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USACE / NAVFAC / AFCEC **UFGS-31 43 13.13 (February 2021)**

Preparing Activity: USACE **Superseding without Revision**
UFGS-31 32 23 (August 2008)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2025
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DIVISION 31 - EARTHWORK

SECTION 31 43 13.13

CONCRETE PRESSURE GROUTING

02/21

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SECTION 31 43 13.13

CONCRETE PRESSURE GROUTING
02/21

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NOTE: This guide specification covers the requirements for drilling exploratory holes; drilling drain holes; drilling, washing and pressure testing grout holes; making grout connections; furnishing, handling, transporting, storing, mixing and injecting the grouting materials; patching the finished grout holes; care and disposal of drill cuttings, waste water and waste grout; clean-up grout galleries and shafts and areas upon completion of the work and all such other operations as are incidental to the drilling and the grouting. This section was originally developed for USACE Civil Works projects.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

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NOTE: This guide specification has been prepared as a section in a general construction specification for concrete dams. By rewording as necessary, this specification may be adapted to other types of

foundation treatment, such as under power plants, locks, cutoff trenches, tunnels, and others.

Methods for listing subdivided items are described in Paragraph 52.2/9109(g) "Variations in Estimated Quantities - Subdivided Items" of Engineer Federal Acquisition Regulation Supplement (EFARS). However, effectiveness of the use of subdivided items in grouting has been questioned as being more hazardous than helpful and that FAR 52.211-16 Variation in Quantity should be used.

Provisions are made for the use of a sanded grout but should generally be limited to those formations where quantities in excess of one cubic foot of grout per linear foot of hole are anticipated. The information contained in EM 1110-2-3506, "Grouting Technology" and EM 1110-2-1302, "Cost Estimates - Government Estimate of Fair and Reasonable Cost to Contractor" should be used as a guide in estimating quantities.

Computer Application of Geotechnical Engineering (CAGE):

a. The CAGE Grouting Task Group has developed a microcomputer program for documentation of grouting operations and graphics for rapid display of data for better field control. Some of the highlights of the program include optional data entry by a laptop or hand held computer in the field, technical review and quality control, preparation of Contractors pay schedules, and preparation of foundation reports. The User's Guide "Microcomputer Grouting Data Package (Multiple Zone and Stage Version for PC and Hand Held Computer)" is available from the U.S. Army Engineer Waterways Experiment Station (USACE-WES-GL). Use of this CAGE package will not require contractual or technical additions to the contract specifications unless the computer equipment, other facilities, or personnel for data entry are to be Contractor supplied. In such case the proper provisions should be included. This program is also an attractive tool for use in grouting operations by Corps of Engineers personnel. Use of this program should be strongly considered for any grouting operation.

b. Computer-aided control and monitoring of the grout injection has recently been used by the U.S. Bureau of Reclamation (USBR) on several of their projects. Their system is appropriate for use on large grouting projects. Use of their system will necessitate certain contractual and technical additions to the specifications which are not included in this guide specification. If interested in this type system for a large grout program more information can be obtained by contacting the CAGE grout task group and the USBR.

Chemical or other specialty grouting applications have not been specifically addressed in this guide specification as most of the CE grouting in rock foundations for concrete structures, cutoff trenches, locks and powerhouses use cement grout. However, the specification may be used as a general outline for chemical or other specialty grouting applications by insertion of the proper equipment, materials, and procedures in the appropriate paragraphs and by modification and deletion of other paragraphs. Engineer Manuals 1110-2-3504, "Chemical Grouting", and 1110-2-3506, "Grouting Technology", should be used as guides when the use of chemical grouts and other specialty grouting applications are being considered. The manufacturer of those systems that meet the potential job requirements should be contacted for verification. Also, consideration should be given to conducting laboratory and field tests and evaluations of the system or systems being considered for a given applications. There may be occasions when the engagement of a consultant would be appropriate and advantageous to assist in the planning, selecting, and evaluating of a system under consideration. Engineer Manual 1110-2-2901, "Tunnels and Shafts in Rock", should be referred to when planning tunnel grouting and the guide specification for Tunnel and Shaft Grouting should be used in the preparation of project specifications.

If grouting is anticipated during extreme temperatures, alteration of certain field procedures may be necessary and should be included in the specifications. Generally, for cold weather grouting, the grout should be maintained at temperatures above 10 degrees C 50 degrees F until injected, and storage of the grouting materials should be at temperatures above freezing. Temperature controls for grouting surface rocks should be specified based on specific site conditions anticipated. Insulation, heated enclosures, water heaters or other equipment or procedures may be required. Grouting in extremely hot weather may also require extra precautions.
****

1.1 SUMMARY

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NOTE: If no separate section on "CONCRETE" is used, the appropriate paragraphs applicable to sampling and testing in SECTION 03 70 00 MASS CONCRETE should be inserted in the following paragraphs in lieu of the section reference given below. If a "CONCRETE" section, other than SECTION 03 70 00 MASS CONCRETE is used, the Designer should ensure that the applicable sampling and testing is included in that section.
****

a. This section covers drilling exploratory holes; drilling drain holes; drilling, washing and pressure testing grout holes; making grout connections; furnishing, handling, transporting, storing, mixing and injecting the grouting materials; backfilling holes; patching the finished grout holes; care and disposal of drill cuttings, waste water and waste grout; clean up of [grout galleries and shafts][the areas] upon completion of the work and all other such operations as are incidental to the drilling and grouting. The work contemplated consists of [constructing a grout curtain and a drainage curtain][area grouting], the approximate locations, limits, and details which are indicated. Perform Government preconstruction sampling and testing as specified below:

b. Perform sampling and testing of sand, cementitious materials, and admixtures in accordance with Section [03 70 00 MASS CONCRETE][03 30 00 CAST-IN-PLACE CONCRETE].

c. Perform sampling and testing of grout materials in accordance with Section [03 70 00 MASS CONCRETE][03 30 00 CAST-IN-PLACE CONCRETE].

