UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2025
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SECTION 31 73 19

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05/25

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SECTION 31 73 19

TUNNEL AND SHAFT GROUTING
05/25

****
NOTE: This guide specification covers the requirements for tunnel and shaft grouting applicable to constructing new or repairing underground structures in rock. 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 nonessential information 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

****
This guide specification may be included in combination with other UFGS grouting specifications for a complete soil and rock grouting program. Foundation grouting in rock is addressed under Section 31 33 10 FOUNDATION DRILLING AND GROUTING IN ROCK. Foundation grouting through concrete structures or galleries is addressed in Section 31 43 13.13 CONCRETE PRESSURE GROUTING. Void and Permeation Grouting for Soil is addressed in Section 31 33 20 VOID AND PERMEATION GROUTING. Low mobility grouting, compaction grouting, and cap grouting in soil is addressed in Section 31 33 30 LIMITED

MOBILITY GROUTING IN SOIL.

This specification may be used as a general outline for cement grouting, chemical grouting (here after referred to as "solution grouting", 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 1110-2-3500, "Chemical Grouting", and 1110-2-3506, "Grouting Technology", should be consulted as guidance documents as appropriate for the grouting techniques under consideration. 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. Consideration must be given to conducting laboratory, field tests, and water pressure test evaluations of the subsurface conditions for a given application.

Caution must be exercised to not prohibit the use of a material or technique that may otherwise satisfactorily achieve the scope. Specific products or manufacturers should not be sole sourced within this specification without a Justification and Approval document from the Office of Counsel and the Contracting Officer. The use of performance criteria defining the problem, subsurface conditions, and the desired strength, durability/permanence and/or permeability must be specified to allow manufacturers and Contractors to submit suitable means and methods that meet the specification requirements and the intended purpose for grouting.

Methods for listing subdivided items are described in Paragraph "Variations in Estimated Quantities-Subdivided Items" of Army Federal Acquisition Regulation Supplement (AFARS) 5152.211-9001. Subdivided items are recommended for all jobs unless there are extenuating circumstances for small jobs having less than 10 holes.

****

1.1 DESCRIPTION OF WORK

****

NOTE: Provide a brief summary of the project scope, the purpose of the grouting, and any prudent references applicable to the layout, depths, and orientation required for the grouting. Include any special restrictions or coordination required.

The work will be under the direction of the Contracting Officer or 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.

Include a statement that the technical specifications govern over the description of work.

****

The work consists of drilling holes and grouting as shown [in the Contract drawings][as defined in the scope of work][as defined in the Geotechnical Baseline Report]. The objective of grouting is to [reduce formation permeability][control of water entering the excavation][temporarily stabilize unsafe subsurface conditions during construction][permanently stabilize unstable subsurface conditions][improve generally strength/stability of excavations][install a ring curtain of grout] [contact grouting between steel/concrete liner][crack/joint repair] as indicated. Grouting mixes, pressures, pumping rates, and the sequence in which holes are drilled [and][or] grouted are defined in this specification, or as submitted and approved in the work plan.

Perform work under this section in accordance with EM 1110-1-3500, EM 1110-2-2901, and EM 1110-2-3506. Provide equipment, materials, access, lighting, utilities, ventilation and labor sufficient to perform drilling and grouting work including any requirements for [drilling rock][, drilling concrete/grout][, drilling drain and exploratory holes,] installing grouting pipe and fittings, connections to grout holes, grout mixers and pumps, furnishing, handling, transporting, storing, mixing, and injecting grout, handling, controlling, and disposing of drill cuttings, waste water, and waste grout,[patching finished grout, concrete, [and][or] exploratory holes,] final cleanup upon completion of work and all other operations incidental to drilling and grouting.[Any overbreak or over-excavation that exceeds the payment lines resulting in additional contact drilling/grouting qualities are the responsibility of the Contractor.]

1.2 TYPE OF GROUTING

****

NOTE: Define the type of grouting. Choose the first paragraph if you are seeking seepage control and stability for tunnel/shaft excavations. Choose the second paragraph if you are completing contact grouting behind a liner. Cementitious grouts must be balanced and stable grout mixtures. Chemical grouts may be effective but will have higher costs and may require additional specialty contractors.

****

[Perform [tunnel grouting][shaft grouting][and][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.]

[

Perform[contact grouting][, 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. The grouting must utilize cement[chemical] grout to fill the annular space.]

The grouting must utilize a balanced and stable cementitious grout [chemical grout] to achieve [stabilization][seepage] control.

1.3 [PROJECT][SITE] CONDITIONS

****

NOTE: This paragraph, or elsewhere in the specifications, should describe the geologic conditions that the Contractor could expect to encounter during drilling and grouting. Work involving tunnels and shafts should consider following the American Society of Civil Engineers (ASCE) guidance for inclusion of Geotechnical Baseline Report (GBR) and Geotechnical Data Report (GDR). This paragraph should reference these documents. Baseline material properties and site conditions can be included in a contractual GBR. If the geotechnical documents are for information only (FIO), delete paragraph 1 and select the bracketed sections. Properly describe and summarize the geologic subsurface parameters and conditions anticipated in the working area. Define any assumptions that may impact the Contractor's effectiveness to complete the work. Provide boring logs and appropriate drawings as part of the project documents. Include baseline conditions and soil properties after the second paragraph if not included elsewhere in the contracting package.

****

Pre-existing subsurface information, boring logs and material properties are provided in the Geotechnical Baseline Report (GBR) and Geotechnical Data Report (GDR), as an attachment to these specifications. [Additional site information is provided in the Contract Drawings.][Select rock samples from recent foundation explorations are available for inspection through coordination with the Contracting Officer.][Subsurface information and boring logs are [provided For Information Only (FIO)][included in the project plans]. Baseline conditions anticipated in the area to be grouted are summarized below:]

1.4 RELATED WORK SPECIFIED ELSEWHERE

[

Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION]

[

Section 02 32 13 SUBSURFACE DRILLING AND SAMPLING]

[

Section 31 71 19 TUNNEL AND SHAFT EXCAVATION IN ROCK]

1.5 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.

Methods for listing subdivided items are described in Paragraph "Variations in Estimated Quantities - Subdivided Items" of Army Federal Acquisition Regulation Supplement (AFARS) 5152.211-9001.

Because it is so difficult to accurately pre-determine grouting quantities, subdivided items are recommended on all but the smallest jobs.

****

1.5.1 [Grouting]Mobilization and Demobilization

****

NOTE: This provision applies for inclusion for instances where grouting is the primary feature of work. A separate "Grouting Mobilization and Demobilization" could also be added where grouting is a minor feature of work as part of a much larger project. Another option is to include Mobilization costs in with the overall mobilization bid cost for the contract.

There may be instances where multiple mobilizations and demobilizations are required when grouting is performed in close association with tunnel/shaft excavation, and/or when subsequently performed as contact grouting between the liner and excavation.

Per the DFARS, there are two separate clauses that involve Mobilization. 252.236-7003 - Payment for Mobilization and Preparatory Work, and 252.236-7004 - Payment for Mobilization and Demobilization. Typically, one or the other clause is used in a contract, not both. If a separate CLIN for mobilizing the grouting equipment is to be used, coordinate it with the clause used for the overall mobilization (if used).

****

1.5.1.1 Payment

Payment will be made for costs associated with mobilization and demobilization, staging areas, temporary construction facilities, Surety Bonds, and for all other work in accordance with[Section 01 50 00 TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS][_____]. Demobilization also includes all site restoration activities. Payment will constitute full compensation for all the work involved in mobilization and demobilization as shown or specified in the Contract documents, and as directed by the Contracting Officer. Mobilization and Demobilization is cost loaded 60 percent mobilization and 40 percent demobilization. Intermittent or staged [mobilization][demobilization] at the convenience of the Contractor is considered incidental to this item and does not constitute additional payment unless directed by the Contracting Officer in writing. The Government makes no additional separate payment for items included herein or by reference.

1.5.1.2 Unit of Measure

Unit of measure: Job.

1.5.2 Drilling Grout Holes Through Rock

****

NOTE: Include a separate measurement item for each

type of drilling required for the project. Determine if rock will be drilled or cored. Drilling by percussion is faster for production. Coring provides additional subsurface information or may be used to verify adequacy of concrete placement and contact grouting. The bid schedule should include the estimated quantity for each type of drilling, or include the quantity as part of this paragraph.

****

1.5.2.1 Payment

Payment will be made for costs associated with drilling and redrilling grout holes. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole drilling; 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. No payment will be made for drilling wasted grout that is rejected or otherwise completed in non-compliance with the [approved work plan][specification requirements] as determined by the Contracting Officer. The Government makes no additional separate payment for items included herein or by reference.

1.5.2.2 Measurement

Grout hole drilling is measured for payment along the axis of the boring up to the nearest linear meter foot per hole drilled. Measurement is made from the [rock][concrete] surface to the bottom of the hole. Casing stickup is not included for measurement. Make all measurements for payment by or in the presence of the Government.[For purposes of bidding, assume [_____] meter feet of drilling is required.]

1.5.2.3 Unit of Measure

Unit of measure: linear meter foot.

[1.5.3 Coring Grout Holes Through Rock

****

NOTE: Include a separate measurement item for each type of drilling required for the project. Coring provides additional subsurface information. The bid schedule should include the estimated quantity for each type of drilling, or include the quantity as part of this paragraph. Verification holes should be cored, if possible.

****

1.5.3.1 Payment

Payment is made for costs associated with coring grout holes. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole coring; 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. No payment will be made for coring wasted grout that is rejected or otherwise completed in non-compliance with the [approved work plan][requirements contained herein] as determined by the Contracting Officer.[This section includes payment for any required verification holes assigned for acceptance.] The Government makes no additional separate payment for items included herein or by reference.

1.5.3.2 Measurement

Grout hole drilling is measured for payment along the axis of the boring up to the nearest linear meter foot per hole drilled. Measurement is made from the [rock][concrete] surface to the bottom of the hole. Casing stickup is not included for measurement. All measurements for payment must be made by or in the presence of the Government.[For purposes of bidding, assume [____] meter feet of coring is required.]

1.5.3.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.4 Drilling Grout Holes Through Liners

****

NOTE: Include a separate measurement item for each type of drilling required for the project. Determine if the liner will be drilled or cored. Drilling is faster for production. Coring of concrete liners provides additional information relative to existing conditions. The bid schedule should include the estimated quantity for each type of drilling, or include the quantity as part of this paragraph.

****

1.5.4.1 Payment

Payment will be made for costs associated with drilling and redrilling grout holes. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole drilling; washing of holes; containment 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. No payment will be made for drilling grout wasted, rejected, or otherwise completed in non-compliance with the [approved work plan][specification requirements] as determined by the Contracting Officer. The Government makes no additional separate payment for items included herein or by reference.

