Preparing Activity: USACE Superseding without Revision
UFGS-31 73 00 (November 2008)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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02/21

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ATTACHMENTS:

[, ___ Form ___, dated _____]

ENG FORM 1836

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SECTION 31 73 19

TUNNEL AND SHAFT GROUTING
02/21

****
NOTE: This guide specification covers the requirements for tunnel and shaft grouting applicable to constructing new and repairing existing underground structures. 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).
****

PART 1 GENERAL

1.1 SUMMARY

****
NOTE: The work will be under the direction of the Contracting Officer or his authorized representative, i.e., Government Representative who will be an engineering geologist or geotechnical engineer experienced in the design and grouting of tunnels and shafts.
****

This section describes the equipment, materials, and procedures to perform drilling and grouting work. It covers the equipment and materials to use;

drilling grout, drain and exploratory holes; installing grouting pipe and fittings; connections to grout holes; furnishing, handling, transporting, storing, mixing, and injecting grout; handling, controlling, and disposing of drill cuttings, waste water, and waste grout; patching finished grout and exploratory holes; final cleanup upon completion of work and all other operations incidental to drilling and grouting. The work consists of drilling exploratory and drain holes as directed or shown and performing [contact][and][tunnel and shaft][and][steel liner][and][ring curtain] grouting as shown. Exploratory drilling may be required to define problem areas or verify results ahead of the working face or through the lining during construction. The total amount of drilling and grouting required is not known and will be determined by conditions encountered as the work progresses. Grouting mixes, pressures, pumping rates, and the sequence in which holes are drilled and/or grouted will be determined in the field and as directed. Perform work under this section in accordance with EM 1110-1-3500, EM 1110-2-2901, and EM 1110-2-3506

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 of assembling all plant and equipment at the site preparatory to initiating the work and for removing it when the drilling and grouting 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

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; containing and disposing 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. [Unless otherwise specified, no][No] separate payment will be made for any material constituent of the grout, including cement and/or chemical grout materials placed in the performance of contract grouting. 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 meters feet of holes actually drilled in concrete, rock or soil, 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, rock, or soil, as shown or as directed.

1.2.3.2 Measurement

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

1.2.3.3 Unit of Measure

Unit of measure: linear meter foot.

1.2.4 Drilling Exploratory Holes

1.2.4.1 Payment

Payment will be made for costs associated with drilling of exploratory holes.[Provide core boxes at no additional cost to the Government.]

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, rock, or soil, as directed by the Contracting Officer.

1.2.4.3 Unit of Measure

Unit of measure: linear meter foot.

1.2.5 Placing Grout

****

NOTE: Select appropriate alternatives.

Under certain conditions it may be desirable to include a pay item for standby time for Government

directed suspension of drilling or grouting operations.
****

1.2.5.1 Payment

[Payment will be made for costs associated with satisfactorily placing grout in contact grout holes[and behind steel liner], which includes full compensation for[furnishing all materials,] proportioning the mix as directed,[drilling grout holes if necessary,] and mixing and injecting the grout as specified or as directed.][Payment will be made for costs associated with satisfactorily placing grout in grout holes, which includes full compensation for proportioning the mix, mixing, and injecting the grout as specified or as directed. Separate payment will be made for all materials used in [contact]grout as provided in unit price pay item(s) "Portland Cement in Grout" "Mineral Filler in Grout", "Sand in Grout", "Fluidifier in Grout", and "Chemicals in Chemical Grout".]

1.2.5.2 Measurement

The operation of placing grout will be measured for payment on the basis of the number of[cubic meters cubic feet of the component materials (bulk 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", "Mineral Filler in Grout", and "Sand in Grout".][hours of satisfactory placing regardless of the proportions of the mixes. Measurement will begin with the initiation of grout injection at the proper elevation or stage and continue until grout injection ceases, for a given hole, exclusive downtime. Downtime is defined as any failure to inject grout continuously, except for intermittent grouting as directed by the Contacting Officer. Time will be measured cumulatively to the next whole hour of operation. Payment for placing grout in holes will be based on the total amount of time required for satisfactorily placing grout, determined by reducing the total number of minutes of operation to the nearest whole hour.]

1.2.5.3 Unit of Measure

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

1.2.6 Connections to Grout Holes

1.2.6.1 Payment

****
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.
****

[Payment will be made for costs associated with connections to grout holes at a rate of [_____] dollars per connection.] [Payment for only one connection will be made for each hole regardless of the number of

settings.]

1.2.6.2 Measurement

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

1.2.6.3 Unit of Measure

Unit of measure: each.

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 kg) cubic feet (94 pounds) of cement used in the grout satisfactorily placed in ring grout holes and in filling 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: meter (42.6 kg) cubic foot (94 pounds).

1.2.8 Mineral Filler in Grout

1.2.8.1 Payment

Payment will be made for costs associated with mineral filler in grout.

1.2.8.2 Measurement

Mineral filler in grout will be measured for payment on the basis of the number of cubic meters (36.3 kg) cubic feet (80 pounds) of filler used in the grout and satisfactorily placed in grout holes.

1.2.8.3 Unit of Measure

Unit of measure: cubic meter (36.3 kg) cubic foot (80 pounds).