1.2 UNIT PRICES

****
NOTE: If Section 01 20 00 PRICE AND PAYMENT PROCEDURES is included in the project specifications, this paragraph title (UNIT PRICES) should be deleted from this section and the remaining appropriately edited subparagraphs below should be inserted into Section 01 20 00.
****

1.2.1 Mobilization and Demobilization

1.2.1.1 Payment

Payment will be made for costs for assembling all plant and equipment at the site, preparatory to initiating the work and for removing it therefrom when the drilling and grouting program has been completed. Sixty (60) percent of the contract lump sum price for mobilization and demobilization will be paid following completion of moving onto the site, including complete assembly, in working order, of all equipment necessary to perform the required drilling and grouting operations. The remaining forty (40) percent of the contract lump sum price will be paid when all equipment has been removed from the site.

1.2.1.2 Unit of Measure

Unit of measure: lump sum.

1.2.2 Drilling Grout Holes

****
NOTE: Delete the bracketed phrase if pay item "Pressure Washing and Pressure Testing" is retained as a pay item.
****

1.2.2.1 Payment

Payment will be made for costs associated with drilling and redrilling grout holes; [washing and pressure testing of grout holes;]care and disposal of waste water and waste grout; clean-up of the site; furnishing, handling, transporting and storing of grout materials; and for furnishing all labor and supplies incidental to the work. This price is subject to the cost limitation imposed by[Section 31 43 13.13 CONCRETE PRESSURE GROUTING,] paragraph PIPE FOR FOUNDATION GROUTING AND DRAINAGE, but only in those locations where pipe is specified. No payment will be made for grout, or the material constituents thereof, wasted due to improper anchorage of grout pipe or connections, or which is wasted due to negligence on the part of the Contractor, nor for grout which is rejected by the Contracting Officer because of improper mixing. Payment will be made at the applicable contract unit prices for materials contained in grout which are wasted, where the wasting is not due to negligence on the part of the Contractor.

1.2.2.2 Measurement

Drilling of grout holes will be measured for payment on the basis of the linear feet of holes actually drilled in concrete or rock, as shown or as directed, including all intermediate holes at locations where pipe was not installed.

1.2.2.3 Unit of Measure

Unit of measure: linear meter foot.

1.2.3 Drilling Drain Holes

1.2.3.1 Payment

Payment will be made for costs associated with drilling of drain holes actually drilled in concrete or rock, as shown or as directed. This price is subject to the cost limitation imposed by[Section 31 43 13.13 CONCRETE PRESSURE GROUTING,] paragraph PIPE FOR FOUNDATION GROUTING AND DRAINAGE.

1.2.3.2 Measurement

Drilling of drain holes will be measured for payment on the basis of the linear meter feet of holes actually drilled in concrete or rock, as shown or as directed.

1.2.3.3 Unit of Measure

Unit of measure: linear meter foot.

1.2.4 Drilling Exploratory Holes

****
NOTE: If a portion of exploratory drilling is to be done through overburden, a separate pay item should be included for this portion.
****

1.2.4.1 Payment

Payment will be made for costs associated with drilling of exploratory

holes.

1.2.4.2 Measurement

Drilling of exploratory holes will be measured for payment on the basis of the linear meters feet of holes actually drilled in concrete or rock, as directed by the Contracting Officer.

1.2.4.3 Unit of Measure

Unit of measure: linear meter foot.

[1.2.5 Pressure Washing and Pressure Testing

[1.2.5.1 Payment

Payment will be made for pressure washing and pressure testing of grout holes, which includes the cost of making and breaking connections incidental to the work. Payment will be based upon the total amount of time required for pressure washing and pressure testing, determined by reducing the total number of minutes of operation to the nearest whole hour. No payment will be made for time lost due to fault or negligence of the Contractor, or due to defective equipment furnished by the Contractor. Time will be measured cumulatively to the next whole minute of operations.

][1.2.5.2 Measurement

Pressure washing and pressure testing will be measured for payment on the basis of the actual time water pumps are operating. Pressure washing and pressure testing will be measured from the time pumping is begun on a hole or section of a hole until the time pumping is completed on the hole or section of the hole as determined by the Contracting Officer. Operation time will be determined by rounding 30 or more minutes of operation up to the nearest whole hour, and rounding 29 or less minutes of operation down to the nearest whole hour. Fractional time will be measured cumulatively to the next whole minute of operation.

][1.2.5.3 Unit of Measure

Unit of measure: nearest whole hour.

]]1.2.6 Steel Pipe and Fittings

1.2.6.1 Payment

Payment will be made for costs associated with grout and drain hole pipe and fittings remaining in the permanent work.

1.2.6.2 Measurement

Pipe and fittings will be measured for payment on the basis of the actual weight of satisfactorily installed pipe and fittings left in place as shown. No additional allowance will be made because of differences in pipe size or length, or the number of pipes required.

1.2.6.3 Unit of Measure

Unit of measure: kilogram pound.

1.2.7 Portland Cement in Grout

1.2.7.1 Payment

Payment will be made for costs associated with Portland cement in grout.

1.2.7.2 Measurement

Portland cement in grout will be measured for payment on the basis of the number of cubic meters (42.6 kilograms) feet (94 pounds) of cement used in the grout satisfactorily placed in grout holes and in exploratory holes, or wasted when such wasting is not due to the Contractor's negligence.

1.2.7.3 Unit of Measure

Unit of measure: cubic meter (42.6 kilograms) foot (94 pounds).

1.2.8 Pozzolans (Fly Ash) in Grout

1.2.8.1 Payment

Payment will be made for costs associated with fly ash in grout.

1.2.8.2 Measurement

Fly ash in grout will be measured for payment on the basis of the number of cubic meters (33.6 kilograms) feet (74 pounds) of fly ash used in the grout satisfactorily placed in grout holes.

1.2.8.3 Unit of Measure

Unit of measure: cubic meter foot.

1.2.9 Sand in Grout

1.2.9.1 Payment

Payment will be made for costs associated with sand in grout.