1.5.4.2 Measurement

Grout hole drilling through liners is measured for payment along the axis of the boring up to the nearest linear meter foot per hole drilled through the liner. Measurement is made from the [concrete][steel] [_____] surface to the liner/bedrock contact, to include up to a [0.3] Meter [1] foot socket into the outer stratum. Casing stickup and overdrill is not included for measurement. All measurements for payment must be made by or in the presence of the Government.[For purposes of bidding, assume [_____] meter feet of drilling is required.]

1.5.4.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.5 Coring Grout Holes Through Liners

****

NOTE: Include a separate measurement item for each type of drilling required for the project. Coring of concrete liners provides additional information relative to existing conditions. The bid schedule should include the estimated quantity for each type of drilling, or include the quantity as part of this paragraph. Verification holes through concrete liners should be cored, if possible. If not cored, the method for verification should be clearly specified or included in the Contractor's Work Plans.

****

1.5.5.1 Payment

Payment will be made for costs associated with coring grout holes through the liner. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole coring; washing of 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. No payment will be made for coring grout wasted, rejected, or otherwise completed in non-compliance with the [approved work plan][requirements contained herein] as determined by the Contracting Officer.[This section includes payment for any required verification holes assigned for acceptance.] The Government makes no additional separate payment for items included herein or by reference.

1.5.5.2 Measurement

Grout hole drilling through liners is measured for payment along the axis of the boring up to the nearest linear meter foot per hole drilled through the liner. Measurement is made from the [concrete][steel] [_____] surface to the liner/bedrock contact, to include up to a 0.3 Meter 1 foot socket into the outer stratum. Casing stickup and overdrill is not included for measurement. All measurements for payment must be made by or in the presence of the Government.[For purposes of bidding, assume [_____] meter feet of coring is required.]

1.5.5.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.6 Drilling Drain Holes

****

NOTE: Drain holes are typically drilled by percussion and not cored. Adjust as needed to fit the conditions of your project. Preferably, allow drain hole drilling to be submitted by the Contractor for approval with the work plan. When using that approach, remove this item for payment

and state that drain hole drilling is incidental to production.

****

1.5.6.1 Payment

Payment will be made for costs associated with drilling of drain holes in concrete and rock. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole drilling; washing; containing and disposing of waste water and waste grout; clean-up of the site; and for furnishing all labor and supplies incidental to the work. The Government makes no additional separate payment for items included herein or by reference.

1.5.6.2 Measurement

Drilling of drain holes will be measured for payment on the basis of the linear meters feet of holes drilled in concrete and rock, as shown in the plans or as directed by the Contracting Officer. All measurement for payment must be made by or in the presence of the Government.

1.5.6.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.7 Drilling Exploratory Holes

****

NOTE: Include a separate measurement item for each type of drilling required for the project. Determine if exploratory holes will be drilled or cored. Drilling is faster for production. Coring provides additional subsurface information relative to existing conditions. The bid schedule should include the estimated quantity for each type of drilling, or include the quantity as part of this paragraph.

****

1.5.7.1 Payment

Payment will be made for costs associated with drilling exploratory holes. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole drilling; 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. No payment will be made for drilling or grout wasted, rejected, or otherwise completed in non-compliance with the [approved work plan][requirements contained herein] as determined by the Contracting Officer. The Government makes no additional separate payment for items included herein or by reference.

1.5.7.2 Measurement

Exploratory hole drilling is measured for payment along the axis of the boring up to the nearest linear meter foot per hole drilled. Measurement is made from the [rock][concrete] surface to the bottom of the hole.

Casing stickup is not included for measurement. All measurements for payment must be made by or in the presence of the Government.[For purposes of bidding, assume [_____] meter feet of drilling is required.]

1.5.7.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.8 Coring Exploratory Holes

****

NOTE: Include a separate measurement item for each type of drilling required for the project. Determine if exploratory holes will be drilled or cored. Drilling is faster for production. Coring provides additional subsurface information relative to existing conditions. The bid schedule should include the estimated quantity for each type of drilling, or include the quantity as part of this paragraph. Verification holes should be cored, if possible.

****

1.5.8.1 Payment

Payment will be made for costs associated with coring exploratory holes. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial set-up on the hole; hole coring; 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. No payment will be made for drilling or grout wasted, rejected, or otherwise completed in non-compliance with the [approved work plan][requirements contained herein] as determined by the Contracting Officer.[This section includes payment for any required verification holes assigned for acceptance.] The Government makes no additional separate payment for items included herein or by reference.

1.5.8.2 Measurement

Exploratory hole drilling is measured for payment along the axis of the boring up to the nearest linear meter foot per hole drilled. Measurement is made from the [rock][concrete] surface to the bottom or end, in the case of non-vertical holes, of the hole. Casing stickup is not included for measurement. All measurements for payment must be made by or in the presence of the Government.[For purposes of bidding, assume [_____] meter feet of coring is required.]

1.5.8.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.9 Hole Redrilling

****

NOTE: To clarify, 'Hole Redrilling' is drilling of hardened grout in a previously drilled length of hole. While this pay item is much more common on

downstage work, communication between boreholes could create the need for hole re-drilling. Consider how setting up on holes will be paid and select brackets accordingly.

****

1.5.9.1 Payment

All incidental costs associated with the performance of work in this section are included in the Contract price for this item when a hole needs to be redrilled or downstage grouted. This item also includes but is not limited to costs associated with[hole set-up;] care and disposal of wastewater and waste grout; hole washing at the end of drilling, clean-up of the site; and for furnishing all labor and supplies incidental to the work. The Government makes no additional separate payment for items included herein or by reference.

[

When downstage grouting is required, the footage must be tracked by the Contractor and the Government. Costs associated with reconnecting grouting equipment to grout holes necessitated by switching to downstage grouting from upstage grouting is not paid for as part of this item and is included in paragraph ADDITIONAL GROUTING SETUP. The Government makes no additional separate payment for items included herein or by reference.]

1.5.9.2 Measurement

Measure hole re-drilling for payment based on the linear meters feet of hole re-drilled along the axis of the previously drilled hole to the nearest linear meter foot. The Government does not allow payment for drilling wasted grout which remains in the hole above the grout stage. All measurement for payment must be made by or in the presence of the Government. Do not measure setups made for the convenience of the Contractor, such as an additional setup to replace a drill or repair a drill.

1.5.9.3 Unit of Measure

Unit of measure: linear meter foot.

][1.5.10 Water Pressure Testing

****

NOTE: Water pressure testing is generally not utilized for tunnel and shaft grouting. Delete this requirement unless water pressure test results are needed to verify final permeability for seepage control applications.

****

1.5.10.1 Payment

Payment made for incidental costs associated with satisfactorily water pressure testing grout holes, including, but is not limited to; initial setup over the hole; making and breaking connections; inflating and deflating packers; moving packers up and down the hole, from hole to hole; replacing broken gauges and damaged hoses; and daily proof testing of packers. No payment will be made for time lost due to fault or negligence, or due to furnished equipment that is defective. [Subdivide each water pressure test into "initial quantity" and "over initial

quantity".] The Government makes no additional separate payment for items included herein or by reference.

1.5.10.2 Measurement

Measure Water Pressure Testing for payment based on each setup completed. All other associated activities are considered incidental and will not be measured separately.[All measurement for payment must be made by or in the presence of the Government.]

1.5.10.3 Unit of Measure

Unit of measure: Each.

]1.5.11 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.
****

1.5.11.1 Payment

Payment is made for costs associated with satisfactorily placing grout in grout holes. This includes full compensation for injection of grout, [and][or] backfill of the hole, as specified in the scope. All incidental costs associated with the performance of work in this section are included in the Contract unit price for this item. Incidental work includes, but is not limited to, initial grout hole setup and grout hole connection, grout mixing time, grout placement, containment 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. Costs for grout mixes will be paid separately for each grout mix successfully injected in the hole, including rock sockets and interface zones, and is not included in this pay item. No payment will be made for time lost due to fault or negligence, or due to defective furnished equipment. The Government makes no additional separate payment for items included herein or by reference.

1.5.11.2 Measurement

Measure grout placement for payment based on the actual grout pumping time. Time measurement begins when grout pumps begin pumping on a hole or grout stage, and continues until the pumping is completed on that hole or grout stage, as determined by the Contracting Officer. The minimum required injection rate when maximum injection pressure is not achieved is 37 liters 10 gallons per minute, unless directed otherwise by the Contracting Officer. Time for the satisfactory placement of grout is determined by rounding to the nearest whole minute. The total duration for this activity is then summed for all holes and rounded to the nearest whole hour for each pay request. No payment for grout placement will be made for time periods when grout is not being placed. If multiple injections are conducted on several holes simultaneously, each injection must be separately measured for payment in the presence of the Government.

1.5.11.3 Unit of Measure

Unit of measure: [nearest whole hour][_____].

[1.5.12 Additional Grouting Setup

****
NOTE: Delete if not downstage grouting.
****

1.5.12.1 Payment

Payment will be made for material and labor cost associated with setting up a hose reel system at a hole location due to downstage grouting or as directed by the Contracting Officer. A setup is when a hose-reel system is placed over the top of a hole, and grouting is performed afterwards with one or more connections. This includes all records required with this item. Unnecessary setups will not be paid by the Government. The movement of a packer or paired-packers up or down the hole does not constitute a setup. The Government makes no additional separate payment for items included herein or by reference.[Payment for only one connection will be made for each hole regardless of the number of settings.]

1.5.12.2 Measurement

The initial setup on any given hole is incidental to the bid item "Placing Grout" and is not included for payment under this item. Measurement includes each setup required for downstage drilling and grouting, or additional connections each time the grout supply line is connected to regrout any previously completed grout stage, unless backfilling the hole. Payment will not be made for unnecessary non-directed set-ups or which are paid for under other items. No payment will be made for movement of a packer (or paired packers) up or down the hole - do not measure them.

1.5.12.3 Unit of Measure

Unit of measure: [Each][_____].

]1.5.13 Cementitious Grout Mixes

****
NOTE: If chemical grout is used instead of cementitious grout, delete all sections in the specification specific to cement grouting, including the following sections. The intent of this line item is that each specific grout mix would have a unique cost. The thicker mixes cost more because they contain less water and more solid constituent components, as well as being more difficult to pump. The spec writer also has the option to allow both types of grout and let the Contractor propose materials in the work plan.
****

1.5.13.1 Payment

All incidental costs associated with the performance of work in this

section are included in the Contract price for this item. Payment will be made for costs associated with furnishing the various grout mixes specified herein; including but not limited to furnishing, handling, transporting and storing of grout materials; proportioning the mixes; mixing; quality control of grout; providing access to lab space and equipment for Government personnel to perform quality assurance testing; and storage and transportation of grout cores. Payment of grout will only be made for grout installed and accepted by the Contracting Officer in accordance with the plans and specifications. No payment will be made for wasted grout from improper/excessive batching, grout wasted due to improper anchorage of grout pipe or connections, or which is wasted due to negligence, nor for grout which is rejected by the Contracting Officer because of improper mixing or for any other reason. Subdivide grouting into "initial quantity" and "over initial quantity." The Government makes no additional separate payment for items included herein or by reference.

