of the rock mass and the innovative nature of most of the major components of the test. The optical deformation measurement system, the flat-jack system, and the cable anchor system were all designed or adapted specifically for this application. The lack of experience forced most of the actual construction techniques to be developed or modified in progress. This is consistent with all aspects of the construction program planning and organization. This learning process involved many problems and unexpected situations that had to be overcome. The deficiencies of experience were buttressed by competent planning and organization, resulting in a timely construction effort with all systems performing as planned.

TEST DESIGN

Block Test 1 is located in the Near-Surface Test Facility in the west wall of Tunnel 2 at its intersection with the Heater Test Tunnel (Fig. 1). This location was chosen to provide the greatest access to the site for drilling and other equipment. The test block was placed in the wall (as opposed to the floor) to allow loading both parallel and perpendicular to the vertical columnar jointing, which is the major structural feature of the rock mass. The force for loading the block is accomplished by a system of flat jacks and tendon-anchored hydraulic rams. Monitoring of the rock is accomplished with several types of modified conventional rock monitoring instruments and a specially developed electro-optical monitoring system called the basalt deformation measurement system (BDMS).

The columnar joint set has a spacing of ~10 to 20 cm with individual vertical joints being generally continuous from 1.0 to 2.5 m in length. The second principal joint set is subhorizontal, dissecting the columns at low angles. The spacing of this set is also ~10 to 20 cm, but the horizontal joints are generally contained within an individual column structure. The overall dimensions of the test section were selected based on the spacing of the joints so that the block contained a sufficient number of structural discontinuities to be representative of the entire rock mass.

The test block is defined by the four slots that contain the flat jacks, as shown in Figure 2. The slots were cut to a total depth of 4.5 m, with the front of the flat jacks recessed 1.5 m from the tunnel wall to avoid the zone of blast damage. The additional 1.0 m behind the flat jacks was intended to reduce the influence of end effects on the test section.

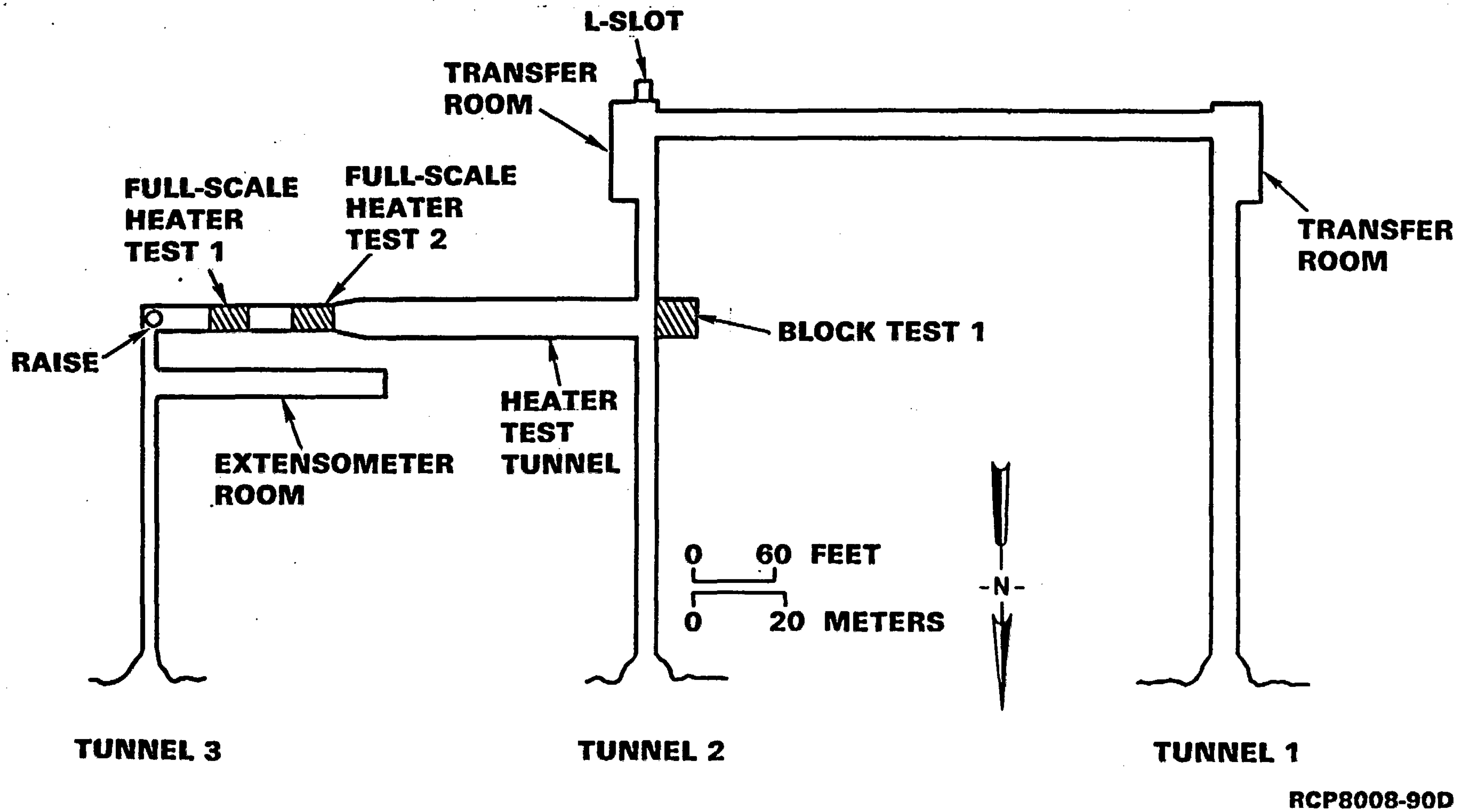

FIGURE 1. Near-Surface Test Facility Layout and Block Test 1 Location.

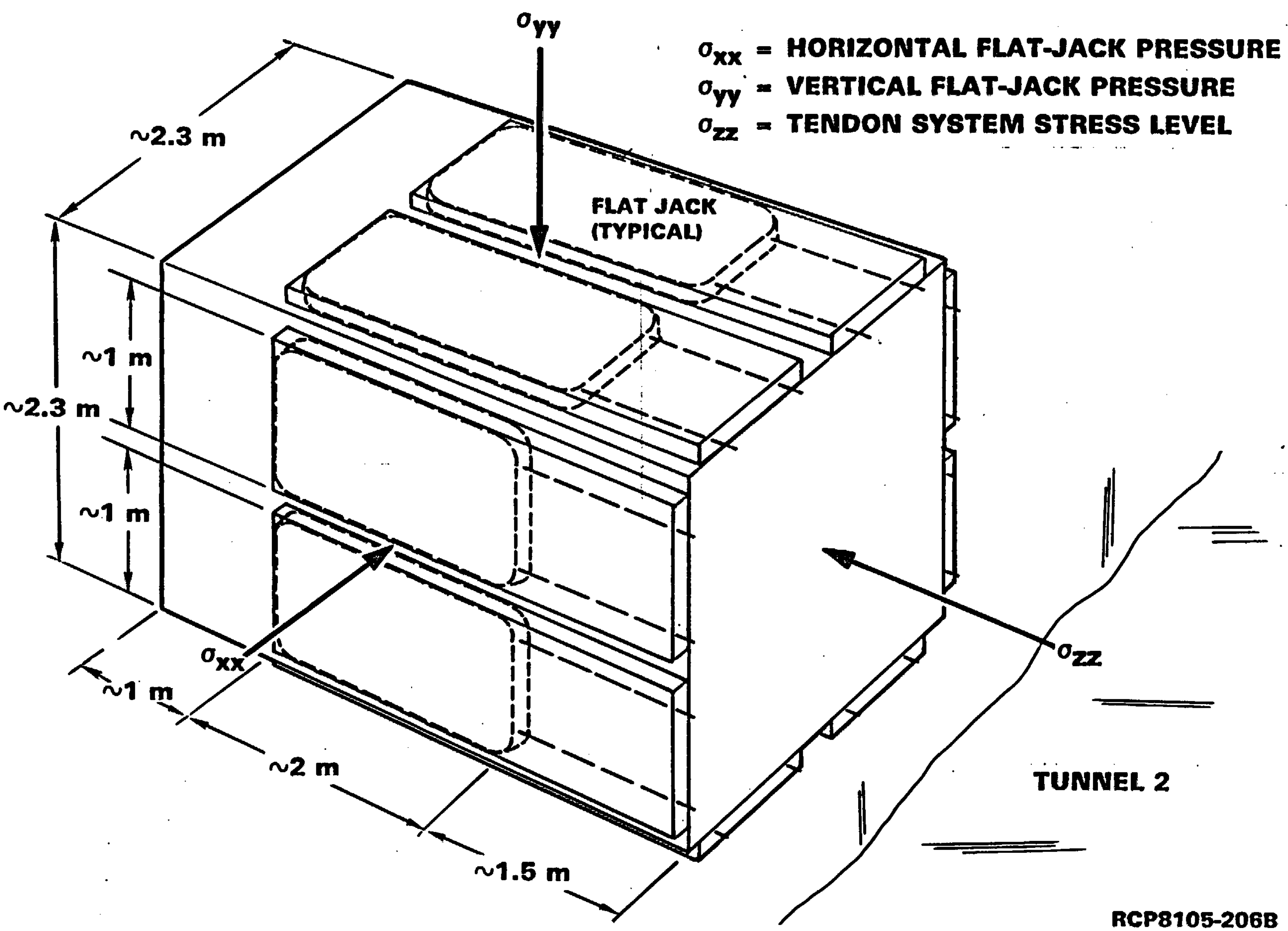

FIGURE 2. Block Test Layout.

A total of eight large flat jacks were installed around the test block with two in each slot. Each flat jack was 198 by 98 by ~2.5 cm. The jacks are of the split-tube design, consisting of a mild steel tube split longitudinally along the inside surface with two steel plates inserted through the slit and welded along the top and bottom contacts (Fig. 3). This configuration was developed over more conventional designs because it tends to produce a more uniform displacement distribution than standard edge-welded jacks. The intent of this design is for the outer tubing to act as a hinge upon pressurization and allow the plates to move apart in a parallel manner. Edge-welded jacks deform significantly more at their center than at the edge, producing an uneven loading pattern. Other anticipated characteristics of this flat-jack system expected to be advantageous include:

- Increased throw of ~1.8 cm
- Increased pressure capacity due to the removal of excessive strain from the weld area
- Ease of fabrication.

An additional unique feature of the flat-jack system was the use of metal forms to line the slots and contain the flat jacks. These grout boxes were 3.81 cm thick by 98 cm wide and 3.5 m deep and were constructed of sheet metal plates tack welded together to offer minimal resistance to the deformation of the flat jacks. The boxes, rather than the flat jacks, were grouted directly into the slots to produce a rectangular, close-fitting form into which the flat jacks could be placed or removed with minimal disturbance of the remaining test setup.

The flat jacks were pressurized by a 10-hp hydraulic pump, adjusted with manually operated pressure control valves that automatically maintainted the desired pressure level. Stainless steel tubing was eventually utilized to connect the pump to the flat jacks because the flexible hydraulic hose originally installed proved unsuitable.

The system used in conjunction with the flat jacks to produce the triaxial stress field is the cable anchor system. This system, with its 10-m free-stressing length, compensates for the strain induced in the block by the flat-jack loading. The eight cable anchors installed in the block test can provide a distributed 5-MPa stress level over the test section. This system consists of high-strength cables anchored behind the test block and tensioned by hydraulic jacks to produce loading in that direction. As shown in Figure 4, each 21-m-long cable was grouted into a borehole over the last 11 m of its length. Each cable consisted of a bundle of 12 Dyform strands, each 15 mm in diameter. Individual strands of the tendon bundle have a yield strength of 273 kN and an ultimate strength of 316 kN. This extrapolates to an ultimate strength of 3,790 kN for the tendon bundle. Stressing of the cable tendons is performed by a hydraulic doughnut jack mounted on the tunnel wall. The jacks have the capability to be shimmed off at a desired extension, which allows the load to be maintained with hydraulic pressure removed. This arrangement extends the life of the seals within the jack and produces a consistent load that does not have to be constantly monitored.

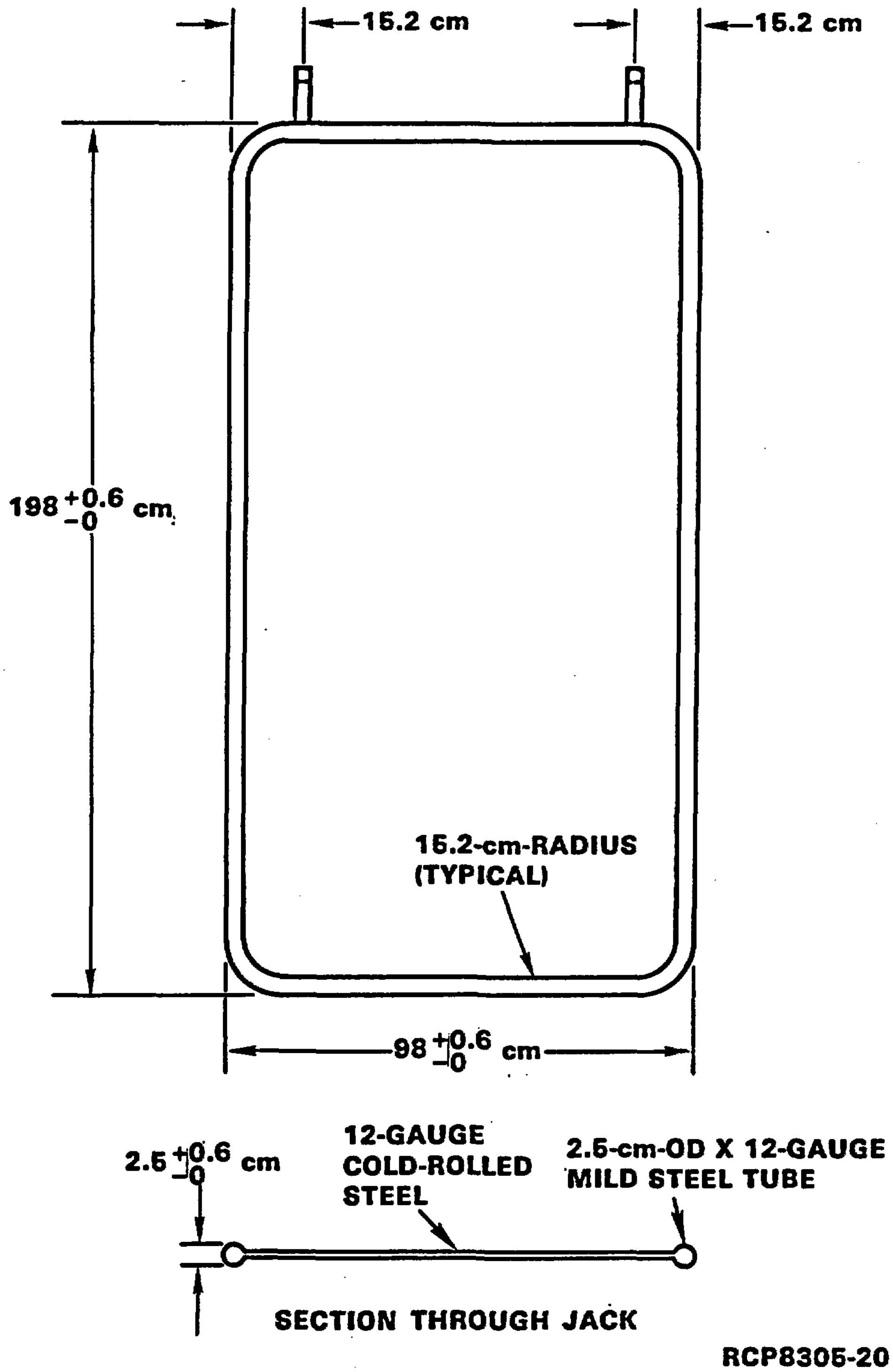

FIGURE 3. Split-Tube Flat-Jack Design.

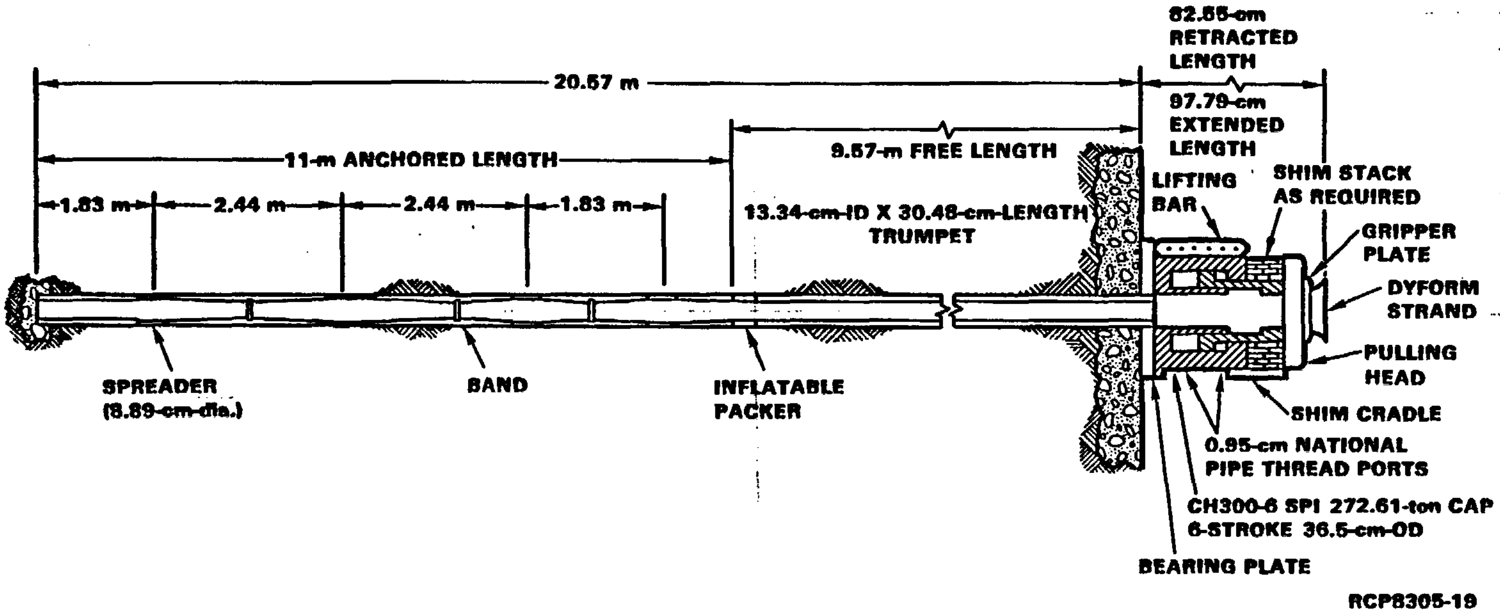

FIGURE 4. Cable Anchor System.