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 cubic feet of sand [, dry rodded measurement,] used in the grout satisfactorily placed in ring grout holes or in filling exploratory

holes.

1.2.9.3 Unit of Measure

Unit of measure: cubic 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 pounds of fluidifier used in the grout satisfactorily placed in ring grout holes.

1.2.10.3 Unit of Measure

Unit of measure: kilogram pound.

1.2.11 Chemicals in Chemical Grout

1.2.11.1 Payment

Payment will be made for costs associated with chemicals in chemical grout.

1.2.11.2 Measurement

Chemicals in chemical grout will be measured for payment on the basis of the number of gallons of chemicals actually used in grout mixtures satisfactorily placed in ring grout holes.

1.2.11.3 Unit of Measure

Unit of measure: kilogram pound.

1.2.12 Steel Pipe and Fittings

1.2.12.1 Payment

Payment will be made for costs associated with embedded grout and drain hole pipe and fittings remaining in the permanent work, which includes costs for removal of pipe and fittings, and patching and cleanup pursuant to Section 31 73 19 TUNNEL AND SHAFT GROUTING, paragraph PATCHING AND CLEANUP. All pipe and fittings removed is the property of the Contractor.

1.2.12.2 Measurement

Embedded pipe and fittings through which holes will be drilled and grouted, as shown and as directed or approved, will be measured for payment on the basis of the actual [kilograms][linear meters] [pounds][linear feet][, as differentiated by pipe size and schedule number,] of satisfactorily installed pipe and fittings left in place. No additional allowance will be made for [overweight][differences] caused by installation of oversized pipe (diameter or length) and pipes that are not

specified or approved. Upon completion of the grouting, no additional allowance will be made for costs of cutting off and removing from the project site all grout pipe connections protruding from the inside face of the concrete liner.

1.2.12.3 Unit of Measure

Unit of measure: kilogram pound.

1.2.13 Pressure Washing and Pressure Testing

1.2.13.1 Payment

Payment will be made for pressure washing, and pressure testing of grout holes and pressure testing of exploratory holes, which includes the cost of preliminary washing, materials for washing and testing, and 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.

1.2.13.2 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. Time will be measured cumulatively to the next whole minute of operations.

1.2.13.3 Unit of Measure

Unit of measure: nearest whole hour.

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
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.9	(2018) Factory-Made Wrought Buttwelding Fittings

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM C117	(2017) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C150/C150M	(2022) Standard Specification for Portland Cement
ASTM C494/C494M	(2019; E 2022) Standard Specification for Chemical Admixtures for Concrete
ASTM C618	(2023; E 2023) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C937	(2016) Grout Fluidifier for Preplaced-Aggregate Concrete
ASTM C939/C939M	(2022) Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
ASTM C940	(2022) Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM C942/C942M	(2021) Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 400	(1963) Requirements for Water for Use in Mixing or Curing Concrete

EM 385-1-1	(2014) Safety -- Safety and Health Requirements Manual
EM 1110-1-3500	(1995) Engineering and Design -- Chemical Grouting
EM 1110-2-2901	(1997) Engineering and Design -- Tunnels and Shafts in Rock
EM 1110-2-3506	(2017) Engineering and Design -- Grouting Technology

1.4 SEQUENCING

Perform grouting in the work sequence as shown and as specified. [Perform [contact grouting][and/or][grouting behind steel liner] at a reasonable time following installation of the permanent liner and prior to any application of internal or external water pressure, air shock, or vibration.][Perform tunnel and shaft grouting or ring grouting at the appropriate time during the excavation/muck/support mining cycle to achieve the desired water flow reduction or stabilization prior to the passage of any water within the tunnel or shaft.] Once grouting is started, normally proceed to completion without significant interruption.

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, Air Force, and NASA 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.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
****

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.][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-02 Shop Drawings

Drilling Operations

Pressure Washing and Pressure Testing Operations

Cement and Chemical Grouting Operations

SD-03 Product Data

Qualifications

Grouting Equipment; G[, [_____]]

Grout Application; G[, [_____]]

SD-04 Samples

Grouting Material Samples; G[, [_____]]

1.6 QUALIFICATIONS

Perform grouting by a specialty Contractor or subcontractor experienced and competent in [cement grouting] [chemical grouting] [both cement and chemical grouting]. Submit evidence that the grouting specialist or grouting foreman has had at least 3 years experience within the past 5 years on similar grouting type projects.

Perform all grouting work under the direct field supervision of a qualified grouting specialist or grouting foreman whose qualifications have been provided to the Contracting Officer. Supervise the performance of the work in compliance with these specifications.

PART 2 PRODUCTS

2.1 GROUTING MATERIALS

Provide grout of a nonshrink type and normally composed of water, cement, and fluidifier with shrinkage compensators (expanding agents). Use sand, admixtures to vary grout properties, and mineral fillers as specified or approved. The grout mixes will be designed or approved by the Contracting Officer and will be varied to meet the characteristics of each hole or situation as determined by the conditions encountered. Furnish the various materials conforming to the following paragraphs.