Grout Mix A
[Grout Mix B]
[Grout Mix C]
[Grout Mix D]
[Grout Mix E]
[Grout Mix F]
[Grout Mix G]

1.5.13.2 Measurement

The grout mixes are measured for payment based on the number of liters gallons of each grout mix placed in grout holes in accordance with the plans and specifications. All work done at the direction of the Contracting Officer above and beyond the quantities shown for the base quantity are the responsibility of the Government and will be paid.

[Grout Mix A]
[Grout Mix B]
[Grout Mix C]

1.5.13.3 Unit of Measure

Unit of Measure:

[Grout Mix A in liters gallons]
[Grout Mix B in liters gallons]
[Grout Mix C in liters gallons]

[1.5.14 Chemical Grout Mixes

****

NOTE: Caution must be exercised to not prohibit the use of a material or technique that may otherwise satisfactorily achieve the scope objective. Chemical grouting products are variable between manufacturers. Specific products or manufacturers must not be specified within this specification. The use of performance criteria defining the problem, subusrface conditions, desired strength and/or permeability must be specified to allow manufacturers and Contractors to submit a suitable material that both meets this specification and the intended purpose of the grouting.

****

1.5.14.1 Payment

Payment will be made for costs associated with chemicals in chemical grout. All incidental costs associated with the performance of work in this section are included in the Contract price for this item. Payment will be made for costs associated with furnishing the various grout mixes and constituent components specified herein; including but not limited to furnishing, handling, transporting and storing of grout materials; proportioning components of mixes; mixing; quality control of grout; providing access to lab space and equipment for Government personnel to perform quality assurance testing; and storage and transportation of specimens. Payment of grout will only be made for grout installed and accepted by the Contracting Officer in accordance with the plans and specifications. No payment will be made for grout wasted as a result of improper/excessive batching, improper anchorage of grout pipe or connections, or due to negligence. Subdivide grouting into "initial quantity" and "over initial quantity." The Government makes no additional separate payment for items included herein or by reference.

[Chemical Grout Mix A]
[Chemical Grout Mix B]
[Chemical Grout Mix C]

1.5.14.2 Measurement

The grout mixes are measured for payment based on the number of liters gallons of each chemical grout mix satisfactorily placed in grout holes. All work done at the direction of the Contracting Officer above and beyond the quantities shown for the base quantity are the responsibility of the Government.

[Chemical Grout Mix A]
[Chemical Grout Mix B]
[Chemical Grout Mix C]

1.5.14.3 Unit of Measure

Unit of measure:

[Chemical Grout Mix A in liters gallons]
[Chemical Grout Mix B in liters gallons]
[Chemical Grout Mix C in liters gallons]

][1.5.15 Steel Pipe and Fittings

1.5.15.1 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, restoration, and cleanup as described herein. All pipe and fittings removed is the property of the Contractor.

1.5.15.2 Measurement

Embedded pipe and fittings through which holes are 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.

1.5.15.3 Unit of Measure

Unit of measure: kilogram pound.

][1.5.16 Drilling and Grouting Closeout Records

****

NOTE: Section 01 78 00 CLOSEOUT SUBMITTALS covers closeout submittals. Verify if closeout submittals are covered in a Contracting Specification. If so, delete this section.

Consider adding this requirement if grouting is part of a larger project and closeout submittals for grouting are required before the official closeout for the project.

Hole records are incidental to their line items, this line item is for these specific submittals: Drilling and Grouting Final Report, Database of Water Pressure Testing and Grouting Results, and As-Built Drilling and Grouting Drawings.

The designer will need to determine if partial payment can be made, but partial payment should not exceed 40 percent.

****

1.5.16.1 Payment

[Payment must be made for material and labor cost associated with completion of all closeout records under the paragraph DRILLING AND GROUTING CLOSEOUT RECORDS.][No more than 40 percent of this line item will be paid before final approval of all closeout records.]

1.5.16.2 Measurement

[Measurement will be made when closeout records have been submitted and given final approval by the Government.][Partial payments up to 40 percent of the lump sum value may be paid once specific closeout submittals receive final Government approval at the discretion of the Contracting Officer.]

1.5.16.3 Unit of Measure

Unit of Measure: Lump Sum.

][1.5.17 Government Directed Stand-by Time for Grouting

****

NOTE: This paragraph has been used on previous grouting jobs where stand-by may be needed. It should not be reflexively utilized unless either intermittent grouting is likely or else the Contracting Officer determines they would like to have a mechanism to pause grouting. If not needed, delete this item. This is different than temporary demobilization of equipment and facilities due to other construction activities or inundation of the excavation.

****

1.5.17.1 Payment

Payment will be made for time that the a temporary cessation of[water pressure testing (WPT) or] grouting is requested by the Government. Payment will not be made for time expended between intermittent grouting.

1.5.17.2 Measurement

Stand-by time begins when the Government directs stand-by and grouting ceases. Stand-by time ends when the Government directs grouting or water pressure testing to resume. Measure stand-by time to the nearest whole minute. Time must be measured and accumulated to the nearest minute for each shift, added by shift in minutes per month, then rounded to the nearest hour for the month.

1.5.17.3 Unit of Measure

Unit of Measure: Hour.

]1.6 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 PETROLEUM INSTITUTE (API)

API RP 13B-1	(2009; R 2016) Recommended Practice for Field Testing Water-Based Drilling Fluids
API Spec 13A	(2010; Errata 1 2014; Errata 2-3 2015) Specification for Drilling-Fluid Materials

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	(2024) Factory-Made Wrought Buttwelding Fittings

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2024) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM C31/C31M	(2025b) Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C39/C39M	(2024) Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C40/C40M	(2020) Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM C70	(2020) Standard Test Method for Surface Moisture in Fine Aggregate
ASTM C87/C87M	(2023) Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
ASTM C109/C109M	(2024) Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
ASTM C117	(2023) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C128	(2022) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

ASTM C142/C142M	(2017; R 2023) Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C150/C150M	(2024) Standard Specification for Portland Cement
ASTM C191	(2021) Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM C204	(2025) Standard Test Methods for Fineness of Hydraulic Cement by Air Permeability Apparatus
ASTM C207	(2024) Standard Specification for Hydrated Lime for Masonry Purposes
ASTM C494/C494M	(2024) Standard Specification for Chemical Admixtures for Concrete
ASTM C566	(2013) Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM C595/C595M	(2025) Standard Specification for Blended Hydraulic Cements
ASTM C618	(2025a) 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
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 C979/C979M	(2024) Standard Specification for Pigments for Integrally Colored Concrete
ASTM C989/C989M	(2025) Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM C1064/C1064M	(2023) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1077	(2025a) Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

ASTM C1240	(2020) Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1602/C1602M	(2022) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1603	(2018a) Standard Test Method for Measurement of Solids in Water
ASTM C1797	(2023) Standard Specification for Ground Calcium Carbonate and Aggregate Mineral Fillers for use in Hydraulic Cement Concrete
ASTM D4219	(2022) Standard Test Method for Short-Term Unconfined Compressive Strength Index of Chemically Grouted Soils
ASTM D4380	(2020) Standard Test Method for Determining Density of Construction Slurries
ASTM D4832/D4832M	(2023) Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
ASTM D6910/D6910M	(2019) Standard Test Method for Marsh Funnel Viscosity of Construction Slurries

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 19115	(2003; Corr 1 2006) Geographic Information - Metadata - First Edition

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
COE CRD-C 112	(1969) Method of Test for Surface Moisture in Aggregate by Water Displacement
COE CRD-C 120	(1994) Test Method for Flat and Elongated Particles in Fine Aggregate
COE CRD-C 661	(2006) Specification for Antiwashout Admixtures for Concrete
EM 385-1-1	(2024) Safety -- Safety and Occupational Health (SOH) Requirements
EM 1110-1-1804	(2001) Engineering and Design -- Geotechnical Investigations
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
ER 1110-1-1807	(2014) Drilling in Earth Embankment Dams and Levees
ER 1110-1-8100	(1997) Laboratory Investigations and Testing

U.S. DEPARTMENT OF DEFENSE (DOD)

SDSFIE Standards	Spatial Data Standards for Facilities, Infrastructure, and Environment

1.7 DEFINITIONS

[1.7.1 Automated Grouting Data Collection System (AGDCS)

****
NOTE: The maturation of computer monitoring of pressure grouting now allows for a second-by-second real-time review of ongoing grouting work and a permanent record of the grouting process. Several contractors have developed advanced Automated Grouting Data Collection Systems, historically referred to as "Computer Grouting". For grouting jobs on structures under the governance of ER 1110-1-1807, or greater than 10,000 linear feet, using an AGDCS is preferred because it provides accurate and precise realtime records that could not be generated by hand. It also saves manpower and cost.
****

A computerized system for receiving, translating, recording, storing, and displaying[water pressure testing and] pressure grouting data. The system is capable of viewing results in real time, or at any time after the stage is tested or grouted. The system can also produce graphic and numerical outputs for grouting[and water pressure testing] data in real-time with digital transmittable files, including but not limited to, PDF, excel, spreadsheets, and raw data files.

]1.7.2 Balanced and Stable Grout

"Stable" means that the grout has nearly zero bleed. "Balanced" means a balance of ingredients to meet desired properties. A balanced and stable grout mixture is a homogenous, balanced blend of water and cement combined with selected additives and admixtures to produce a stable product that experiences minimal to near zero bleed and maintains a constant rheology (viscosity, cohesion, pressure filtration) during placement. Therefore, 1 liter gallon of injected fluid grout becomes 1 liter gallon of cured hard grout in the foundation eliminating water pathways.

1.7.3 Bleed

Separation of excess water from a particulate suspension grout as a result

of settlement. Commonly expressed as a percentage of the initial volume of the mixed cementitious grout.

1.7.4 Centipoise (cP)

For solution grouts, a common unit of measurement for viscosity allowing for a direct comparison to the viscosity of water. Water has a viscosity of 1 cP at 20 degrees Celsius 68 degrees Fahrenheit.

1.7.5 Chemical Grouting

Chemical grout is typically composed of materials that are combined to form a liquid solution that hardens into a solid material composed of: 1) matrix forming base materials, 2) reactants, and 3) accelerators or retarders. Also referred to as "solution grouts".

[1.7.6 Closure

****
NOTE: Closure is only required for projects with an objective of controlling groundwater inflows and reducing seepage. As the work progresses the Contracting Officer reserves the right to establish closure based on apparent Lugeons measured during the grouting or the Lugeons from water pressure tests.
****

Closure is defined as the completion of all grouting within a section to established criteria, including refusal, split spacing, and permeability closure criteria. Closure is confirmed through grout takes, water pressure testing, and verification holes where the residual permeabilities following grouting are measured in each completed section.

]1.7.7 Communication

Communication is the passage of water or grout from one hole to another or to any opening or observation point during the course of drilling, water pressure testing, [and][or] grouting.