1.2.9.2 Measurement

Sand in grout will be measured for payment on the basis of the number of cubic meters feet of sand[, dry rodded measurement,] used in the grout satisfactorily placed in grout holes or in exploratory holes.

1.2.9.3 Unit of Measure

Unit of measure: cubic meter foot.

1.2.10 Fluidifier in Grout

1.2.10.1 Payment

Payment will be made for costs associated with fluidifier in grout, including full allowance for the payment by the Contractor of all required royalties.

1.2.10.2 Measurement

Fluidifier in grout will be measured for payment on the basis of the number of kilograms pounds of fluidifier used in the grout satisfactorily placed in grout holes.

1.2.10.3 Unit of Measure

Unit of measure: kilogram pound.

1.2.11 Bentonite in Grout

1.2.11.1 Payment

Payment will be made for costs associated with bentonite in grout.

1.2.11.2 Measurement

Bentonite in grout will be measured for payment on the basis of the number of kilograms pounds of bentonite actually used in grout mixtures satisfactorily placed in grout holes.

1.2.11.3 Unit of Measure

Unit of measure: kilogram pound.

1.2.12 Placing Grout

****

NOTES: Select appropriate Alternative.

Under certain conditions it may be desirable to include a pay item for standby time for Government directed suspension of drilling or grouting operations.

****

1.2.12.1 Payment

Payment will be made for costs associated with satisfactorily placing grout in grout holes[, which includes full compensation for proportioning the mix as directed and mixing and injecting the grout as specified[in Section 31 43 13.13 CONCRETE PRESSURE GROUTING]. Separate payment will be made for all materials used in grout as provided in unit price pay item(s) "Portland Cement in Grout"[, "Pozzolans (Fly Ash) in Grout", "Sand in Grout", "Fluidifier in Grout", and "Bentonite in Grout"].][. No payment will be made for time lost due to fault or negligence of the Contractor or due to defective equipment furnished by the Contractor.]

1.2.12.2 Measurement

Placing grout will be measured for payment on the basis of [the number of cubic meters feet of materials, satisfactorily placed, exclusive of water [and fluidifier] and regardless of the proportions of the mixes, measured individually as specified in unit price pay items "Portland Cement in Grout", "Pozzolans (Fly Ash) in Grout", and "Sand in Grout".][the actual time grout pumps begin pumping on a hole or portion of hole and continuing until the time pumping is completed on that hole or portion of hole, as determined by the Contracting Officer. Time for satisfactory placement of

grout will be determined by rounding 30 or more minutes of placement time up to nearest whole hour, and rounding 29 or less minutes of placement time down to the nearest whole hour. Fractional placement time will be measured cumulatively to the next whole minute of operation.]

1.2.12.3 Unit of Measure

Unit of measure: [cubic meter foot.] [nearest whole hour.]

[1.2.13 Connections to Grout Holes

****
NOTE: The price to be inserted in this paragraph should be determined on the basis of the estimated cost to the Contractor for the operation of moving the grout supply line onto the hole. This price should not include any allowance for pipe or other materials used in making the connections. This unit price pay item may be optional for grout payment on an hourly basis.
****

[1.2.13.1 Payment

[Payment will be made for costs associated with connections to grout holes at a rate of [_____] dollars per connection. Where stop grouting method is used [payment for at least one connection will be made for each packer setting in a hole].][Payment for only one connection will be made for each hole regardless of the number of settings.]

][1.2.13.2 Measurement

Connections to grout holes will be measured for payment per connection for each time the grout supply line is connected to a grout hole for the purpose of injecting grout regardless of the number of times connections are made per hole or the amount of grout actually injected.

][1.2.13.3 Unit of Measure

Unit of measure: each.

]]1.3 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically

be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.3	(2021) Malleable Iron Threaded Fittings, Classes 150 and 300

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2024) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM C70	(2020) Standard Test Method for Surface Moisture in Fine Aggregate
ASTM C91/C91M	(2018) Standard Specification for Masonry Cement
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C150/C150M	(2024) Standard Specification for Portland Cement
ASTM C618	(2023; E 2023) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C937	(2023) Grout Fluidifier for Preplaced-Aggregate Concrete

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 100	(1975) Method of Sampling Concrete Aggregate and Aggregate Sources, and Selection of Material for Testing

1.4 DEFINITIONS

1.4.1 Zone

A zone is a predetermined partial depth of curtain. The first zone extends [_____] m feet downward from [the contact between the concrete and the rock] [the bottom of the cutoff trench] [overburden and the top of rock] overburden and elevation [_____]. The second zone extends [_____] m feet downward from the bottom of the first zone. The third zone extends [_____] m feet downward from the bottom of the second zone. [Define additional zones as needed]. Finish all grouting in a given zone and section before work is started in the next [higher] [lower] zone.

1.4.2 Section

A section is a reach along the grout curtain, not more than [_____] feet in length in which grouting operations will not be permitted at the same time that drilling is in progress. Insofar as practicable, the grout curtain will be subdivided into sections in a manner which will facilitate the Contractor's operations.

1.4.3 Stage

A stage is one complete operational cycle of drilling, cleaning, pressure washing, pressure testing, pressure grouting, and grout cleanout within a zone. The actual depth of a stage depends upon geologic conditions encountered in drilling. It may vary from a fraction to the full depth of the zone, and is marked by the loss or gain of drill water in appreciable amounts.

1.4.4 Stop

A stop is a predetermined depth at which the expanding plug or packer is positioned.

1.4.5 Split Spacing

Split spacing is the procedure of locating an additional grout hole midway between two previously drilled and grouted holes.

