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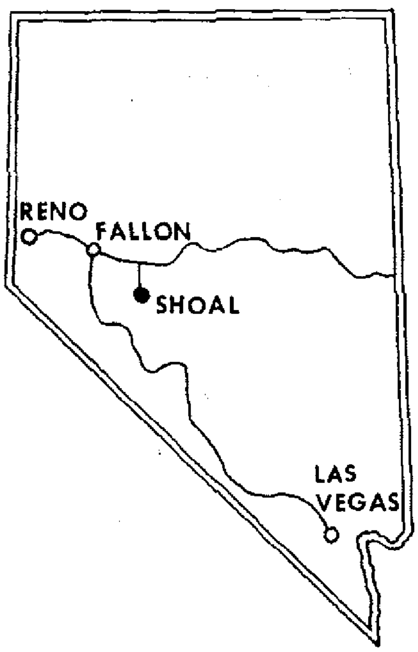
FALLON, NEVADA
OCTOBER 26, 1963



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Project 9.1

LABORATORY AND FIELD GROUTING SUPPORT

U.S. Army Engineer Waterways Experiment Station
James M. Polatty / James E. McDonald

Issuance Date: May 7, 1965

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PROJECT SHOAL

PROJECT OFFICERS REPORT - PROJECT 9.1

LABORATORY AND FIELD GROUTING SUPPORT

James M. Polatty, Project Officer
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ABSTRACT

In Project SHOAL, a low-yield nuclear device was to be detonated underground in granodiorite at a site approximately 28 miles southeast of Fallon, Nevada. The U. S. Army Engineer Waterways Experiment Station determined pertinent physical properties of the granodiorite (as described in the appendix) and developed a grout mixture with similar properties for use in embedding instruments to measure earth motion, particle motion, etc. Two other mixtures were developed to meet less rigid requirements. In all, WES grouted 10 surface stations, 4 surface and 30 tunnel instrument holes, 5 instrument niches, and 1 exploratory hole. From specimens cast at the project site, the physical properties of the grout on the device-detonation date were determined. The compressive strength and ultrasonic pulse velocity of the specimens of the grout intended to match the granodiorite, though considerably greater than those of conventional grouts, were somewhat less than desired. However, the density of the grout was almost identical with that of the granodiorite, and it is believed that all instruments were well embedded in and bonded to the grout and that the field grouting operations were successful in all respects.

PREFACE

The work performed by the U. S. Army Engineer Waterways Experiment Station (WES) in connection with Project SHOAL was accomplished in the summer and fall of 1963 for the Defense Atomic Support Agency (DASA) and the U. S. Atomic Energy Commission (AEC).

It is desired to acknowledge the excellent cooperation, logistic support, and assistance furnished WES by the organizations and personnel participating in the Project SHOAL test. Among these organizations were: DASA, AEC, Sandia Corporation, Lawrence Radiation Laboratory, U. S. Bureau of Mines, and Reynolds Electrical and Engineering Co., Inc.

The WES participation in the overall project was under the direction of Mr. Thomas B. Kennedy, Chief, Concrete Division, and under the supervision of Messrs. James M. Polatty, Project Officer, W. O. Tynes, R. L. Curry, E. E. McCoy, Jr., and J. E. McDonald, and Mrs. Katharine Mather. The laboratory investigation and actual field grouting were conducted under the direct supervision of Mr. McDonald, who also prepared this report.

Col. Alex G. Sutton, Jr., CE, was Director of the WES during the investigation and the preparation and publication of this report. Mr. J. B. Tiffany was Technical Director.

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CHAPTER 1

OBJECTIVE AND BACKGROUND

In Project SHOAL, a low-yield nuclear device was to be detonated underground in granodiorite at a site approximately 28 miles southeast of Fallon, Nevada (see Figure 1.1).

Since measurements of earth motion, particle motion, etc., appear to be most reliable when the measuring instruments are emplaced and embedded in a grout that matches as closely as possible such physical properties of the surrounding medium as density, ultrasonic pulse velocity, compressive strength, etc., the primary objectives of the [redacted] participation in Project SHOAL were to: (1) develop and pump into instrument holes and niches a grout that would match as nearly as possible the in-situ physical characteristics of the rock at the project site, and (2) provide other grouting support as requested by the various agencies participating in Project SHOAL.

WES had successfully developed a matching grout mixture and performed the field pumping of the grout for the Project HARD HAT test conducted in granodiorite at the U. S. Atomic Energy Commission's Nevada Test Site.[1] Experience gained in Project HARD HAT was most beneficial in the development of a grout mixture and performance of field pumping for Project SHOAL.

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[1] J. M. Polatty and J. E. McDonald, "Operation NOUGAT, Shot HARD HAT, Grouting Support," POR 1807, Defense Atomic Support Agency. USAEC Division of Technical Information Extension, Oak Ridge, Tennessee, April 1963. Unclassified.