[1.7.8 Downstage Grouting

****
NOTE: Shallow grouting in the immediate perimeter of shaft and tunnel excavations rarely are deep enough to warrant more complex grouting strategies such as downstage grouting. Grout holes for perimeter water inflow control grouting prior to installation of liners are seldom deep enough to practice downstage grouting.
****

Downstage grouting is the drilling and grouting of a zone before proceeding to the next deeper zone within the same borehole. It is the installation of a grout curtain by repeated drilling and grouting in successively deeper stages in the downward direction in each hole.[In EM 1110-2-3506, this is termed as "Stage Grouting".]

]1.7.9 Drilling Setup

A drilling setup is when a drill is placed over the top of on a hole prior to drilling.

1.7.10 Effective Pressure

The sum of all head losses and head gains in the injection system and the ground.

1.7.11 Effective Grouting Pressure

Effective grouting pressure is the pressure exerted by an injected fluid on the formation at the point of injection minus the initial water pressure.
Calculate effective pressure based on the sum of all head losses and head gains in the injection system and the ground.
[
For instrumented packers, measure effective grouting pressure in the ground with the use of an instrumented packer. The effective pressure at the instrumented packer sensor can be determined by subtracting the initial water pressure from the measured total pressure. To obtain the effective pressure at the middle of the stage, the static pressure from the ground water and grout between the sensor and the middle of the stage elevation is to be considered.]

1.7.12 Exploratory Hole

Exploratory holes are drilled to investigate subsurface conditions across the site ahead of grout holes.

1.7.13 Final Set

****
NOTE: Use final set and initial set with cementitious grouts, use gel time with chemical grouts. Edit entire specification as appropriate.
****

A degree of stiffening of a grout mixture indicating the time in hours and minutes required for cement paste to stiffen sufficiently to resist the penetration of a weighted test needle (Vicat needle). Also called 'Final Set Time' or 'Time of Final Set'.

[1.7.14 Gel Time

****
NOTE: Use final set and initial set with cementitious grouts, use gel time with chemical grouts. Edit entire specification as appropriate.
****

The time or period after mixing for a liquid grout to exhibit measurable shear strength, or the onset of change from the liquid to plastic state.

]1.7.15 Grout Take

The volume of grout placed. This can be for a specific grout stage, specific grout hole, a grout line, or for the entire job. The "take"

referenced should specify which.

1.7.16 Grouting Setup

A grouting setup is when grouting is accomplished with one or multiple connections. The movement of a packer or paired packers up or down the hole does not constitute a setup.

1.7.17 Hold Pressure

The unique pressure for each stage that is to be reached and held constant during[water pressure testing or] pressure grouting. Also referred to as the "target pressure".

1.7.18 Hole Washing

A process of washing, using pressurized water, to remove sediment, cuttings, and loose material from cracks and seams in the rock.

1.7.19 [Hydrofracture][Hydrofracturing]

The fracturing of a subsurface stratum by pumping water, drilling fluid, air or grout under a pressure in excess of the tensile strength and minor principal stress.

1.7.20 Initial Set

A degree of stiffening of a grout mixture indicating the time in hours and minutes required for cement paste to stiffen sufficiently to limit penetration of a weighted test needle (Vicat needle) to 25 mm. Also called 'Initial Set Time' or 'Time of Initial Set'.

[1.7.21 [Instrumented Packer][Instrumented Packer Assembly]

An instrumented packer assembly measures total pressures during water pressure testing and grouting either: a) between the base of the packer and the bottom of the borehole, b) between the packers of a double-packer assembly, or c) immediately above the packer. The assembly is part of a system that [measures][indicates] total pressure in real-time by monitor display, and records pressure data for later comparison with the water pressure and grouting pressure versus time. A manually read gauge is not acceptable for use as an instrumented packer.

]1.7.22 Lugeon

****

NOTE: The use of Lugeon calculations is more applicable to permability grouting in grout curtains. Grouting in the immediate perimeter of shaft and tunnel excavations may not warrant extensive analysis that is more applicable to extensive grout curtains.

****

Lugeon value refers to the permeability of the geologic formation or zone. A Lugeon unit is a metric unit defined as a flow of 1 liter of water per minute per meter of borehole length at a pressure of 10 bars. The English measurement would be 0.26 gallons per minute per 3.28 feet of borehole length at a pressure of 145 psi.

1.7.22.1 Apparent Lugeon

Apparent Lugeon refers to the grouting permeability of the geologic formation or zone, using a grout that behaves as a Bingham fluid with a known apparent viscosity. The evolution of the apparent Lugeon value during grouting must govern the variation of the grout mix and other injection parameters. Correct the apparent Lugeon for pressure as appropriate.

1.7.22.2 Modified Lugeon

A modified Lugeon is a permeability value corrected for a pressure lower than the 10 bar pressure, equivalent to 145 psi, defined for the Lugeon. When pressures anticipated for work are below 10 bars (145 psi), or the length of the stage is greater than 1 meter3 feet, the Modified Lugeon is the normal unit of measure, and for convenience is referred to as a Lugeon.

1.7.23 Primary Hole

The first series of holes to be drilled and grouted, usually at the maximum allowable spacing. Grouting of primary holes is completed prior to secondary holes being drilled.

1.7.24 Refusal

The point during grout injection when little or no grout is accepted under the maximum allowable pressure or other specified conditions.

1.7.25 Refusal Criteria

Refusal Criteria is defined in each grout stage of each hole. Rate-of-take criteria is satisfied by the measurement of apparent Lugeon value for grout or Lugeon value for water. Refusal determines when grouting operations stop at each stage.

1.7.26 Contact Grouting Refusal

The grouting of any hole may be considered complete when that hole has zero flow for a period of 1 minute when grouted at the hold pressure.

1.7.27 Rock Grouting Refusal

The grouting of any hole may be considered complete when that hole refuses to take grout at a rate less than [one][_____] gallon per minute for a period of [10][_____] minutes when grouted at the hold pressure.

1.7.28 Residual Permeability

Residual permeability is the permeability at the conclusion of the grouting work.

1.7.29 Rock Grouting

The injection of grout into the rock mass for the purpose of controlling water inflow or increasing [strength][stability]. Rock grouting must only occur after newly excavated rock has drained and is not required to occur until before the tunnel liner is ready to be cast.

1.7.30 Secondary Hole

Secondary holes must be drilled midway between primary holes and the grouting completed before drilling the tertiary series of holes.

1.7.31 Section

A linear or a real subdivision of the grout treatment pattern without regard to the depth of treatment.

1.7.32 Set Time

See "initial set time" and "final set time".

1.7.33 Split Spacing

****

NOTE: Split spacing and split space criteria are most applicable to seepage and groundwater control. For strength and stability, split spacing may still be utilized, but strength requirements between holes must be edited into the specification in place of permeability requirements.

****

The procedure by which additional grout injection holes are located equidistant from previously grouted holes. Split spacing is utilized when a higher order of hole fails the split-spacing criteria.

[1.7.34 Split Space Criteria

The split space criteria (or split space criterion) is a minimum Lugeon value or grout take value that mandates that additional holes be added through the split spacing method. The split space criteria may vary depending on the stage, zone, series, or section that is under consideration.

]1.7.35 Stage

A stage is a specific segment of hole that is grouted or water pressure tested.

1.7.36 Stop

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

1.7.37 Succeeding Series

Locate each of the succeeding series of holes based on the split space criteria.

1.7.38 Target Pressure

See paragraph HOLD PRESSURE.

1.7.39 Tertiary Hole

Tertiary holes are drilled midway between the secondary and primary holes

along the grout lines. Drilling and grouting is completed in the tertiary hole before any succeeding series of holes are drilled or grouted.

1.7.40 Tunnel Contact Grouting

The injection of grout into voids behind the tunnel lining to achieve continuous contact between the tunnel lining and the surrounding rock/shotcrete.

1.7.41 Upstage Grouting

****

NOTE: Shallow grouting in the immediate perimeter of shaft and tunnel excavations rarely are deep enough to warrant more complex grouting strategies such as upstage grouting. Grout holes for perimeter water inflow control grouting prior to installation of liners are seldom deep enough to practice upstage grouting.

****

Upstage grouting involves drilling a grout hole to its final depth and grouting from the bottom up in stages.[In EM 1110-2-3506, this is termed as "stop grouting".]

1.7.42 Verification Hole

A verification hole is drilled to verify the grouting results meet closure criteria at the conclusion of grouting. The location of verification holes are selected by the Contracting Officer.

1.7.43 Viscosity

Friction within a liquid due to mutual adherence of its particles, i.e., the "thickness" of a mixture.

1.7.44 [Water Pressure Test][Water Pressure Testing]

A test performed to measure the rate at which water can be forced into a hole under a specific pressure.[Colloquially and in EM 1110-2-3506, this is called "pressure test" or "pressure testing".]

1.7.45 Water Pressure Testing Setup

A water pressure testing setup is when water pressure testing equipment is placed on a hole and water pressure testing accomplished thereafter with one or multiple connections. The movement of a packer or paired packers up or down the hole does not constitute a setup.

1.7.46 Zone

A zone is a predetermined partial depth of a grout line or length of grouting section along the alignment.

1.8 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-01 Preconstruction Submittals

Qualifications; G, [_____]

Drilling and Grouting Work Plan; G, [_____]

Cementitious Grout Mix Design; G, [_____]

Chemical Grout Mix Design; G, [_____]

Automated Grouting Data Collection System (AGDCS); G, [_____]

Drilling and Invasive Program Plan (DIPP); G, [_____]

Laboratory Accreditation; G, [_____]

SD-02 Shop Drawings

Monthly Grouting Red Line Drawings; G, [_____]

SD-03 Product Data

Drilling Rigs and Equipment; G, [_____]

Hole Washing Equipment; G, [_____]

Cement Grouting Equipment; G, [_____]

Chemical Grouting Equipment; G, [_____]

Instrumented Packer Equipment; G, [_____]

Permits, Certifications, and Licenses; G, [_____]

SD-06 Test Reports

Grout Materials Test Reports; G, [_____]

Mixing Water Test Reports; G, [_____]

Weekly Grout Test Results; G, [_____]

Drill Logs; G, [_____]

Hole Washing Log; G, [_____]

Grouting Reports; G, [_____]

Water Pressure Testing Reports; G, [_____]

SD-11 Closeout Submittals

Database of [Water Pressure Testing and] Pressure Grouting Results; G, [_____]

Drilling and Grouting Final Report; G, [_____]

As-Built Drilling and Grouting Drawings; G, [_____]

1.9 QUALIFICATIONS

****

NOTE: Staff and experience requirements listed below must be coordinated with the requirements of 01 45 00 CONTRACTOR QUALITY CONTROL. Edit the following sections as needed to select the QC staff needed as appropriate to the scale and scope of the project. Drill Rig Operator and a Lead Grouting Geotech/Geologist is required for projects that must comply with ER 1110-1-1807 for work near a USACE Dam.Personnel do not need professional certification in the state in which they are operating to be competent in the work, and this may be prohibitive for contractors in staffing the job.

****

Submit the qualifications at least [30][60] days prior to commencement of drilling and grouting activities. Changes in personnel require additional submittals for approval by the Contracting Officer.