Several types of instrumentation are used to monitor the deformation and the stress field induced by the applied loads: borehole deformation gauges; vibrating wire stressmeters; a multiple-position borehole extensometer; deformeters installed in the flat jacks; and the principal monitoring system, the BDMS. The BDMS is an electro-optical system developed for this project to monitor the deformation of the center test block zone, in both the horizontal and vertical directions, at a depth of ~2.5 m from the tunnel wall. The BDMS has two major components, the reference light sources (targets) installed in four boreholes within the block test section and the remote optical system installed in front of the tunnel wall. The target is anchored in place by seven C-type extensometer anchors over a length of ~25 cm. The light source is brought from the flash unit outside the borehole through fiber optics and reflected back toward the face by a parabolic mirror. This collimated light is transmitted through three reticle slits at the front of each target. These slits produce the three images sensed by the electro-optical periscope. Cameras within the external apparatus detect the location of the images and a microprocessor determines relative change in position between the target image and the image location derived from another respective target. A total of six measurements are performed, including the displacement in the horizontal and vertical directions and four diagonals of the diamond formed by the four target boreholes. Resolution of the instrument is ~1 μm with a precision of 30 μm. This system is further illustrated in Figure 5.

CONSTRUCTION SEQUENCE

The block test construction consisted of five major phases:

- Drilling cable anchor, heater, and instrumentation boreholes
- Drilling flat-jack slots
- Installing grout boxes and flat jacks
- Installing cable anchor system
- Assembling borehole instrumentation and optical deformation measurement system.

The drilling of the boreholes for the cable anchor system and the other instrumentation was a fairly straightforward operation, although it was complicated by the high borehole density. A total of 26 boreholes from EX_2 (3.81-cm-) to HQ (9.63-cm-) drilling bit diameters were drilled in the 4-m^2 test block area (Fig. 6). Having boreholes in this close proximity required that alignment and setup tolerances be tightly controlled to ±1/4° and ±60 mm, respectively, to prevent potential stability problems between neighboring locations. All holes were core drilled through the 4.5-m test section. The remaining 16.5 m of the cable anchor boreholes were drilled with a downhole hammer, both to increase the production rate and to provide a slightly rougher borehole wall to improve the grout-rock bond of the anchor.

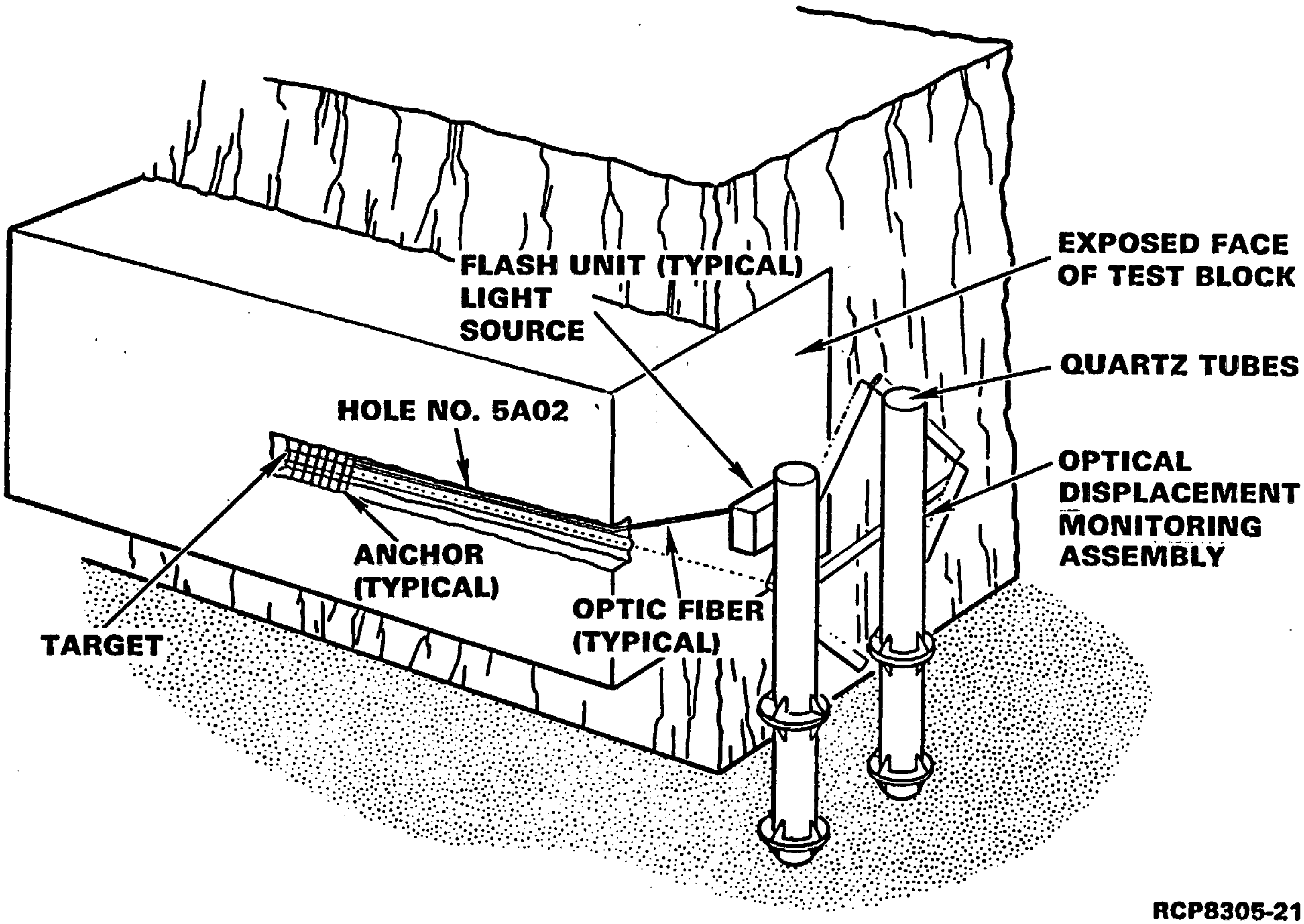

FIGURE 5. Basalt Deformation Measurement System, Conceptual Arrangement.

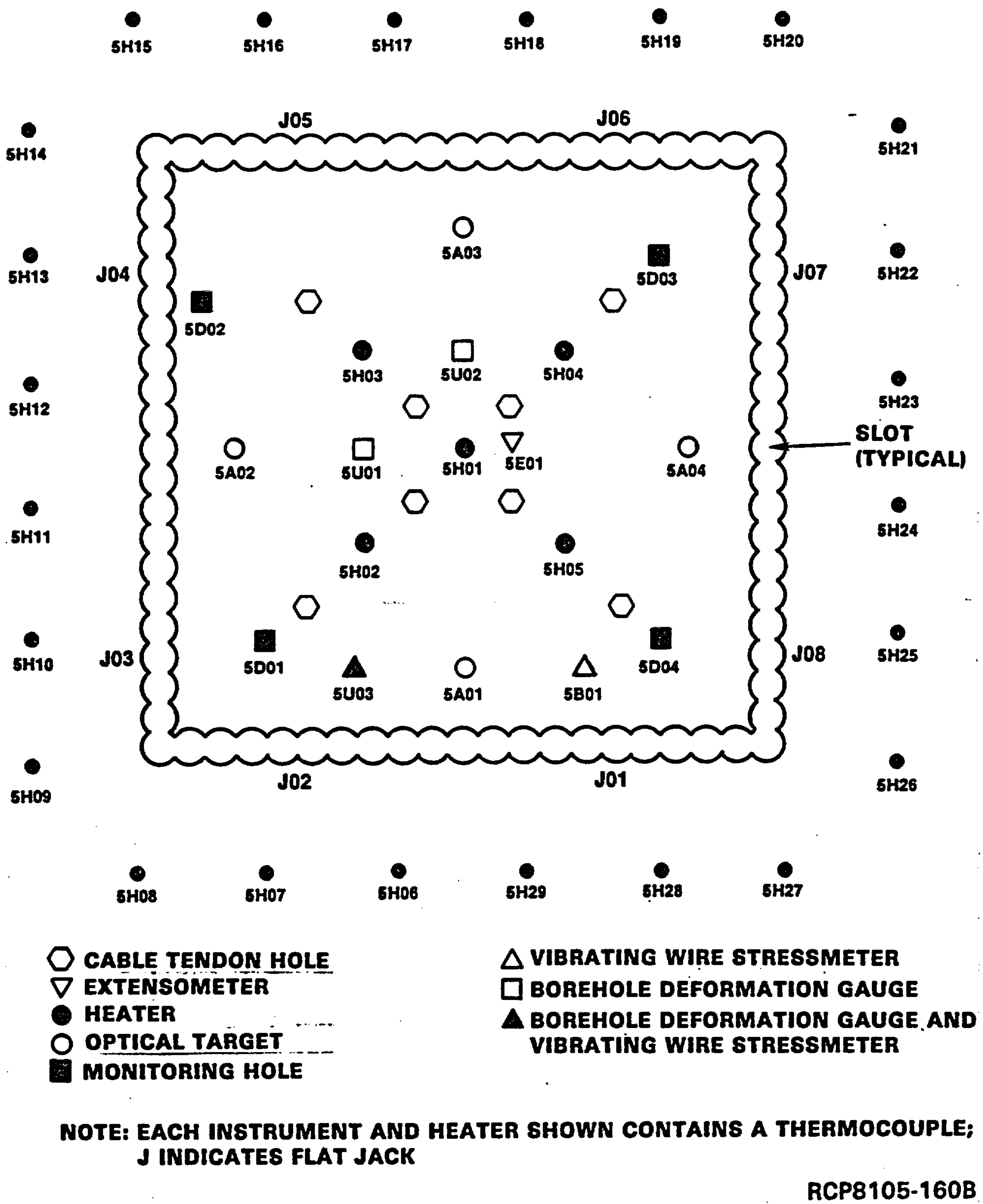

FIGURE 6. Block Test Instrument Layout.

The slot-cutting operation was a difficult and critical component of the construction effort. The slot-cutting was enhanced by a 1-m long slot drilled in an "L" shape prior to starting drilling of the block test slots. It was determined that the use of a down-the-hole-hammer mounted on an air-track boom equipped with an air-motor rotation drive offered the best alignment control and production rate. The same equipment supplied with a smaller diameter down-the-hole-hammer was used for the final 16.5 m of the cable anchor holes. The core drill (Model CP-65) was used for the heater and instrumentation holes and served as a backup for the down-the-hole-drilling. The lower horizontal slot was drilled and two flat jacks were installed prior to completing the two vertical and top horizontal slots. This was accomplished to ensure sufficient support was given to the block during subsequent slot drilling by applying a stabilization pressure to the jacks (0.2 MPa).

A single-slot flat-jack test was also conducted using this arrangement. Twenty-three overlapping 14-cm boreholes were required to complete a 2-m slot. The lack of a complete confining perimeter around the bit provided an obvious tendency to drift into the previously drilled borehole. Equally difficult was the need to maintain the integrity of the partially opened slot, since the closely jointed and fractured rock mass could "unravel."

Several different drilling sequences were attempted before the final technique was developed. This consisted of drilling boreholes on 20-cm centers across the slot and coming back to drill out the web. This sequence reduced the amount of unraveling and enhanced cutting removal. The drill string was susceptible to binding prior to adopting this sequence. Alignment was maintained using 13.3-cm-outside diameter pipes with two concave lateral grooves inserted into the adjacent boreholes. These guides also aided in the removal of cuttings, which was a particularly troublesome problem in the vertical slots where the backflush of the cuttings and slippage of the lower pipe guide (due to the weight of the downhole hammer), caused drifting and binding of the drill string. This problem was solved by increasing the hole spacing to 22 cm and air lifting out all chips from a borehole after completion. Overall, an average drilling rate of 1.35 m/hr was achieved for the slot cutting by the fixed price contractor.

The installation of the grout boxes (flat-jack receivers) also presented some unusual problems. The actual grouting procedure was quite simple, with the box being centered in the slot, all seams taped to prevent grout intrusion, and a plywood form inserted for structural support. The remaining volume of the slot outside the box was then grouted using a pressure level of ~0.5 MPa. A colloidal grout pump was used for all grouting to provide consistency to the mix and increase workability. A void was found in the upper left horizontal slot. This was regrouted using a bleeder tube located ~1 m (3 ft) above the grout surface, which was located at the grout surface during initial grouting. The regrouting was successful. The plywood form was removed subsequent to grouting. This process required elimination of voids to inhibit overexpansion and failure of the jack.

The most significant problem encountered during the grouting operation occurred after the vertical slots were cut and the boxes were installed. The plywood forms were removed due to the lack of clearance for the drill boom and the grout boxes were empty. The drilling of the upper horizontal slot was under way and approximately one-half completed when the upper box in each vertical slot collapsed away from the grout. This was apparently due to the redistribution of stresses under the upper slot, which caused the boxes to collapse. These boxes had to be removed and regrouted before the flat jacks could be installed. The installation of the flat jacks was complicated by a tolerance buildup between the flat jacks and the grout boxes. The flat-jack/grout-box interface was tight due to the stroke limitations of the flat jacks. The solution of the longitudinal alignment for the length of the grout boxes proved to be the most troublesome due to the fabrication tolerances. A graphite lubricant used in conjunction with very high forces was required for insertion.

The installation of the cable anchors, a fairly standard procedure, was complicated by the fact that the 7.6-cm bundle had to be inserted into a 9.2-cm borehole, rather than the 15-to 20-cm borehole that would normally be used. The major concern was getting the inflatable packer, which sealed off the grouted zone, down the hole intact. Several types of packer material were tried, with an air hose of 6.4-mm wall thickness finally producing the best results. The fixed price contractor installed the tendon anchors.

The assembly of the BDMS and the installation of the borehole instrumentation were successful. The onsite cost plus award fee contractor installed the flat jacks, rock monitoring instruments, and the BDMS. No major problems or delays were encountered. The precision installation of instruments required a substantial (10-wk duration) portion of the 25-wk construction effort.

CONCLUSIONS

The Block Test 1 construction effort, although complicated by a number of concerns, was completed on schedule and in a satisfactory manner. During the initial loading cycles, all systems performed as desired, producing excellent results. Beyond the actual success of this testing, what may be the most important outcome of the construction effort is the experience gained, which can be applied to future tests. For example, the drilling sequence that was eventually developed greatly improved slot-cutting capabilities in the closely jointed basalt. Additionally, the successful application of the cable anchor system and the BDMS, two devices that had not been previously used in experiments of this type, have demonstrated their viability and potential for expanded applications.

Conversely, the concerns encountered with the flat-jack/grout-box system have indicated that these devices need further development before they can be incorporated into future work. The capability of removing and replacing flat jacks during the course of a test is obviously desirable in a complex effort. One modification that may be applied to this system is the use of an inner box that fits into the existing grout box assembly. The flat jack will be placed in this inner box, which will be filled with grout to completely confine the jack. When this assembly is placed in the grout box, the system will fit together smoother and provide support to the flat jack. Modifications to the flat-jack design are also being investigated to increase the pressure capacity. Other ideas that are being considered include simplification of the BDMS arrangement to increase its flexibility and arrangements to increase the loading capacity of the cable anchor system. Overall, the experience and developments gained during this block test operation should greatly increase the simplicity and productivity of future in situ tests of this type.

DISTRIBUTION

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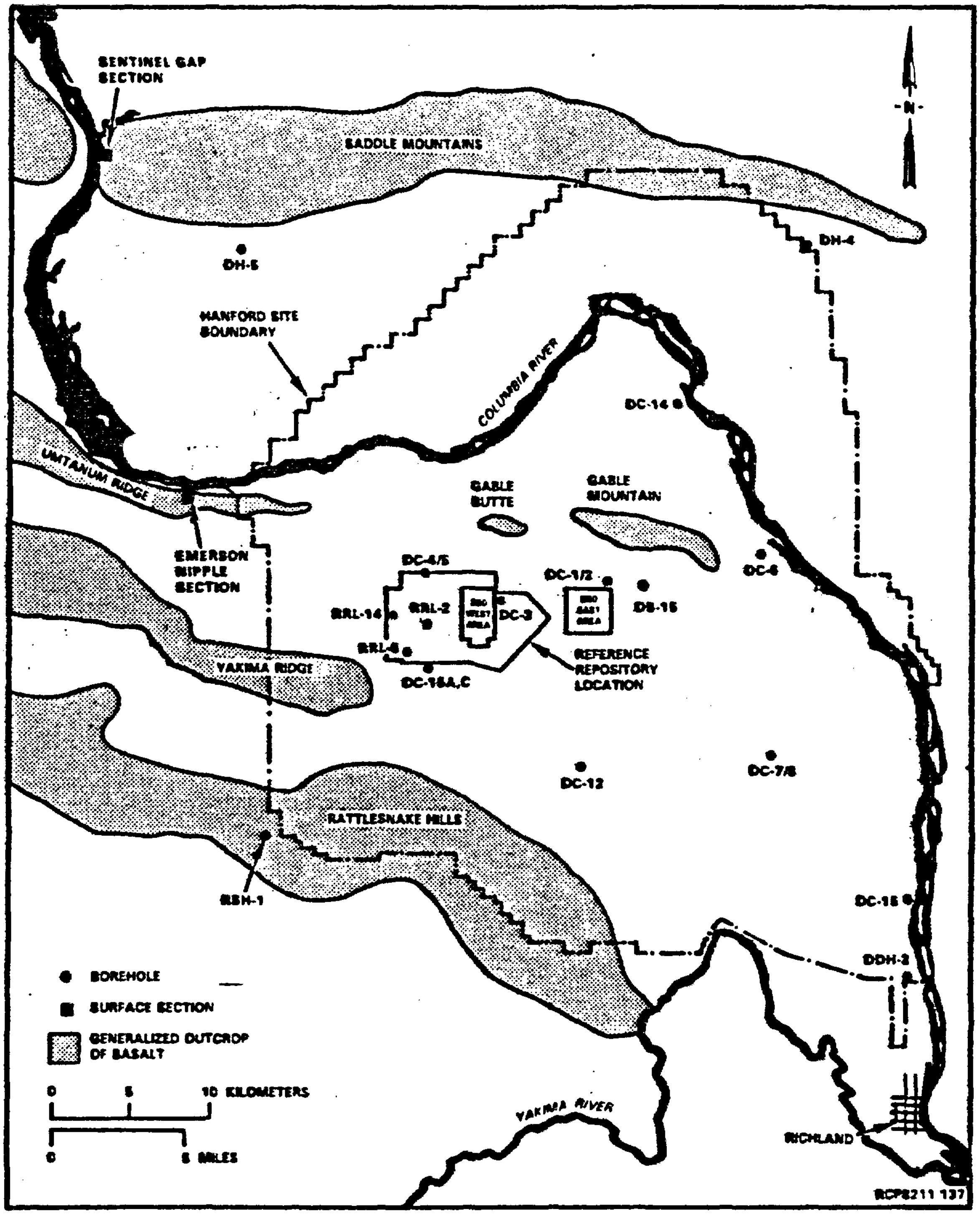
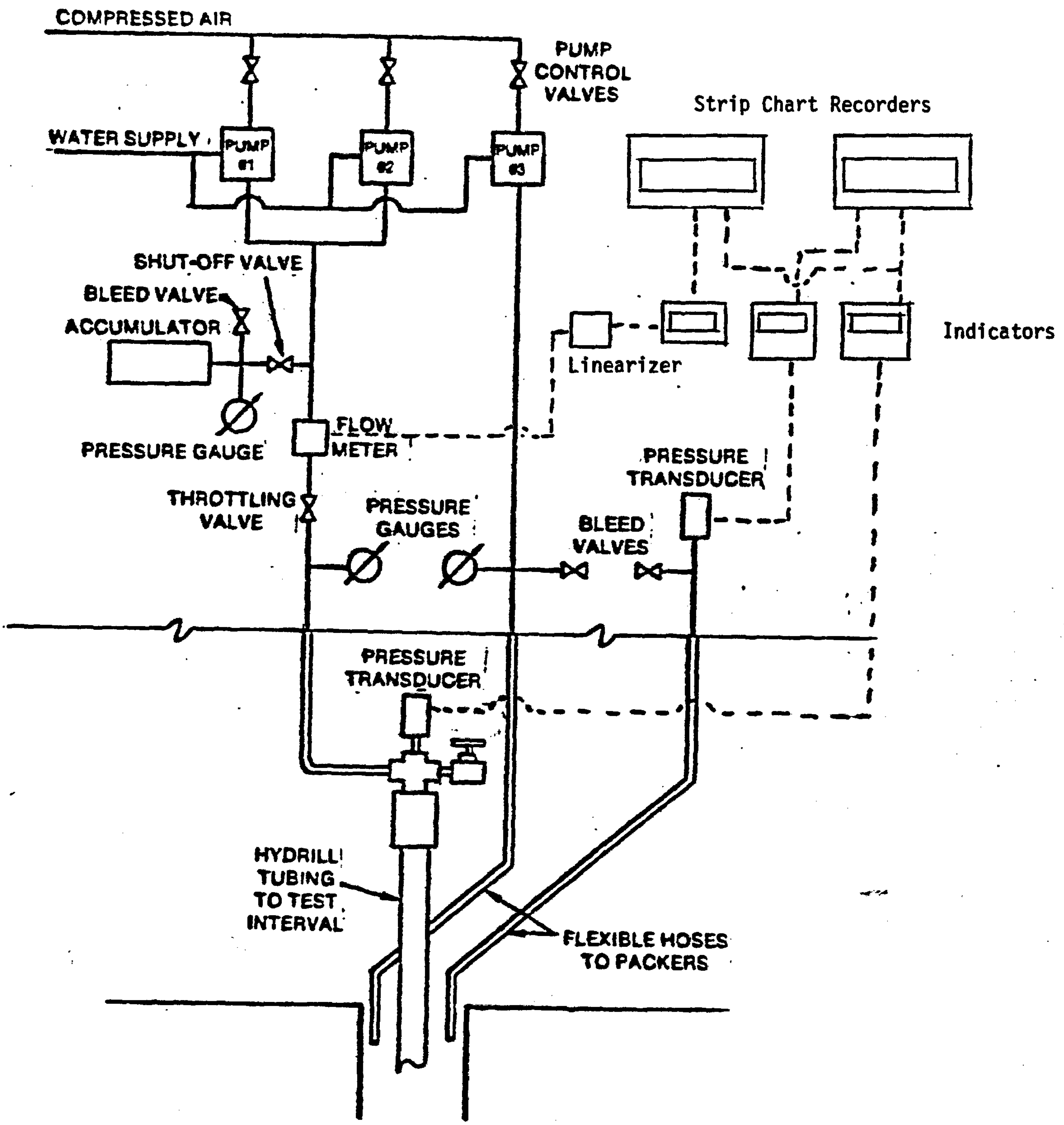