1.5 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL

PROCEDURES.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Drilling Equipment

Grouting Equipment

Grout Plant; G, [_____]

1.6 DELIVERY, STORAGE, AND HANDLING

****
NOTE: If no separate section on "CONCRETE" is used, the appropriate paragraphs applicable to material delivery, storage, and handling in SECTION 03 70 00 MASS CONCRETE should be inserted in this paragraph in lieu of the section reference given below. If a "CONCRETE" section, other than SECTION 03 70 00 is used, the Designer should ensure that the applicable material delivery, storage, and handling paragraphs are included in that section.
****

Furnish transportation and storage of materials in accordance with section [03 70 00 MASS CONCRETE][03 30 00 CAST-IN-PLACE CONCRETE]. Store a sufficient quantity of cement at or near the site of the work to insure that grouting operations will not be delayed by shortage of cement. In the event the cement is found to contain lumps or foreign matter of a nature and in amounts which, in the opinion of the Contracting Officer, may be deleterious to the grouting operations, screening through a standard 100 mesh screen may be required. No payment will be made for such screening.

1.7 PROJECT/SITE CONDITIONS

The program shown and described is based on currently available information. Conditions encountered during construction may require additions or deletions. Do not modify or curtail the grouting program as a construction expediency. It is a required part of design and is not secondary to any time or scheduling restrictions. Determine grouting mixes, pressures, injection rate and the sequence in which the holes are drilled and grouted in the field and as directed.

PART 2 PRODUCTS

2.1 GROUTING MATERIAL

Provide grout composed of water and cement, [pozzolans, admixtures, and fillers]. The grout mixes will be designed by the Contracting Officer and

will be varied to meet the characteristics of each hole as determined by conditions encountered. Furnish various materials conforming to the specifications listed in paragraphs below.

2.1.1 Water

[Furnish the water used in the grout. Provide fresh, clean water that is free from injurious amounts of sewage, oil, acid, alkali, salts, or organic matter.][Water suitable for use in the work will be furnished by the Government. It is the responsibility of the Contractor to provide any necessary connections and extensions to the Government supply line shown.]

2.1.2 Cement

****
NOTE: Avoid specifying the use of air entrained cement, except on rare occasions when grout may be exposed to severe freezing and thawing conditions.
****

Provide cement used in grout conforming to the requirements of ASTM C91/C91M and ASTM C150/C150M. The use of bulk cement will be permitted provided the Contractor employs methods of handling, transporting, and storage that are satisfactory to the Contracting Officer, otherwise only cement furnished in cloth or paper bags will be accepted to use in the work. Store cement in accordance with paragraph DELIVERY, STORAGE, AND HANDLING.

2.1.3 Pozzolans

Provide fly ash pozzolans [or other raw or calcined natural pozzolans] conforming to ASTM C618. Sampling will be done by an authorized representative of the Government. All tests will be made by and at the expense of the Government. Pozzolans may be furnished in paper sacks or in bulk. Transport, handle, and store it so as to avoid damage, waste, or absorption of moisture.

2.1.4 Admixtures

****
NOTE: Refer to EM 1110-2-3506, "Grouting Technology", for discussions of properties, characteristics and limitations for principal admixture and filler materials. Only the more commonly used are included here.
****

Add admixtures to the grout immediately before or during its mixing that consist of [accelerators, retarders, water reducers, aluminum powder, and fluidifiers].

2.1.5 Fluidifier

Furnish fluidifier that is a compound possessing characteristics which will increase the flowability of the mixture, assist in dispersal of the cement grains, and neutralize the setting shrinkage of the grout. The quality of the material must meet the requirements specified in ASTM C937. Sample fluidifier by an authorized representative of the Contracting Officer. Trial mixtures should be tested prior to using the materials in

field work. All tests will be made by and at the expense of the Government. Furnish fluidifier in moisture-resistant paper sacks shipped in sealed containers and handle and store so as to avoid absorption of moisture, damage or waste. Material which has become caked due to moisture absorption will be rejected.

2.1.6 Bentonite

Provide sodium (Na) cation, powdered montmorillonite bentonite. Add 2 percent to 5 percent by weight of cement to the cement grout. Adjust the percentage as directed by the Contracting Officer. A separate colloidal bentonite mixer is required to mix the bentonite and water to ensure fully dispensing and hydrating the bentonite before adding to the grout mixer. Handle and store the bentonite so as to avoid absorption of moisture, damage, or waste. Bentonite which has become caked due to moisture absorption will be rejected. Store a sufficient quantity of bentonite at or near the site of the work to insure that grouting operations will not be delayed by shortage of bentonite.

2.1.7 Sand

a. Provide clean sand for grout consisting of hard, tough, durable, uncoated particles with no more than [_____] percent passing the No. 200 sieve. Provide generally rounded or cubical shaped particles [containing no more than [_____] percent of flat or elongated pieces having a maximum dimension in excess of five times the minimum dimension]. Provide sand that is generally well graded from fine to coarse in accordance with ASTM C136/C136M with 100 percent passing the [No. 8][_____] sieve.

b. Subject the sand to such tests as are necessary to determine its acceptability. Perform sampling of sand in accordance with the applicable sampling provisions contained in COE CRD-C 100 or as directed. Unless otherwise directed, take all test samples under the supervision of the Contracting Officer and deliver to a designated point, at the expense of the Contractor, at least [_____] days in advance of the time when sand will be required at the site of work. All tests will be made by the Government at its expense. The tests to which the sand will be subjected will include specific gravity, absorption, soundness in magnesium sulfate, petrographic analyses, and any other tests that are necessary to demonstrate that grout of adequate durability can be produced.

c. The percentage of surface moisture in terms of the saturated surface-dried sand will be determined in accordance with ASTM C70, or other method giving comparable results.

d. Store sand in such a manner as to avoid the inclusion of any foreign materials in the grout. Maintain all sand in free draining storage for at least 72 hours prior to use.

2.2 METAL PIPE AND FITTINGS

Furnish, cut, thread, and fabricate pipe and fittings required for constructing grout, drainage and exploratory holes.

2.2.1 Pipe

Pipe will be black steel of the diameter and in the location indicated.

Furnish pipe conforming to ASTM A53/A53M.

2.2.2 Fittings

Provide black, malleable iron fittings in accordance with ASME B16.3.