Perform grouting by a specialty Contractor experienced and competent in [cement grouting][chemical grouting][both cement and chemical grouting]. If multiple Contractor's are proposed, submit these qualifications for each contractor and identify which work they are submitted for (rock grouting or tunnel contact grouting).

1.9.1 Grouting Contractor

All grouting is to be performed by a grouting Contractor. The grouting Contractor must be experienced and competent in types and methods of grouting specified for this Contract and have completed at least [3][_____] similar jobs over the past [10][_____] years.

1.9.2 Lead Grouting [Geotechnical Engineer][Geologist]

The lead grouting geologist or lead grouting geotechnical engineer must be licensed as a Professional Engineer (PE) or Professional Geologist (PG). The professional must have [2][3] years of experience over the past [10][_____] years, or 5 years equivalent engineering and construction experience specific to drilling and grouting for [shaft][tunnel] construction. The lead grouting [geotechnical engineer][geologist] is responsible for quality control, [mapping][documentation], and identification of potential issues in the field.

1.9.3 Grouting Superintendent

All grouting operations for the [shaft][tunnel][liner] must be performed under the direction of an experienced grouting superintendent with at least[[3][_____] years experience within the previous [10][_____] years][[3][_____] successfully completed projects of similar scope] supervising crews conducting grouting required for this project.

1.9.4 Shift Supervisor

Each shift and grouting crew requires a supervisor working under the direction of the grouting superintendent. Shift supervisors of each grouting crew must have a minimum of [2][_____] years [5][_____] projects of experience in the types of grouting to be supervised. For smaller jobs, the shift supervisor and grouting superintendent may share duties.

[1.9.5 Drill Rig Operator

[The drill rig operator(s) must have a minimum of [3][_____] projects as a driller in similar geologic, designs, and working environments as this project.][The Drill Rig Operator must have completed at least [3][_____] projects complying with requirements of ER 1110-1-1807.]

]1.10 DRILLING AND GROUTING WORK PLAN

****

NOTE: Grouting Work Plan should be a government approved submittal. It must include ALL equipment, materials, practices, coordination, and contingencies. A separate Work Plan may be used for grouting before lining and a separate contact grouting plan because the extent and need for contact grouting may not be defined until after the lining is in place. The requirements below may be duplicative to other submittals.

Initial water control or structural grouting is feature-driven. A decision is made by the designer/construction personnel early on to determine criteria used to determine if a feature (often joints or shear zones in rock, running ground or more permeable areas in soft ground) require grouting. In many cases the inflow of groundwater or the degree of disturbance or extent of running ground is at its greatest immediately upon exposure, and diminishes over time. If the integrity of the excavation is not impacted significantly, it may be possible to alter/delay work while the disturbance diminishes if time permits. This may cut overall costs by reducing the need to grout. This may be a decision made by the designer/qualified construction QA/Engineering During Construction personnel or may be proposed by the Contractor and either accepted or rejected based upon engineering review, long term stability concerns, safety, and time considerations.

Elements of contractors' work plans and personnel MAY be parts of proposals submitted in response to Best Value Solicitations. The required submittals for Best Value submittals are addressed specifically in the Instructions to Proposers of these solicitations.

****

At least [30][45][60][90] days prior to the commencement of work, submit a Drilling and Grouting Work Plan to include a narrative of the equipment, materials, personnel required to complete the work, and any required shop drawings. For each type of drilling and grouting operation proposed, submit the following:

a. A list, details, and data on the [drilling][coring] equipment and procedures; and example boring logs. Equipment must be in accordance with paragraphs EQUIPMENT and DRILLING PROCEDURES.

b. Define the methods and types of grout placement. Include a list, details, and data on the grouting equipment, grout monitoring equipment, and example grouting data. Include the proposed batching equipment, mixers, holding tanks, pumps, piping, valves, packers, water test equipment gauges to measure volume and pressure, equipment and fittings for drilling grout holes and calibrating gauges. All equipment for reliably controlling grout pressures below the maximum pressure specified for the particular grouting type. This section must be in accordance with paragraphs GROUT HOLE WASHING PROCEDURES[, WATER PRESSURE TESTING PROCEDURES,] and GROUTING PROCEDURES.

c. The overall sequence and schedule of work including the anticipated staffing and shifts. Include a personnel chart identifying key personnel, points of contact, and their responsibilities.

d. The [specified][proposed] grout hole layout and naming convention. Include a schematic layout showing the size and length of holes required to [stop inflows from a typical: point source, fracture, bedding plan, initial support].[Provide support and stability to maintain safe working geometries for the excavation.] This section

must be in accordance with paragraph HOLE SEQUENCES or as amended in the work plan.

e. Grout mix changes, include the procedures, protocols, means, and methods for changing grout mixes expeditiously to the grout hole during production.

f. Shop drawings summarizing the layout for equipment and operations in a-e above, including how hole washing,[water pressure testing,] and grouting operations are to be conducted.

g. Grout testing protocols, time frames and procedures, frequency of testing, including a plan that identifies quality control procedures and the individual responsible for management of each grouting stage and the quality control measures that must be implemented. Must comply with paragraph GROUT QUALITY CONTROL TESTING and paragraph[CEMENTITIOUS GROUT MIX DESIGN][CHEMICAL GROUT MIX DESIGN].

h. Production estimates including the identification of steps in communications and decision-making processes that impact the progress of work.

i. Proposed format for records of injected volume, pressure, and rate drawings with drilling,[water pressure testing] and grouting work progress. Must comply with paragraphs HOLE RECORDS, PERIODIC RECORDS, and AS-BUILT DRILLING AND GROUTING DRAWINGS.

j. Contingency plan in the event of early stoppage of grouting (i.e., equipment breakdown, severe weather stand downs, end-of-work shift, or other factors that could cause early cessation of grouting activities). General guidelines and procedures for identifying and isolating zones of grout take, and procedures to be followed in the event of communication in grout holes.

k. Detailed plans for the care and disposal of soil and grout cuttings, wastewater, and waste grout. List any environmental [permits][compliance], and details of required clean up including procedures, locations, and time intervals.

l. Identify any discrepancies between the Contract drawings and Contractor's survey.

[
m. Submit details for patching and restoration for [concrete][steel][shotcrete][exposed rock surface] per the requirements of paragraph "PATCHING AND RESTORATION".]

1.10.1 Proposed Grout Mix Design

****

NOTE: The grout mix design is a separate submittal. The designer can tailor this section to have the Contractor pre-submit the grout mix proposed before trial batching, or to include the results of trial batching as part of the work plan. There are advantages for small/large projects for either case.

****

Submit the recommended mix design per the results of mixture proportioning

and trial batching as required in paragraph CEMENTITIOUS GROUT MIX DESIGN[and][or][CHEMICAL GROUT MIX DESIGN]. The work plan must include the following for each type of grout proposed for use in the Work Plan:

a. Mix design data and requirements as defined in paragraph CEMENTITIOUS GROUT MIX DESIGN[and][or][CHEMICAL GROUT MIX DESIGN], including all mix components and test results to meet minimum design criteria.

b. Manufacturer's product data sheets indicating mixing and handling requirements, personal safety equipment, first aid measures and methods for proper storage and disposal of waste materials, including containers.

c. Certificates of compliance of all mix components with specified standards.

d. Written affidavits from respective suppliers of grouting materials stating that the proposed product to be used in the mix is compatible with all other components in the proposed mix.

e. Certifications that all admixtures are non-corrosive.

f. Certificate of compliance stating the chloride content of accelerators.

[1.11 DRILLING AND INVASIVE PROGRAM PLAN (DIPP)

The requirements for the DIPP are found in ER 1110-1-1807. Complete the DIPP using the outline sequence found in the ER. Address every part of the regulatory outline. Sections that do not apply require at least one sentence explaining why the section is not applicable. Perform all drilling in accordance with the DIPP requirements.

][1.12 TEST SECTION REQUIREMENTS

****

NOTE: This paragraph should only be used when utilizing a test section, which is atypical. If no test section is utilized, then this paragraph needs to be deleted.

A second test section is required if the first test section fails. Clarify what additional demonstrations may be required in the text below.

****

A test section is required using the same personnel, equipment, and materials required for production.[Complete the test section as part of production.] The test section must include the full scale implementation of all procedures to [stabilize the excavation][reduce permeability to acceptable levels][complete contact grouting with no void spaces] in the sequential order submitted as part of the work plan. In addition, the following criteria are required:

a. All of the Contractor-proposed methods are to be trialed in the test section.

b. Full deliverables required as part of the project must be provided for

review and acceptance before beginning full scale production.

[
c. If the Test Section is rejected by the Government and new means and methods are considered necessary, then the Contractor must repeat the test section, in a new location directed by the Contracting Officer, and submit a new Quality Control Plan and Work Plan.]

]1.13 CARE AND DELIVERY OF SAMPLES

Do not leave samples or core unprotected or staged at the hole location. Ensure all descriptive labels and designations on sample jars, tubes, and boxes remain clean, and legible, until final delivery of samples to and acceptance by, the Contracting Officer. Keep samples [protected from freezing][in a climate-controlled environment] suitably protected from moisture and undue exposure to the elements in a temporary storage facility. Deposit the samples and cores in the storage facility no later than the completion of each shift, or more frequent pending prevailing weather conditions. Reserve the Temporary Storage Facility for the use of the Government for logging, classifying, and studying the samples and cores, and do not use the facility for storing equipment or supplies. The minimum floor space to adequately lay out core must have dimensions of at least [_____]. Keep the storage facility organized and safe, with aisles unobstructed and core boxes stacked securely. At all times, stack core boxes such that all side labels are upright and visible from aisles. Do not stack full pallets over two pallets high, with a maximum of [20][_____] core boxes per pallet.

1.14 DISPOSAL OF DRILL CUTTINGS, WASTE WATER, AND WASTE GROUT

****
NOTE: Either provide for onsite or offsite disposal of drill cuttings and waste grout. Select the appropriate disposal paragraph, and delete the other.
****

Comply with Section 01 57 19 TEMPORARY ENVIRONMENTAL PROTECTION AND PERMITS for containment, treatment, and disposal of waste materials, including water.

[
Dispose of all drill cuttings on site, in [a location designated by the Contracting Officer][the area designated in the Contract drawings].[All waste grout, once solidified, may also be disposed of in the same location.]]

[
Dispose of all drill cuttings off site, approximately[_____] kilometers [_____] miles away from the work site, in the location [indicated in the Contract drawings][designated by the Contracting Officer][designated by the local sponsor].[Disposal locations must meet all local, state, and federal laws and regulations].[All waste grout, once solidified, may also be disposed of in the same location.]]

1.15 PERMITS, CERTIFICATIONS, AND LICENSES

****
NOTE: The designer should add any known permits, certifications, and or licenses known to be required to perform the work. These could include: water withdrawal permit, city business permit, noise permit, etc. The designer should contact the city or

county and state to determine if any permits are required.

****

Submit all permits, certifications, and licenses required for the work.

[

Known permits requirements are: [_____].]

1.16 DATA REQUIREMENTS

Provide all generated data - no data source or format is subject to exemption.[All data generated as part of this specification is subject to the requirements in Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION.]