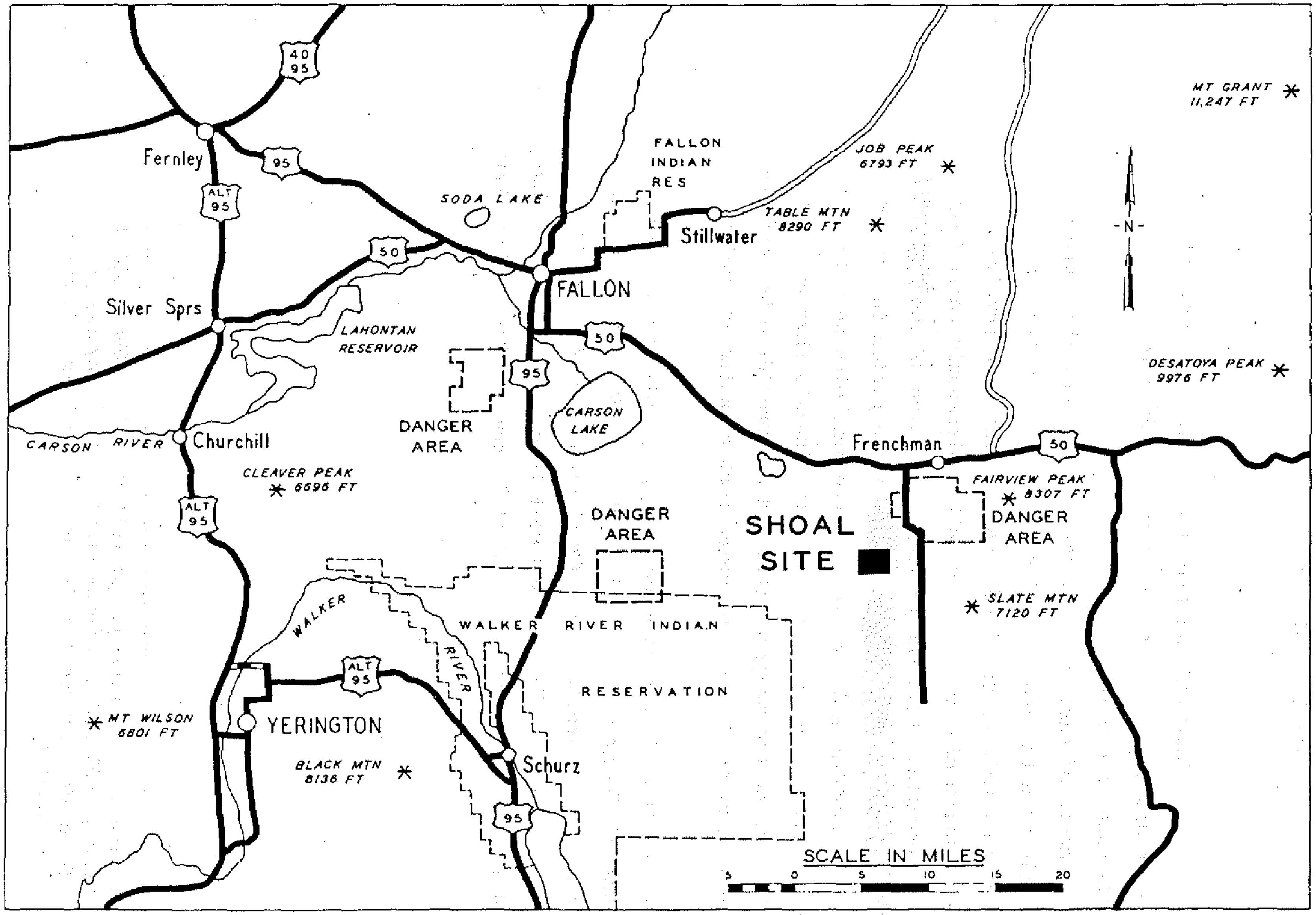

Figure 1.1 Project SHOAL location map.

CHAPTER 2

LABORATORY INVESTIGATION

2.1 DESIGN CRITERIA

A careful review of the grouting requirements of the various participating agencies revealed that three basic grout mixtures would be required. These three mixtures were as follows:

a. Mixture 1 was to match as nearly as possible the in-situ physical properties of the rock at the project site. Design requirements for this grout were based on the results of physical tests (see Appendix) performed on core specimens obtained from exploratory hole ECH-D at the project site. The principal physical properties to be matched by the grout were a density of 164.1 lb per cu ft, an ultrasonic pulse velocity of 16,940 fps, and a compressive strength of 15,960 psi.

b. Mixture 2 was to have physical properties appreciably different from those of the granodiorite at the test site. It was agreed in discussions between WES and Sandia Corporation personnel that a grout with a density of 90 to 100 lb per cu ft, an ultrasonic pulse velocity of 2000 to 4000 fps, and a compressive strength of 200 to 400 psi would be satisfactory. This mixture, to be used in the upper 480 ft of hole PM-8, was considerably weaker than mixture 1 and was to be used in an effort to minimize instrument cable damage during shifting and spalling of the formation at detonation.

c. Mixture 3 did not have to meet rigid physical property requirements because it was to be used for stemming purposes rather than for grouting instrumentation in place. Sandia Corporation left the selection of a grout for this purpose to the discretion of WES personnel.

2.2 MATERIALS

The following materials were used in the laboratory proportioning studies to develop grout mixtures with the desired physical properties.

Material	Specific Gravity	Unit Weight lb/cu ft
Aluminous cement ("Lumnite")	3.08	191.88
Magnetite sand	4.38	272.87
Bentonite*	2.48	154.50
Aluminum powder**	--	--
Grouting aid†	--	--

* Blaine fineness, 3390 sq cm/gm

** 50:50 blend of 3-XD and atomized No. 1-511.

† Blend of fluidifying, air-entraining, and water-reducing agents.

Sand grading was as follows:

Sieve No.	Cumulative Percent Passing
8	100
16	95
30	53
50	28
100	14
200	8

2.3 MIXTURES

The following three grout mixtures were proportioned in the laboratory to meet the requirements described in paragraph 2.1.

Material	Solid Volume, cu ft	Dry Batch Weight,* lb
	Mixture 1	
Aluminous cement	0.490	94.0
Magnetite sand	0.550	150.0
Water	0.668	41.6
Aluminum powder	Negligible	(4.0 gm
Grouting aid	Negligible	1.0
	Mixture 2	
Aluminous cement	0.490	94.0
Bentonite	0.065	10.0
Water	1.846	115.0
Aluminum powder	Negligible	(2.0 gm
	Mixture 3	
Aluminous cement	0.490	94.0
Water	0.562	35.0
Aluminum powder	Negligible	(6.0 gm

* Based on 1-bag batch.

2.4 PHYSICAL TESTS OF LABORATORY MIXTURES

Specimens of the three grout mixtures were tested at 28 days age to determine their pertinent physical properties. Results were as follows:

Test	Mixture No. 1	2	3
Density (hardened), lb/cu ft	167.4	93.1	--
Ultrasonic pulse velocity, fps	12,070	2430	--
Compressive strength, psi	8,200	220	8450

2.5 DISCUSSION

In an effort to obtain optimum strength and high-velocity characteristics, the water content of mixture 1 was reduced to the minimum which would result in a grout of pumpable consistency. The compressive strength and ultrasonic pulse velocity of the specimens of this grout, intended to match the properties of the granodiorite, remained somewhat less than desired but considerably greater than those of conventional grouts. However, the density satisfactorily matched that of the in-situ granodiorite.

Mixtures 2 and 3 satisfactorily complied with the less stringent design criteria, and had excellent pumping characteristics.

CHAPTER 3

FIELD GROUTING

3.1 EQUIPMENT

The following major items of equipment were used in grouting holes drilled from the surface and in grouting holes and niches in a tunnel excavated at the site:

a. One Wagner steam simplex pump, air-operated.

b. Two Robbins and Myers Moyno pumps, air-operated.

c. Two 7-cu-ft-capacity, tub-type grout mixers, air-operated.

d. One conventional 16-S concrete mixer, gasoline-operated.

e. One 2500-gal-capacity water trailer with gasoline-operated centrifugal pump.

f. One Joy-Carpuller hoist, electrically operated.

g. Perforated plastic pipe, 2-in. inside diameter (ID).

h. Plastic grout injection hoses, 3/4- and 1-in. ID.

[redacted]

Approximate locations of the four, deep instrument holes drilled from the surface and the ten surface stations, all of which were grouted from the surface using mixture 1, are shown in Figure 3.1.

3.2.1 Surface Stations. [redacted] each consisted of a trench and shallow drill hole, as shown in Figure 3.2.

[redacted] consisted [redacted]

For grouting the surface stations, the grout materials and mixers were loaded on a flatbed truck which was positioned in the immediate vicinity of a station. Upon completion of instrument emplacement, grout mixing was begun. As soon as each batch of grout was sufficiently mixed, the mixer valves were opened and the grout flowed by force of gravity into the trench or drill hole.

3.2.2 [redacted] The depths of the four, deep, 11-in.-diameter holes and the type of grout used in each are given in the following tabulation:

Hole No.	Hole Depth, ft	Grout Mixture No.
PM-1	1360	1
PM-2	1298	1
PM-3	1090	1
PM-8	930	1 and 2

The tower shown in Figure 3.3 was used by Sandia Corporation and WES personnel to expedite instrumentation placement and grouting in each of these holes. Two grout injection hoses (1-in. ID) were used in holes PM-1, -2, and -3. The discharge end of the first hose was attached to the messenger cable immediately above the deadweight (Figure 3.4), and the second hose was attached to the messenger cable approximately 50 ft above the discharge end of the first hose. This second hose was provided for use in case of grout stoppage in the first hose, and also to expedite pumping by eliminating the necessity of pumping against a high head of grout. These hoses were attached to the messenger cable with clamps and Kellum grips at approximate intervals of 50 and 200 ft, respectively.