2.1.1 Water

[Furnish the water used in the grout. It must be fresh, clean, and free of sewage, oil, or organic matter and injurious amounts of acid, alkali, and salts or other damaging substances as determined by COE CRD-C 400.][Water suitable for use in the work will be furnished by the Government. Provide any necessary connections and extensions to the Government supply line.]

2.1.2 Cement

****
NOTE: Designer should insert the Section number and title that specifies the storage requirements for cement.
****

Provide cement used in grout conforming to the requirements of ASTM C150/C150M, portland cement Type [_____]. Store cement in accordance with Section [03 30 00 CAST-IN-PLACE CONCRETE] [03 30 53 MISCELLANEOUS CAST-IN-PLACE CONCRETE] [_____]. Employ methods of handling, transporting, and storage that are satisfactory to the Contracting Officer. Only cement furnished in cloth or paper bags will be accepted for use in the work unless bulk cement is approved. Store a sufficient quantity of cement at or near the site of the work to ensure that grouting operations will not be delayed due to shortage of cement. Take care in storage and handling to protect the cement from contamination and moisture. In the event the cement contains lumps or foreign matter that will not pass through a standard #100 mesh screen, remove the cement from the work site and replace it at no cost to the Government.

2.1.3 Sand

Provide sand for grout consisting of hard, tough, durable, uncoated particles. It may be composed of [natural sand][manufactured sand][a combination of natural and manufactured sand]. Provide generally rounded or cubical shaped particles containing no more than 5 percent of flat or elongated pieces having a maximum dimension in excess of five times the minimum dimension. If the sand is a combination of separately processed sizes, classification, or a combination of natural and manufactured sands, batch the different components separately, or, subject to written approval, blend prior to delivery to the mixing plant. Provide sand that is well-graded from fine to coarse, of the gradation, as determined in accordance with ASTM C136/C136M and ASTM C117, conforming to the following requirements:

SIEVE DESIGNATION (U.S. STANDARD SQUARE MESH)	CUMULATIVE PERCENTAGE BY WEIGHT	
	PASSING	RETAINED
8	100	0
16	95-100	0-5
30	60-85	15-40

SIEVE DESIGNATION (U.S. STANDARD SQUARE MESH)	CUMULATIVE PERCENTAGE BY WEIGHT	
	PASSING	RETAINED
50	20-50	50-80
100	10-30	70-90
200	0-5	95-100

In addition to the grading limits shown, use sand that has a fineness modulus within the range of 1.50 to 2.00. Control the grading of the sand as delivered to the mixes, during any 24-hour period of operation, so that the fineness moduli of samples taken will not vary more than 0.10 from the average fineness modulus. The results of previous tests and the service record may be used to determine the acceptability of the sand. Store sand in a manner to facilitate drainage and avoid the inclusion of any foreign materials in the grout. Construct storage piles to prevent segregation and contamination.

2.1.4 Admixtures

An admixture is any material other than water, sand, and cement added to the grout immediately before or during its mixing to alter its chemical or physical properties to a desired characteristic during its fluid or plastic state. Provide admixtures conforming to ASTM C494/C494M at the time of acceptance testing sample submittal; furnish certification from the manufacturer that the material meets all the requirements of these specifications. Package all admixtures to be used in each batch of grout separately and weigh prior to use. Provide grout fluidifier and expanding agents conforming to the requirements of ASTM C937. Provide accelerator additive that is calcium chloride ($CaCl_2$) in amounts up to 2 percent of the cement by weight or an approved product manufactured for the specific purpose of accelerating grout set-up time. Provide granular or flaked calcium chloride and add to the grout by dissolving it in a portion of the mix water.

2.1.5 Mineral Filler

Use fly ash fillers in grout as replacement for a portion of the cement composed of finely divided siliceous residue and in accordance with ASTM C618, Class F. The maximum amount of fly ash should not exceed 30 percent of the cement by weight.

2.1.6 Chemical Grouting Materials

****

NOTE: Designers should seek information from chemical grout suppliers and manufacturers and other reference material on the subject about which type(s) of chemical grout is best suited for their particular application and job.

****

Furnish nonflammable grouting materials and use either water-based (gel forming) or water-reactive (foam forming) in grouts. Use only the

following water-based chemical types; silicates, acrylates, polyacrylamides, acrylamides (only certain products), modified tannin, and epoxy resins. Use only the following water-reactive chemical types; polyurethanes and elastomers. Provide EPA approved chemical compounds. Store a sufficient quantity of chemical grouting materials at or near the work site to ensure that grouting operations will not be delayed due to storage of these materials. Storage requirements, mixing, and handling of all component materials as well as the grout mixture itself must be in accordance with the manufacturer's or supplier's recommendations.

2.2 EQUIPMENT

Provide drilling and grouting equipment of a type, capacity, and mechanical condition suitable for the work, as approved by the Contracting Officer. Power, compressed air, all other equipment, and the layout thereof must meet the requirements of local, State, and Federal regulations and codes, both with respect to safety and otherwise. The use of gasoline internal combustion engines for operation of drilling and grouting equipment underground is not permitted. Internal combustion engines must be diesel powered fitted with suitable and efficient scrubbers and in compliance with EM 385-1-1.