Borehole Location Map

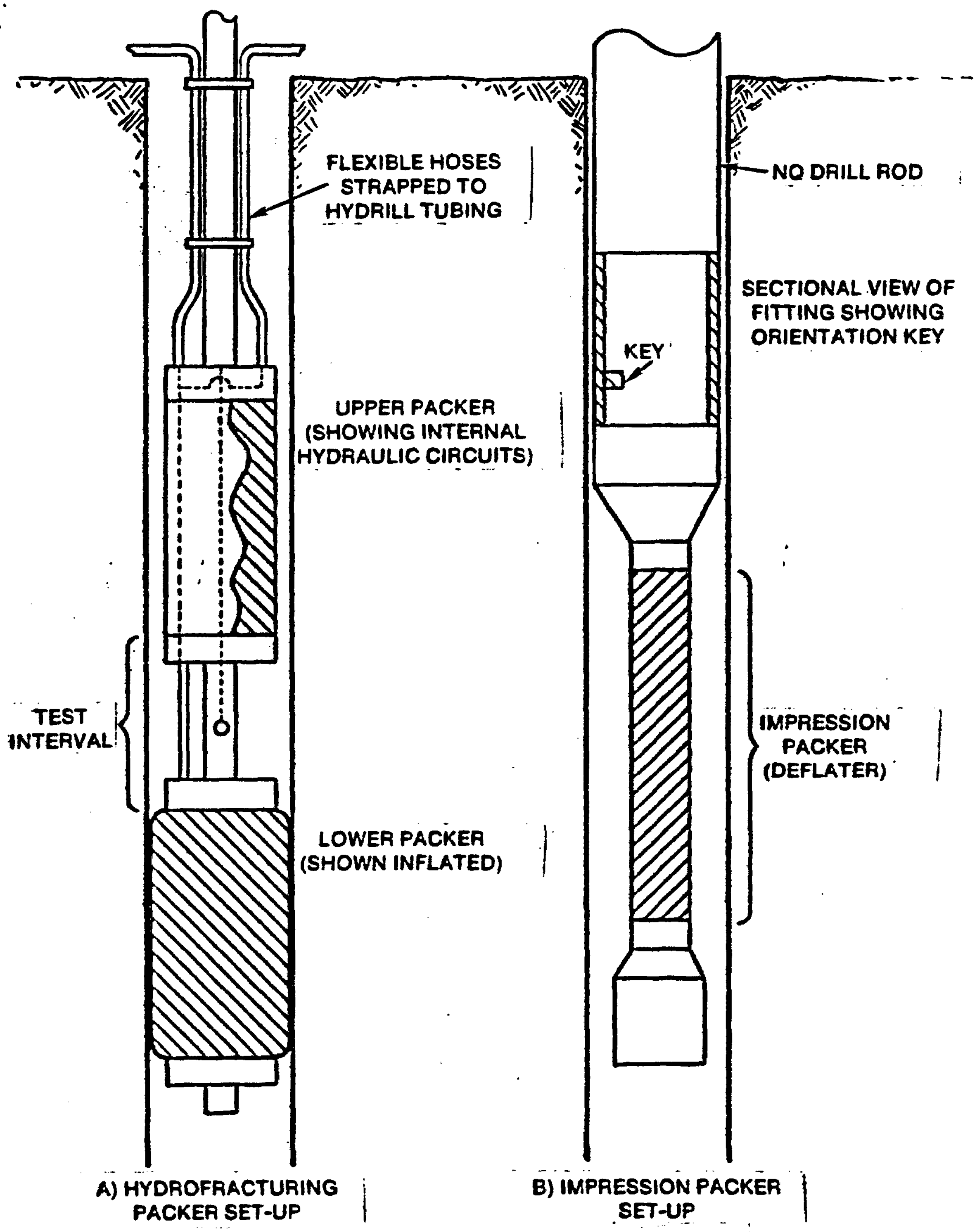
HYDROFRACTURING TESTS CONDUCTED TO DATE

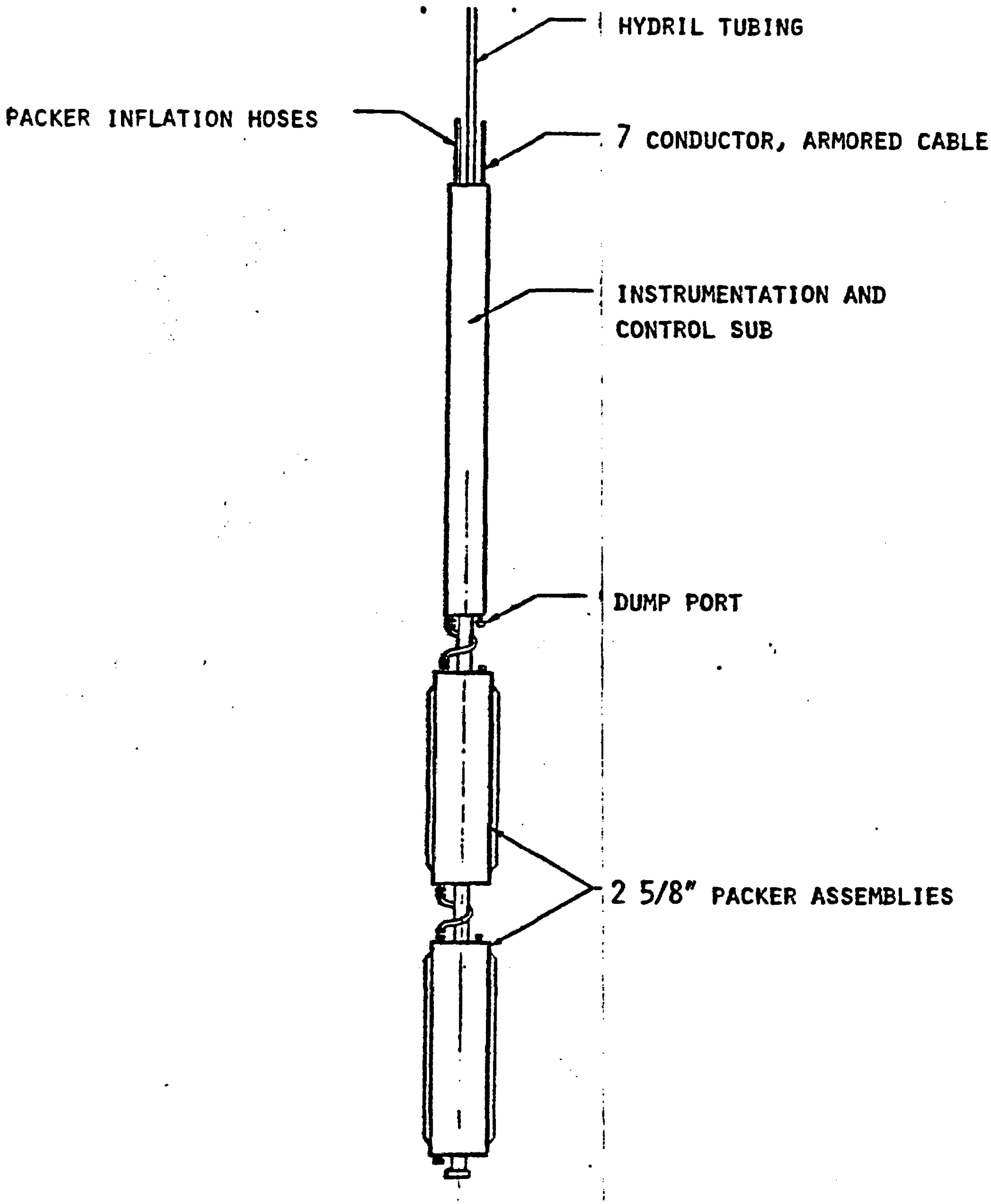
Borehole #	Test #	Depth to center of fracture interval *	Basalt flow
DC-12	1	3417	Umtanum
	2	3400	
	3	3382	
	4	3350	
	5	3323	
	6	3288	
RRL-2	1B	3831	Umtanum
	1A	3822	
	2B	3806.5	
	2A	3801	
	3B	3786	
	3A	3782	
	4B	3768	
	4A	3762	
	5B	3471	Grande Ronde #7
	11A	3466	
	6B	3457.5	
	7B	3251.5	Cohassett
	10A	3247.5	
	5A	3244	
	8B	3234	
	6A	3231	
	9B	3181	
	7A	3174	
	10B	3106	
	8A	3102	
	11B	3053	
	9A	3043.5	
	12A	3030	
RRL-6	9	3919	Umtanum
	8	3900.5	
	7	3709	McCoy Canyon
	6	3637	
	5	3624	
	4	3340.5	Cohassett
	3	3336	
	2	3306	
	1	3084	Rocky Coulee
DC-4	2	3202	Cohassett
	1	3170.5	
	3	3021	

* Fracture interval is two feet in length for all tests

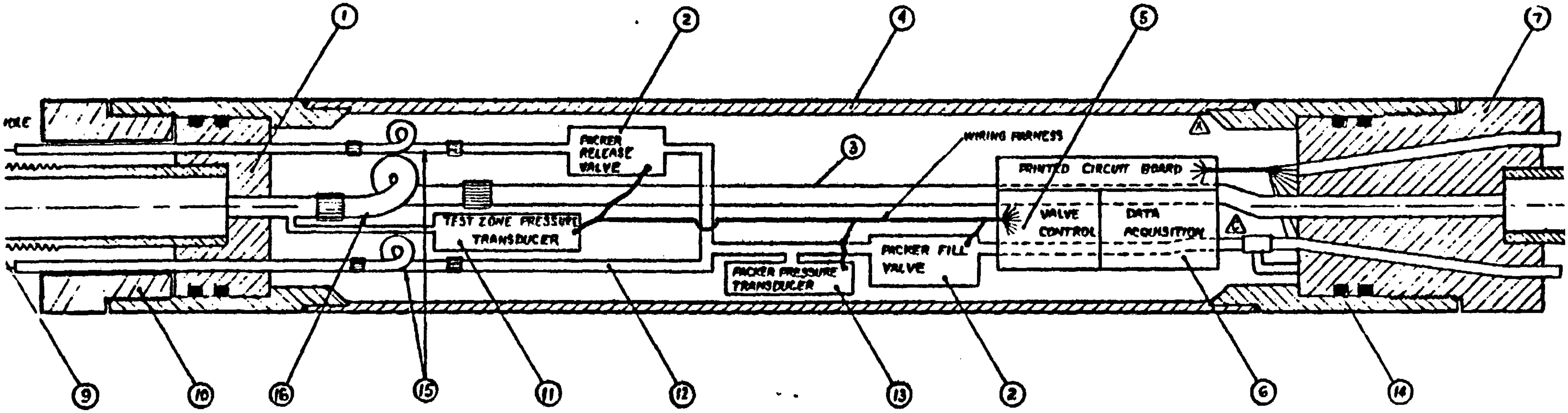


Instrumentation and Mechanical layout for Hydrofracturing Tests

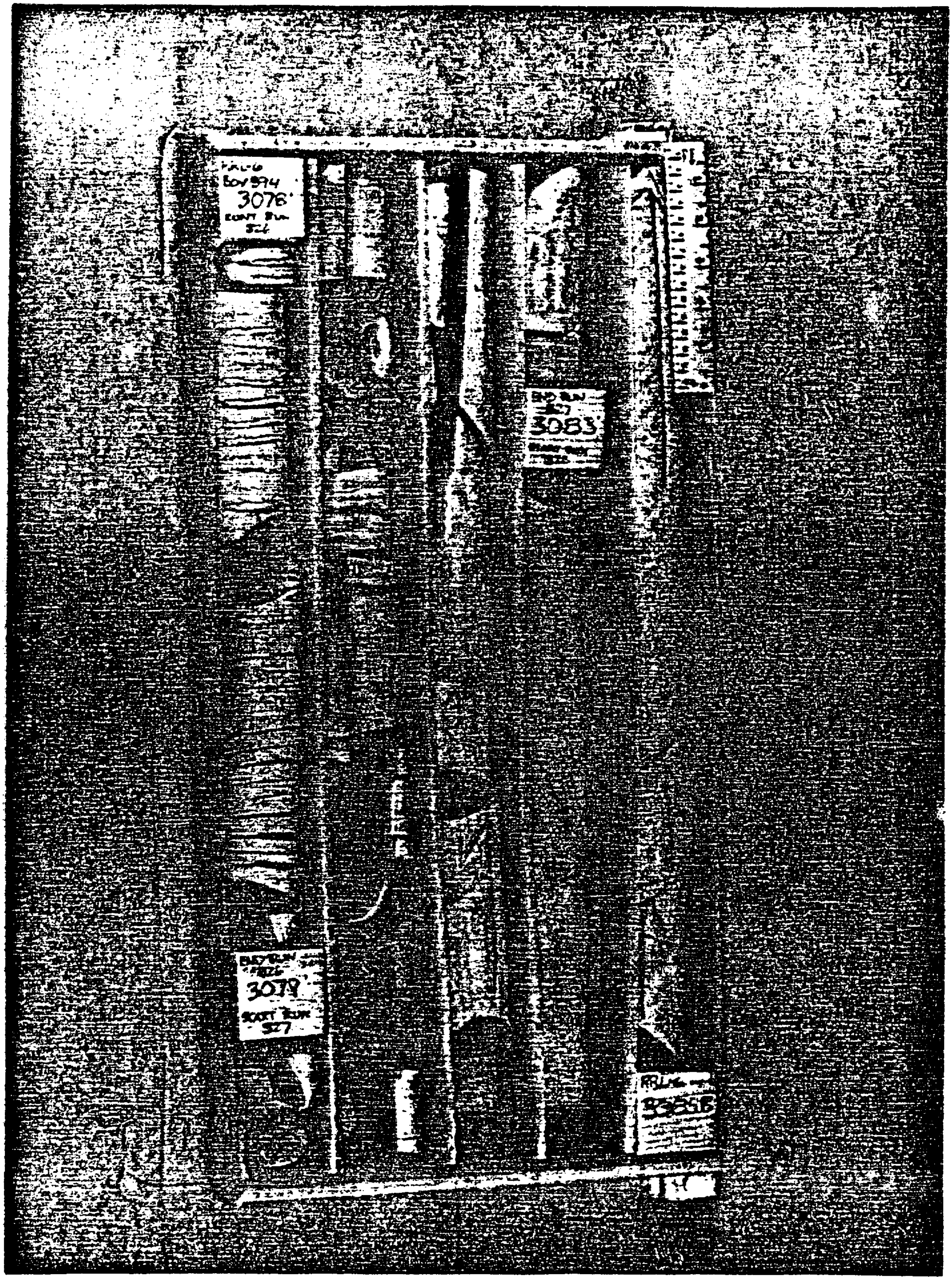

FLEXIBLE HOSES STRAPPED TO HYDRILL TUBING
UPPER PACKER (SHOWING INTERNAL HYDRAULIC CIRCUITS)
TEST INTERVAL
LOWER PACKER (SHOWN INFLATED)
A) HYDROFRACTURING PACKER SET-UP
NQ DRILL ROD
SECTIONAL VIEW OF FITTING SHOWING ORIENTATION KEY
KEY
IMPRESSION PACKER (DEFLATER)
B) IMPRESSION PACKER SET-UP