After the instrument array was lowered to the desired depth and final instrument checks and orientation had been completed, grout injection was begun through the first hose and continued until the grout level was approximately 25 ft above the discharge end of the second hose. Grout injection was then discontinued through the first hose and started through the second hose and continued until the total required amount (approximately 125 lin ft) had been injected.

The grouting procedure for hole PM-8 was somewhat different from that for the other three holes, because it was necessary to completely fill this hole with grout. To allow withdrawal of the grout injection hose as grout filled the hole, it was decided to place perforated, semi-rigid, plastic pipe the entire depth of the hole as a casing for the injection hose. This pipe was clamped and taped to the messenger cable at approximately 50-ft intervals. The plastic pipe had an inside diameter of 2 in. and an outside diameter of 2-3/16 in., and was obtained in 10-ft lengths perforated with diametrically opposed, 1-in.-diameter holes spaced 1 ft center to center along the pipe length. The sections of pipe were connected by means of glued slip connections which had an outside diameter of 2-9/16 in. (Figure 3.5).

After the instrument array had been lowered to the desired level in hole PM-8 and instrumentation checks completed, a 1-in.-ID grout injection hose was attached to a 1/4-in. messenger cable and lowered inside the perforated pipe the entire depth of the hole. Grout injection (mixture 1) was then begun (see Figure 3.6) and continued until approximately 450 lin ft of grout had been pumped into the hole. The grout injection hose was then withdrawn from the hole and flushed with water. This stage of the grout was allowed to harden for approximately 24 hr, at which time the grout injection hose was lowered to the level of the first stage and the remaining portion of the hole was filled using mixture 2. This hole required approximately 20 percent more grout than the computed volume which was determined assuming an 11-in.-diameter hole. No caliper logs were available on this hole; however, logs of hole ECH-D, approximately 10 ft away, indicated considerable "washout" down to a depth of about 300 ft. This washout is probably the reason for the extra quantity of grout required to fill hole PM-8.

[redacted]

The drift excavated at a depth of approx 1300 ft in the granodiorite formation extended 320 ft west of the shaft and 1050 ft east ending in a vertical buttonhook at the weapon point. Instrument holes and niches were drilled and excavated at various angles in the tunnel roof, walls, and floor at various intervals along the entire length of the tunnel.

The tunnel grouting was divided into four phases: Particle Motion, Hydyme, Bureau of Mines and LRL, and Miscellaneous Grouting. Pertinent physical characteristics of the tunnel holes and the types of grout used in the four phases are contained in the following tabulation:

Phase	Hole No.	Nominal Hole Diameter, in.	Hole Depth ft	Grout Mixture No.
Particle Motion	PM-4	10	57	1
Particle Motion	PM-5	10	57	1
Particle Motion	PM-6	10	127	1
Particle Motion	PM-7	10	132	1
Hydyme	HD-1	10	11	3
Hydyme	HD-2	10	7	3

(Continued)

Phase	Hole No.	Nominal Hole Diameter, in.	Hole Depth ft	Grout Mixture No.
Hydyme	HD-4	3	108	3
Hydyme	HD-5	3	112	3
Hydyme	HD-7	3	4	1
Hydyme	HD-8	3	4	1
Hydyme	HD-11	3	4	1
Bureau of Mines and LRL	9-hole cluster	4	5	1
Bureau of Mines and LRL	6-hole cluster	4	5	1
Bureau of Mines and LRL	*	4	5	1
Bureau of Mines and LRL	LRL-V	4	10	1
Bureau of Mines and LRL	**	--	--	1
Miscellaneous Grouting	Geophone	6	5	1
Miscellaneous Grouting	Geophone†	--	--	1
Miscellaneous Grouting	E-1	4	200	3

Note: Station references begin at the shaft, station 0+00.

* Three unnumbered holes, stations 9+51, 9+75 and 9+84.

** Four 1- by 1- by 2-ft niches in tunnel wall; two each at stations 7+60 and 8+55.

† One 1- by 1- by 3-ft niche in shaft wall approximately 700 ft below ground level.

3.3.1 Particle Motion Grouting. To grout the instruments to be used in measuring particle motion, two 1-in.-ID grout injection hoses, cut to desired lengths, were laid out along the tunnel while Sandia Corporation personnel were making canister connections and checking the instruments for each of the four, horizontal 10-in.-diameter (approximately) holes involved in this phase of the grouting. Upon completion of the assembly and instrument checks, the first grout injection hose was attached to the pipe used to push instruments into the hole as near to the front end of the instrument array as possible (Figure 3.7). It was desirable to locate the hose in this position to ensure complete and satisfactory embedment of the array.

The instrument array was pushed into the hole in approximately 10-ft increments to permit connecting of additional pipe sections and taping of the first grout hose to the pipe as required. The second grout injection hose was attached to the pipe by two to three layers of tape at a point approximately 20 ft from the discharge end of the other hose. The second hose was attached in this manner so that it could be pulled free from the pipe when a small force was applied to the outside end.

After the instrument array was placed in the desired position and final checks, orientation, etc., were completed, a quick-set-cement dry pack was used to form a partial plug approximately 1 ft long with a diameter equal to 3/4 of the hole diameter (see Figure 3.8). This was necessary to hold the grout inside the drill hole until the hole was almost entirely filled. The dry-pack plug was allowed to harden for approximately 30 min before grout injection with the first injection hose was begun. Grout was injected through this hose until the grout level was well past the discharge end of the second hose; grout injection was then shifted to the second hose. The second hose was slowly withdrawn as the hole filled with grout. When grout began to flow out of the hole, additional dry pack was used to plug that portion of the hole remaining open so that the hole would be completely filled. A typical setup of grout mixers and pump for this grouting is shown in Figure 3.9.

3.3.2 Hydyme Grouting. Holes HD-1 and -2 (10 in. in diameter) were instrumented and checked before the grout injection and bleeder hoses (each 1-in. ID) were placed in the holes. The position and alignment of the holes (drilled almost vertically in the tunnel roof) necessitated construction of a simple plywood bulkhead, braced against the tunnel floor, around each hole collar to support the grout until it developed sufficient bond strength to become self-supporting. Burlap bags were placed around the bulkhead to minimize grout leakage. The end of the bleeder hose was positioned as high as possible in the hole to ensure complete grouting, while the end of the injection hose was positioned approximately 1 ft below the bleeder hose. Grout mixture 3 was injected until grout return was obtained through the bleeder hose, indicating that the hole was completely filled. Injection operations were then stopped, and the injection and bleeder hoses were "crimped" simultaneously to ensure that the hoses were left full of grout.

In vertically slanted holes HD-4, -5, -7, -8, and -11 (3 in. in diameter), the grout injection and bleeder hoses (each 3/4-in. ID) were placed simultaneously with the instrumentation. The end of the bleeder hose was positioned as near the closed end of each hole as possible, and the injection hose was positioned 1 to 2 ft behind the bleeder hose. Upon completion of hole instrumentation operations, a quick-set-cement dry pack was used to form a plug in the open end of each hole. This plug was allowed to harden before grout injection operations began. Injection operations were terminated when grout return was obtained through the bleeder hose, at which time the hoses were crimped to prevent loss of grout.