[1.17 LABORATORY ACCREDITATION

****

NOTE: This requirement is for all USACE contracts. Non-USACE can delete this paragraph, however the agency's own requirements should be added if applicable.

****

All laboratories submitting testing results for this Contract must be accredited in accordance with ER 1110-1-8100. Submit written proof of accreditation for each laboratory utilized. If the accreditation expires during the Contract period, the accreditation renewal must be submitted prior to the expiration. Submit each laboratory separately.

]PART 2 PRODUCTS

****

Cementitious grout materials requirements are based predominately on high mobility grouting applications in rock detailed in EM 1110-2-3506 Grouting Technology, and updated based on lessons learned since publication. Significant edits to the material properties for cementitious grout are not recommended. Cementitious grouting material requirements should remain in the specification, even if not anticipated for use, so the contractor has the most flexibility to submit a mix design to satisfy the project scope.

Provisions for sanded grout are made, but sanded grouts are a low mobility grout most applicable for large void filling. If there is not a need for low mobility grouting, then remove provisions for sanded grout throughout the specification, including measurement and payment.

For structural support in sands and gravels, consider the use of Specification 31 33 20 Void and Permeation Grouting to better address those scope features.

Chemical grouts are highly dependent upon manufacturer and manufacturer's recommendations.

Therefore for chemical grouts, the materials requirements are required to be performance based. Define the objective of the project (structural support, excavation stability, seepage control) and allow the contractor to submit products that are best suited to accomplish the scope. If there are specific products and capabilities that are desired, consider obtaining a Justification and Approval (J and A) from the local District Office of Counsel and including additional information within this specification. It is not practical to provide tables of manufacturers and product details within this specification

For USACE, all laboratory testing must be completed by a USACE validated laboratory in accordance with Engineering Regulation ER 1110-1-8100.

****

2.1 DELIVERY, STORAGE, AND HANDLING

Transport and store grout materials per manufacturer's recommendations and as required herein. Store enough constituent components of [cement][chemical] grout, at or near the site to ensure grouting operations are not delayed by shortages. All materials are required to be adequately protected from inclement weather, including rain, snow, and freezing conditions. Provide suitable enclosures to prevent the degradation of the various materials prior to use.[If cement is found to contain lumps or contaminants that may be deleterious to the grouting operation, the cement must be screened through a standard No. 16 mesh screen, or else replaced. No payment will be made for such screening or replacement.]

2.2 GROUTING MATERIAL

[Provide grout composed of water and cement[, supplementary cementitious [materials][pozzolans], admixtures, fillers, and pigment].]Design and vary the grout mixes to meet the characteristics of each hole based on encountered subsurface conditions. The various furnished materials required by this Contract must be in accordance with the requirements herein, including the GROUT MATERIALS TEST REPORTS Submittal. Ensure that all grouting materials are compatible. Replace any material found to be incompatible - no additional payment will be made for replacement of incompatible materials. Testing of the replacement material and revised grout mixes are subject to approval by the Contracting Officer - no additional payment will be made for this testing.

2.2.1 Grout Materials Test Reports

****

NOTE: The intent of this requirement is for the constituent grout material information, including cement, to be provided with each significant delivery. Mill Certificates and manufacturers test reports should include the location of manufacture, batch number, date, and any other pertinent manufacturers or product information.

****

Submit [mill test certificates][manufacturer's test certifications] materials reports showing that all grouting materials meet the quality and soundness requirements specified. Submit Material Safety Data Sheets (MSDS) for each material. Submit the material test reports package as part of the [Work Plan][Mix Design]. For portland cement, include [[6 month][1 year][2 years] of mill tests,] and an ASTM C150/C150M compliance certificate.[For blended hydraulic cement, include [[6 month][1 year][2 years] of mill tests,] and an ASTM C595/C595M compliance certificate.]

2.2.2 Cements

****

NOTE: The specification has a requirement that the grout mix contain 30 percent portland cement by dry weight. That is due to problems on some projects where contractors have proposed 85 percent slag with poor results. Therefore, a minimum cement dosage is included in this specification as a precaution. Consideration for a waiver of this requirement should be taken if the contractor is able to satisfactorily demonstrate performance of an alternative mix design. Note that cement grout not containing sufficient portland cement may be erodible when subjected to a differential head and flowing conditions.

The designer must ensure the mix design and performance are adequate for the subsurface conditions at the site. Strength requirements must consider the stress condition present at the depth of grouting. This requirement is in tandem with the compressive strength requirement.

If grouting is for water inflow into excavations during construction and prior to installation of a permanent water-barrier liner, less permanent grouts may be considered.

****

The grout mixes must contain at least [30][_____] percent cement by dry weight of the mixture.

2.2.2.1 Portland Cement

****

NOTE: Typically, Type I-III cement is what is used. Type III cement has advantages for some grouting due to the fineness of the cement particles, which applies primarily to seepage control grouting projects. Type V cement has high sulfate resistance for environments with the potential for chemical attack by hydrogen sulfide. Some cement types are not locally available. Availability must be confirmed prior to specifying. On USACE jobs, it is recommended (by materials engineers) to require 2 years of mill certificates for Portland Cements, but this may not apply to smaller jobs.

****

Cement used in grout must be in accordance with ASTM C150/C150M Type [I,][II,][III,][IV,][or V]. The use of bulk cement is permitted provided methods of handling, transporting, and storage that are satisfactory to the Contracting Officer are employed. Otherwise, only cement furnished in fabric or paper bags is acceptable for use in the work.[The Grout Mix Design and Trial Batches Submittal must include the source[s] of cement, [[6 month][1 year][2 years] of mill tests,] and an ASTM C150/C150M compliance certificate.] Storage of cement must be in accordance with paragraph DELIVERY, STORAGE, AND HANDLING.

2.2.2.2 Blended Hydraulic Cement

****

NOTE: Technical requirements, market conditions, and local practice will govern selection of cement types. Include blended hydraulic cements as an option for all cementitious grouting applications. The designer is recommended to perform market studies and determine the best alternative (straight portland or blended cement) based on price and availability.

This paragraph should not be deleted, even where the designer would prefer a pure portland cement for grout, due to the potential for the non-availability of pure portland cement.

Type IT(PX)(PY)X is a secondary component and Y is a tertiary component.

****

Blended Hydraulic Cement is a combination of Portland cement and one or more Supplementary Cementitious Materials (SCM's)/pozzolans or limestone. Blended Hydraulic Cements must be in accordance with ASTM C595/C595M. This ASTM recognizes four types of blended cements: Type IS (X), Type IP (X), Type IL (X), and Type IT. The "X" in the name refers to the percentage of secondary ingredient in the blend. Type IS (X) has slag as the secondary component, Type IP (X) has Pozzolan, typically fly ash, as the secondary component. Type IL Cement has limestone as the secondary component, and Type IT(PX)(PY) has two types of pozzolans. For example, Type IP (15) would contain 15 percent pozzolan. All four types of blended cements are permissible for use in grout.[Verify fresh and hardened grout properties through trial batching and field demonstrations.] Test Blended Cement with Limestone in accordance with ASTM C1797 to determine the chemical composition of the lime.

The use of bulk cement is permitted provided the Contractor employs methods of handling, transporting, and storage that are satisfactory to the Contracting Officer, otherwise only cement furnished in fabric or paper bags are acceptable for use in the work. The Grout Mix Design and Trial Batches Submittal must include the source[s] of cement, [6 month][1 year][2 years] of mill tests, and an ASTM C595/C595M compliance certificate. Storage of cement must be in accordance with paragraph DELIVERY, STORAGE, AND HANDLING.

2.2.3 Supplementary Cementitious Materials (SCM's) and Pozzolans

2.2.3.1 Fly Ash

****
NOTE: Fly ash is typically used as an inexpensive filler. It has slight pozzolanic properties. It also increases pressure filtration resistance. As a waste product, the properties vary.
****

Fly ash[or other raw or calcined natural pozzolans], if used, must be in accordance with ASTM C618. Fly Ash may be furnished in paper sacks or in bulk. It must be transported, handled, and stored so as to avoid damage, waste, or absorption of moisture. Reclaimed ash and alternatives to Class F and Class C ash are not permitted for use.

2.2.3.2 Ground-Granulated Blast Furnace Slag

****
NOTE: GGBF is a byproduct of iron and steel making. It increases durability and strength, lowers heat of hydration, decreases ASR reactions, and decreases the chance of chemical attack.
****

Ground-Granulated Blast Furnace Slag (GGBF), if used, must be in accordance with ASTM C989/C989M, [grade 100][grade 120]. It must be transported, handled, and stored to avoid damage, waste, or absorption of moisture.

2.2.3.3 Silica Fume

****
NOTE: Silica fume is very fine, with a maximum particle size of 1 micron. It improves pressure filtration resistance, reduces bleed, improves water repellency, and increases grout strength.
****

Silica Fume, if used, must be in accordance with ASTM C1240. Pelletized Silica Fume must not be used. It must be transported, handled, and stored to avoid damage, waste, or absorption of moisture.

2.2.3.4 Hydrated Lime

****
NOTE: Hydrated lime can be used a pozzolan. It is found in some blended cement. It should not be confused with calcium carbonate (limestone), which is not pozzolanic. Hydrated Lime is created by powdering limestone and heating it to 900 C1650 F and then adding water.
****

Hydrated Lime, also colloquially called 'Lime' is calcium oxide or calcium hydroxide that has pozzolanic properties. If used, hydrated lime must be in accordance with ASTM C207.

2.2.4 Admixtures

****

NOTE: Refer to USACE's Engineering Manual (EM)1110-2-3506, "Grouting Technology", for discussions of properties, characteristics and limitations for principal admixture and filler materials.

****

Furnish admixtures in containers that are adequate for the purposes at hand, and of suitable volume to allow measurement and dispensing on a production basis without delay or error. Additives include, but are not limited to, the following: [superplasticizers,][water reducing admixtures,][viscosity modifiers,][and anti-washout admixtures]. If additive not specified is proposed for use, Contracting Officer approval is required for the material and its property qualities. Provide certification from the manufacturer for all admixtures. When multiple admixtures are used in a grout mix, all of the admixtures must be certified as compatible with each other, and the other ingredients in the mix.

Ship, handle, and store admixtures in such a way as to prevent deterioration, contamination, damage, or waste. Storage vats must contain paddle type agitators and the entire admixture dispensing system must be protected from extreme temperatures and conditions. Admixtures allowed to freeze are to be rejected and replaced at no cost to the Government. Alternatives may be proposed, contingent upon approval by the Contracting Officer based on test results and review of available literature. No time extension will be allowed for the time required to review alternative materials.

2.2.4.1 Superplasticizer

****

NOTE: Superplasticizers reduce the amount of water needed for mixes and reduces viscosity and cohesion. It does this by overprinting solid particles with a charge and making them repel each other.

Previous versions of this specification required the use of super-plasticizer, and zero-bleed mixes require their use in 2023. However, technology changes have produced alternatives through the advancement of high range water reducers.