2.2.1 Drilling Equipment

Use standard drilling equipment of the rotary, percussion, or rotary-percussion type to perform grout hole, drain hole, and exploratory hole drilling. The use of hand-held equipment, such as jackhammer or jackleg percussion-type drills for drilling holes above the horizontal, is not permitted. Furnish equipment of a type and condition that will allow a drilling rate which will not delay the work and will be adequate to maintain an alignment within a tolerance of 4 percent or less of the depth. Properly maintain all drilling equipment and keep a sufficient supply of bits, tools, and spare parts at the job site to avoid delays. In the case of equipment breakdown, make repairs promptly. Accomplish exploratory drilling using rotary core drilling rigs and equipment. Use a standard ball bearing, swivel type, triple-tube, or double-tube core barrel at all times when drilling exploratory holes. The core barrel must be of a length, generally 1.5 or 3 meters 5 or 10 feet, appropriate for the working space and the type of material being drilled. Appropriate coring bits for exploratory holes and drain holes must be NW size except wire line bits must be NQ in size or as directed. Grout hole sizes must be EW. Use a wire line system on downward inclined holes that are [15][_____] meters [50][_____] feet or greater in depth.

2.2.2 Grouting Equipment

2.2.2.1 Cement Grouting Equipment

Submit a plan of the proposed grouting equipment types and layout for approval. An example of a typical grouting equipment layout is included at the end of this section. Furnish grout plant capable of supplying, mixing, stirring, and pumping the grout as specified. Provide plant with a minimum capacity of [0.11][_____] cubic meters per minute [4][_____] cubic feet per minute (cfm) of grout injected at a pressure not greater than [690][_____] kPa [100][_____] pounds per square inch (psi). Maintain it in first-class operating condition at all times, and replace any grout hole lost or damaged due to mechanical failure of equipment or inadequacy of grout supply at no expense to the Government. Furnish the following grouting equipment:

2.2.2.1.1 Grout Pump

Air or electrically powered grout pump(s) of the progressive cavity (helical screw) type that is free of surging are capable of pumping a great range of grout consistencies, provide close control of pumping pressures and variable rates of injection, and can be easily and quickly serviced during grouting operations. Keep a minimum of one spare grout pump and spare pump parts available on site during all grouting operations.

2.2.2.1.2 Grout Mixer

Grout mixers either mechanically driven, high-speed, shear-type tub mixers with either vertical or horizontal drum, or high-speed colloidal mixers. Provide mixers that are capable of effectively mixing and stirring a capacity of at least 0.11 cubic meters 4 cubic feet of grout with water to cement ratios from 0.6:1 to 6.0:1 and achieve mixing by constant rapid circulation of grout. Equip the mixer with a suitable volume-measuring water metering device for batching water for the grout mix. Calibrate the water meter to read in cubic meters and thousandths cubic feet and tenths and design in a manner that after each delivery the hands can be conveniently set back to zero. The water meter must have a certificate of calibration from an independent laboratory. Prior to each use, check the water meter for accuracy and, if necessary, recalibrate.

2.2.2.1.3 Holding Tank or Sump

Holding tank(s) or sump(s) of the mechanically agitated type to provide a high volume and continuous injection of grout. The sump must be capable of holding the solids of the mix in suspension and have a capacity of at least 0.34 cubic meters 12 cubic feet of grout or three times the capacity of the mixing system. Measure the volume of grout used from the agitator holding tank(s) or sump(s) by a vertical graduated stick or marks at different levels in the tank(s)/sump(s).

2.2.2.1.4 Supply and Pressure Control

Valves, pressure gauges, grout lines, header arrangements, and accessories as necessary to provide a continuous supply of grout and accurate pressure control. Convey grout between the pump and the hole using a [single-line system consisting of a pipe or hose or combination of both extending from the pump discharge to the header at the hole collar with grout injection rate controlled by the pump speed][or][circulating double-line system composed of a supply line to the header at the hole collar and a return line from the header to the grout pump, sump, or holding tank]. Grout lines must consist of either black steel pipe or reinforced rubber or plastic hose or a combination of both. The maximum inside diameter of all grout lines must be 25 millimeters 1 inch. Control the grout injection rate for the single-line system by the pump speed so that settlement of solids within the lines will not occur when pumping at or above the minimum discharge capacity of the pump. Control the pressure in the double-line system by one or more valves on the control line. Make the distance between the hole and the pump or holding tanks as short as possible to minimize the accumulation of solids and possible clogging. Pressure gauges must be high precision, graduated with divisions not greater than 10 kPa 2 psi on the dial face, calibrated and certified correct prior to use. Test gauges for accuracy[daily] during the work by cross comparison with a standard set of oil-filled gauges. Protect the moving parts of all gauges from dust, grit, and direct contact with grout.

2.2.2.1.5 Flow Cone

Flow cone(s) to ascertain the fluidity of grout mixtures. The flow cone and method of test must be in accordance with ASTM C939/C939M.

2.2.2.1.6 Communications

Telephone or radio communications between the grout plant and the hole being grouted when the site conditions such as distance, noise level, or visual obstructions negatively impact on the proper control of grouting operations.