3.3.3 Bureau of Mines and LRL Grouting. The 17, 4-in.-diameter, horizontal holes included in this phase of the grouting operations each contained several canisters which were approximately 3 in. in diameter and 8 in. long. After the canisters were placed in the drill holes, quick-set-cement dry packs were used to form partial plugs at the hole collars. After the partial plugs had hardened, 3/4-in.-ID grout injection hoses were extended the entire lengths of the holes, and grout was injected until it began to flow out over the partial plugs. The injection hoses were then slowly withdrawn, as pumping was continued, until they were removed; the holes were then completely plugged to prevent any loss of grout.

Hole LRL-V was a 4-in.-diameter, vertical hole drilled in the roof; the canister was inserted prior to placing the grout hoses in the hole. The end of the bleeder hose (3/4-in. ID) was positioned as near the top of the hole as possible, and that of the injection hose (3/4-in. ID) was placed approximately 1 ft below the bleeder hose. A quick-set-cement dry pack was used to form a plug which was supported by a simple plywood bulkhead similar to those described for the Hydyme phase. When the plug hardened, grout injection was begun and continued until grout return was obtained through the bleeder hose. The hoses were then crimped to prevent loss of grout.

In addition to the drill holes, four niches (approximately 1 ft square and 2 in. deep) in the tunnel wall were grouted. Samples were placed in each of the niches immediately prior to placing a quick-set-cement dry pack over the front of the niches. Only a small opening in the extreme top of the dry pack was left. After the dry pack hardened, a grout injection hose (1-in. ID) was inserted in the dry pack opening and the niche was completely filled with grout.

3.3.4 Miscellaneous Grouting. Due to the small quantity of grout required for the shallow geophone hole in the tunnel floor, the grout was mixed in the conventional manner but was poured into the hole rather than pumped. The geophone niche in the shaft wall was grouted in the same manner as the niches described in the preceding paragraph, except that the grout was mixed in the tunnel and transported in buckets on the shaft hoist up to the niche location and funnelled through a 1-in.-ID hose into the niche instead of being pumped.

To plug exploratory hole E-1, a grout injection hose was attached to a pipe extending from a packer which had been placed in the hole by the drillers. The valve on the packer line was opened, and the volume of grout (mixture 3) necessary to fill the hole with a grout column approximately 50 ft long was injected. It was desired to have this grout plug in the hole in case the packer should fail at shot time allowing water to fill the tunnel. Inspection of the hole after the grout hardened showed that the grout plug had satisfactorily stemmed the water which was flowing (with the packer valve open) from the hole at a rate of approximately 70 gal per min prior to the grouting.

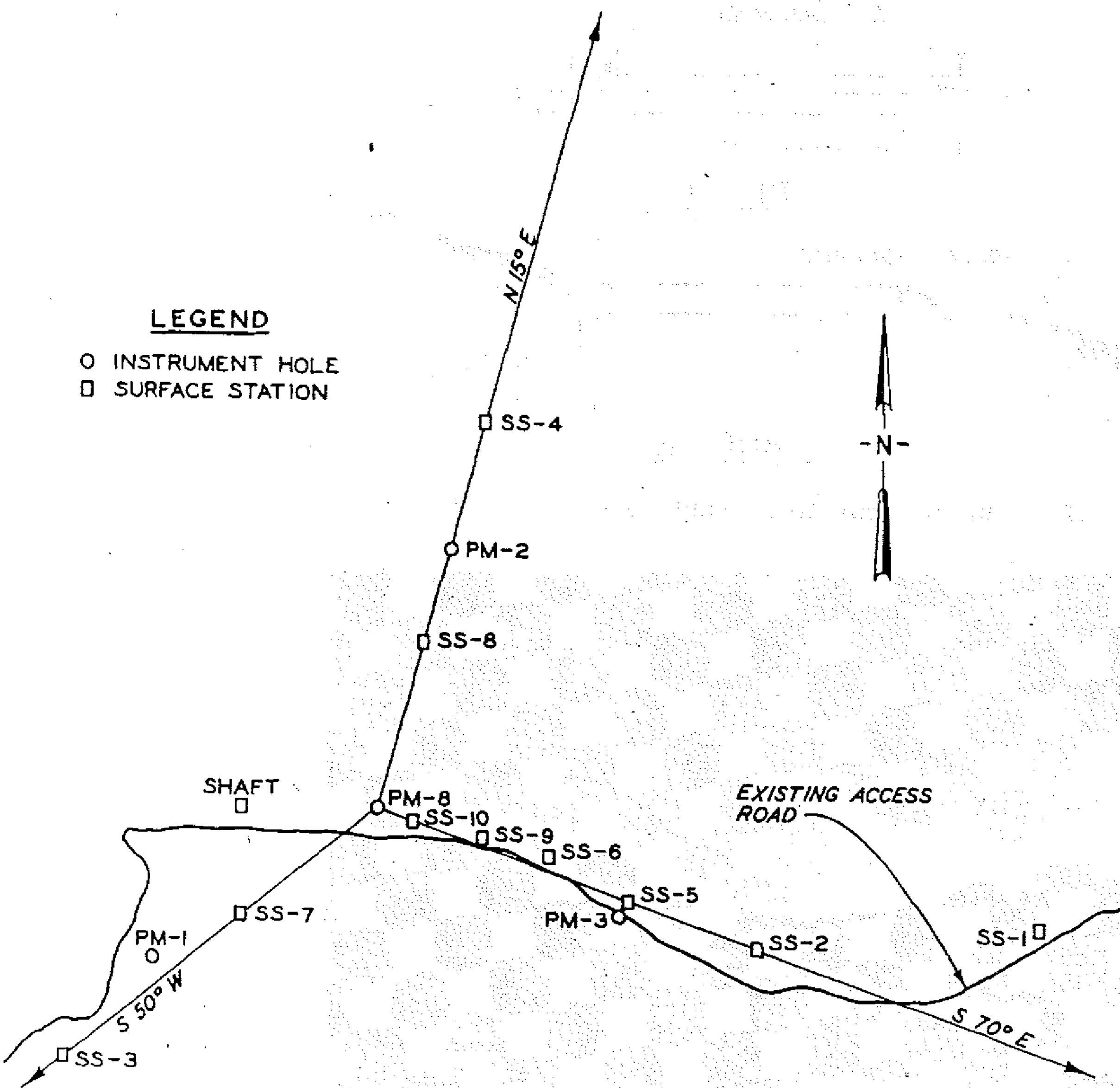

Figure 3.1 Approximate locations of surface stations and instrument holes.