****

A superplasticizer is a high-range water reducer. If used, superplasticizers must possess characteristics that reduce the water demand by at least 12 percent, and be in accordance with ASTM C494/C494M, type F.[Naphthalene sulphonate or polycarboxylate with the ability to coat grout particles in the suspension with a film having a negative charge must be used.]

2.2.4.2 Water-Reducing Admixture

Water Reducing Admixtures, if used, must be in accordance with ASTM C494/C494M, type A.

2.2.4.3 Viscosity Modifier

****

NOTE: Gums, specifically diutan gum and welan gum, have been used as viscosity modifiers in the past. The gums reduce bleed, resist pressure filtration, and make the grout more water repellant. See Chapter 7 of USACE's Engineering Manual EM 1110-2-3506, entitled 'Grouting Technology' for more details.

****

Viscosity Modifier, if used, will be a[natural,] soluble, copolymer having a high molecular weight which enhances the stability of the suspension grouts. Viscosity Modifiers must be in accordance with ASTM C494/C494M Type S.

2.2.4.4 Fluidifier

Fluidifier, if used, must be a compound possessing characteristics which 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 be in accordance with ASTM C937.

2.2.4.5 Anti-Washout Admixture

****

NOTE: Anti-washout admixture was designed to be used for underwater concrete placement and in flowing water conditions. This use of this admixture may make the grout slightly more resistant to washout if exposed to flowing water conditions. Anit-washout admixture has properties that produce a retarding effect which may prolong set times, and in effect, grouting production. They also increase time to clean up tooling and equipment. Designers should not be surprised to see much greater costs for the anti-washout grout mix.

Anti-washout admixtures are cellulose based and may have compatibility issues with other admixtures. Consultation with the supplier is recommended before use, along with additional mix design testing.

****

Anti-washout admixtures, if used, must be in accordance with ASTM C494/C494M Type S and COE CRD-C 661. Consult with the anti-washout admixture manufacturer to ensure compatibility with the other grout mix components.

2.2.4.6 Retarder

****

NOTE: Retarders delay the set-up time of grout. Set times can be delayed from hours to days.

****

Retarders, if used, must be in accordance with ASTM C494/C494M, Type B.

2.2.4.7 Other Chemical Admixture

Other Chemical Admixtures, if used, must be in accordance with ASTM C494/C494M, and be submitted with written justification, for approval by the Contracting Officer.

2.2.5 Fillers

2.2.5.1 Bentonite

****
NOTE: Bentonite is a mined clay which reduces bleed and increases pressure filtration resistance. It increases viscosity and cohesion. Bentonite replaces cement and reduces the strength of the grout. If high strength is required for stabilization, bentonite percentages recommended in this specification may need to be reduced.
****

If used, bentonite must be sodium (Na) cation, and powdered montmorillonite must be added to the cement grout at a ratio between [2][_____] to [8][_____] percent by weight of cement. Adjust the percentage as directed by the Contracting Officer, based on the mix design. Use a separate colloidal bentonite mixer to mix the bentonite and water to ensure full dispersion and hydration of the bentonite before adding to the grout mixer. Handle and store bentonite to avoid absorption of moisture, damage, or waste. Reject all bentonite which has become caked due to moisture absorption. Store enough bentonite at or near the site of the work to ensure that grouting operations are not delayed by shortage of bentonite.

[2.2.5.2 Sand

****
NOTE: Provisions are made for the use of a sanded grout. Sanded grout is used for large void filling and plugging holes. The use of sanded grout should generally be limited to formations and conditions where solution features and cavities are anticipated that may require hole plugging and split spacing due to the inability to build up to the hold pressure or exceeding the injected grout volume threshold for the stage. The use of sanded grout can damage high mobility grouting equipment more quickly than sand-free grouts. Modern grouting operations should allow the cement/bentonite blended grout to be batched separately with the sand added to the mix in a secondary mixing unit before being transferred to the grout cart.

Lime is a less-damaging filler that should be considered over sand.

Sand properties for local sources need to be evaluated prior to setting sand requirements, including the gradations.
****

a. Sand for grout must be clean and consist of hard, tough, durable, uncoated particles with no more than [5][_____] percent passing the 0.075 mm No. 200 sieve in accordance with ASTM C117. The shape of the particles must be generally rounded or cubical[and must not contain more than [_____] percent of flat or elongated pieces having a maximum dimension in excess of three times the minimum dimension]. When coarse sand is used, the sand must be well graded from fine to coarse in accordance with ASTM C136/C136M with 100 percent passing the 2.36 mm No. 8 sieve.

b. Test sand, at no additional cost to the Government, as necessary to determine its acceptability. Sample all sand in accordance with the applicable sampling provisions contained in COE CRD-C 100, or as directed. Test the sand as follows:

(1) Table 1: Sand Properties

Property	Standard	Criteria
Specific Gravity	ASTM C128	[greater or equal to 2.55]
Absorption	ASTM C128	[less than or equal to 2.0]
Flat and Elongated	COE CRD-C 120	[less than 25 percent]
Clay Lumps and Friable Particles	ASTM C142/C142M	[less than 1 percent]
Organic Impurities	ASTM C40/C40M and if fails then ASTM C87/C87M	[3 maximum or minimum, 95 percent strength retention]

c. The percentage of surface moisture in terms of the saturated surface-dried sand must be in accordance with ASTM C70, ASTM C566, COE CRD-C 112 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. All sand must remain in free draining storage for at least 72 hours prior to use.

e. The GROUTING MATERIAL submittal must include the source(s) of sand and all required test results.

][2.2.5.3 Calcium Carbonate

****

NOTE: This specification allows for the calcium carbonate to have a maximum grain size, as determined by the Blaine fineness test. The designer should add a value. If there is no need for small grain sizes, such as when the calcium carbonate is used instead of sand, then the size requirement can be eliminated.

****

If used, Calcium Carbonate must be limestone or dolostone,[ground to a Blaine fineness of [_____] cm^2-per-gram][ground to the same Blaine fineness as the cement used]. Test lime in accordance with ASTM C1797.[Test Blaine fineness in accordance with ASTM C204.]

][2.2.6 Pigment

****

NOTE: Pigment can be used to differentiate between historic and current grouting or between different grout lines. Pigment will complicate wastewater treatment somewhat, so it should not be reflexively used, but the overall cost of pigment in grout is low. Fluorescent pigment/dyes may be useful in tracking surface communication during Grouting, especially where lighting is limited.

****

Pigment (also known as dye or colorant) must be in accordance with ASTM C979/C979M.

]2.2.7 Water

****

NOTE: The designer needs to determine if either potable or non-potable water is readily available. If neither is readily available, water will have to be trucked in at a considerable expense. This must be addressed in the "Description of Work" paragraph.

The specification allows for one of four conditions: 1) Potable water to be provided by the contractor, 2) Potable water on-site and provided by the government, 3) non-potable water is utilized for grouting, 4) no water is available onsite, 5) water will need to be trucked in. Choose the appropriate paragraph(s) and delete the non-applicable paragraphs.

In high sulfate environments, such as those found in foundations with gypsum and anhydrite deposits, high levels of sulfate can be found in potable water which may be deleterious to grout setting. In these instances, water testing of potable water supplies may be warranted.

****

[Water is not available on-site. Furnish[potable] water for grout including transportation of water to the site.][Commercial water trucking companies are present in [_____] county, bidders are encouraged to price the cost of the needed quantity of water prior to bidding. The closest potable water source is [_____] kilometers miles away at [_____]. The closest non-potable water source is [_____] kilometers miles away at [_____].][Potable water is furnished by the Government. Provide any necessary connections and extensions to the provided supply line.][Withdrawing water from the [lake][river] requires a permit from the [_____].]

****

NOTE: Typically, water only needs to be tested quarterly. However, if water quality varies significantly, then the frequency of water testing could be changed to account for these changes.

If desired, the designer can add the frequency at the beginning of the name, for instance "Quarterly" or "Monthly". If so, check and ensure all occurrences utilize the same name.

This paragraph could potentially be deleted if potable water is available and the Contractor will be forbidden from using non-potable water.

****

Potable water does not need to be tested. If non-potable water is utilized for the grouting, conduct testing [quarterly][_____] and submit mixing water test reports in accordance with ASTM C1602/C1602M and ASTM C1603, and then submit Mixing Water Test Reports to the Contracting Officer within 72 hours of ASTM test completion.

2.3 CEMENTITIOUS GROUT MIX DESIGN

2.3.1 Design Requirements for Grout Mixes

****

NOTE: This specification requires that all grout be batched and injected between 10-32 degrees C 50 and 90 degrees F. Storage of the grouting materials should be at temperatures above freezing.

Trial batches for USACE projects must be completed by a USACE validated laboratory.

If sanded grouts are not required, it is recommended to submit only 3-4 grout mixes. Contact grouting may require higher strengths based on strain compatibility and patching considerations for the concrete liner.

****

Provide the grout mix designs for the grout mixes on Tables 2 and 3 below, and all associated laboratory test results.[Include physical samples of the trial batches for the grout mixes.]

At least [30][60] days prior to production grouting, submit a minimum of [3][5] proposed grout mixes. Perform mix variation and characterization testing, conducted in advance of production grouting. For different types of mixers, slightly different formulations are required to obtain the desired theological characteristics. Consequently, adjustments to the base formulations are anticipated following the series of mix variation/characterization testing. The water-cement ratio must range between [2:1 and 0.6:1][_____]. During the performance of these mix tests, develop and deliver to the Contracting Officer the following test data for the proposed balanced-stabilized grout mixes, and for each of the subsequent mix variations developed:

Table 2: Foundation Grout Mix Consistent Requirements		
Test Type	Standard Reference	Test Requirement
Temperature	ASTM C1064/C1064M	10 - 32 degrees C 50-90 degrees F
Bleed	ASTM C940	less than [1][2] percent
Pressure Filtration Coefficient (kPf)	API Spec 13A, low-temperature / low-pressure for testing, and EM 1110-2-3506 for kPf calculation.	less than [0.05][0.10]
Time of Final Set	ASTM C191, method 'A'	Varies by mix from [14] to [24] hours
Sample Collection and Curing for Unconfined Compressive Strength Samples	ASTM C31/C31M	comply with specification procedures
Unconfined Compressive Strength	ASTM C109/C109M for grout cubes or ASTM D4832/D4832M for grout cylinders less than ~8400 kPa 1200 psi or ASTM C39/C39M for grout cylinders greater than ~ 8400 kPa 1200 psi	Minimum of [3400][1500] kPa [100][200][500] psi at 28 days. Requirement applies to average of [two][three] breaks for acceptance.