PART 3 EXECUTION

3.1 EQUIPMENT

****

NOTE: For jobs where the estimated quantity of solids is between zero and 30 cubic meters 1,000 cubic feet, a pumping capacity of 950 cm^3/s 15 gpm is recommended; from 30 to 1400 cubic meters 1,000 to 50,000 cubic feet, a 1900 cm^3/s 30 gpm pump; and for jobs greater than 1400 cubic meters 50,000 cubic feet, a 3800 cm^3/s 60 gpm pump. Also, for jobs where large grout quantities are anticipated it may be desirable to specify an automated batching plant with batch tickets for all items in the mix.

****

The use of internal combustion engines within dam galleries for operation of drilling and grouting equipment will not be permitted. Submit details and data on the drilling and grouting equipment.

3.1.1 General

Use drilling [including exploratory hole drilling] and grouting equipment of a type, capacity and mechanical condition suitable for performing the work, as determined by the Contracting Officer. Provide power and equipment and the layout thereof meeting all applicable requirements of local, State, and Federal regulations and codes, both safety and otherwise.

3.1.2 Drilling Equipment

Use standard drilling equipment of the rotary [or percussion] type to perform the drilling as specified in paragraphs GROUT HOLE DRILLING, DRAIN HOLE DRILLING, COMPLETION OF GROUTING AND DRAIN HOLE DRILLING, and EXPLORATORY HOLE DRILLING. Use [water] [air] for removing cuttings from the hole during drilling operations. Equip air driven drills used in galleries with suitable mufflers. Supplies include all bits, drill rods, tools, casing, piping, pumps, water, and power to accomplish the required drilling. All drilling rigs and pumps will be equipped with pressure gages.

3.1.3 Grouting Equipment

Furnish grout plant capable of supplying, mixing, stirring and pumping the grout and additives, to the satisfaction of the Contracting Officer. Submit a detailed plan showing equipment and grout plant layout proposed for mixing and placing grout. Furnish plant with a minimum capacity of [[_____] mL/s] [[_____] cm^3/s] [[_____] gpm] [[_____] cfm] of grout injected at a pressure not greater than [_____] kPa psi. Maintain it at all times and replace any grout hole that is lost or damaged due to mechanical failure of equipment or inadequacy of grout supply by another hole, drilled by the Contractor, at its expense. Provide the amount of

grouting equipment as necessary to perform the work specified herein. Include the following:

a. A progressive cavity pump capable of passing particles up to a top size of [_____] mm inches, generating pressures up to [_____] kPa psi and pumping a maximum of [[_____] mL/s] [[_____] cm^3/s] [[_____] gpm] [[_____] cfm]. In no case will the pump be separated by more than [_____] meters feet of grout line from the header of a hole being grouted. Where grout lines are more than [_____] meters feet long, place an additional pump in the line within [_____] meters feet of the header.

b. A [colloidal] [paddle] type grout mixer having a minimum drum capacity of approximately [_____] cubic meters feet with a mix batch of [_____] cubic meters feet. Provide mixing time of approximately [_____] seconds per batch.

c. A separate colloidal mixer for mixing and hydrating bentonite.

d. A mechanically agitated sump having a minimum capacity of [_____] cubic meters feet.

e. A circulating grout header with control valves and a pressure gage with protector as shown on the plans. Connect control valves to the return line and header. Join the header directly to the riser pipe at the hole by means of a quick connector union.

f. A water storage tank or suitable source of clean auxiliary water for use in washing, pressure testing and flushing operations.

g. A water meter graduated in cubic meters feet and tenths having a direct reading totalizer and capable of conveniently being set back to zero.

h. Such valves, packers, pressure gages, pressure hose, supply lines, and small tools as may be necessary to provide a continuous supply of grout at accurately controlled pressures as specified. The inside diameter of the pressure hose and grout supply line less than [_____] mm inches is not permitted. Use an accurately calibrated, high precision pressure gage to check the accuracy of all gages used in the grouting. Chec gages at least every 24 hours, or more frequently if the Contracting Officer so determines. When defects are found, grouting operations will be stopped until calibration of gages has been obtained.

3.2 GROUT, DRAINAGE AND EXPLORATORY HOLES

Drill all holes for grouting, drainage or exploration at the locations, in the direction, angle, and to the depths indicated or as directed by the Contracting Officer.[Provide a maximum tolerance for deviation in angle and direction of [_____].] Drill and grout the first series of holes at [_____] meter foot intervals and hereinafter are referred to as primary holes. Determine the location of secondary and succeeding series (intermediate) holes by the split spacing method as defined in paragraph SPLIT SPACING. Increase the number of grout holes progressively by the split spacing method as defined in paragraph SPLIT SPACING. Increase the number of grout holes progressively by the split spacing method as deemed necessary by the Contracting Officer until the amount of grout used indicates that the foundation is tight. Protect each hole drilled from

becoming clogged or obstructed by means of a cap or other suitable device on the collar and clean out any hole that becomes clogged or obstructed due to fault of the Contractor before completion of operations in a manner satisfactory to the Contracting Officer or provide another hole at the expense of the Contractor. That portion of holes which penetrates concrete of the dam must be [formed by embedding pipes in the concrete at the time of its placement] [drilled] as specified in paragraph PIPE FOR FOUNDATION GROUTING AND DRAINAGE. Payment will be made for such partial depth of holes at the unit contract price for [Item No. [_____] "Steel Pipe and Fittings"], [Item No. [_____] "Drilling Grout Holes"], [Item No. [_____] "Drilling Drain Holes"], [Item No. [_____] "Drilling Exploratory Holes"].

3.2.1 Pipe for Foundation Grouting and Drainage

Embed all metal pipe and fittings required for constructing grout, drainage and exploratory holes. Thoroughly clean pipe and fittings of all dirt, grease, oil, grout and mortar immediately before embedment. Make all joints snug and hold the assembly firmly in position and protect from damage or displacement while the concrete is being placed. Take all necessary precautions to prevent any pipe from becoming clogged or obstructed from any cause and clean out any pipe which becomes clogged in a manner satisfactory to the Contracting Officer at the Contractor's expense. Consider the presence of tramp metal such as nails, wire, bolts, nuts and other foreign material in the pipes through which diamond drilled holes are to be drilled as obstructions. As an option, substitute percussion or diamond drilled holes through the concrete in lieu of pipe, provided that the method proposed meets with the approval of the Contracting Officer and provided further that such substitution does not result in any increased cost to the Government.