2.2.2.2 Chemical Grouting Equipment

The chemical grout plant must be of the continuous mixing and pumping type. Provide all chemical grouting equipment in strict compliance with the grout manufacturer or supplier recommendations for the specific grout and The method to be used in grout application approved by the Contracting Officer. Provide all equipment of a type, capacity, and mechanical condition suitable for doing the work, compatible with the chemical to be handled, and maintain in first-class operating conditions throughout the job.

2.3 GROUT

2.3.1 Cement Grout

Design the grout mixture to expand [3 to 5 percent][2 to 4 percent] when tested in accordance with ASTM C940. Grout flow time-of-efflux, when tested in accordance with ASTM C939/C939M must be [between 10 and 30 seconds]. The unconfined compressive strength of the solidified grout must range between [3.5 and 13.8][13.8 and 20] MPa [500 and 2,000][2,000 and 3,000] psi when tested in accordance with ASTM C942/C942M.

2.3.2 Chemical Grout

Provide chemical grout composed of commercially available materials consisting of base material, reactant, water, and accelerator if required. Set times for chemical grout must be controllable from 1 to 30 minutes following injection. Provide components that are compatible with each other and with the rock or soil and groundwater. Certify that the proposed grout is chemically stable and will not render surrounding groundwater unpotable.[The grout mix must be such that when injected in medium dense Ottawa 20-30 sand and tested by an approved method, the unconfined compressive strength of the grouted sand must average at least 690 kPa 100 psi.]

2.3.3 Grouting Material Samples

****
NOTE: The Designer should insert the name and address of the Division Laboratory where material samples are to shipped and tested.
****

Ship grouting material samples for acceptance laboratory testing to:

[_____] Division Laboratory

[_____]
[_____]

The samples must include:

Cement	5 sacks (or 213 kg 470 pounds)
Additive(s)	2.25 kg 5 pounds of each
Sand	0.75 cubic meter 1 cubic yard
Mineral Filler	68 kg 150 pounds
Chemical Grout (to include reactant and catalyst)	4 L 1 gallon

Provide sample from the manufacturer or supplier and representative of the materials to be used in the work or from the shipment received at the work site. Make shipment to permit arrival at the lab 28 calendar days before the earliest start of grouting. Any substitution of materials after mix design is approved will require a new mix design and an additional 28 days. State the intended grout pumping temperature range. Grout mixes will be designed and approved only for the stated temperature range.

2.4 PIPE AND FITTINGS

Furnish all pipe conforming to ASTM A53/A53M standard weight. Provide fittings that are malleable iron Type I in accordance with ASME B16.3, ASME B16.5, and ASME B16.9, Class 150. Furnish black steel pipe of the diameter shown or as directed.

PART 3 EXECUTION

3.1 GROUT, DRAINAGE, AND EXPLORATORY HOLES

Locate holes through shotcrete or concrete or into the surrounding rock, for the purpose of injecting grout or air release and providing drainage, in the direction and to the depths shown or as directed or approved. Form holes by embedding pipe in the concrete or shotcrete at the time of placing or made by drilling through the concrete, shotcrete, or rock as indicated below for the various kinds of holes. Drill all grout, drainage, and exploratory holes using only water or compressed air.

3.1.1 Embedded Pipe

Provide all metal pipe and fittings required for constructing grout holes, grout hole connections, and air vents. Thoroughly clean al pipe and fittings embedded in concrete of dirt, grease, grout, and mortar immediately before embedding and firmly hold in position and protect from damage or displacement while the concrete is being placed. Take great care to avoid premature clogging of pipes and claen out any pipe that becomes clogged or obstructed before completion of operations in a satisfactory manner or replace at the expense of the Contractor. Cut, thread, fabricate, and install all piping required for the work as required.

3.1.2 Grout and Vent Hole Drilling

Locate grout and vent holes as shown and as directed. Drill grout holes through shotcrete or concrete of sufficient size to permit the caulking or grouting of short lengths of 40 mm 1-1/2 inch diameter pipe into the hole for attachment of the grout supply line. Grout hole diameters in rock must be as shown within a tolerance of 6 mm 0.25 inch and not less than 35 mm 1-3/8 inch at the point of deepest penetration. Check the size of completed grout holes frequently during the work to assure proper hole diameters are achieved. It is anticipated that the required depth of [ring][tunnel and shaft] grout holes will not exceed [15][_____] m [50][_____] feet. Protect each hole drilled from becoming clogged or obstructed by means of a cap or other suitable device on the collar. The use of greases, "rod dope," or other lubricants on the drill rods or in grout holes will not be permitted. No core recovery will be required, and the drilling fluid must be water or compressed air. During the drilling of grout holes, take all precautionary measures to control dust, fumes, and noise in conformity with [other sections of these specifications and] the applicable local, State, and Federal laws, codes, and regulations. Do not accomplish drilling of tunnel and shaft or ring grout holes until all contact grouting within [60][_____] m [200][_____] feet has been completed.

3.1.3 Drain Hole Drilling

Locate drainage holes as shown and as directed, and drill through the permanent liner after all grouting from holes within [60][_____] m [200][_____] feet has been completed. Drain hole diameters must be as shown but not less than [50][_____] mm [2][_____] inches with a tolerance of 6 mm 0.25 inch for their full lengths.