DOWNHOLE EQUIPMENT USED FOR HYDROFRACTURING TESTS IN DC-4

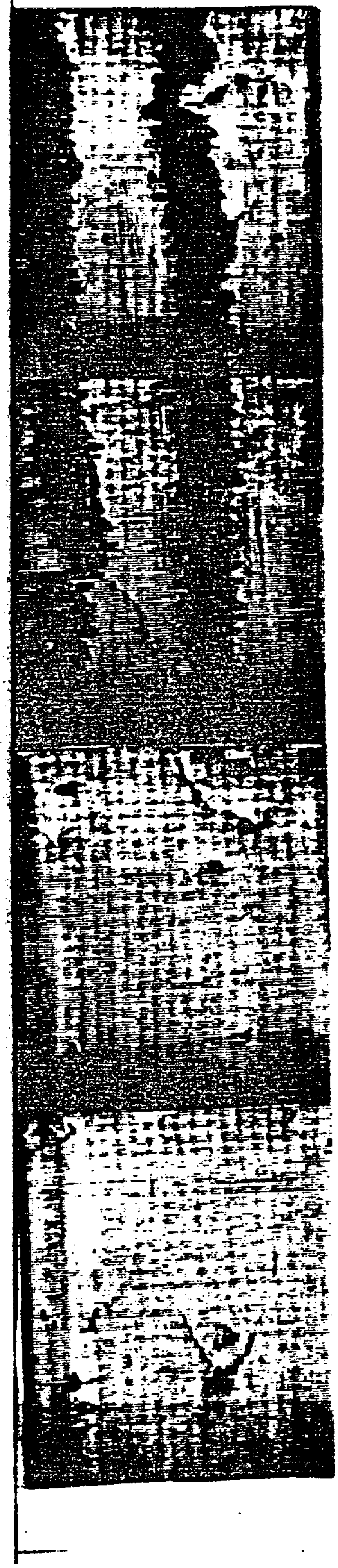


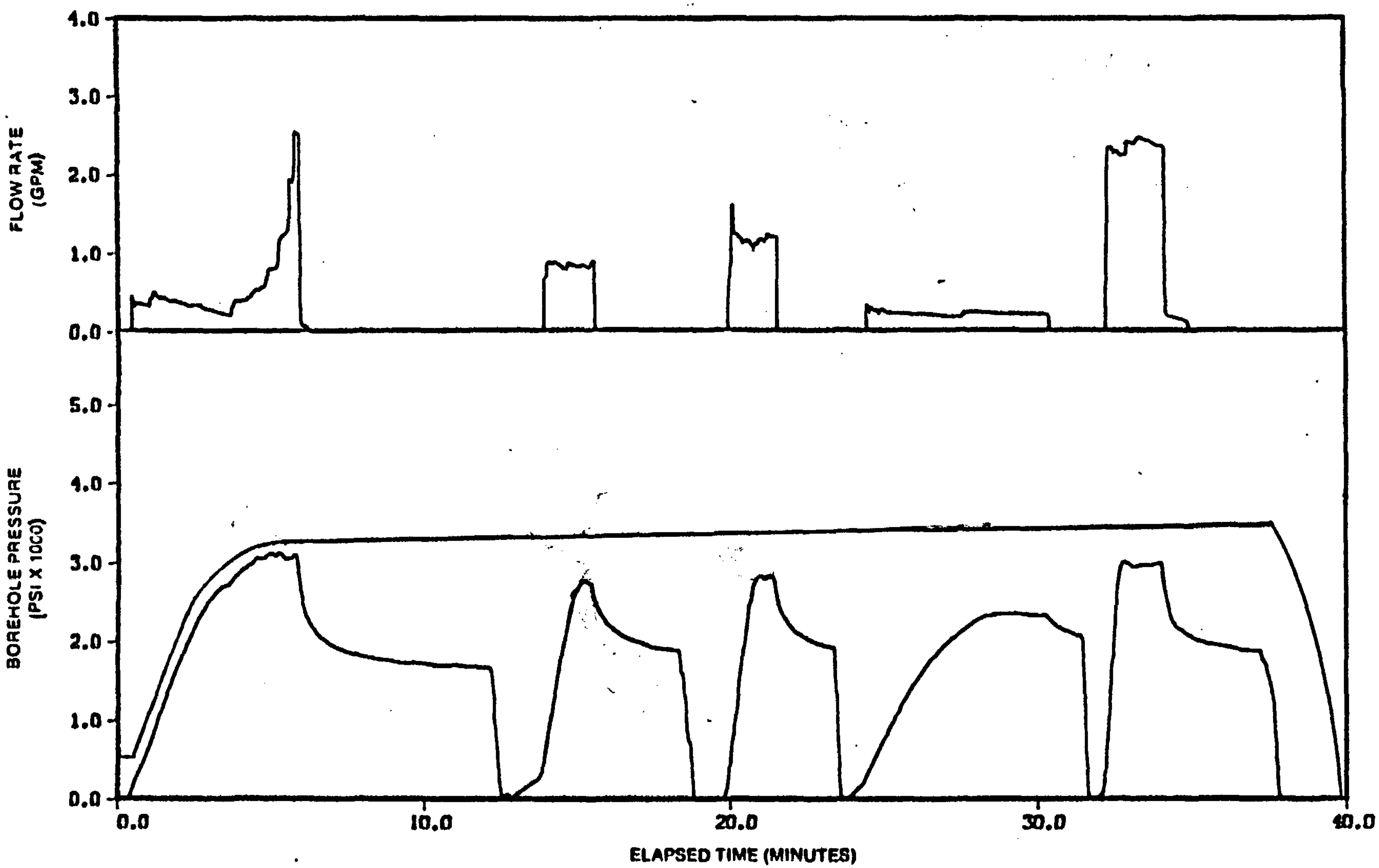
CONCEPTUAL DRAWING ONLY



Core Photo from Borehole RRL-6

COREHOLE RRL-6
USGS SEISVEIW
ROCKY COULEE



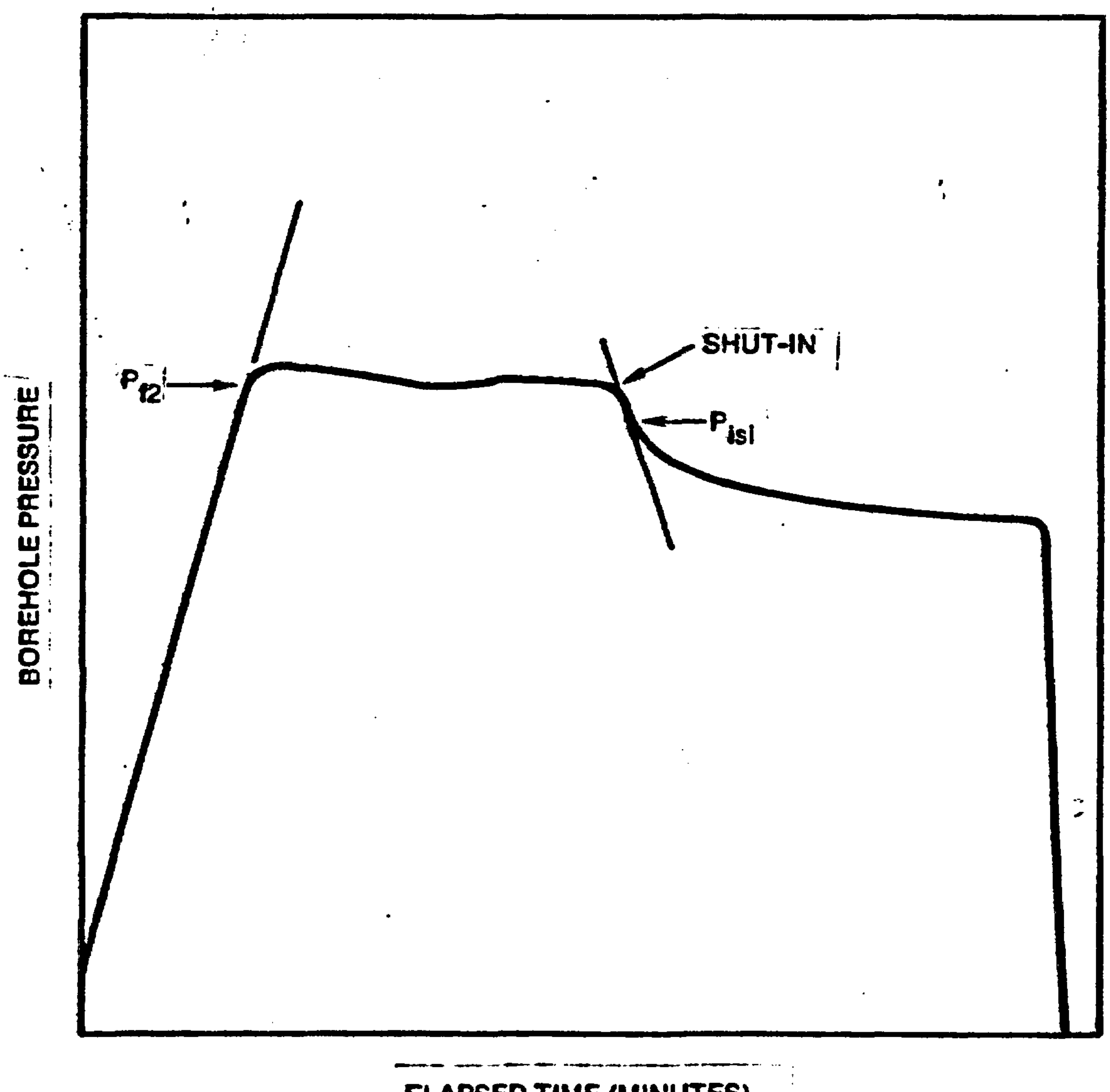

4.0
3.0
2.0
1.0
0.0
FLOW RATE (GPM)
5.0
4.0
3.0
2.0
1.0
0.0
BOREHOLE PRESSURE (PSI X 1000)
0.0
10.0
20.0
30.0
40.0
ELAPSED TIME (MINUTES)

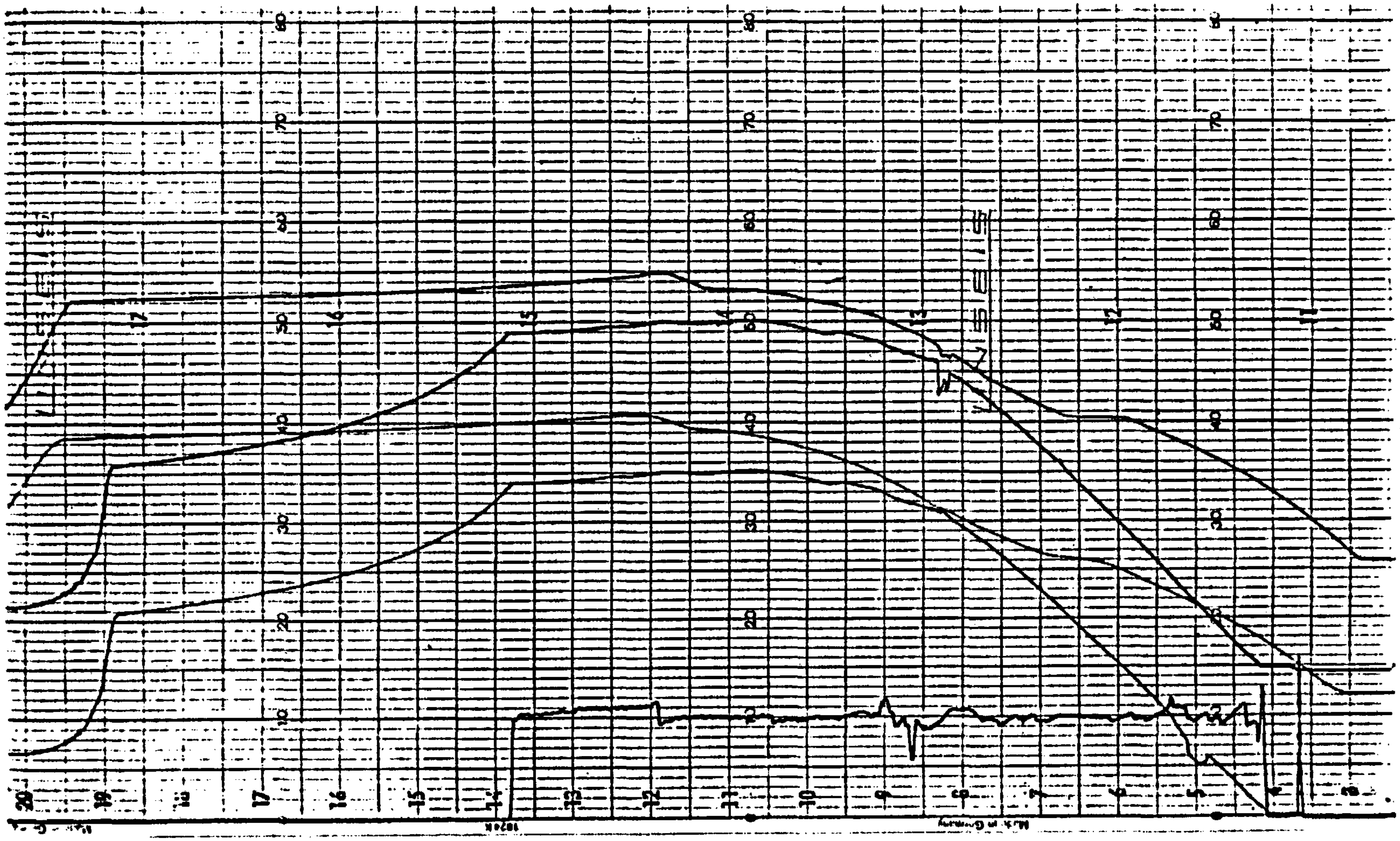
$$\sigma_H = 3\sigma_h - P_b - P_o + T$$

$$T = P_b - P_{f2}$$

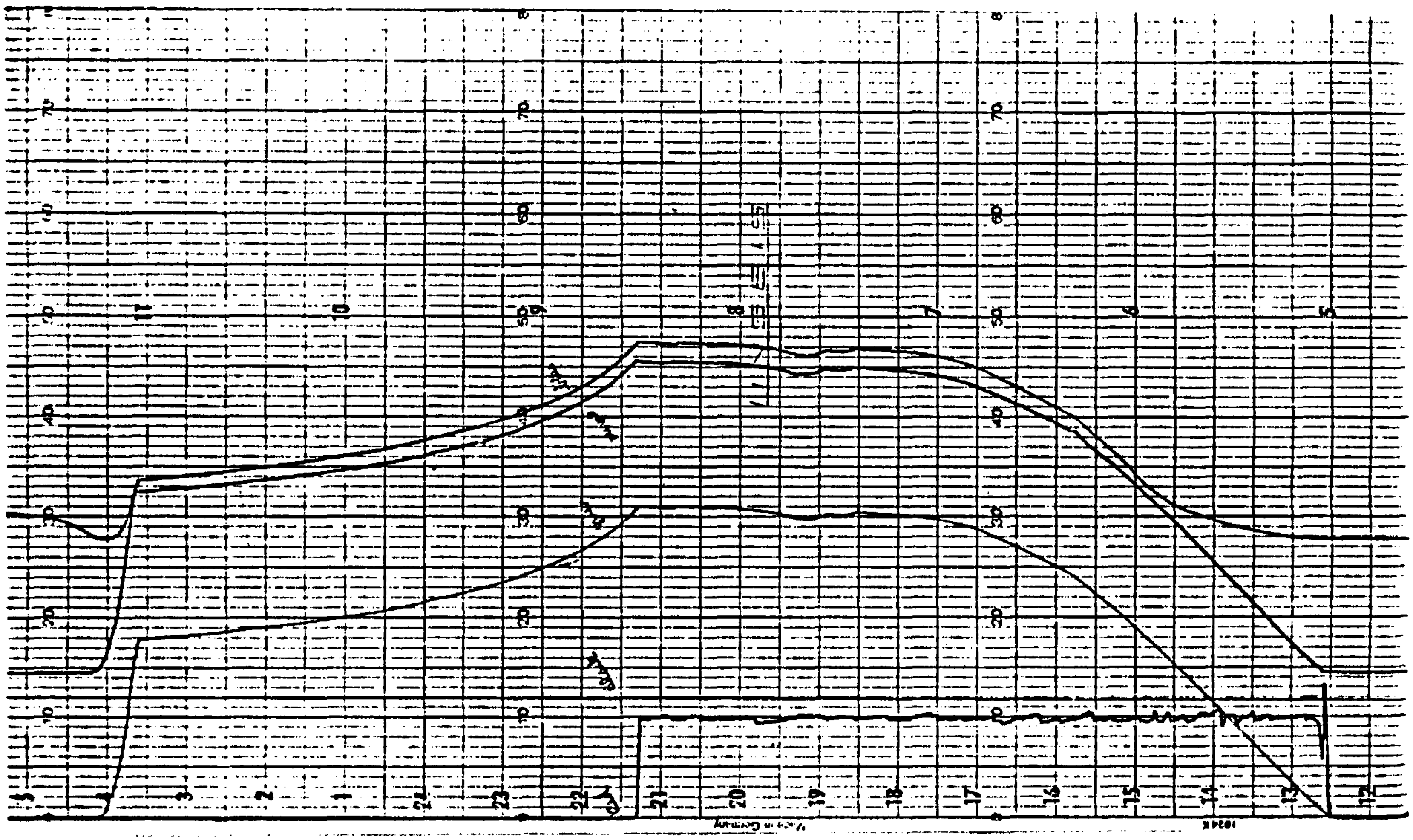
$$\sigma_H = 3\sigma_h - P_{f2} - P_o$$

$$\sigma_h = P_{isi}$$

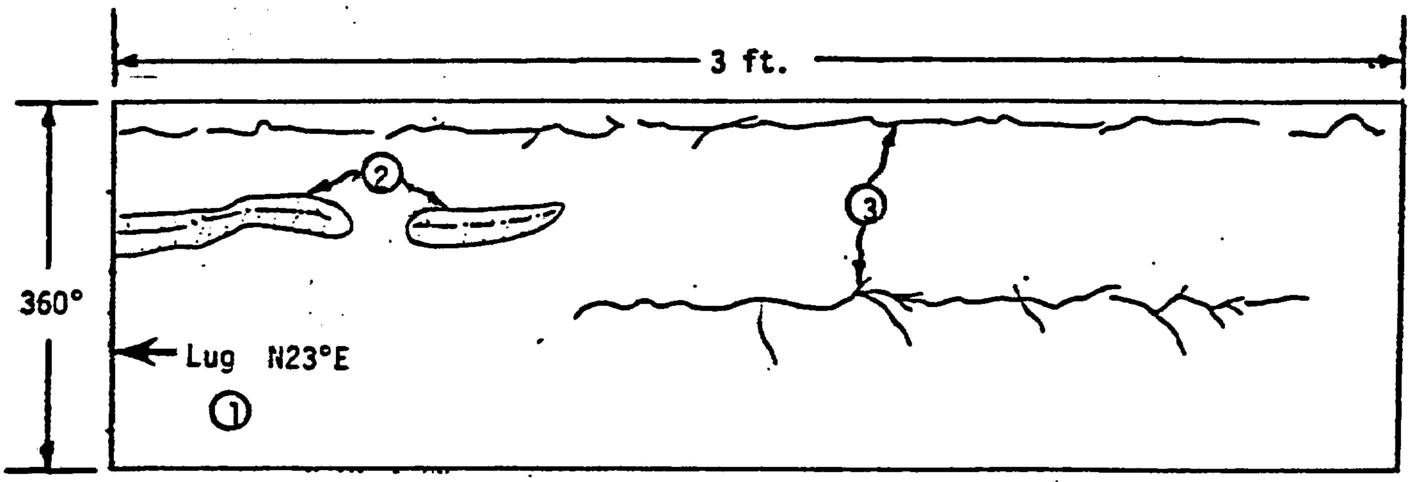




UPHOLE AND DOWNHOLE DATA COLLECTED FROM A HYDROFRACTURING TEST WITH PACKER PRESSURES CONTROLED FROM THE SURFACE.