3.2.2 Grout Hole Drilling

a. Drill grout holes with standard rotary [or percussion] drilling equipment. No core recovery will be required and the type bit used will be optional with the Contractor. [Provide hole of sufficient diameter to allow use of an expansion plug or packer with an effective inside diameter of not less than 13 mm 1/2 inch]. The minimum diameter of hole must be [35] [_____] mm [1 3/8] [_____] inches at the point of maximum penetration. No grout hole will be drilled at an angle greater than [_____] degrees measured from the vertical nor to a depth greater than [_____] meters feet measured from the collar of the hole. If, as the work progresses, it is determined that holes to depths greater than indicated are necessary, drilling to such greater depth will be ordered in writing, and the drilling to depths in excess of [_____] meters feet will be paid for at a negotiated unit price.

b. Perform drilling in accordance with the applicable grouting method hereinafter described. Whenever as much as [_____] percent of the drill water is lost or the cumulative total of successive water losses is estimated to amount to [_____] percent loss, or artesian flow is encountered, stop the drilling operations, wash the hole, pressure test and grout before drilling operations are resumed in such hole. Remove injected grout from a partially completed hole by washing or other methods before it has set sufficiently to require redrilling. Redrilling required because of the Contractor's failure to clean out a hole before the grout has set must be performed at the Contractor's expense except that where the grout has been allowed to set by direction of the Contracting Officer, the redrilling will be paid for

at the contract price for drilling the grout hole. Upon completion of drilling of any hole and prior to pressure testing, remove all drill cuttings and slurry by applying water to the bottom of the hole [through open end rods] and returning the wash water through the hole to the surfaces until the return water is clear. No separate payment will be made for this washing.

3.2.3 Drain Hole Drilling

Drill drain holes with standard diamond drilling equipment, but no core recovery will be required and the Contractor may elect to use coring or noncoring bits. The minimum diameter of hole must be [72] [_____] mm [2 7/8] [_____] inches, measured at the point of maximum penetration. No drain hole will be drilled at an angle greater than [_____] degrees from the vertical nor to a depth greater than [_____] meters feet, measured from the collar of the hole. Do not drill drainage holes in any location until all adjacent grout holes within a minimum distance of 50 meters 150 feet have been drilled and grouted to full depth.

3.2.4 Completion of Grouting and Drain Hole Drilling

Complete all grouting operations and all drain hole drilling in proper working condition prior to the time of impounding water. At that time complete all work in the [grouting and drainage galleries] [tunnels], uncover and unobstruct all drain holes, and make [galleries and their gutters] [tunnels] free of all construction debris. Nipples for grout hole drilling will be removed from the [gallery] [cutoff trench] and disposed of and the finished grout holes will be patched.

3.2.5 Exploratory Hole Drilling

a. Perform such exploratory drilling as may be required to determine the condition of the rock prior to grouting or the effectiveness of the grouting operations during or after grouting. Perform all exploratory drilling with rotary drilling equipment using coring type bits. Since the maximum recovery of unpredictable soft or friable materials is of prime importance, make every effort to recover 100 percent of the core by use of the appropriate equipment and drilling procedures.

b. The holes may be required to be drilled to varying depths, with a maximum depth of [_____] meters feet. No exploratory hole will be drilled at an angle greater than [_____] degrees measured from the vertical.

c. Special care should be exercised to obtain cores in as good condition as possible. Keep, in a manner satisfactory to the Contracting Officer, an accurate Driller's Log of all exploratory holes drilled. Include a nontechnical description of all materials encountered in the drilling, their location in the holes and the location of special features such as seams, open cracks, soft or broken rock, points where abnormal loss or gain of drill water occurred, and any other items of interest in connection with the purpose for which the exploratory drilling is required.

d. Wooden or other approved core boxes will be furnished by [the Government] [the Contractor], and place the cores in the boxes in the correct sequence and separated accurately by wooden blocks, according to the measured distances in the hole. Do not contain cores from more than one hole. Fasten the covers securely to the core boxes and

deliver in the vicinity of the work as directed.

e. Grout exploratory holes under pressure, if conditions so indicate, by [stop grouting] [grouting to full depth in one operation] and backfilled in accordance with paragraph BACKFILLING OF HOLES.

3.3 PROCEDURES FOR DRILLING AND GROUTING

3.3.1 General

Accomplish drilling and grouting in single or multiple lines as shown. Drill and grout by [zones, using the split spacing, stage grouting method] [split spacing, stop grouting method] as described herein.

3.3.2 Stage Grouting

Perform stage grouting of progressively deeper zones in stages with the placement of a grout curtain by drilling and grouting in successive operations in accordance with the following general procedure.

3.3.2.1 Primary Holes

Drill primary holes for foundation grouting to their first stage of depth within the first zone. The depths will be governed by the foundation conditions.

a. Wash and pressure test the holes thus drilled and then grout, except that when pressure testing indicates a relatively tight hole, the Contracting Officer may direct that the grouting of that hole be omitted for that stage and the hole be left open for drilling and grouting of the next stage.

b. After the grouting of any hole, [remove the grout within the hole by washing or by other methods before it has set sufficiently to require redrilling][allow the grout within the hole to set and subsequently redrillthe holes].

c. After the interval of time as specified in paragraph SECOND STAGE, drill the primary holes not already drilled to the limit of the first zone as directed to additional depths not exceeding the zone limit.

d. Wash the primary holes thus deepened again and pressure test and then grout at higher pressures as directed. Again, remove the grout within the hole as described above.

e. Repeat the process of successively drilling primary holes to additional depths and grouting at higher and higher pressures in stages, as directed, until all of the primary holes on the maximum spacing (see paragraph GROUT, DRAINAGE AND EXPLORATORY HOLES) have been completely drilled and grouted to the depth of the first zone in that section of the grout curtain.