3.1.4 Exploratory Hole Drilling

Perform exploratory drilling as directed when required to determine the condition of the rock prior to grouting or the effectiveness of the grouting operations. Such drilling may be required at any inclination and in advance of the excavation face or from the perimeter of the tunnel or shaft. Exploratory drill hole depths may vary but will not exceed a maximum of [15][_____] m [50][_____] feet. Core drill the entire length of each exploratory hole using water or compressed air. Core size must be[either] NW (54 mm 2-1/8 inch diameter)[or HQ (54 mm 2-1/2 inch diameter)]. Perform core drilling by competent and experienced drillers and take special care to obtain cores in as good condition as possible. Core logging [will][must] be performed by [the Government Representative][a qualified geologist experienced in core logging]. Suitable wooden core boxes [will be furnished by the Government][as shown in Section [02 32 13 SUBSURFACE DRILLING AND SAMPLING] [03 37 29 CONCRETE FOR CONCRETE CUTOFF WALLS]] [must be furnished by the Contractor] for core storage in a suitable area on site. Protect core boxes from the weather prior to being delivered to the storage area upon completion of each exploratory drill hole. Place the core in the boxes in the correct sequence with each run marked by accurately labeled wooden blocks according to the measured distances in the holes. No box is permitted to contain cores from more than one hole.

3.1.5 Disposal of Drill Cuttings

Remove drill cuttings and water produced during the drilling process from the tunnel or shaft area on a routine basis to avoid buildup that may impede the function of temporary or permanent drainage system components

such as slotted pipe, sumps, and pumps. Dispose of drill cuttings at an approved location outside the tunnel or shaft.

3.2 GROUTING PROCEDURES

Perform grouting in the presence and under the direction of the Contracting Officer. Remove cement grout, which is not injected into the hole within 1 hour after mixing (30 minutes if the mix contains fluidifier with expanding agent), from the mixer, sump, and supply line and waste it.

3.2.1 Washing and Pressure Testing Holes

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NOTE: Develop the appropriate form to record test results and attach it to the end of this section.

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Immediately before the injection of grout into any hole drilled for the purpose of tunnel and shaft grouting or exploratory drilling, wash the hole thoroughly under pressure and then pressure test to provide an indication of potential grout take.

a. 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 practicable (normally this means until the return wash water runs clean). The maximum pressure at which air and water are introduced for any separate washing operation must be as directed.

b. Wash all holes sufficiently tight to build up the maximum required pressure at such pressure, and continue washing as long as there is any increase in the rate at which water is taken. Wash holes in which the required pressure cannot be reached or maintained as long as there is any increase in the rate of flow or drop in pressure when the pump is delivering a capacity flow. Wash open holes in which no pressure can be built up for a period of 5 minutes or for such a period of time as fracture-filling is being removed, as determined by the venting of muddy water through surface openings or other grout holes. Water pressure testing is also required in grout holes and exploration holes for the purpose of either assessing the grout take potential or the imperviousness of a grouted area.

c. Provide the necessary fittings, a gauge for measuring hydraulic water pressure up to [690][_____] kPa [100][_____] psi and a meter large enough to measure 0.14 cubic meter per minute to the nearest 0.001 cubic meter 5 cfm to the nearest 0.1 cubic foot. The volume of water available at the drill hole must be a minimum of [0.11][_____] cubic meters per minute [4][_____] cfm. Test drill holes as directed with clean water under a continuous pressure as determined in the field. After the waterline or header has been secured to the collar of the hole, pump water into the system until approximately [100][_____] kPa [15][_____] psi pressure is obtained. Maintain the pressure by control of a bypass valve and continue the flow test for 5 minutes. If no flow occurs, shut in the pressure and hold for 5 minutes and recordany pressure drop. Both the hold test and the flow test may be repeated in the same interval if necessary to confirm indications of grout take or tightness of an already grouted area. During each test, record the data on the Government supplied form [, ___ Form ___, dated _____]. Do not drill, wash, and water pressure test in previously

grouted areas before 24 hours following the completion of all the planned grouting in that particular area.

3.2.2 Contact Grouting

Contact grouting is defined as the injection of grout behind cast-in-place concrete lining (shaft and/or tunnel), or grouting behind the initial support system, to achieve continuous contact between the lining and the surrounding rock or soil. Tunnel plug contact grouting is also included in this definition. Perform contact grouting in such a manner as to ensure that all voids between the concrete or initial support members and the rock or soil face will be filled with grout. No pressure washing or testing is required prior to injecting grout. Leave cast-in-place concrete final lining in place at least [7][_____] days before grouting commences. Grout must be a [neat][sanded][[cement][chemical] grout] mixture. Do not terminate grouting of any hole until all voids have been filled to the maximum extent practicable and the Government Representative directs the Contractor to stop grouting. Provide vent pipes, for the release of air and water during grouting of crown overbreak cavities[which may not be filled with concrete], as shown and in such locations as directed or approved. The installation requirements of paragraph EMBEDDED PIPE applies to vent pipes. Perform contact grouting at the highest safe pressure as directed but initially not exceeding [69][_____] kPa [10][_____] psi. Initiate grouting from the lower end and at the invert of a tunnel and the grout behind the liner displaced upward. Grouting in the tunnel crown area may require secondary grouting to completely fill all the void space due to overbreak. Perform secondary grouting with expansive grout mixtures after the initial contact grout has been injected and set up. For shaft linings, radially locate grout holes or nipples and grout from inside the shaft. Split spaced grout injection holes or nipples may be necessary in shaft liner grouting.