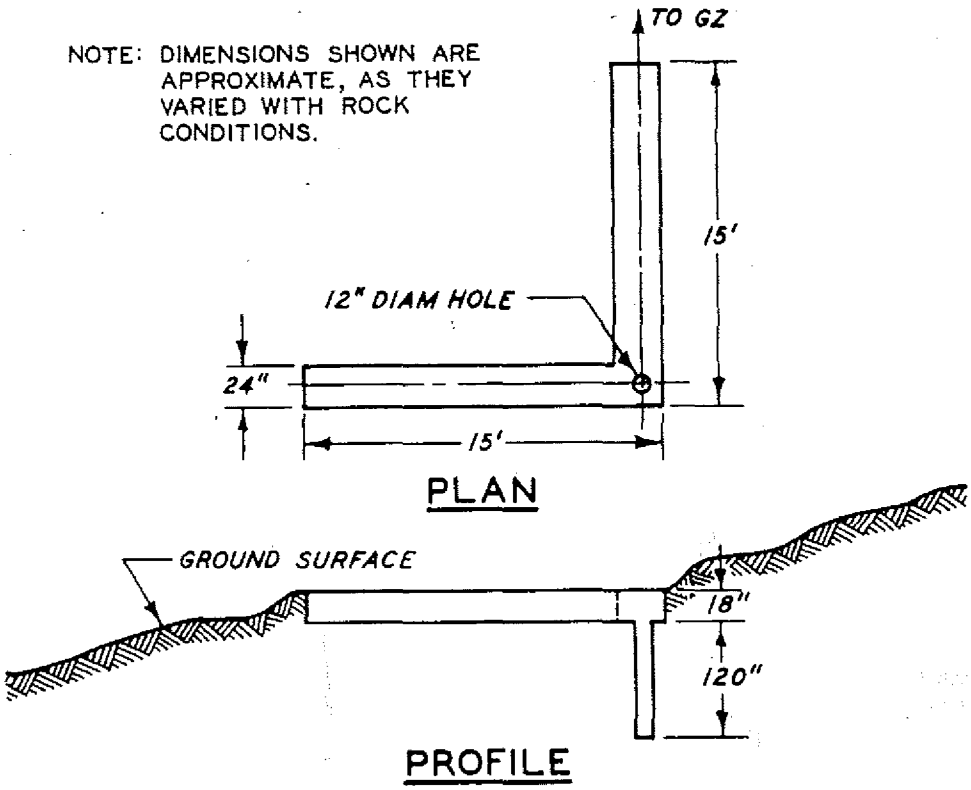

Figure 3.2 Plan and profile of surface stations SS-1, -2, and -3.

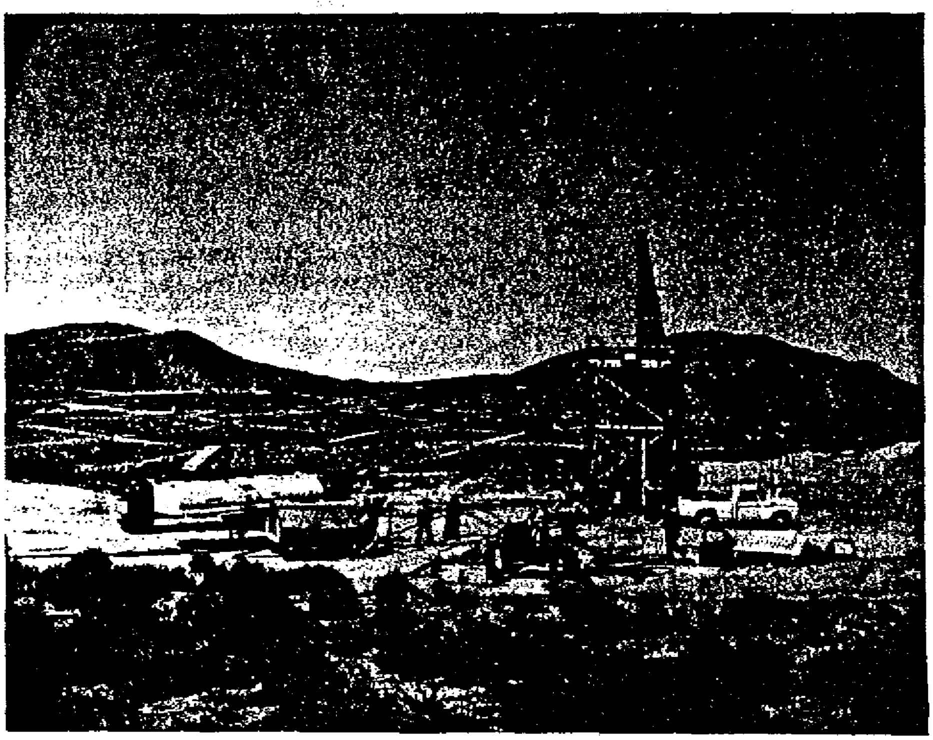

Figure 3.3 General view of activities at hole PM-2 as instrument array is being lowered into the hole. (FCWT DASA 148-36-FTS-63).

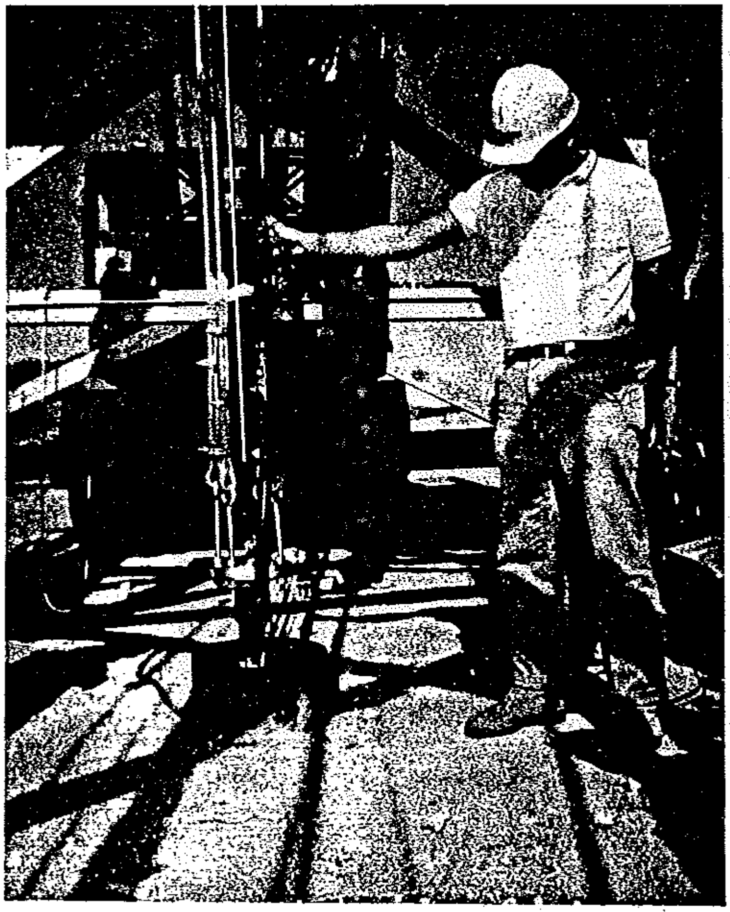

Figure 3.4 First grout injection hose attached to messenger cable immediately above the dead-weight. (FCWT DASA 148-49-FTS-63).

Figure 3.5 Connecting sections of perforated plastic pipe to serve as a casing for the grout injection hose, hole PM-8. (FCWT DASA 148-76-FTS-63).

Figure 3.6 Grouting operations for hole PM-8. (FCWT DASA 148-82-FTS-63).