3.3.2.2 Successive Holes

After the primary holes in the first zone have been completed in any section as specified above, drill and grout the second and succeeding series of holes, as determined by the "split spacing method," to the depth of the first zone in like manner until the first zone of that section is completely grouted as directed.

3.3.2.3 Completion of Section

Repeat the process of successively drilling to additional depths and grouting at higher and higher pressures in stages for the first series of holes and then for succeeding series of holes for the second and subsequent zones of that section. Grout other sections along the grout curtain in like manner until grouting of the foundation is completed to the satisfaction of the Contracting Officer. As the drilling and grouting work progresses, it may develop that conditions are such that all or parts of the foundation already grouted require additional grouting. In such event, return the equipment and drill and grout additional holes as directed.

3.3.3 Stop Grouting

Stop grouting is a method whereby each hole is drilled to a final depth and grouted by stops through an expansion plug or packer which is set at successively shallower depths. It involves the placement of a grout curtain by drilling and grouting in accordance with the following general procedure:

a. Drill hole to the full depth and wash as specified in paragraph GROUT HOLE DRILLING.

b. Pressure test holes thus drilled and washed, and pressure washd as specified in paragraph PRESSURE WASHING AND PRESSURE TESTING.

c. Place the expansion plug, or packer, in the hole at the top of the interval to be grouted blocking off the higher portion of the holes, and the interval is grouted. The lowest zone is grouted first. In no case will the Contractor be required to set the packer deeper than [_____] meters feet.

d. After placing the grout at the pressure and mix directed by the Contracting Officer, leave the expansion plug, or packer, in place until the grout pressure drops to that pressure required for the next higher stop or as directed by the Contracting Officer.

e. Move the expansion plug, or packer, to the next higher stop and place grout at the lower pressure as directed by the Contracting Officer.

f. Repeat the procedures described in subparagraphs "d" and "e" above until grouting of the hole is complete.

g. After the primary holes in the first zone have been completed in any section as specified above, grout the second and succeeding series of holes, as determined by the "split spacing method" in like manner until all zones of that section are completely grouted as directed.

h. Grout other sections along the grout curtain in like manner until grouting of the foundation is completed to the satisfaction of the Contracting Officer.

i. As the drilling and grouting work progresses, it may develop that conditions are such that all or parts of the foundation already grouted require additional grouting. In such event, return the equipment and drill and grout additional holes as directed and no allowance above contract unit prices will be made for drilling and

grouting such holes or for the expense of any movement of equipment necessary to the performance of such work.

3.3.4 Pressure Washing and Pressure Testing

Immediately before the pressure grouting operation, thoroughly wash the hole under pressure and pressure test. Wash all intersected rock seams and crevices containing clay or other washable materials with water [and air] under pressure to remove as much of these materials as possible. If practicable, as determined by the Contracting Officer, eject such material from one or more holes by introducing water [and air] under pressure into an adjacent hole. Do not exceed the maximum grouting pressure as directed. Test all grout holes with clean water under continuous pressure up to the maximum grouting pressure as directed. Wash all holes sufficiently tight to build up the maximum required pressure and continue washing as long as there is any increase in the rate at which water is taken, such increase indicating the fractures are being opened by the washing operation. Wash open holes in which no pressure can be built up for a period of 5 minutes, with the pump operating at full capacity, or for such period of time as fracture-filling is being removed, as evidenced by the escape of muddy water through surface openings or other grout holes.

3.3.5 Stage Grouting Procedures

3.3.5.1 First Stage

Perform the first stage, or low-pressure, shallow-curtain grouting by washing and grouting holes at locations indicated or as directed, using the "split spacing" method described in paragraph SPLIT SPACING. Similar stages of drilling and grouting are repeated as necessary to reach the bottom of the first zone. Before grouting is begun in any hole of a given series in any section, completely drill at least the nearest two holes in advance of each such hole in that series for the same stage and completely wash the adjacent hole to facilitate washing and flushing out of any intervening clay-filled seams, fractures, or solution channels. Do not grout hole beneath any portion of the dam until all concrete within [35] [_____] meters [100] [_____] feet has been placed to [full height] [_____] unless otherwise directed.

3.3.5.2 Second Stage

After all first stage grouting in any section has been completed, as specified above, proceed, when so directed, with second stage drilling and grouting in accordance with the procedure outlined herein but in no case commence the deepening of any hole preparatory to grouting before the previously placed grout has set nor conduct second stage grouting within a distance of approximately 35 meters 100 feet of any hole in which a previous stage of grouting has been completed until the grout in such previous stage hole has [taken its set] [set for a period of 24-hours]. Perform grouting at subsequent stages conforming to the same requirements as to minimum time and distance. Upon completion of all holes to the bottom of the first zone, and after the waiting period the primary holes are drilled to the next stage in the second zone and grouted at higher pressures. The process of drilling, washing, pressure testing, pressure washing, and grouting at progressively higher pressures are continued until the ground is satisfactorily tight to the required depth.

3.3.6 Stop Grouting Procedures

3.3.6.1 Stop Grouting of Grout Holes

Perform the grouting by washing and grouting holes at locations indicated or as directed. Before grouting is begun in any hole of a given series in any section, completely drill at least the nearest two holes in the advance of each such hole in that series and completely wash the adjacent hole to facilitate washing and flushing out of any intervening clay-filled seams, fractures, or solution channels.

3.3.6.2 Grouting of Existing Exploratory Holes

Clean [pressure-test], and [pressure grout] [gravity grout] existing exploratory holes or portions of holes more than five feet deep after excavation as specified for grout holes. Backfill holes less than 1.5 meters five feet deep with grout mixed in proportions directed by the Contracting Officer. Gravity grout or backfill in accordance with paragraph BACKFILLING OF HOLES.

3.3.7 Grouting Pressures

****
NOTE: Refer to EM 1110-2-3506, "Grouting Technology" for discussions of grouting pressures as an aid in selecting allowable pressures under different conditions.
****

Grouting pressures to be used in the work will vary with conditions encountered in the respective holes and use pressures as directed. It is anticipated that pressures will range from [_____] kPa psi to [_____] kPa psi but in no event will pressures in excess of [_____] kPa psi be required or allowed.