UPHOLE AND DOWNHOLE DATA COLLECTED FROM A HYDROFRACTURING TEST PRESSURE CYCLE WITH THE PACKER INFLATION VALVE CLOSED.



① Indicates orientation of that point on the record and the direction to the surface.

② Borehole breakout zones.

③ Hydraulically induced fractures.

EXAMPLE OF A TRACING FROM AN IMPRESSION PACKER

TEST PLANS

SD-BWI-TP-018

"Test Plan For In Situ Stress Measurement by the Hydraulic Fracturing Method in Borehole RRL-2."

SD-BWI-TP-030

"Test Plan For In Situ Stress Measurement by the Hydraulic Fracturing Method in Boreholes RRL-6 and DC-4."

TEST REPORTS

SD-BWI-TD-006

"Summary of Borehole RRL-2 Hydraulic Fracturing Test Data and Data Analysis Methods."

RHO-BW-SA-257 P

"In Situ Stress Measurement at a Candidate Repository Horizon."

ROCK MECHANICS LABORATORY TESTING ACTIVITIES

- Existing Data
- Current Work
- Data Base Organization
- Future Work

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ROCK MECHANICS LABORATORY DATA

Location	Reports
DC-10	C-11
DC-11	C-38
DH-4	C-38
DH-5	C-38, LBL-7038
DDH-3	C-38
DC-2	C-38, C-92
DC-4	C-55
DC-6	C-50
DC-8	C-54
DB-5	C-76, LBL-7038
DB-15	C-76
NSTF	LBL Letter Report
FS#1	C-77
FS#2	C-85
Area 3	C-100
RRL-2	SD-BWI-TD-002 LBL Letter Report
RRL-6	SD-BWI-TD-003
RRL-14	SD-BWI-TD-004

Summary Reports: SD-BWI-DP-041
RHO-BWI-C-90

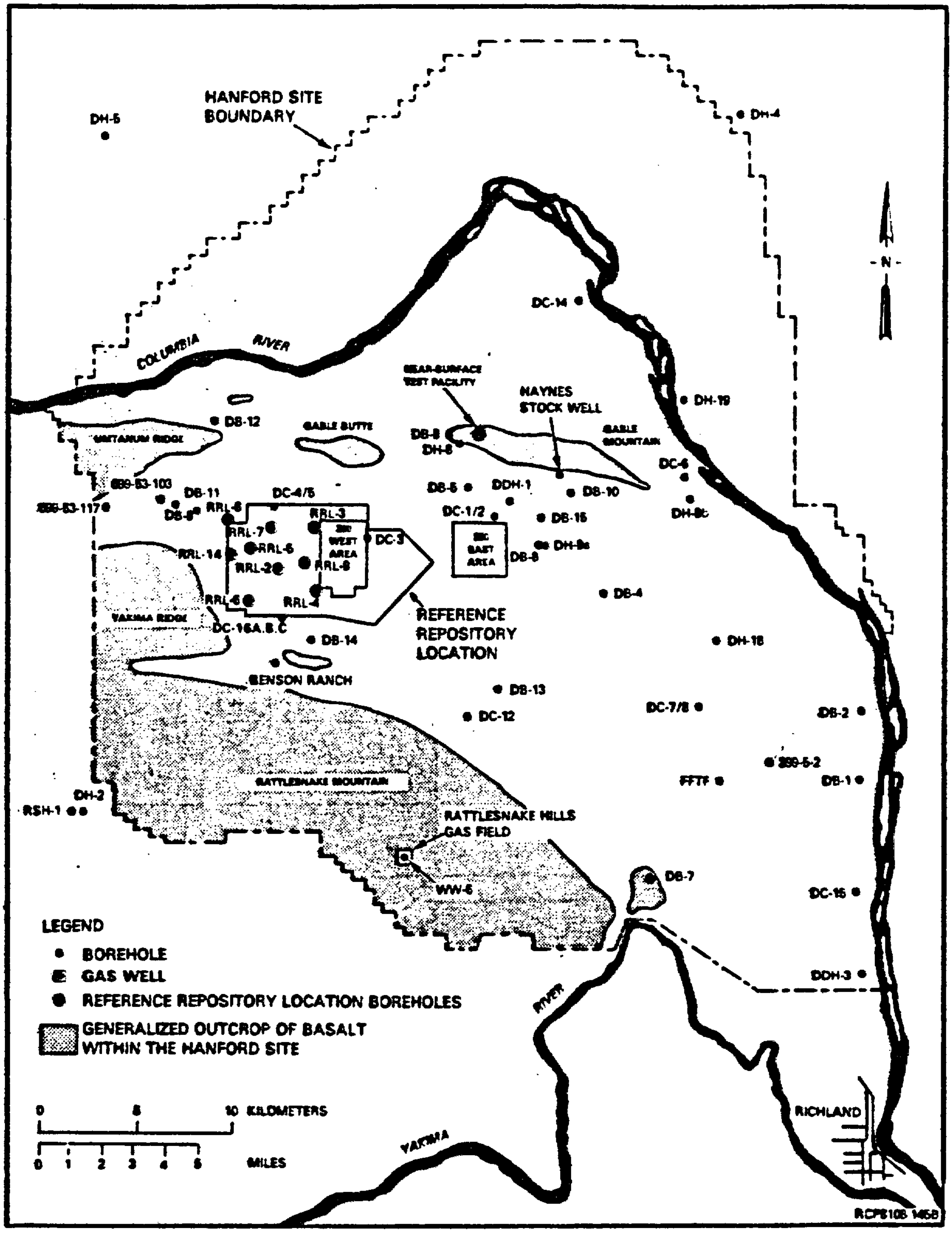

FIGURE 3-3. Location Map for Key Boreholes Used in Basalt Waste Isolation Project Studies.

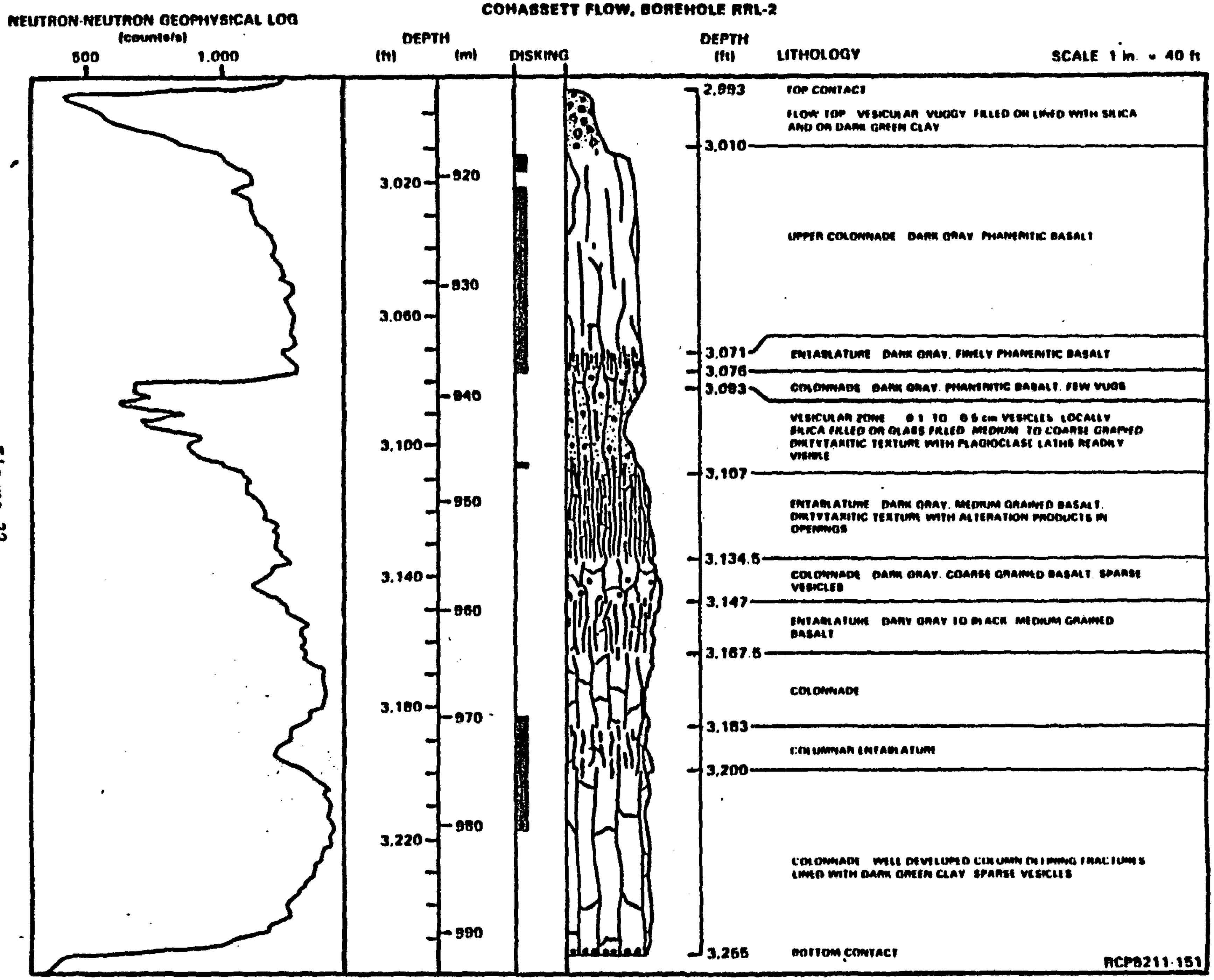
COHASSETT FLOW, BOREHOLE RRL-2
NEUTRON-NEUTRON GEOPHYSICAL LOG (counts/s)
500
1,000
DEPTH (ft) (m)
DISKING
DEPTH (ft)
LITHOLOGY
SCALE 1 in. = 40 ft
2,993 TOP CONTACT
FLOW TOP VESICULAR VUGGY FILLED OR LINED WITH SILICA AND OR DARK GREEN CLAY
3,010
UPPER COLONNADE DARK GRAY PHANERITIC BASALT
3,071 ENTABLATURE DARK GRAY, FINELY PHANERITIC BASALT
3,076
3,083 COLONNADE DARK GRAY, PHANERITIC BASALT, FEW VUGS
VESICULAR ZONE 0.1 TO 0.5 cm VESICLES LOCALLY SILICA FILLED OR GLASS FILLED MEDIUM TO COARSE GRAINED DIKTYTAXITIC TEXTURE WITH PLAGIOCLASE LATHS READILY VISIBLE
3,107
ENTABLATURE DARK GRAY, MEDIUM GRAINED BASALT, DIKTYTAXITIC TEXTURE WITH ALTERATION PRODUCTS IN OPENINGS
3,134.5
COLONNADE DARK GRAY, COARSE GRAINED BASALT, SPARSE VESICLES
3,147
ENTABLATURE DARY GRAY TO BLACK MEDIUM GRAINED BASALT
3,167.5
COLONNADE
3,183
COLUMNAR ENTABLATURE
3,200
COLONNADE WELL DEVELOPED COLUMN DEFINING FRACTURES LINED WITH DARK GREEN CLAY SPARSE VESICLES
3,265 BOTTOM CONTACT
3,020
3,060
3,100
3,140
3,180
3,220
920
930
940
950
960
970
980
990
RCP8211-151

Figure 32

TABLE 4. PHYSICAL AND MECHANICAL PROPERTIES OF INTACT COHASSETT RRL BASALT

INTRAFLOW STRUCTURE	UNIAXIAL COMPRESSIVE STRENGTH	BULK DENSITY	YOUNG'S MODULUS (Static)	POISSON'S RATIO (Static)	BRAZILIAN TENSILE STRENGTH	MODULUS OF RUPTURE
	MPa	g/cc	GPa	dimensionless	MPa	MPa
Flowtop/Breccia						
No. of Samples	10	26	2	2	15	-
Mean	62.08	2.28	31.79	.20	6.53	-
Standard Deviation	19.10	.115	4.87	.08	1.82	-
Range	18.70-97.60	1.92-2.47	28.34-35.23	0.14-0.25	2.65-12.10	-
80% Confidence Interval	53.53-70.62	2.24-2.30	21.19-42.39	.048-.342	5.89-7.17	-
Vesicular						
No. of Samples	9	20	4	4	8	-
Mean	163.63	2.62	51.44	.29	9.99	-
Standard Deviation	63.34	0.09	6.39	.06	1.99	-
Range	70.13-244.38	2.45-2.77	45.02-56.13	0.21-0.33	6.25-14.43	-
80% Confidence Interval	133.24-194.03	2.59-2.65	45.41-57.46	.228-.342	8.95-10.03	-
Entablature						
No. of Samples	18	73	41	41	22	1
Mean	291.6	2.84	75.60	.25	14.54	42.09
Standard Deviation	18.90	.214	5.83	.02	3.32	-
Range	214.74-407.84	2.72-2.89	62.80-85.74	0.22-0.29	8.73-19.57	-
80% Confidence Interval	285.60-297.56	2.80-2.87	74.44-76.77	.248-.254	13.60-15.48	-
Colonnade						
No. of Samples	11	62	30	30	23	2
Mean	288.30	2.81	72.76	.25	15.8	39.40
Standard Deviation	38.31	.05	7.23	.02	2.36	4.45
Range	214.06-355.16	2.64-2.88	51.78-86.67	0.20-0.28	8.27-20.62	36.25-42.54
80% Confidence Interval	272.08-304.53	2.81-2.82	71.02-74.50	.246-.254	15.17-16.48	29.72-49.09

TABLE 4. PHYSICAL AND MECHANICAL PROPERTIES OF INTACT COHASSETT RRL BASALT

INTRAFLOW STRUCTURE	YOUNG'S MODULUS (Dynamic)	SHEAR MODULUS (Dynamic)	BULK MODULUS (Dynamic)	POISSON'S RATIO (Dynamic)	GRAIN DENSITY	APPARENT POROSITY	TOTAL POROSITY
	GPa	GPa	GPa	dimensionless	g/cc	percent	percent
Flowtop/Breccia							
No. of Samples	4	4	4	4	7	26	7
Mean	43.55	17.95	26.05	.22	2.91	13.93	23.24
Standard Deviation	3.75	2.00	2.29	.06	.05	3.6	5.32
Range	31.2-57.0	12.6-23.1	15.9-35.6	0.13-0.24	2.86-3.00	9.3-25.0	16.8-29.5
80% Confidence Interval	40.02-47.08	16.06-19.84	23.89-28.21	.16-.27	2.88-2.94	13.03-14.85	20.16-26.32
Vesicular							
No. of Samples	8	8	8	8	5	20	5
Mean	54.68	21.99	37.49	.24	2.92	5.07	12.02
Standard Deviation	5.19	1.83	4.85	.02	.02	1.92	1.50
Range	39.8-64.0	17.2-24.6	19.2-55.6	0.16-0.31	2.91-2.94	1.6-10.1	11.3-14.8
80% Confidence Interval	51.97-57.38	21.03-22.94	34.95-40.02	.23-.25	2.903-2.937	4.493-5.637	10.76-13.29
Entablature							
No. of Samples	64	64	64	64	19	73	20
Mean	76.09	31.00	47.70	.24	2.92	1.60	2.85
Standard Deviation	5.67	2.84	8.17	.02	.02	.76	.79
Range	62.6-86.0	24.0-45.1	13.1-60.1	0.17-0.31	2.87-2.97	0.1-5.2	1.4-5.1
80% Confidence Interval	75.18-76.99	30.54-31.46	46.39-49.01	.23-.24	2.91-2.93	1.48-1.71	2.62-3.08
Colonnade							
No. of Samples	52	52	52	52	21	62	20
Mean	74.01	29.81	48.21	.24	2.95	2.74	4.37
Standard Deviation	6.92	2.82	6.48	.03	.03	1.45	1.47
Range	55.1-83.3	22.6-34.4	30.4-63.8	0.15-0.30	2.89-3.01	0.1-8.9	1.7-10.1
80% Confidence Interval	72.78-75.24	29.31-30.32	47.06-49.36	.24-.25	2.94-2.96	2.51-2.98	3.92-4.81

TABLE 12. Thermal Properties of Hanford Basalts.*

PROPERTY	GRANDE RONDE BASALT		SADDLE MOUNTAINS BASALT
	COHASSETT FLOW	UMTANUM FLOW	POMONA FLOW
Heat Capacity			
(cal/g°C)			
No. of Samples	3	9	26
Linear Regression	$Cp=0.183 + 1.95 \times 10^{-4}T^*$	$Cp=0.206 + 1.4 \times 10^{-4}T^*$	$Cp=0.202 + 1.24 \times 10^{-4}T^*$
Standard Deviation			
o of y about x	2.23×10^{-3}	0.0164	0.0153
o slope	6.17×10^{-6}	2.69×10^{-5}	1.54×10^{-5}
Thermal Conductivity			
(W/m°C)			
No. of Samples	6	11	30
Mean	1.51	1.71	1.85
Standard Deviation	0.152	0.478	0.38
Range	1.32-1.74	1.27-2.46	1.16-2.65
80% Confidence Interval	1.42-1.60	1.51-1.91	1.76-1.94
Coefficient of thermal Expansion			
(με/°C)			
No. of Samples	2	9	38
Mean	6.02	6.51	6.40
Standard Deviation	0.42	0.33	1.16
Range	5.72-6.31	5.93-7.00	4.80-8.73
80% Confidence Interval	5.11-6.92	6.36-6.67	6.16-6.64

*T = Temperature (°C): 20° to 200°C

McCoy Canyon ?
Rocky Coulee ?