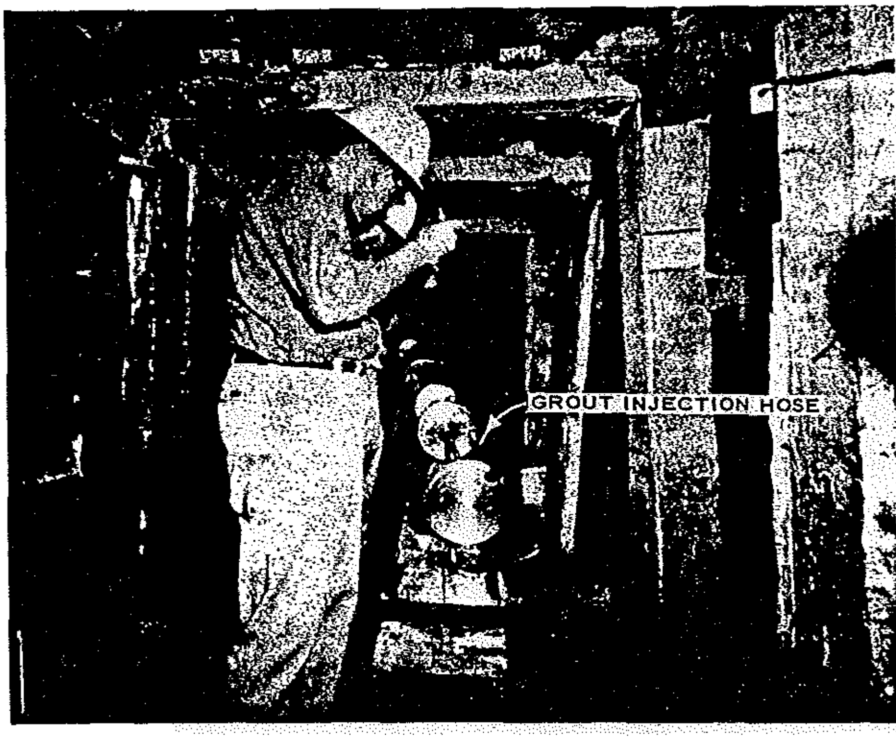

Figure 3.7 Instrument array immediately prior to emplacement in hole PM-5. Note grout injection hose near end of the array. (FCWT DASA 160-70-FTS-63).

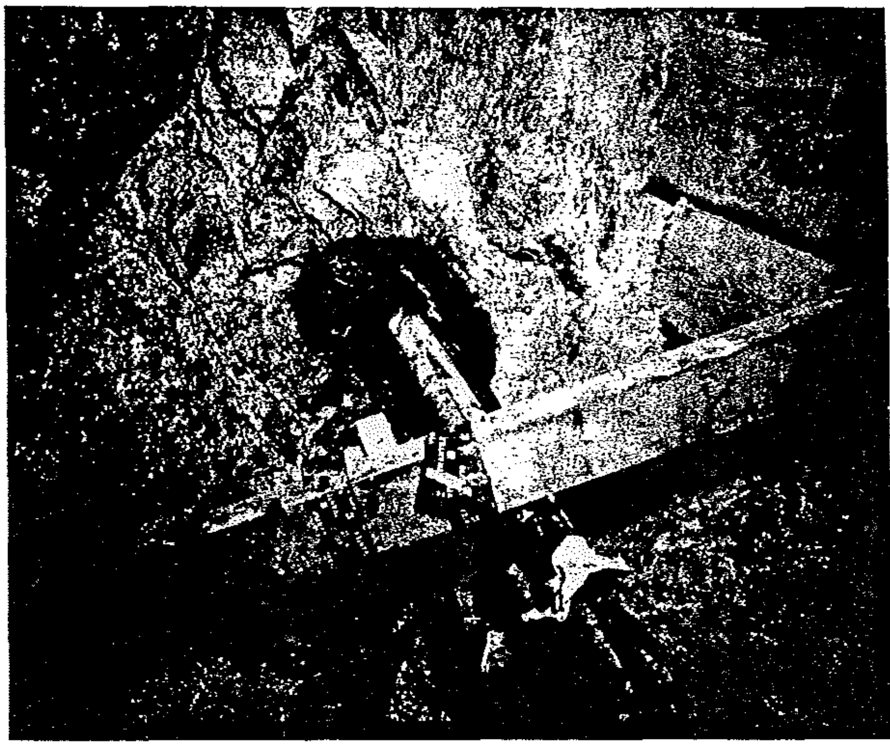

Figure 3.8 Quick-set-cement dry pack to hold the grout inside the drill hole. (FCWT DASA 160-72-FTS-63).

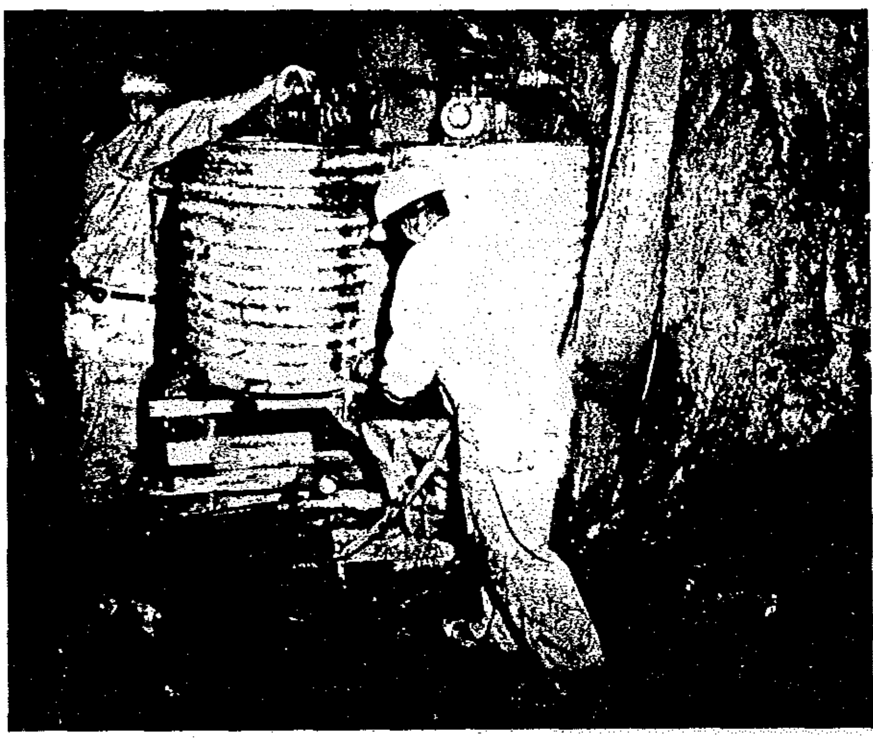

Figure 3.9 Typical grouting equipment setup for tunnel grouting. (FCWT DASA 160-73-FTS-63).

CHAPTER 4

PROPERTIES OF FIELD-MIXED GROUTS, AND CONCLUSIONS

4.1 RESULTS OF LABORATORY TESTS ON FIELD-CAST SPECIMENS

The following physical properties of grout specimens cast at the project site from mixtures 1, 2, and 3 were determined on the device-detonation date.