[3.2.3 Grouting Behind a Steel Liner

This type of grouting, often called "skin" grouting, consists of placing neat cement grout in the annular space surrounding a steel liner or "can" to fill the void between the steel liner and the cast-in-place concrete final lining. Grouting procedures are the same as those described in paragraph CONTACT GROUTING with the following exceptions:

a. Provide grout holes and sealing plugs in the steel liner plates during fabrication. Provide pattern as shown.

b. Furnish grouting equipment such that sudden surges in pressure at refusal do not occur.

c. Grind grout hole plugs flush with the steel liner and finish smooth.

d. After grouting is completed, the Government Representative will sound the liner with hammer blows to determine if all voids are filled. If directed, drill and tap additional grout holes to receive a nipple. The use of a cutting torch to cut-in and weld-on a nipple is prohibited.

]3.2.4 Tunnel, shaft, and Ring Curtain Grouting

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NOTE: Tunnel, shaft, and ring curtain grouting are defined as the grouting in areas of the work

including, but not limited to, ahead of the tunnel or shaft face or along any reach of tunnel or shaft to control water flows or aid in stabilizing and filling voids in the formation.
****

Accomplish tunnel, shaft, and ring curtain grouting at the locations shown and/or as directed. Replace any grout hole that is lost or damaged due to mechanical failure of equipment, inadequacy of grout supply, or Contractor error by another hole or holes at the Contractor's expense.

3.2.4.1 Grout Injection (Cement Grout)

a. If the water pressure testing indicates a relatively tight hole, start grouting with a thin grout mixture. For an open hole condition, reduce the water-cement ratio accordingly and, with the grout pump operating as nearly as practicable at constant speed at all times, reduce the ratio further, if necessary, until the required pressure has been reached. If the pressure tends to rise too high, as determined by the Government Representative, change the water-cement ratio as directed. Provide grout mixes in the proportions directed by the Government Representative who will direct changes to suit the conditions existing in the particular grout hole. The water-cement ratio by volume will be varied to meet the characteristics of each hole as revealed by the pressure washing and testing operations and will normally range between [3.0:1.0 and 0.6:1.0][[_____] and [_____]].

b. Vary grouting pressures as directed with conditions encountered in the respective holes. If it is found impossible to reach the required pressure after pumping a reasonable volume of grout at the minimum workable water-cement ratio, use a sanded grout mix, reduce the pumping speed, or stop pumping temporarily and perform intermittent grouting, allowing sufficient time between grout injections for the grout to stiffen. If necessary to relieve premature stoppage, make periodic applications of water under pressure at the direction of the Government Representative. If the desired results are not obtained with this mix, discontinue grouting in the hole if so directed.

c. In such event, clean the hole, allow the grout to set, and perform additional drilling and grouting in this hole or in the adjacent area, as directed, until the desired resistance is built up. Do not increase the pressure or rate of pumping suddenly, because either may produce a water-hammer effect which may promote stoppage. After the grouting of any hole is completed, maintain the pressure by means of a stopcock or other suitable device until the grout has set to the extent that it will be retained in the hole.

3.2.4.2 Refusal

Do not consider the grouting of any hole complete until that hole refuses to take grout at a rate of less than [0.015 cubic meter 0.5 cubic foot of solids (cement) per 1/2 hour][0.03 cubic meter 1.0 cubic foot of solids (cement) per 10 minutes] at whatever grout mixture and pressure is being used.

3.2.4.3 Grout in Drains

If leakage of grout into drains occurs, immediately stop the grouting operations and remove all grout from the drains by washing, to the

satisfaction of the Contracting Officer. No separate payment will be made for such work. Such stopping of grouting operations and washing of drains must be repeated as often as required to complete the grouting.

3.2.4.4 Stage Grouting

Stage grouting is the procedure by which a grout hole or a ring curtain hole is drilled, pressure tested, and grouted in successive stages within progressively deeper zones from the top of the grout hole, either from the ground surface or from the tunnel or shaft wall, to the depth shown or as directed, prepared for grouting, and then grouted. After the grout has achieved an initial set, wash, clean and deepen the hole and then grout to the bottom of the next stage. If the Contractor allows the grout to harden within the grout hole, no payment will be made for redrilling the grout hole. A minimum period of [24][_____] hours must elapse between the completion of grouting in one stage and the start of drilling for the next stage. Repeat this procedure for the full depth of the grout application. Increase grouting pressures [as directed][as shown] as successive stages deepen the grout holes. Normally the grout holes are split spaced by locating secondary holes midway between two previously drilled and grouted primary holes, and the stage grouting process is repeated until the desired results are attained for the full depth of the grout application. Also drill and grout tertiary and succeeding series of split spaced holes in stages if directed by the Government Representative.