MECHANICS LABORATORY
TESTING ON RRL 14 CORE SPECIMENS

SAMPLE NUMBER	BULK DENSITY (g/cc)	GRAIN DENSITY (g/cc)	APPARENT POROSITY (%)	TOTAL POROSITY (%)	DYNAMIC ELASTIC PROPERTIES: P WAVE VELOCITY (M/SEC)	S WAVE VELOCITY (M/SEC)	YOUNG'S MODULUS (GPa)	SHEAR MODULUS (GPa)	BULK MODULUS (GPa)	POISSON'S RATIO	STATIC ELASTIC PROPERTIES: YOUNG'S MODULUS (GPa)	POISSON'S RATIO	STRENGTH: CONFINEMENT PRESSURE (MPa)	COMPRESSIVE STRENGTH (MPa)	BRAZILIAN TENSILE STRENGTH (MPa)	MODULUS OF RUPTURE (MPa)	CHARACTERIZATION I = INTACT; J = JOINTED	COMMENTS
RRL 14-3122-4	2.76	-----	3.5	------	5496	3422	76.5	32.3	40.3	0.18	B---	B---	0	280.83	----	----	J	Col
3122-6A	2.76	2.88	4.1	4.2	5247	3022	63.1	25.2	42.4	0.25	62.06	0.27	0	159.85	----	----	J	Col
3122-6B	2.75	2.88	4.0	4.5	5159	3106	64.5	26.5	37.8	.22	B---	B---	0	168.90	----	----	J	Col
3122-9A	2.72	-----	4.5	----	5061	3037	61.1	25.1	36.2	.22	51.64	.20	0	264.98	----	----	J	Col
3122-9B	2.74	-----	4.3	-----	5286	3031	63.2	25.2	43.0	.26	B---	B---	0	166.75	----	----	J	Col
3123-1	2.78	2.96	3.1	6.1	5346	3089	66.3	26.5	44.1	.25	---	---	---	-----	16.54	----	I	Col
3130-0A	2.82	------	2.3	-----	5386	3176	70.2	28.4	43.9	.23	67.50	.22	27.6	593.73	----	----	I	Ent
3130-0B	2.82	------	2.2	-----	5438	3221	72.0	29.3	44.4	.23	67.64	.24	20.7	496.62	----	----	I	Ent
3135-2	2.80	2.95	2.8	5.1	5428	3177	70.1	28.3	44.8	.24	71.71	.26	0	323.20	----	----	J	Ent
3164-5A	2.84	-----	2.6	----	5638	2976	65.7	25.1	56.7	.31	67.98	.23	0	365.57	----	----	I	Ent
3164-5B	2.84	-----	2.6	----	5534	3253	74.3	30.1	46.9	.24	70.88	.25	20.7	572.68	----	----	I	Ent
3164-7	2.84	-----	1.8	-----	5580	3291	75.9	30.8	47.4	.23	----	----	----	----	18.70	----	I	Ent
3164-9	2.83	------	2.8	-----	5566	3305	75.9	30.9	46.5	.23	----	----	----	----	10.57	-----	J	Ent
?5-1A	2.85	2.94	2.1	3.1	5630	3304	77.0	31.1	48.8	.24	72.05	.24	34.5	678.32	----	-----	I	Ent
3165-1B	2.83	2.94	3.0	3.7	5674	3317	77.3	32.1	49.6	.24	------	------	------	-----	----	-----	J	Ent; Held for later testing
3193-9A	2.58		7.4		4903	2959	54.8	22.6	31.9	.21	B---	B---	0	157.56	----	-----	I	Ves

A = no "P" or "S" wave   B = Not gauged   Ent = Entablature   Col = Colonnade   Ves = Vesicular   Fltp = Flowtop   Brec = Breccia
NOTE: An "A", "B", or "C" included in the sample number means that more than 1 sample was re-cored from the "parent" sample.

Joint Shear properties?
shear & normal stiffness of joints?

CURRENT WORK SUPPORTS THE NSTF PHASE I REPORT

- FS#2 Comparative Analysis
- Block Test Joint Properties
- Block Test Pretest Laboratory Testing

DATA BASE ORGANIZATION

- Geotechnical Logs
- Sample Photographs and Characterization Sheets
- Computerization
- Evaluation of Future Data Needs

FUTURE WORK

- Implement Thermal Property Test Capability
- Core Inventory to Ascertain Available Sample Population
- Bench-Scale Joint Testing

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NSTF OPERATING PROCEDURES

Section

002 - EMERGENCY

Procedure No:

MO-002-001 - Fire Alarm

MO-002-002 - Evacuation Alarm

020 - ADMINISTRATIVE

Procedure No:

MO-020-004 - Training Records (NSTF Operations Personnel)

MO-020-005 - Protective Clothing And Safety Equipment

MO-020-007 - Preventive Maintenance Monitoring And Control

MO-020-008 - Visitor Control

MO-020-009 - Personnel Control

MO-020-010 - NSTF Operations Log Entry

040 - FACILITY FUNCTION ALARMS

Procedure No:

MO-040-200 - Annunciation Panel ANP-2 Alarm Procedures - General

MO-040-201 - Full Scale Test 1 Alarm

MO-040-202 - Full Scale Test 2 Alarm

MO-040-204 - S/S Power XFR Switch Standby Power

MO-040-205 - Master Shutdown By-Pass Switch-Open

MO-040-206 - Sump Tunnel 3 Level Hi

MO-040-207 - Sump Tunnel 3 Level Lo

MO-040-208 - Facility Water Pressure Lo

MO-040-209 - OP'S Trailer XFR Switch Standby Power

MO-040-210 - Computer Alarm

MO-040-211 - Sump Tunnel 2 Level Hi

MO-040-212 - Sump Tunnel 2 Level Lo

MO-040-213 - Batteries (UPS No. 1) Supplying Load

MO-040-214 - UPS No. 1 XFR Switch Standby Power

MO-040-216 - UPS No. 1 Bus Failure
MO-040-217 - UPS No. 2 Bus Failure
MO-040-218 - Batteries (UPS No. 2) Supplying Load
MO-040-219 - UPS No. 2 XFR Switch Standby Power
MO-040-220 - Normal Power XFMR T1 Off
MO-040-221 - Generator No. 1 System Not Ready
MO-040-222 - Engine No. 1 Overcrank
MO-040-223 - Engine No. 1 Oil Pressure Lo
MO-040-224 - Engine No. 1 Water Temp Hi
MO-040-225 - Generator No. 1 Power On
MO-040-226 - Generator No. 1 Start Batt Voltage Lo
MO-040-228 - Engine No. 1 Fuel Lo
MO-040-229 - Engine No. 1 Overspeed
MO-040-230 - Normal Power XFMR T2 Off
MO-040-231 - Computer Encl HVAC Failure
MO-040-232 - Computer Encl Temp Hi
MO-040-233 - Computer Encl Humidity Lo
MO-040-234 - Instrument Test Rack Temp Hi
MO-040-235 - Computer Rack Temp Hi
MO-040-236 - Instrument Encl 1 HVAC Failure
MO-040-237 - Instrument Encl 1 Temp Hi
MO-040-238 - Extensometer Room Fan No Flow
MO-040-239 - XFR Switch ATS-1 Standby Power
MO-040-240 - Inlet Fan XFR Switch Standby Power
MO-040-241 - Instrument Encl 2 HVAC Failure
MO-040-243 - UPS Room Fan No Flow
MO-040-244 - UPS Room Temp Hi
MO-040-246 - Inlet Fan #3 Reverse Low Flow
MO-040-247 - Inlet Fan #3 Forward Low Flow
MO-040-248 - Inlet Fan #2 Reverse Low Flow
MO-040-249 - Inlet Fan #2 Forward Low Flow
MO-040-301 - Annunciation Panel ANP-3 Alarm Procedure

055 - DATA ACQUISITION SYSTEM

Procedure No.:

MO-055-101 - Trouble Shooting The M600 And Terminals

MO-055-201 - Orderly Shutdown Of The M600

MO-055-202 - Emergency Shutdown Of The M600

MO-055-301 - Starting The M600 After Normal Shutdown

MO-055-302 - Running Fixup On The M600 After Abnormal Shutdown

MO-055-303 - Powering Up The M600

MO-055-401 - Mounting Tape On The M600 Tape Drive

MO-055-402 - Dismounting Tape From The M600 Tape Drive

MO-055-601 - Columbia Tape Drives

060 - VENTILATION

Procedure No.:

MO-060-001 - Air Handling Unit Operation

070 - FACILITY SUPPORT

Procedure No.:

MO-070-002 - Tunnel Vehicles And Control

MO-070-003 - Flammable Liquids-Control In Tunnel Areas

MO-070-006 - NSTF Area Inspection - Daily

MO-070-008 - Water Chlorination System

MO-070-009 - Housekeeping And Safety Inspections NSTF Area - Weekly

MO-070-010 - Housekeeping And Safety Inspections NSTF Area - Monthly

MO-070-011 - Intercommunication System Operation

MO-070-013 - Security Control - Trailer Village, NSTF Operational Sites

MO-070-015 - Extensometer Measurements

MO-070-016 - Telescoping Work Platform Operation

MO-070-017 - Mobile Work Platform

MO-070-018 - Extensometer Monitoring And Adjustment

MO-070-019 - Dewatering/Desteaming Module Operation

MO-070-020 - Tunnel Area Inspection

991 - TESTING

Procedure No.:

STP-M-991-001 - Heater Operation

STP-M-991-002 - Block Test No. 1

STP-M-991-00010 - Operational Checkout of the Bottom-Loading Transporter

Reviewer J. Buckley

Date 1/24/84

(10)

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.

Jointed Block Test # 1. Test begun on July 15, 1982. Test still ongoing. No heat is yet applied.

1a. What is the overall objective of the test?

I. Development and validation of numerical modeling techniques. (see page 1 of APPLICATION OF BLOCK TEST RESULTS TO REPOSITORY DESIGN)

1b. What specific parameters are to be determined by the test?

1. Coefficient of thermal expansion.
2. Deformation response (Poisson's ratio, stress-strain curves, will not be related to rock failure at this time)
3. Thermal conductivity

1c. Is there redundancy in the test concept?

- ONE SAMPLE
- WILL RUN 16 CYCLES FOR REPEATING LOADING CYCLES
- MULTIPLE INSTRUMENTS IN MOST CASES
- STRESS WILL BE measured by borehole deformation gauges and vibrating wire STRESSMETERS

1d. What criteria were used for test site (or sample) selection?

It has never been written down as to why the block test area was selected for that particular test. A managerial decision was made as to the layout of the NSTF. The test location was selected before tunnel development.

1e. How is the rock at the test site characterized?

- Core logging & examination of instrumentation holes
- Rock face is mapped structurally
- Cores were not oriented but Rockwell expressed a desire to do so.

1f. How was the test designed?

A comprehensive test development plan was not written prior to test initiation. Test plans describe the test evolution and the test description. Check references in "APPLICATION OF BLOCK TEST RESULTS TO REPOSITORY DESIGN"

1g. Comments.

Reviewer John Buckley

Date 1/24/84

2. Is the procedure documented and complete, and is it in written form?

The test procedure is documented in written form. Two revisions during the testing period. The initial procedure is 0-0. The first revision is A-0. The second revision is A-1. A-1 will take affect by 3/1/84. An operational procedure manual (A-1) and a detailed test plan manual is available.

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

Test procedure is not a standard ASTM procedure. Colorado School of Mines published information on block test.

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

Rockwell observed CSM block test technique and used valuable information. Test procedure was internally reviewed and externally reviewed by Bienawski, Hustrulid and Russell. All comments are incorporated in test procedure revision.

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

There have been three test procedure revision. Each revision to procedure to incorporate new loading cycles, new instruments, etc... up to this point no new methods for collecting the same data have been implimented.

2d. Comments.

Loading rates are not specified in the procedure manual. At current time, the loading rate is as fast as possible for the equipment used. It has not yet been determined whether or not the loading rate has an effect on data and test results.

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

3. How many of these tests have been performed?

one block test has been performed.

3a. According to what procedure revisions?

Current procedure revision is A-0. Test results are also available for revision 0-0.

3b. How may test results, obtained under different revisions, be compared?

Test results for the two revisions (0-0 and A-0) are similar and comparable. The revisions incorporate new tests and test redundancies.

3c. How many tests are in progress and which revision is in use?

The test revision currently in use is A-0. Revision A-1 will be in effect as of 3/1/84.

3d. How many tests are planned?

A continuation of the block test will start when the thermal loading is applied.

3e. Comments.

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

4. What instrumentation is used for the test?
   - BDMS (Basalt Deformation Measurement System) which is patented by Rockwell.
   - HEATER & thermocouples
   - USBM deformation gage
   - Flat jacks
   - Extensometers
   - Vibrating wire stressmeters

4a. How were the reliabilities* of the instruments specified?
   - BDMS has been monitored in place over periods of several weeks
   - Stress meters and deformation gages were checked for heat damage.
   - Flat jacks have not yet been checked for reliability. For now there is no calibration method for checking flat jacks.

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?
   - For deformation gages there is no recalibration for thermal effects.
   - Borehole deformation gages are calibrated once a year or so.
   - Stressmeters are <u>not</u> calibrated over the life of instrument.
   - Flat jacks cannot be calibrated at current 2' size.
   - Extensometer has not be calibrated, because it is not easily accessible due to test setup.

4c. Are the calibrations traceable to national or industrial standards?

   Calibration records are present, and available.

4d. Comments.

   It is the impression and conclusion of Rockwell employees that instruments will be able to be developed to handle a waste repository environment.

   Equipment calibration is not done extensively.

* <u>Reliability</u> is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

5. What are the data collection, reduction, and presentation techniques?

All instruments are connected to DAS. DAS consists of two data loggers. one data logger transmitts to data general and put on tapes, and other data logger goes to DAS. Raw data is electronic impulses. Raw data is reduced by algorythms on the computer

5a. How can the raw numerical data be retrieved?

Raw data (voltage vs. voltage) can be output and retrieved at any time.

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated? There is two independently parallel data acquisition systems.

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

Data can be presented in any fashion by a set of canned programs. Plots, numerical lists etc. can be presented from raw data.

5d. Are the data keyed to geological, environmental, and other experimental conditions?

Data plots are referred to as ambient temperature phases or such things. Environmental conditions are not noted. Data does not specify many times what test the data comes from, or the date of test.

5e. Are the data traceable to a written procedure?

The test data currently is not traceable to the written test procedure. The data report programs are user friendly

5f. Comments.

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

6. What techniques are involved in analyzing and interpreting the data?

6a. What empirical techniques?

No empirical techniques used.

6b. What analytical techniques?

- Deformation modulus is taken from slope of line
- Have not addressed heat expancion and thermal conductivity.

6c. What numerical techniques?

- Data from block test was put into models to provide data for heater test.
- UDEC and ANSYS were used. ANSYS was used for test design and boundry condition
- ORTHO – boundry element code used to look at stresses around instruments.

6d. Comments.

Reviewer John Buckley

Date 1/24/84

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

- DAS 3 – used for collecting, reducing, storing, presenting and statistical data analysis. Don't know if DAS 3 has gone out for external review.

7a. How are these programs verified, validated, documented, and controlled?

Computer group handles computer programs.

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

8. What are the acceptance/rejection criteria for the test data?

No acceptance/rejection criteria. No data points are ever removed from data set.

8a. Were these criteria established prior to test development?

N/A

8b. What is the logic behind the criteria?

N/A

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)

N/A

- Data Handling

- Review Procedure

- Corrective Action

8d. Comments.

A procedure has not been developed. An understanding of the problems associated with rejection criteria was presented.

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

9. How are deviations from established procedures documented?

To this point no significant deviations from procedure have taken place.

9a. What is the cause of the deviation?

Mechanical failure of instruments.

9b. How are deviations considered in data reduction and/or analyses?

N/A

9c. Is the use of deviated data controlled? (For example, not used withoug approval of system designer or authorized project manager.)

N/A All data is saved. In one case radio frequencies messed up the data. The data is still on tape.

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

100/MSN/84/01/17/1

Reviewer John Buckley

Date 1/24/84

10. General comments (such as, relationship among different tests, impacts on interpretation, instrument redundancy, factors resulting in test closure, accuracy of measurements, limitations, additional uses of data, and other miscellaneous comments).

1. The test is a learning experience.

2. The test is most important because now data is available for models.

3. Block test is used as basis for development of UDEC

4. Flat jack installation method has had an influence on the boundry conditions. By changing installation methods the results could change.

(11)

Reviewer M. S. Nataraja

Date 1/24/84

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.

JOINTED BLOCK TEST # 1

Test began July 15, 1982, still ongoing.
No heat applied. only ambient conditions are tested.

1a. What is the overall objective of the test?

Development and validation of Numerical modeling Techniques
See Ref. hand out by Mike Cramer

1b. What specific parameters are to be determined by the test?

- Coeff. Th. expansion
- Deformation Response < modulus - poisson's ratio, Stress-strain Relationships.
- Thermal conductivity

1c. Is there redundancy in the test concept? {Failure has not been reached. May attempt in future}

- only one Sample
- 16 cycles of testing - repeted
- multiple instruments BDMS, MPBX, Thermo couples, BDG, Vibrating wire

1d. What criteria were used for test site (or sample) selection?

- NSTF Layout was predetermined
- No document logic for test location other than convenience and room to work.

1e. How is the rock at the test site characterized?

- mainly thro' core extraction of instrument holes.
- mapping of the face.
- Cores were not oriented

1f. How was the test designed?

Ref. "The Design and construction of A Block Test in closely Jointed Rock" by {M.T. Black, M.L. Cramer}. June 1983

1g. Comments.

see list of documents (last two pages of Mike's handout)

Reviewer M.S. Nataraja

Date 1/24/84

2. Is the procedure documented and complete, and is it in written form?

SD-BWI-TP-001 Rev. A-0 is the current version – Testplan
SD-BWI-TI-042 Rev. 1 → operating procedure
These two documents were shown. Procedures are still being revised
Rev. A-1 is under review.

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

- No.
- Apparently an ASTM STP is currently under preparation

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

Colorado School of Mines (CSM) see ref in handout Hardin et al. 1981.

Internal review + overview committee
Bienavsky - Hustrulid & Jim Russel.

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

- currently A-1 is under review.
- Revision are basically to increase the scope of test and increase the number of loading cycles – add instrumentation

2d. Comments.

Revisions are signed off according to procedures before continuing work.

Day to day activities are written down in a log book.

100/MSN/84/01/17/1

Reviewer *M. S. Nataraja*

Date *1/24/84*

3. How many of these tests have been performed?

   - One
   - but many cycles

3a. According to what procedure revisions?

   A-0

3b. How may test results, obtained under different revisions, be compared?

   Rev. 0-0 }
   A-0 } no apparent problems
   future - A-1 } in comparison

3c. How many tests are in progress and which revision is in use?

   - Test is in progress. }
   - all instruments are in progress } as per A-0

3d. How many tests are planned?

   - Continuation of the same test with heat input

3e. Comments.

100/MSN/84/01/17/1

Reviewer M. S. Nataraja

Date 1/24/84

4. What instrumentation is used for the test?
   - BDMS (Basalt deformation measurement system (Electro optical)
   - MPBX
   - Irad vib. wire gage
   - USBM - BDG   Thermo couples
   - Flat jack
   - Deformeters

4a. How were the reliabilities* of the instruments specified?

-BDMS → has been monitored for a long time

* - Thermal calibration
- exposure to steam

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?

BDG → no national or industry standards for thermal calibration

Results vary from 'perfect' to unsatisfactory.