Test	Mixture No. 1	2	3
Density (hardened), lb/cu ft	165.4	92.5	--
Ultrasonic pulse velocity, fps	12,870	2180	--
Compressive strength, psi	9,340	200	8620

4.2 CONCLUSIONS

The properties of the field-cast specimens agree closely, particularly those of mixtures 2 and 3, with the results of the laboratory investigation (paragraph 2.4). The strength and velocity of mixture 1 were slightly higher in the field-cast specimens, though still somewhat lower than desired. The density of mixture 1 closely matched that of the in-situ granodiorite.

In general, it is believed that the instruments were well embedded in grout in all holes, that good bond of grout to instrument canisters was obtained, and that the grouting operation was successful in all respects.

APPENDIX

TESTS TO DETERMINE PHYSICAL PROPERTIES OF GRANODIORITE CORES

A.1 PURPOSE

Prior to the Project SHOAL event, tests were conducted in the laboratory at WES on three granodiorite cores from core hole ECH-D at the Project SHOAL site to provide information on the physical characteristics of the granodiorite formation in the area. Results of these tests were used as design criteria for grout mixtures simulating the granodiorite formation. The three granodiorite cores were identified as follows:

Core No.	Diameter, in.	Depth from Ground Surface ft
NTS-11 DC-1(A)	4	606.77-608.20
NTS-11 DC-1(B)	4	843.27-845.87
NTS-11 DC-1(C)	4	1158.0-1161.0

In the following paragraphs these cores will be referred to as A, B, and C.

A.2 PREPARATION OF CORES

After the three cores were measured and logged, they were sawed and numbered as shown in Figure A.1. The numbered cores were tested as follows:

Test	Core No.
Density	2, 5, 9
Ultrasonic pulse velocity	2, 5, 9
Petrographic examination	1, 3, 4, 7, 8, 11
Tensile-splitting strength	2(1),* 6, 10
Static chord modulus of elasticity	2(2), 5(1), 9(1)*
Compressive strength	5(2), 9(2)*

* Upon completion of density and ultrasonic pulse velocity tests, two 8-in. specimens were sawed from each of the three 20-in. specimens.

A.3 TESTS PERFORMED

A.3.1 Density. After the cores had been soaked for three days, their saturated, surface-dry densities were determined.

A.3.2 Ultrasonic Pulse Velocity. Using a soniscope, the velocity was determined according to the procedure described in Method CRD-C 51 of the Corps of Engineers "Handbook for Concrete and Cement."[1]

A.3.3 Modulus of Elasticity. Electrical resistance gages were mounted (diametrically opposite each other) on the granodiorite specimens to determine strains at 1000-psi unconfined compressive stress intervals. Stress versus strain was plotted, and the chord modulus of elasticity was determined between 4000- and 12,000-psi stresses.

A.3.4 Tensile-Splitting and Compressive Strengths. These strengths were determined according to procedures described in Methods CRD-C 77 and CRD-C 14, respectively, in "Handbook for Concrete and Cement."

A.4 TEST RESULTS

Results of the tests were as follows:

Test	Results		
	Core A	Core B	Core C
Density, lb/cu ft	163.9	165.1	165.1
Ultrasonic pulse velocity, fps	17,075	16,785	16,940
Compressive strength, psi	15,560	17,120	15,210
Tensile-splitting strength, psi	940	950	965
Static chord modulus of elasticity, psi	7.14×10^6	7.14×10^6	7.34×10^6

A.5 PETROGRAPHIC EXAMINATION

In addition to the previously mentioned tests, specimens of the three cores were subjected to petrographic examination.

A.5.1 Test Procedure. The top and bottom portions of cores A, B, and C were examined using a stereomicroscope, and one thin section from each core, oriented parallel to the long axis of the core, was prepared and examined with a petrographic microscope. Small pieces of rock from each sample were crushed to pass the No. 325 sieve and examined as powder samples on the XRD-5 diffractometer using copper radiation at 50 kvp and 16 ma.

A.5.2 Description of Rock. The cores were coarse-grained, gray granodiorite with granitic texture. The tops of two of the cores (A and C)

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[1] U. S. Army Engineer Waterways Experiment Station, CE, "Handbook for Concrete and Cement," with quarterly supplements (Vicksburg, Miss., August 1949).

were calcite-coated joint surfaces. The major constituents, as determined by X-ray tests and thin-section examination, were plagioclase (oligoclase) feldspar, potash feldspar, quartz, and biotite. The minerals detected in small amounts were chlorite, calcite (in small filled cracks), and amphibole. The texture was coarse-grained granitic, with subhedral feldspars and quartz well interlocked with each other and with the micas.

A.5.3 Summary. The cores appeared to be dense, cohesive, and unweathered. It was concluded that the feature most likely to affect the resistance to explosion was the presence of joints which, if not thoroughly sealed by grouting, would probably be lengthened by the shock. The X-ray patterns and thin sections were compared with results of previous tests of granite at the Nevada Test Site (NTS G-1) and were found to be very similar, except for the absence of sulfide-filled fractures in the Project SHOAL area cores.