3.3.8 Grouting

Perform all pressure grouting operations in the presence of the [Contracting Officer][Government Inspector], and in accordance with the following general procedures.

3.3.8.1 Grout Mixes

****
NOTE: Appropriate additives will be used for specific cases.
****

Provide mixese in the proportions directed by the Contracting Officer who will, from time to time, direct changes to suit the conditions found to exist in the particular grout hole. [The cement grout will include 2 percent to 5 percent (by weight of cement) of sodium bentonite]. The water/cement ratio by volume will be varied to meet the characteristics of each hole as revealed by the grouting operation and will range between [_____] and [_____]. Provide the types of grout as follows:

[a. Cement Grout consisting of cement, (bentonite) and water.]

[b. Mortar Grout consisting of cement, (bentonite), sand, and water.]

3.3.8.2 Grout Injection

a. In general, if pressure tests indicate a tight hole, start grouting with a thin mix. If an open hole condition exists, as determined by loss of drill water or inability to build up pressure during washing operations, then start grouting with a thicker mix and with a grout pump operating as nearly as practicable at constant speed at all times; decrease the ratio, if necessary, until the required pressure has been reached. [If this procedure does not produce the desired pressure, use mortar grout and vary the mix as necessary to produce the desired results.]

b. When the pressure tends to rise too high, increase the water/cement ratio [and/or change or discontinue the mix of mortar grout] as may be required to produce the desired results. If necessary to relieve premature stoppage, make periodic applications of water under pressure. Do not suddenly increase the pressure or rate of pumping as either may produce a water-hammer effect which may promote stoppage.

c. Do not consider the grouting of any hole complete until [that hole refuses to take any grout whatever at three-fourths of the maximum pressures required for that stage] [that hole takes grout at the rate of one cubic foot of grout or less in ten minutes measured over at least a five minute period at the pressure required for that portion of the hole being grouted.]

d. Should grout leaks develop, caulk such leaks when and as directed, the cost thereof being included in the contract price for unit price pay item "Placing Grout", in accordance with Section 01 20 00 PRICE AND PAYMENT PROCEDURES.

e. If, due to size and continuity of fracture, it is found impossible to reach the required pressure after pumping a reasonable volume of grout at the minimum workable water/cement ratio [or mortar grout with the maximum volume of sand at the minimum water/cementing materials ratio] reduce the speed of the pumping or stop pumping temporarily and perform intermittent grouting, allowing sufficient time between grout injections for the grout to stiffen. Following such reduction in pumping speed, if the desired result is not obtained, discontinue grouting in the hole when directed. In such event, clean the hole, allow the grout to set, and perform additional drilling and grouting in this hole or in the adjacent areas as directed, until the desired resistance is built up.

f. After the grouting of any [stage] [stop] of a hole is finished, maintain the pressure by means of a stop-cock or other suitable device until the grout has set to the extent that it will be retained in the hole.

g. Grout that cannot be placed, for any reason, within two hours after mixing must be wasted. If such grout is mixed at the direction of the Contracting Officer or with his knowledge and consent, such wasted grout, except as specified in Section 01 20 00 PRICE AND PAYMENT PROCEDURES, must be paid for at the contract unit prices for the materials contained therein.

3.3.8.3 Backfilling of Holes

Backfill holes with grout proportioned as directed by the Contracting Officer and generally having a water/cement ratio less than 1.0. Accomplish backfilling by injection of grout through a tremie pipe or hose inserted to full depth of hole. When grout vents at the surface, gradually withdraw the tremie, maintaining grout in pipe or hose until completely removed. Do not backfill holes containing freshly injected grout until the injected grout has set. No separate payment will be made for backfilling holes; however, grout will be paid for at the contract unit price for the Portland cement therein.

3.3.8.4 Equipment Arrangement and Operation

Arrange the grouting equipment to provide a continuous circulation of grout throughout the system and to permit accurate pressure control by operation of a valve on the grout return line, regardless of how small the grout take may be. Prevent the equipment and lines from becoming fouled by the constant circulation of grout and by the periodic flushing out of the system with water. Flush with the grout intake valve closed, the water supply valve open, and the pump running at full speed.

3.3.8.5 Protection to Work and Cleanup

[Except as otherwise specified, no grouting will be permitted within [_____] meters feet of installed perforated pipe or gravel filters for foundation drains. Where permitted in such locations, maintain a flow of water through the drains likely to be affected, to serve as tell-tales. In case leakage of grout into drains does occur immediately stop the grouting operations and remove all grout from the drains affected by washing to the satisfaction of the Contracting Officer. Payment for washing will be in accordance with unit price pay item "Pressure Washing and Pressure Testing" in [this Section][Section 01 20 00 PRICE AND PAYMENT PROCEDURES]. Repeat such stopping of grouting operations and washing of drains as often as required to complete the curtain grouting.] During grouting operations take such precautions as may be necessary to prevent drill cuttings, equipment exhaust oil, wash water, and grout, from defacing or damaging the permanent structure. Daily maintenance may be required along grout lines, in order to offer better inspection of interconnected holes and breakouts. The Contractor will be required to furnish such pumps as may be necessary to care for waste water and grout from his operations. Upon completion of these operations, clean up all waste resulting from his operations that is unsightly or would interfere with the efficient operation of the project as anticipated by the original design.

3.3.9 Records

The Contracting Officer will keep records of all grouting operations, such as a log of the grout holes, results of washing and pressure testing operations, time of each change of grouting operation, pressure, rate of pumping, amount of cement for each change in water/cement ratio, and other data as deemed by him to be necessary. Furnish all necessary assistance and cooperation to this end.

3.3.10 Communications

When, for its own convenience, the Contractor has the individual elements of the plant so located that communication by normal voice between these

elements is not satisfactory, the Contracting Officer may require him to install a satisfactory mechanical means of communications, such as a telephone or other suitable device.

-- End of Section --