4c. Are the calibrations traceable to national or industrial standards?

Manufacturers' calibrations are depended up on

A letter report (NO. 10410-IMM-82-091) was shown. The report contains BDG calibration details.

4d. Comments.

* NO calibration of Flat Jacks

- Kaiser & Woodward clyde Studies on Instrumentation
- Rockwell is optimistic that technology will be available.
- BDG's calibrated once a year

* Reliability is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

100/MSN/84/01/17/1

Reviewer M.S. Nataraja
Date 1/24/84

5. What are the data collection, reduction, and presentation techniques?

- Data Aquisition System (DAS)
- Two computers - Two programs
- Raw data in most cases consist of Voltage signals

5a. How can the raw numerical data be retrieved?

by calling up a Data General computer

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated?

- Two parallel independent systems.

* - Manual computation is possible but extremely difficult

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

- good plotting routines
- versatality in the package to make changes

5d. Are the data keyed to geological, environmental, and other experimental conditions?

- ambient temp. = phase - I - II - III

5e. Are the data traceable to a written procedure?

DAS is a user friendly
gives step-by-step procedure.

5f. Comments.

* walkie-Talkies screw up the signals.
Many raw data print outs can be improved by adding more descriptions
ex. date ?
. stress → from which instrument

100/MSN/84/01/17/1

Reviewer M. S. Nataraja
Date 1/24/84

6. What techniques are involved in analyzing and interpreting the data?

6a. What empirical techniques?

none

6b. What analytical techniques?

* – Deformation modulus comes from slope of stress-strain curve.

Thermal properties still not computed

6c. What numerical techniques?

– Data from Block Test are being used in analyzing Heater Test data.

– Also UDEC code is being used

6d. Comments. ANSYS was used for designing the test.

* 3-D effects are not considered in computation of E

→ Also 'NONSAP' was used 3-years ago in aiding the test design

Boundary element code called ORTHO was used to analyze stresses around instruments (Scoping Calculation)

100/MSN/84/01/17/1

Reviewer M.S. Nataraja

Date 4/24/84

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

- DAS-3 C-R-S-P & A → statistical

- Desk Top computer System.

7a. How are these programs verified, validated, documented, and controlled?

* DAS is verified ⟶

Desk Top computer System → not well documented.

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

- Basalt Tech. Computer System has responsibility for DAS maintenance.

* Data Verification plan for NSTF

100/MSN/84/01/17/1

Reviewer M. S. Nataraja

Date 1/24/84

8. What are the acceptance/rejection criteria for the test data?

- Do not have written criteria
- No data has been eliminated.

8a. Were these criteria established prior to test development?

N/A

8b. What is the logic behind the criteria?

N/A

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)

° Data Handling

° Review Procedure

° Corrective Action

8d. Comments.

This has not been attempted.

100/MSN/84/01/17/1

Reviewer M.S. Nataraja

Date 1/24/84

9. How are deviations from established procedures documented?

There haven't been any significant deviations

9a. What is the cause of the deviation?

- Mechanical failure

9b. How are deviations considered in data reduction and/or analyses?

No occasion so far

9c. Is the use of deviated data controlled? (For example, not used without approval of system designer or authorized project manager.)

N/A

- Regenerate data if possible
- make notes of the problem

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

100/MSN/84/01/17/1

Reviewer M. S. Nataraja

Date 1/24/84

10. General comments (such as, relationship among different tests, impacts on interpretation, instrument redundancy, factors resulting in test closure, accuracy of measurements, limitations, additional uses of data, and other miscellaneous comments).

- Learning experience
- Data will be used to validate models
- Basis to develop UDEC code
- Development of Instrumentation
- Repeatability independent of operators
- Boundary conditions have significant influence on results.
-

100/MSN/84/01/17/1

(12)

Reviewer *Ernie Corp*

Date *1/24/84*

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.

Jointed Block Test #1 Jan. 14, 1981 to present

1a. What is the overall objective of the test?
See p. 1 of handout at 1/24/84 meeting. -- coeff. of thermal expansion E, μ, σ-ε (pre-failure) thermal conductivity

1b. What specific parameters are to be determined by the test?

See p. 1 of handout

1c. Is there redundancy in the test concept? *1 block*
run 16 cycles, with repeats
multiple instruments -- 6 deform. meas. by optical sys. (BDMS system)
deform. measurements in flat jacks also
stress - USBM & VSM

1d. What criteria were used for test site (or sample) selection?
- site established in original design of NSTF -- no rock preference
- Entablature of Pomona flow
- Good work area in terms of space at intersection.

1e. How is the rock at the test site characterized?
Cores from instrument holes -- not oriented - (caused some later problems)
tunnel face mapped.

1f. How was the test designed?
Basic block test concept to isolate a representative volume of rock.
see p. 3, 4 & 5 of handout

1g. Comments.

Reviewer *Corp*

Date *1/24/84*

2. Is the procedure documented and complete, and is it in written form?

yes, SD-BWI-TP-001 (A1 (newest revision) 2nd during test period

First plan was available prior to Jan. 14, 1981.

prior plan → A0 Test plan & procedure manual.
or earlier - 00

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

No

ASTM is circulating STP -- Hardin & Vogle (Terratec)

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

Other block tests have been conducted
ie Colorado School of Mines experimental mine (1981) report by Hardin, Vogle, Board
- no set procedure established -- different objectives
RHO plan subject to internal review -- (see publ. TP-001 A1)

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

See 2. above

also { - added 2nd extensometer ⊥ to face (upper left hand corner) # 5002
- increased the No. of loading cycles }

2d. Comments.

→ External review committee -- Hustrulid -- CSM
Russell - Texas A&M
Bienawski -

100/MSN/84/01/17/1

Reviewer *Corp*

Date *1/24/84*

3. How many of these tests have been performed?

"one" with repetitive loading -- see p.6 handout
16 cycles

3a. According to what procedure revisions?
A-0 is current procedure
0-0 earlier procedure

3b. How may test results, obtained under different revisions, be compared?

3c. How many tests are in progress and which revision is in use?

one - A-0

3d. How many tests are planned?
Heater tests will be added as part of this test #1

3e. Comments.

100/MSN/84/01/17/1

Reviewer Corp

Date 1/24/84

4. What instrumentation is used for the test? — see pgs of handout.

- BDMS displacement (Basalt Def. meas. System) - optical
- MP Borehole extensometers — Thermocouples
- USBM gage
- VWS
- flatjacks
- deformeters within flat jacks

4a. How were the reliabilities* of the instruments specified?

BDMS -- checked under no load change for several weeks
-- temp. checked in lab
other instruments -- temp. & environ. calibrated
flatjacks -- no facility as yet for calibration with temp. (must build one)

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?

yes, -- temp, steam, humidity

4c. Are the calibrations traceable to national or industrial standards?

Data loggers -- national std. -- annual check
VWS -- factory calibrated -- need their own procedure for calibration
Extensometers -- 2 of 3 can be recalibrated
1 is inaccessible

4d. Comments.

Problem finding instruments that will operate under repository conditions -- stiffness of basalt requires high resolution.

Will probably encounter problems with USM when subjected to 'g' forces in blasting

* Reliability is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

100/MSN/84/01/17/1

Reviewer Corp

Date 1/24/84

5. What are the data collection, reduction, and presentation techniques? 2 DAS collects readings { 1 connected to computer (Data General on surface) } 2nd records on tapes -- goes to desk computer } 2 redundant systems -- same algorithm

5a. How can the raw numerical data be retrieved? -- retrieved by calling up Data General Computer or back-up tapes.
UWS - period signal
others -- voltage signal

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated?

-2 independent DAS's
- occasionally found descrepencies requiring checkout

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

yes -- but need more clarification on printouts -- date, specific test, etc may prevent confusion if new person comes in.

Utility ok

5d. Are the data keyed to geological, environmental, and other experimental conditions?

Ambient temp. cycles {Phase 1, 2, & 3}
Confinement specified
Moisture not checked

5e. Are the data traceable to a written procedure?

None specified

5f. Comments.

100/MSN/84/01/17/1

Reviewer Corp

Date 1/24/84

6. What techniques are involved in analyzing and interpreting the data?

E is a simple 1-D computation and is not accurate. It should take into account Poisson's ratio & confining stresses. This may take out their variability due to confining pressure.

Analysis program is User Friendly

6a. What empirical techniques?

1/23/84 update – May be OK if we assume E's & ν's are constant. Must check method of calculation.

6b. What analytical techniques? E -- slope of curve only -- need eqn with $\epsilon_{xx}, \sigma_{xx}, \epsilon_{zz}$ & σ_{zz}

Conductivity

Thermal expansion

6c. What numerical techniques?

Used UDEC FE-code to model block & explore different deformations

also used ANSYS to design test

" " Non-SAP earlier to design test

ORTHO -- Boundary Element code -- look at stresses around instruments

6d. Comments.

Reviewer *Corp*

Date *1/24/84*

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

DAS 3 system for collecting, reducing, storing, presenting, & statistical analysis.

DAS-3 is a formal system (Basalt Computer Mgmt. Group) that is documented & updated.

7a. How are these programs verified, validated, documented, and controlled?

- verified independently & against each other.
- 3 desk top versions compared against Data General Computer for check.
- Hand check calculations

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

100/MSN/84/01/17/1

Reviewer Corp

Date 1/24/84

8. What are the acceptance/rejection criteria for the test data?

None established. -- no data rejected to date

Human judgement -- Instruments operating out of range

No procedure developed!

8a. Were these criteria established prior to test development?

No

8b. What is the logic behind the criteria?

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)

- Data Handling
- Review Procedure
- Corrective Action

8d. Comments.

100/MSN/84/01/17/1

Reviewer Carp

Date 1/24/84

9. How are deviations from established procedures documented?

Daily log book
Only deviate when there is a mechanical failure.

9a. What is the cause of the deviation?

Mechanical failure -- i.e. radio interference (tape file ok)
No significant ones have occurred

9b. How are deviations considered in data reduction and/or analyses?

No occasion as yet

9c. Is the use of deviated data controlled? (For example, not used withoug approval of system designer or authorized project manager.)

NA

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

100/MSN/84/01/17/1

Reviewer *Corp*

Date *1/24/84*

10. General comments (such as, relationship among different tests, impacts on interpretation, instrument redundancy, factors resulting in test closure, accuracy of measurements, limitations, additional uses of data, and other miscellaneous comments).

FEA analysis indicates problem with uneven confining stress in σ_z direction caused by 8 anchor jacks. Trying to correct.

- Data helpful in developing a model --

- Basis for UDEC code -- study future approaches.

- Boundary conditions (flat jack) may alter results.

(13)

Reviewer *R. Cummings*

Date *1/26/84*

Info from T.A. Rundle, RHO/BL

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.

Hydrofracturing Tests, 1982 to date

1a. What is the overall objective of the test?

Provide an estimate of the in-situ stress field at depth -- magnitudes and directions in the horizontal plane.

1b. What specific parameters are to be determined by the test?

Breakdown, shut-in, and reopening pressures
Flow rates, impressions of post-test fracturing
Combined with geologic data, leads to horizontal stress components.

1c. Is there redundancy in the test concept?

- Similar data will be derived from overcoring tests at depth at a later date; further hydrofracturing is planned
- Tests have been performed in several holes and at several depths in each.
- In DC-4 both surface and downhole pressures were measured.

1d. What criteria were used for test site (or sample) selection?

- Availability of boreholes, NX size, and of sufficient depth
- Occurrence of candidate horizons (Grande Ronde #7 tests were checks)
- In DC-12 and RRL-2 criteria were absence of fracturing in core. In DC-4 and RRL-6, wall conditions (acoustic televiewer) also considered

1e. How is the rock at the test site characterized?

Geophysical logs, core descriptions, and acoustic televiewer information. In RRL-6 and DC4, and in future tests, televiewer will be used both before and after the test.

1f. How was the test designed?

Evolved from earlier practice by a subcontractor. Improvements in equipment and procedure have been made to deal with specific conditions as they have arisen.

1g. Comments.

Procedures are somewhat flexible to enable the analyst to deal with test conditions. Procedural improvements have chiefly been aimed at accounting for prior fracturing and stress conditions in the borehole and for obtaining clearer data at great depth

Reviewer R. Cummings

Date 1/26/84

Info from T.A. Rundle, RHO/BWIP

2. Is the procedure documented and complete, and is it in written form?

- Existing written procedure is complete but general; as written, it is too vague to enable reconstruction of all pertinent test conditions. Exceptions are often taken, however, efforts are made to follow the same process for all tests.

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

No applicable ASTM test procedure.

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

- Procedure evolved from oilfield practice, techniques for determination of stress field in mining and construction industries are widely used.
- Existing BWIP procedure follows usual BOP review and approval process.

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

Formal revisions were submitted prior to RRL-6 and DC-4 testing, but timing was such that testing had to be completed before review process could be fully carried out.

2d. Comments.

- Proposed revised procedures were used by all operators for RRL-6 and DC-4 testing for consistency.
- Revisions to procedures are still in review/approval status.

Reviewer *R. Cummings*

Date *1/26/84*

Info from T. A. Rundle, RHO/BWIP

3. How many of these tests have been performed?

- By Rockwell: 35 (23 in RRL-2, 9 in RRL-6, 3 in DC-4)

- By subcontractor (Haimson): 6 (all in DC-12)

3a. According to what procedure revisions?

- RRL-6 and DC-4 tests were performed according to proposed revised procedures

- DC-12 tests were performed by Haimson according to his own procedure

- RRL-2 tests were performed according to original proc.

3b. How may test results, obtained under different revisions, be compared?

Revisions to procedures have sought to improve test interval characterization, data clarity, and instrument response. Comparisons would have to consider the range of possible interpretations of data given information from acoustic televiewer and the difference made by downhole pressure monitoring, as shown in RRL-6 and DC-4 tests.

3c. How many tests are in progress and which revision is in use?

None in progress

3d. How many tests are planned?

Depends on drilling. None presently planned. Hydrofracturing from ES facility is being considered.

3e. Comments.

Essence of procedure revisions is:

1. Monitoring of surface and down-hole pressures

2. Pre- and post-test assessments of borehole wall conditions with acoustic televiewer.

3. Equipment-related changes, such as the use of a new chart recorder to enable comparison of packer and interval pressures.

Reviewer R. Cummings

Date 1/26/84

Info from T.A. Rundle, RHO/BWIP

4. What instrumentation is used for the test?

Pressure transducers
Chart recorders
Flowmeter
Televiewer (US Geol. Survey)

4a. How were the reliabilities* of the instruments specified?

No detailed reliability analysis.

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?

- Pressure transducers are calibrated as a system together with their indicators, for indicated pressure and voltage output.
- Flowmeter calibration is by mfgr., capability is not present on-site
- Pressure transducers were calibrated on-site by HEDL and are traceable.

4c. Are the calibrations traceable to national or industrial standards?

Yes -- see 4.d., Comment.

4d. Comments.

After RRL-2 testing (no calibration was done prior) a calibration check was run by HEDL and components were found to be within 0.2% of correct. The equipment was calibrated as a system with chart recorder attached. A full calibration was performed prior to testing in RRL-6 and DC-4. These tests used a new chart recorder certified by the manufacturer as to compliance with NBS standards.

* Reliability is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

Reviewer R. Cummings

Date 1/26/84

Info from: T. A. Rundle, RHO/BWI

5. What are the data collection, reduction, and presentation techniques?

- Test histories are recorded in a field notebook that is document-controlled.
- Data collection is via strip chart recorder.
- Data reduction is by hand.
- Presentations involve condensing curves through a digitizer.

5a. How can the raw numerical data be retrieved?

- Charts are available directly.
- Digitized data are stored.

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated?

By manually inspecting strip-chart records.

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

Yes. Condensed plots that are released for publication are only semiquantitatively accurate, however, and are not suitable for checking test results.

5d. Are the data keyed to geological, environmental, and other experimental conditions?

Choice of data for analysis is made after considering environmental, televiewer, and impression data, together with test results.

5e. Are the data traceable to a written procedure?

Generally traceable, see (2).

5f. Comments.

- Impression packers have no raw data as such. Tracings are made on mylar and these tracings, although subject to a certain amount of interpretation, must be considered basic data
- Hydrofracturing tests are generally not amenable to a high degrees of automation.

Reviewer R. Cummings

Date 1/26/84

Info from T.A. Rundle, RHO/BWIP

6. What techniques are involved in analyzing and interpreting the data?

Manual constructions on charts, using tangent deviation method.

6a. What empirical techniques?

- The suitability of the tangent deviation method is based on empirical criteria.
- No empirical techniques are used in analysis.

6b. What analytical techniques?

Closed-form equations

6c. What numerical techniques?

None

6d. Comments.

- Stress directions are selected visually from impression packer fracturing directions using judgement. Fracturing not fitting a clear hydro-frac pattern are regarded as non-determinate and the data from such tests are not accepted.

Reviewer R. Cummings

Date 1/26/84

Info from T.A. Rundle, RHO/BWI

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

- None in raw and hard-copy data

- Digitizing routine, DISPLAY, is a standard commercial routine.

7a. How are these programs verified, validated, documented, and controlled?

DISPLAY is an established routine. It has not been separately verified for hydrofracturing data except for comparison with original strip-chart records.

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

Computer processing is for data presentation only. Some error is always possible when using a digitizer since the curves have to be followed by hand.

Reviewer R. Cummings

Date 1/26/84

Info from T. A. Rundle, RHO/BWI

8. What are the acceptance/rejection criteria for the test data?
Essentially, the criteria are the nature of the fracture impressions. Well-defined, vertical fractures are grounds for test acceptance. Incomplete vertical fracturing or considerable inclined fracturing, or significant breakout occurrence are grounds for test rejection.

8a. Were these criteria established prior to test development?
The criteria are implicit in the assumptions and concepts of the test, but have not been explicitly defined.

8b. What is the logic behind the criteria?
Non-satisfaction of acceptance criteria implies that assumptions critical to the test, such as borehole circularity, homogeneity/isotropism of surrounding medium (rock), and parallelism of one principal stress to borehole, may not be valid.

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)
Through inspection of test and supporting geologic data

- Data Handling
Rejected data are not considered in summary statements and concluding statements.

- Review Procedure

- Corrective Action

8d. Comments.
Judgement enters in in assessing the severity of the rejection factors. It must be appreciated by the analyst that the assumptions are almost never strictly realized in nature, and that even accepted data must be regarded accordingly.

Reviewer R. Cummings

Date 1/26/84

Info from T.A. Rundle RHO/BWIP

9. How are deviations from established procedures documented?

Field notebooks detail test histories. Reports mention critical deviations. Deviated raw data are provided.

9a. What is the cause of the deviation?

Factors related to conditions of the test and site are numerous and may require deviations such as changes in flow rates, additional cycles, and equipment changes.

9b. How are deviations considered in data reduction and/or analyses?

Allowances are made by applying rejection criteria if applicable or other measures according to the judgement of the analyst.

9c. Is the use of deviated data controlled? (For example, not used withoug approval of system designer or authorized project manager.)