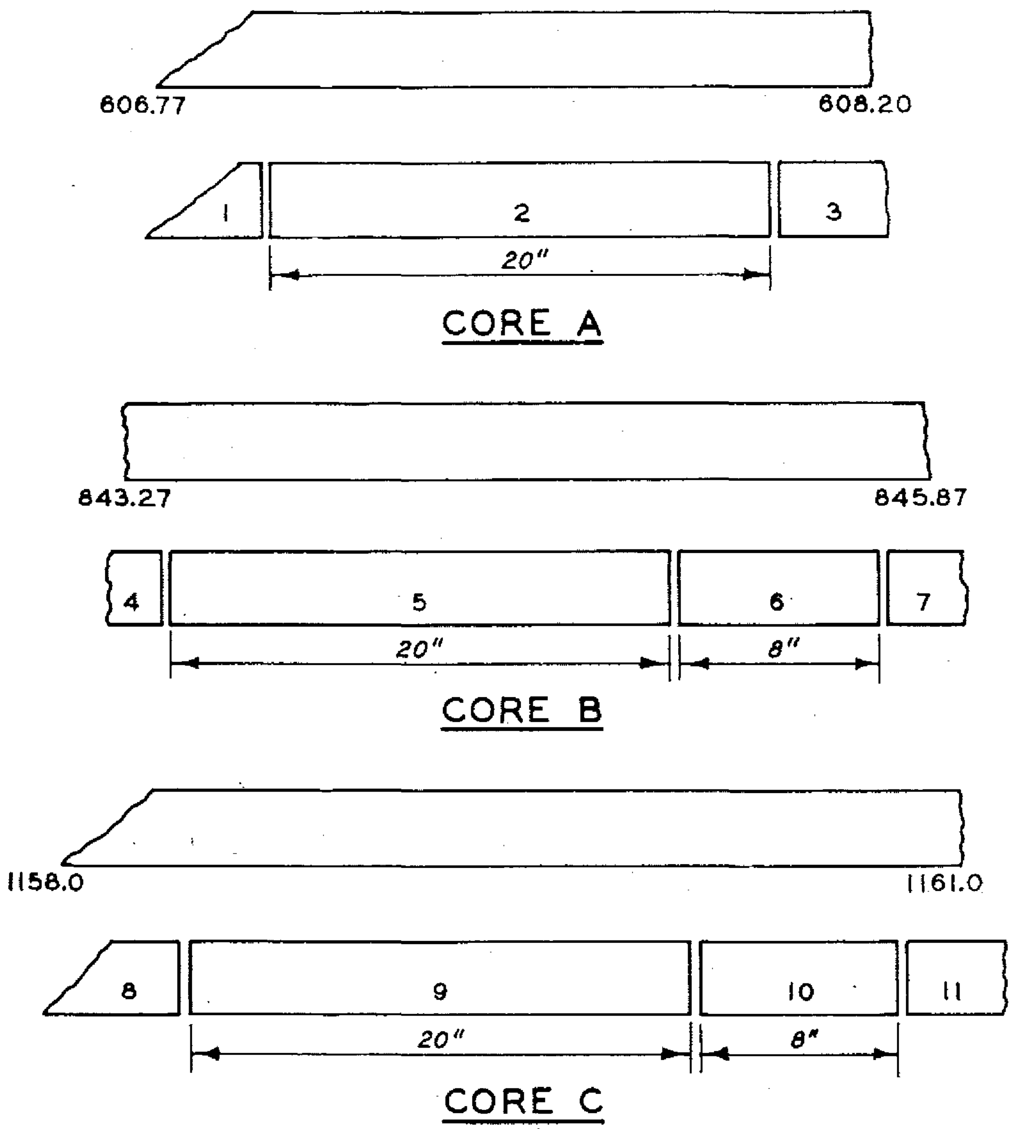

Figure A.1 Cores before and after sawing.

TECHNICAL REPORTS SCHEDULED FOR ISSUANCE BY AGENCIES PARTICIPATING IN PROJECT SHOAL

AEC REPORTS

Agency	Report No.	Project No.	Subject or Title
NBM	VUF-1001	33.2	Geological, Geophysical and Hydrological Investigations of the Sand Springs Range, Fairview Valley and Fourmile Flat, Churchill County, Nevada
SC	VUF-1002	40.5	Seismic Measurements at Sandia Stations
SC	VUF-1003	45.3	Hydrodynamic Yield Measurements
SC	VUF-1004	45.5	Device Support, Arming, Stemming and Yield Determination
SC	VUF-1005	45.6	Radiological Safety
EG&G	VUF-1006	60.4	Final Timing and Firing Report - Final Photo Report
USBM-PRC	*		Subsurface Fracturing From Shoal Nuclear Detonation
USWB	VUF-1008		Weather and Surface Radiation Prediction
USPHS	VUF-1009		Off-Site Surveillance
USBM	VUF-1010		Structural Survey of Private Mining Properties
USC&GS	VUF-1011		Seismic Safety Net
REECo	VUF-1012		On-Site Health and Safety Report

Agency	Report No.	Project No.	Subject or Title
RFB, Inc.	VUF-1013		Analysis of Shoal Data on Ground Motion and Containment
H-NSC	VUF-1014		Shoal Post-Shot Hydrologic Safety Report
H&N	VUF-1015		Pre-Shot and Post-Shot Structure Survey
H&N	VUF-1016		Test of Dribble-Type Structures
FAA	VUF-1017		Federal Aviation Agency Airspace Advisory
		DOD REPORTS	
SC	VUF-2001	1.1	Free Field Earth Motions and Spalling Measurements in Granite
SC	VUF-2002	1.2	Surface Motion Measurements Near Surface
** USC&GS	VUF-2300	1.4	Strong Motion Seismic Measurements
LPI	VUF-2600	1.6	In-Situ Stress in Granite
WES	VUF-2700	9.1	Grouting Support
** STL	VUF-2400	1.7	Shock Spectrum Measurements
SRI	VUF-3001	7.5	Investigation of Visual and Photographic On-Site Techniques
SRI	VUF-3002	7.6	Local Seismic Monitoring - Vela CLOUD GAP Program

TI	VUF-3003	7.8	Surface and Subsurface Radiation Studies
USGS	VUF-3004	7.9	Physical and Chemical Effects of the Shoal Event
ITEK	VUF-3005	7.10	Airborne Spectral Reconnaissance
BR Ltd.	VUF-3006	7.15	The Mercury Method of Identification and Location of Underground Nuclear Sites
NRDL	VUF-3007	7.16	Multi-Sensor Aerial Reconnaissance of an Underground Nuclear Detonation
GIMRADA	VUF-3008	7.17	Stereophotogrammetric Techniques for On-Site Inspection
ISOTOPES	VUF-3009	7.19	Detection in Surface Air of Gaseous Radionuclides from the Shoal Underground Detonation
*** USC&GS		8.1	Microearthquake Monitoring at the Shoal Site
**** GEO-TECH		8.4	Long-Range Seismic Measurements

* This is a Technical Report to be issued as PNE-3001 which will receive TID-4500 category UC-35 Distribution "Nuclear Explosions-Peaceful Applications"

** Project Shoal results are combined with other events, therefore, this report will not be printed or distributed by DTIE

*** Report dated March 1964 has been published and distributed by USC&GS

**** Report dated December 9, 1963, DATDC Report 92, has been published and distributed by UED

LIST OF ABBREVIATIONS FOR TECHNICAL AGENCIES

BR Ltd.	Barringer Research Limited Rexdale, Ontario, Canada
EG&G	Edgerton, Germeshausen & Grier, Inc. Boston, Massachusetts Las Vegas, Nevada Santa Barbara, California
FAA	Federal Aviation Agency Los Angeles, California
GEO-TECH	Geo Technical Corporation Garland, Texas
GIMRADA	U. S. Army Geodesy, Intelligence and Mapping Research and Development Agency Fort Belvoir, Virginia
H-NSC	Hazleton-Nuclear Science Corporation Palo Alto, California
H&N, Inc.	Holmes & Narver, Inc. Los Angeles, California Las Vegas, Nevada
ISOTOPES	Isotopes, Inc. Westwood, New Jersey
ITEK	ITEK Corporation Palo Alto, California
LPI	Lucius Pitkin, Inc. New York, New York
NBM	Nevada Bureau of Mines University of Nevada, Reno, Nevada
NRDL	U. S. Naval Radiological Defense Laboratory San Francisco, California
REECo	Reynolds Electrical & Engineering Co., Inc. Las Vegas, Nevada
SC	Sandia Corporation Albuquerque, New Mexico
SRI	Stanford Research Institute Menlo Park, California

RFB, Inc.	R. F. Beers, Inc. Alexandria, Va.
STL	Space Technology Laboratories, Inc. Redondo Beach Park, California
TI	Texas Instruments, Inc. Dallas, Texas
USBM	U. S. Bureau of Mines Washington, 25, D. C.
USBM-PRC	U. S. Bureau of Mines Bartlesville Petroleum Research Center Bartlesville, Oklahoma
USC&GS	U. S. Coast and Geodetic Survey Las Vegas, Nevada
USGS	U. S. Geologic Survey Denver, Colorado
USPHS	U. S. Public Health Service Las Vegas, Nevada
USWB	U. S. Weather Bureau Las Vegas, Nevada
WES	Waterways Experiment Station U. S. Army Engineers Vicksburg, Mississippi