3.2.4.5 Grout Injection (Chemical Grout)

In the zones to be chemically grouted, perform chemical grouting in such a way as to produce a continuous cylinder or mass of chemically grouted ground outside the excavation perimeter of the tunnel or shaft in either soils or finely fissured rock strata, increasing the strength and reducing the permeability of the material. Grout in place must be chemically stable and nontoxic for the environment in which it is placed. Do not commence excavation through grouted areas until the grouting work has been completed and approved by the Government Representative. Perform regrouting if the required degree of waterproofing and/or stabilization is not achieved by the first application. The method of injection must be the continuous mixing method, with the proper amounts of grout base material, water, reactant, and accelerator automatically proportioned and continuously supplied at proper flow rates and pressures. The batch system of mixing grout is not permitted unless high volumes of chemical grout with shortened gel times are necessary in flowing water conditions. The base material and the water-accelerator-catalyst solution must pass through parallel separate hoses to a suitable baffling chamber near the top of the hole. Place a sampling cock to allow frequent gel time checks after the baffling chamber. Place suitable check valves in the grout lines at the proper locations to prevent backflow and unintentional gelations. Perform all mixing, handling, pumping, and injection operations in accordance with the manufacturer's recommendations. A technical representative of the manufacturer or supplier must be present at the work site during the initial grouting operations.

[3.2.4.6 Grout Injection Pipes

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NOTE: The following paragraph may be specified for grouting when it is desirable to exercise maximum control over the grout injection process, i.e., to grout or regrout at any specific depth.

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Grout pipes are commercially available or field fabricated as illustrated by the attached sketch. Perform installation with care to assure the sealing grout encapsulates the entire pipe and completely fills the annulus. Use grout to fill the annulus consisting of portland cement, bentonite and fly ash, be thick enough to prevent infiltration into the soil or rock, and be of low strength and brittle.

]3.2.5 Waste Water and Grout

Waste grout that cannot be placed or injected prior to initial set or maximum specified time limit. If such grout is mixed at the direction or approval of the Government Representative, it will be paid for at the applicable contract unit prices for the material constituents of the wasted grout. During the progress of the work, provide for adequate disposal of all wash and waste water and remove all waste grout, on a daily basis if necessary, to maintain a safe and effective grouting operation.

3.3 PATCHING AND CLEANUP

Upon completion of the grouting operations, remove all grout supply connections from embedded pipe to a minimum depth of 25 mm 1-inch, measured from the face of the concrete [shotcrete]. Patch holes or depressions thus formed with a damp-pack mortar composed of water, one part portland cement to two parts sand. One teaspoonful of aluminum powder will be added to each sack of cement used in the mortar mix to compensate for shrinkage. An unpolished, nonleafing powder of high purity and low grease will be used. Use damp-pack mortar just moist enough to form a ball in the hands. Thoroughly tamp into the hole using hard wooden tools. Patch in a neat workmanlike manner to provide a surface smoothness at least equal to undisturbed areas of the final lining. Pack exploratory holes which have not been grouted to the full depth of the final lining with tightly rammed dry mortar and then patch as described above. Prior to final acceptance of the work, clean the interior surface of the final lining of excess cement or chemical grout, mortar, oil, and grease to the greatest extent practicable, as determined by the Government Representative.

3.4 RECORDS

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NOTE: Attach ENG FORM 1836 to the end of this section.

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Prepare, on a daily basis, records of all grout hole and drain hole drilling operations, all pressure washing and pressure testing operations and all cement and chemical grouting operations. Include: driller's logs of all grout holes, drain holes, and exploratory holes; pressure washing information and pressure testing results[on Government provided form]; grouting data including time of each change of operation, rate of pumping, grouting pressures, changes in water-cement ratio, changes in proportions of additives such as fluidifier, accelerator, or sand, and amounts of various materials injected[on Government provided form]; [core logging data on Government provided ENG FORM 1836 at a vertical scale of 1 inch equals 1 foot]; and other data considered necessary as determined by the Government Representative. Blank report forms of the type to be used are

attached at the end of this specification.

Duplicate records of all grout hole and drain hole drilling operations, all pressure washing and pressure testing operations, and all cement and chemical grouting operations. The Government must receive the originals of all such records before final payment will be processed.

3.5 CONTRACTOR QUALITY CONTROL

In accordance with Section 01 45 00 QUALITY CONTROL 01 45 00.00 40 QUALITY CONTROL, establish and maintain quality control that specifically includes, but is not limited to, inspections to assure that:

a. The specified qualification requirements are met.

b. Drilling and grouting equipment is provided as specified and maintained in satisfactory condition.

c. The required amount of [cement is][chemical grout materials are] kept on hand during grouting operations.

d. Grouting is performed in the presence of a Government Representative.

e. Required records are kept and submitted as specified.

f. Accurate [cement][chemical] grout mixture proportions are maintained [as directed][as recommended by the manufacturer or supplier].

g. Materials are properly protected from moisture and contamination after delivery and transportation to the site.

h. Only approved materials are used.

i. The quantity of bulk materials used equals the computed amount.

-- End of Section --