Deviated data that are unacceptable are rejected.

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

Deviated data may be accepted or rejected. If the data are supportable and can be manipulated to reflect the results that would have been obtained without the deviation, in the judgement of the analyst, the data are deemed useful and are accepted. Deviated, unsalvageable data are not relatable to the undeviated case, generally because of a lack of knowledge of the test behavior at depth in the borehole and are rejected as non-reflective of true conditions. Most deviations are attributed to equipment performance.

Reviewer R. Cummings

Date 1/26/84

Info from T.A. Rundle, RHO/BWIP

10. General comments (such as, relationship among different tests, impacts on interpretation, instrument redundancy, factors resulting in test closure, accuracy of measurements, limitations, additional uses of data, and other miscellaneous comments).

1. Hydrofracturing is dependent on the assumptions of linear elasticity, planarity of the induced fracture, parallelism of one principal stress with the borehole, verticality (more generally, borehole parallelism) of the fracture induced, and the continuity of these conditions in the rock affected by the test. Other assumptions, such as borehole cross-section circularity, generate additional qualifications to data significance. It is important that the experimenters and downstream users of the data from hydrofracturing appreciate the limitations of the technique. Discussions with personnel involved with the testing touched extensively on the subject of limitations and it is evident that there has been an awareness of this throughout the testing.

2. Full documentation, and rigorous procedural and quality control practices are affected by the need to exercise scientific judgement in test conduct and data interpretation.

3. Hydrofracturing at the BWIP has been an evolving process that began with a need to preliminarily assess the in-situ stress state. Hydrofracturing in the geologic environment of the BWIP is affected by a complex set of factors, not the least of which is depth, and the procedures have been and continue to be adapted to site-specific conditions.

(19)

Reviewer J. Daemen

Date 1-24-84

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.
   Hydraulic fracturing - Series of tests performed during 1982/1983

   1a. What is the overall objective of the test?
   Determine in situ stress state

   1b. What specific parameters are to be determined by the test?
   Interval (test) pressure, flow rate, fracture orientation

   1c. Is there redundancy in the test concept?
   Yes, by repeating tests at multiple position.
   No, in that very few redundant measurements are taken.

   1d. What criteria were used for test site (or sample) selection?
   Core logs/photographs: look for unfractured test section

   1e. How is the rock at the test site characterized?
   Geology group

   1f. How was the test designed?
   Based on published experience and on initial tests performed at BWIP by recognized authority in the field.

   1g. Comments.

Reviewer J. Daemen

Date 1-24-84

2. Is the procedure documented and complete, and is it in written form?

Procedure is written up, but has been written up only very recently, and procedure has not been reviewed. Not in a formal acceptable form.

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

No.

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

Developed very carefully based on input from authorities (widely recognized) in the field, and on further internal developments and improvements.

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

There have been numerous revisions, not reviewed, partially documented in notebooks, not approved.

2d. Comments.

100/MSN/84/01/17/1

Reviewer J. Daemen

Date Jan. 24 - 1984

3. How many of these tests have been performed?

41. Source: BWIP hand-out, list of hydrofractures.

3a. According to what procedure revisions?

Continuously evolving procedures.

3b. How may test results, obtained under different revisions, be compared?

Test records provide sufficient raw data to allow detailed comparisons, which appear to be very satisfactory.

3c. How many tests are in progress and which revision is in use?

None are in progress.

3d. How many tests are planned?

Large number are planned.

3e. Comments.

100/MSN/84/01/17/1

Reviewer *J. Daemen*

Date *Jan. 24 - 1984*

4. What instrumentation is used for the test?

Has gradually evolved

4a. How were the reliabilities* of the instruments specified?

Not specified.

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?

No approved procedure. A yearly calibration of overall system performance has been implemented recently.

4c. Are the calibrations traceable to national or industrial standards?

Yes.

4d. Comments.

* Reliability is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

100/MSN/84/01/17/1

Reviewer *J. Daemen*

Date *Jan. 24- 1984*

5. What are the data collection, reduction, and presentation techniques?

Chart recorders; manual analysis.

5a. How can the raw numerical data be retrieved?

By going back to original charts for recent (1983) measurements, to photocopies for 1982 measurements.

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated?

No data reduction (except conversion of electrical signal to pressures and flowrates).

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

Yes. Widely used format.

5d. Are the data keyed to geological, environmental, and other experimental conditions?

Only partially, needs considerable effort, but can be done.

5e. Are the data traceable to a written procedure?

Only recent measurements.

5f. Comments.

100/MSN/84/01/17/1

Reviewer J. Daemen

Date Jan. 24 1984

6. What techniques are involved in analyzing and interpreting the data?

Conventional hydrofracturing analysis based on repressurization.

6a. What empirical techniques?

None

6b. What analytical techniques?

Conventional analysis as documented in SCR

6c. What numerical techniques?

None.

6d. Comments.

Reviewer *J. Daemen*

Date *Jan 24 1984*

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

Digitizer for final report preparation, no influence on data analysis or results.

7a. How are these programs verified, validated, documented, and controlled?

Not relevant for results, only for graphical presentation.

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

Digitized plots in final reports are not very accurate.

100/MSN/84/01/17/1

Reviewer J. Daemen

Date Jan. 24 1984

8. What are the acceptance/rejection criteria for the test data?

Judgment by operator-analyzer; comparison with "expected," "conventional" results.

8a. Were these criteria established prior to test development?

Not explicitly in written form.

8b. What is the logic behind the criteria?

Professional judgment.

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)

- Data Handling

  Rejection of inacceptable data.

- Review Procedure None, except informally by technical specialist on BWIP staff.

- Corrective Action

  Not possible after test.

8d. Comments.

100/MSN/84/01/17/1

Reviewer *J. Daemen*

Date *Jan. 24 - 1984*

9. How are deviations from established procedures documented?

laboratory notebooks, reports, notes on charts.

9a. What is the cause of the deviation?

Primarily operational difficulties, or conceptual changes in test procedures.

9b. How are deviations considered in data reduction and/or analyses?

Only by judgment that data is improving as procedures are improving.

9c. Is the use of deviated data controlled? (For example, not used withoug approval of system designer or authorized project manager.)

System designer is operator and controls data.

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

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7

DRAFT

(15)

Reviewer V. Rajaram

Date Jan. 24 and 26, 1984.

Data obtained from Randy Ames & Christine Gregory. RHO/BWIP.

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.

Full Scale Heater Test No. 1, FS #1, conducted from July 1, 1980 through January 24, 1983 (940 days).

1a. What is the overall objective of the test?

To determine the thermomechanical behavior of the rock mass under expected repository conditions

1b. What specific parameters are to be determined by the test?

Thermal conductivity, heat capacity, coefficient of thermal expansion, stresses and deformations in the rock

1c. Is there redundancy in the test concept?

Yes, two heater tests FS #1 and #2 were conducted. Redundant instrumentation and data acquisition systems were utilized.

1d. What criteria were used for test site (or sample) selection?

The test site was selected in the Pomona Flow, a flow representative of the basalt at the expected repository depth.

1e. How is the rock at the test site characterized?

Line mapping, core hole logging of instrumentation and heater holes, core testing and borehole jacking techniques were used.

1f. How was the test designed?

The test was designed in 1978 using the scoping analysis performed by LBL and Terra Tek (LBL-7069, Dec '78). The test program is described in BWI-02-TP-0101.

1g. Comments.

Data analysis from this test is an ongoing effort, with results from the block test being used to improve the prediction model and comparing predicted versus actual (measured) rock mass response.

Reviewer V. Rajaram

Date 1/24/84

2. Is the procedure documented and complete, and is it in written form?

Yes. There are several references which describe the test procedure and instrumentation development efforts during the test.

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

No

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

The procedure was developed by Rockwell in consultation with personnel from Lawrence Berkeley Laboratory (LBL).

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

Revisions to the test procedure and instrumentation evolved as the test progressed. The major revision was the overpower test in which the maximum heater temperature was increased from 500°C to 670°C. These are well documented in several references.

2d. Comments.

100/MSN/84/01/17/1

Reviewer V. Rajaram

Date 1/24/84

3. How many of these tests have been performed?

One

3a. According to what procedure revisions?

Not Applicable

3b. How may test results, obtained under different revisions, be compared?

Not Applicable.

3c. How many tests are in progress and which revision is in use?

The test has been completed and post-test characterization of instrumentation and heater holes is in progress.

3d. How many tests are planned?

None in the Near Surface Test Facility (NSTF)

3e. Comments.

100/MSN/84/01/17/1

Reviewer V. Rajaram

Date 1/24/84

4. What instrumentation is used for the test?

The major types of instrumentation that have been used are thermocouples, vibrating wire stressmeters (VWS), borehole deformation gage (BDG) and MPBX (multiple position borehole extensometers).

4a. How were the reliabilities* of the instruments specified?

Document HWS-10090-Rev.009 specified the temperature, moisture, time period, and functional requirements for the instruments.

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?

Yes - calibrations were carried out before, during and after the test.

4c. Are the calibrations traceable to national or industrial standards?

Yes.

4d. Comments.

Instrumentation failures during the test were analyzed by Rockwell, and a subcontract let to Soil and Rock Instrumentation (SRI) to improve the instrumentation reliabi

* Reliability is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

100/MSN/84/01/17/1

Reviewer V. Rajaram

Date 1/26/84

5. What are the data collection, reduction, and presentation techniques?

RHO-BW-ST-33P describes the algorithms used to convert the measured data for obtaining plots. The Data Acquisition System (DAS) has data loggers, and the algorithms used in these loggers are manually verified.

5a. How can the raw numerical data be retrieved?

The raw data can be retrieved from the DAS system using on line or back up tapes.

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated?

Data reduction algorithms are independently verified by the geomechanics engineer, and verified by the Basalt Technical computer Systems (BTCS) before installation on the DAS system

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

Yes. Several types of plots can be obtained from the DAS.

5d. Are the data keyed to geological, environmental, and other experimental conditions?

Yes.

5e. Are the data traceable to a written procedure?

Yes. Several references are available.

5f. Comments.

100/MSN/84/01/17/1

Reviewer V. Rajaram

Date 1/26/84

6. What techniques are involved in analyzing and interpreting the data?

Statistical techniques are used to convert the measured data to useful plots. Finite element analysis is used to obtain predicted values for comparison with actual data.

6a. What empirical techniques?

The cubic spline fit is used : The median values from the measured data during a given time period are used to obtain plots from the DAS.

6b. What analytical techniques?

Algorithms are used to convert measured data to displacements, temperatures and stresses.

6c. What numerical techniques?

The DAMSWEL computer code has been used to predict test results for comparison with actual data.

6d. Comments.

Reviewer V. Rajaram

Date 1/26/84

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

DAS-III is the computer program used to collect, reduce and store data from the test

DAMSWEL is used for analysis of test results.

7a. How are these programs verified, validated, documented, and controlled?

(1) DAS-III is documented in ST-33P. Any changes are initiated by the technical group, verified by BTCS, and then implemented. Control is maintained by BTCS.

(2) DAMSWEL has a user's manual. Revisions to the code are being incorporated by Applied Mechanics, Inc (AMI).

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

The AMI report gives the assumptions, and the input and output parameters for DAMSWEL.

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Reviewer V. Rajaram

Date 1/26/84

8. What are the acceptance/rejection criteria for the test data?

The data from the test is reviewed to monitor instrument performance. If instrument is malfunctioning, it is corrected, if possible. Rejected data is maintained on the DAS.

8a. Were these criteria established prior to test development?

Data outside the normal operating range of the instrument is rejected; however, all data is retained on the DAS.

8b. What is the logic behind the criteria?

(1) Instrument testing provided the ranges of performance

(2) Reject erratic or anomalous data outside the equipment/instrument operating range.

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)

- Data Handling

  All data is stored on the DAS.

- Review Procedure

  Data is reviewed once a week, or more often if necessary.

- Corrective Action

  - Replace erroneous instrument, if possible.

8d. Comments.

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Reviewer V. Rajaram

Date 1/26/84

9. How are deviations from established procedures documented?

Revisions are approved and documented by Rockwell management.

9a. What is the cause of the deviation?

Planned Power level changes caused most of the deviations.

9b. How are deviations considered in data reduction and/or analyses?

Material properties from the block test and power level changes are being modeled by Applied Mechanics, Inc.

9c. Is the use of deviated data controlled? (For example, not used withoug approval of system designer or authorized project manager.)

Yes

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

100/MSN/84/01/17/1

Reviewer K. K. Wahi

Date 1/24 — 1/26

(16)

Draft Rock Mechanics Data Review Checklist
(Revision No. 0, January 18, 1984)

1. Name/type, identification number, and date of test.

NSTF FS#2
Heater on July 1, 80 } total ~940 days
Heater off Sept. 30, 82 } (Jan. 24, 83 — last data)

1a. What is the overall objective of the test?

Thermomechanical behavior of rock-mass.
Overload conditions
Model verification/re-evaluation, instrument response

1b. What specific parameters are to be determined by the test?

θ, K, C_p, Disp, stresses

1c. Is there redundancy in the test concept?

Yes. Data aquisition System, back up systems

1d. What criteria were used for test site (or sample) selection?

Pomona flow closest in character to at-depth; near the surface (easy access)

1e. How is the rock at the test site characterized?

line mapping, boreholes, core from instrument holes, borehole jacking, laboratory testing

1f. How was the test designed?

Stripa served as a "model". Scoping analyses to determine heater power levels

1g. Comments.

Data Analysis is still on-going; noted references

Reviewer ____________________

Date ____________________

2. Is the procedure documented and complete, and is it in written form?

Yes. ~~To~~ See Ref. List

2a. Is it a standard (ASTM) procedure? If yes, provide reference.

No

2b. If non-"standard", how was the procedure developed, reviewed, documented, and approved? For example, COE, USBM, USBR, USGS, NBS, or other (internal) processes.

Internal & subcontractors (Foundation Sciences)

2c. Have there been revisions and how and when were the revisions reviewed, documented, approved, and implemented?

Yes. See attachment to test plan.

2d. Comments.

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Reviewer [signature]

Date 1/24/84

3. How many of these tests have been performed?

One

3a. According to what procedure revisions?

NA

3b. How may test results, obtained under different revisions, be compared?

NA

3c. How many tests are in progress and which revision is in use?

Test Completed
(Post test characterization in progress)

3d. How many tests are planned?

No more at NJTF

3e. Comments.

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Reviewer ____________________

Date ____________________

4. What instrumentation is used for the test?

TC's, BDG, Vib. Wire Stress meter, Borehole extensometer, Acoustic Emis.

4a. How were the reliabilities* of the instruments specified?

In terms of temp. range, operating conditions & environment. "No failure" (ref. HWS-10090 Rev. 009)

4b. Is there a calibration system and were calibrations systematically carried out according to approved procedure?

Yes. All instruments calibrated before test. Some during and after as well.

4c. Are the calibrations traceable to national or industrial standards?

Yes.

4d. Comments.

If a standard does not exist, some indirec or partial (component) calibrations are done with traceable standards

* Reliability is defined as the probability of an instrument to perform a stated function under a stated environment for a stated time.

Reviewer ______________

Date ______________

5. What are the data collection, reduction, and presentation techniques?

Collect → D.A.S. — data logger (remote) with manual checks, back-up tapes w/ each of the two loggers

Reduction → Computerized, with documented algorithms

Presentation → tables, graphs (smoothed or raw), scatter plots

5a. How can the raw numerical data be retrieved?

Using DAS, some observation & photographic records

5b. How can all data reduction steps prior to data storage be independently checked and/or duplicated?

By independent software programs used by geotech. engineers.

5c. Are the data presented in a complete and clear format? (Comment also on the utility of the presentation.)

Yes

5d. Are the data keyed to geological, environmental, and other experimental conditions?

Bad question

5e. Are the data traceable to a written procedure?

Yes.

5f. Comments.

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Reviewer ____________________

Date ____________________

6. What techniques are involved in analyzing and interpreting the data?

all of the below

6a. What empirical techniques?

Cubic spline fit, ~~sto~~ median/day, least squares

6b. What analytical techniques?

~~statistical~~ closed-form solns.

6c. What numerical techniques?

finite element, finite difference

6d. Comments.

100/MSN/84/01/17/1

Reviewer ______

Date 1/26

7. What computer programs are used in collecting, reducing, storing, presenting, and analyzing the data?

DAS III "~~DASS~~" and other Rockwell programs (data logger, computer systems & post-process.)

DAMSWEL for analysis

7a. How are these programs verified, validated, documented, and controlled?

DAS III → Is documented (see ref.)
progr. request change form, letter after verification accepts or rejects the change Bas. Tech. Comp. Sys. (control) makes the actual change, initiator checks the changes made

DAMSWEL → user's manual, revisions (verification)
PRIME 750 Stores plotting data AMI maintains DAMSWEL for BWIP

7b. Comments (for example, implicit assumptions, sensitivities, other comments).

User's manual SA-951 Contractor Report
DAMSWEL → will be made available

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Reviewer ______________

Date ______________

8. What are the acceptance/rejection criteria for the test data?

Instrument malfunction (outside the e.g. operation nominal range)

No thermocouple data were rejected

Instruments were not designed for overpower levels

Replace, if possible

8a. Were these criteria established prior to test development?

yes. If data were outside the normal operating

8b. What is the logic behind the criteria?

vendor specs, calibration, instrument testing, eng. experience

8c. How are the criteria implemented? (Data handling, review procedure, corrective action.)

- Data Handling

  All data collected by DAS, stored with backup

- Review Procedure

  Once a week (as a minimum)
  More frequently at the start of the test

- Corrective Action

  Replace, if possible
  Some instrument designs were modified and some modified instruments emplaced to continue data collection

8d. Comments. Some procedures evolved during the test and are documented now

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Reviewer ____________________

Date ____________________

9. How are deviations from established procedures documented?

Procedure revision — approved and documented

9a. What is the cause of the deviation?

Power level schedule changes
Changes reqd. to meet operating
Instrument installation changes due to identified problem

9b. How are deviations considered in data reduction and/or analyses?

deviations in "procedure" were not accounted for in comparing the predictive data to the test data (ie., no additional predictions were made until after the test ~~based on~~ was over and mat'l prop. changes were also included)

9c. Is the use of deviated data controlled? (For example, not used without approval of system designer or authorized project manager.)

Yes

9d. Comments. (For example, equipment performance and its effect on test validity, other comments.)

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Reviewer ______________________

Date ______________________

10. General comments (such as, relationship among different tests, impacts on interpretation, instrument redundancy, factors resulting in test closure, accuracy of measurements, limitations, additional uses of data, and other miscellaneous comments).

Final evaluation of heater tests to be based on rock-mass properties obtained from the block test data

· 2 types of stress measurements
symmetric placement of MPBX's and TC's

Redundancy in DAS with back up power supplies, simult. recording on disk & tape, two data loggers

Test completed as planned.

Overpower test was the major deviation
Some instruments weren't designed to handle overpower loads.
Due to the evolutionary nature of the test, not all the procedures and QA steps were in place at the start of the test.

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