Table 3: Foundation Grout Mix Variable Requirements			
Mix Name	Grout Mix Viscosity Value	Method: Marsh or Flow Cone	Standard Reference
A	[<40 Seconds] Marsh	Marsh Funnel	ASTM D6910/D6910M
B	[40-55 Seconds] Marsh	Marsh Funnel	ASTM D6910/D6910M
C	[55-70 Seconds] Marsh	Marsh Funnel	ASTM D6910/D6910M

Table 3: Foundation Grout Mix Variable Requirements			
Mix Name	Grout Mix Viscosity Value	Method: Marsh or Flow Cone	Standard Reference
D	[Slower than Mix C, (> 70 seconds) with Marsh, and faster than mix E with Flow cone.]	[Marsh Funnel][Flow Cone]	ASTM D6910/D6910M [ASTM C939/C939M]
E	[Slower than Mix D measured by flow cone. 20-35 seconds]	Flow Cone	[ASTM C939/C939M]
F (sand mix)	[35-50 Seconds] Flow Cone	Flow Cone	[ASTM C939/C939M]
G (Sand Mix with Anti-Washout Admixture)	[35-50 Seconds] Flow Cone	Flow Cone	[ASTM C939/C939M]

2.3.2 Trial Batch Laboratory Testing

****

NOTE: USACE jobs require that all laboratory testing be done at a USACE-validated lab. Delete this requirement for non-USACE jobs.

Generally grout cubes are preferred to grout cylinders for samples with low unconfined compressive strength. If using the cylinders, the following considerations apply:

Grout cylinders with unconfined compressive strength less than 1,200 psi or 8400 MPA, must be tested in accordance with ASTM D4832/4832M.

Grout cylinders with unconfined compressive strength over 1,200 psi or 8400 MPA, must be tested in accordance with ASTM C39/C39M.

****

All labs must be in accordance with ASTM C1077 requirements.[Complete all laboratory testing using a USACE validated laboratory, in accordance with ER 1110-1-8100 for each test.] Collect grout strength samples and test them in the laboratory. Utilize [grout cubes][grout cylinders] for unconfined compressive strength testing. Do not change the approved sampling approach without the prior written approval of the Contracting Officer. Forward test results to the Contracting Officer within [48][72] hours of test completion.

For grout cubes, perform unconfined compressive strength testing in accordance with ASTM C109/C109M.[Test grout cylinders with unconfined

compressive strength less than ~8400 kPa 1200 psi in accordance with ASTM D4832/D4832M.][Test grout cylinders with unconfined compressive strength over ~8400 kPa 1200 psi in accordance with ASTM C39/C39M.]

2.3.3 Trial Batch Field Testing

a. Grout temperature must be between 10 and 32 degrees Celsius 50 and 90 degrees Fahrenheit at all times from the end of mixing to injection (measured at the header), in accordance with ASTM C1064/C1064M. Test trial batches for temperature at [5 and 30][10 and 60] minutes after mixing.

b. Measure specific gravity using a mud balance. Perform Specific Gravity tests in accordance with ASTM D4380 for each trial batch.

c. Measure viscosity using a Marsh funnel or Flow Cone as appropriate. Perform Marsh Funnel testing in accordance with ASTM D6910/D6910M. Conduct Flow Cone testing in accordance with ASTM C939/C939M. Viscosity requirements are shown in Table 3. Perform testing of each batch within [10][30] minutes of mixing for each trial batch.

d. Perform Bleed tests in accordance with ASTM C940. Grout bleed must not exceed [1][2] percent. Perform grout bleed tests for each trial batch.

e. Conduct pressure filtration testing per API Method API RP 13B-1, low-pressure/low-temperature, and then calculate the pressure filtration coefficient (Kpf). The API standard addresses the test method, then the calculation method for pressure filtration coefficient (Kpf) is defined in EM 1110-2-3506. The pressure filtration coefficient (Kpf) must not exceed [0.05][0.10]. Conduct testing for each trial batch.

****

NOTE: USACE's Engineering Manual EM 1110-2-3506 entitled "Grouting Technology", on section 7.7.i, on page 7-26 states: "A suite of mix designs for grouting fractured rock might have initial set times of 10–16 hrs and final set times of 12–20 hrs. The set time can be varied, depending on the purpose of the grouting program, by using admixtures such as retarders or accelerators." Also see the book "Dam Foundation Grouting" by Bruce and Weaver (2007), section 5.2.8, pages 162-163 for more details. The recommendations for set times in foundation grouting may be significantly different than shallow grouting to control water inflow into tunnels and shafts prior to lining. Coorelate with tables 2 and 3.

****

f. Final set must not exceed [14][18][_____] hours for the thickest mix, and [24][_____] hours for the thinnest mix per set time must be determined in accordance with ASTM C191, Method A. Measure initial set for information only, in accordance with ASTM C191, Method A. Perform setting time testing, obtaining both initial set and final set, on each mix type for each trial batch.

g. Perform Unconfined Compressive (UC) Strength sample collection and curing in accordance with ASTM C31/C31M. Test Grout strength samples

for each trial batch; [Cylinders][Cubes]. Perform unconfined compressive (UC) strength testing for all trial batches. Perform tests at intervals of[3,] 7,[14,] and 28 days, with three three samples for each time interval tested. In addition, test the 2+ standard concrete [cylinders][cubes] for UC Strength at 28 days.

[2.4 CHEMICAL GROUT MIX DESIGN

****

NOTE: Remove any sections that are not applicable to the scope to be executed.

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. Chemical grouting material requirements are best left as performance based and submitted by the contractor.

Polyurethane grout can be used for seepage control in boulders, cobbles,and open graded stone. These grouts can strengthen these soils.

Sodium silicates are only recommended for short term grouting applications and are subject to strength loss over time. These grouts should not be used for high flow conditions or cracks in concrete.

Note for viscosity requirements in Part g, below. These requirements are site specific and should be informed by a site investigation to fully capture the conditions anticipated on site. In general viscosity requirements should generally be:

Less than 2 cP for hydraulic conductivities less than 1E-4 cm/s 4E-5 in/s.

Between 2-5 cP for hydraulic conductivities between 1E-4 cm/s 4E-5 in/s and 1E-3 cm/s 4E-4 in/s.

Between 5-12 cP for for hydraulic conductivities between 1E-3 cm/s 4E-4 in/s and 1E-2 cm/s 4E-3 in/s.

****

Provide components that are compatible with each other and with the [rock][soil][concrete] and groundwater. Furnish nonflammable grouting materials and use either water-based (gel forming) or water-reactive (foam forming) grouts. Use only the following water-based chemical types: silicates, acrylates, polyacrylamides, acrylamides (only specified products), modified tannin, and epoxy resins. Use only the following water-reactive chemical types: polyurethanes and elastomers. Certify that the proposed grout is chemically stable and will not render surrounding groundwater unpotable. 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, 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. Include Material Safety

Data Sheets (MSDS) and any safe handling instructions as part of the mix design submittal. Provide chemical grout with the following properties:

a. Batch weight of each solid component and weight of water on a per [liter][cubic meter] [gallon][cubic yard] basis in accordance with ASTM C128.

b. Viscosity must be compatible with the material to be grouted. The materials to be be grouted consist of [strata of][Silt][Sand][Gravel][fractured bedrock][interbedded bedrock]. The anticipated hydraulic conductivity of the layer to be grouted is [_____].[The [residual permeability][outflow seepage volume] after grouting must be reduced to [_____].]

[
c. [7][28]-day unconfined compressive strength test with results exceeding [34][172][345] kPa [5][25][50][100] psi in accordance with ASTM D4219. For each trial batch, test at least [2][3] samples for each strength test to establish a working average.]

****

NOTE: Delete strength requirements if seepage control and permeability requirements are the intent the goal of the scope of work. For structural support, the strength should be equivalent to support a safe geometry for the excavated soil/rock. Strengths greater than 500 psi are likely not required. For contact grouting, consider using a strength that will be strain compatible to the liner and stratum the liner contacts.

****

d. Test results establishing the working time/gel time of the mix design at [5/30 minutes][30/50 minutes][in accordance with manufacturer's recommendations and field demonstrated].[Verify gel time in the field with "cup tilting test" where product is poured from one cup to another until it gels.] Cure time for all grouts must be [0.5-10] hours.

e. All solution grouts must be non-toxic and non-flammable during and after grouting and non-toxic in the set form.

f. Batch volume[[_____] liters gallons][[1][4][8][_____] cubic meter(s) yard(s)][submitted by the Contractor as part of the work plan].

[
g. Seepage Control Grouting.[For seepage control applications the grout must be less permeable than 1x10-6 cm/s 3.9x10-7 in/s.]

The volume change of the grout must not exceed [10][20][50][100] percent of the initial volume.]

[
h. Void Grouting.[If a polyurethane grout is used, the grout must have a specific gravity between 1 and 1.4.] The viscosity must be less than [40][100][500][1,000] cP.]

[i. Sodium Silicate Grouts (Chemical Grout for temporary strengthening and seepage control). The minimum sodium silicate concentration must be 40 percent of the mix by volume. The sodium silicate must be delivered in sealed containers or certified tank truck and must be accompanied by the supplier's certificate of origin. Sodium silicate

in non-gelled liquid form, while not considered toxic, is strongly alkaline and must be handled by authorized personnel only. Grout gel [and][or] grouted material must not exhibit objectionable odors such as ammonia. Sodium bicarbonate, sodium aluminate and other reactants that produce a temporary grout will not be allowed. The accelerator, if required, must be technical grade, water soluble calcium chloride or other approved metal salt and must contain a minimum amount of insoluble.]

][2.5 Core Boxes

****

NOTE: If coring is not required by this specification section, then this sub-section should be deleted. Note that there are measurement and payment paragraphs, as well as equipment and procedures in part 3, for coring, that need to be utilized if coring is required.

For USACE jobs, Engineering Regulation ER 1110-1901, page 6-7, requires the retention of all cores until release of claim on the construction job, unless borehole camera images exist, in which case only representative cores need to be retained. In addition, representative cores need to be retrained for 5 years after final project completion in case of unforeseen foundation conditions develop.

The designer will need to choose between wooden and corrugated plastic core boxes. The appropriate paragraph will be chosen and the non-chosen type paragraph deleted.

****

Box all rock core and concrete core drilled at the site. Make core boxes out of [wood][corrugated plastic]. Supply wooden core boxes built using plywood and dressed lumber, having longitudinal partitions, a hinged top, and spacer blocks.[Make Core boxes lockable.] Construct wooden core boxes using [screws][staples][nails].

[Supply Plastic Corrugated core boxes with longitudinal partitions, a removable lid, and spacer blocks.][Provide rubber bands to keep the lid on each box.]

]2.6 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 EQUIPMENT

****

NOTE: USACE Projects must comply with EM 385-1-1. Utilize that bracket for all USACE projects. Gas powered equipment must not be permitted without

approval of the local safety office. Equipment requirements must meet OSHA requirements.

****

Provide drilling and grouting equipment of a type, capacity, and mechanical condition suitable for the work, as approved by the Contracting Officer. The power, equipment, and the layout of activities must meet all applicable safety and other requirements of local, state, and federal laws and regulations.[Additionally, all work must be in accordance with EM 385-1-1.][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 to provide a safe working environment in compliance with[EM 385-1-1][and] OSHA requirements.]

3.1.1 Drilling Rigs and Equipment

****

NOTE: Most projects should require a drilling tolerance of 1-2 percent, depending on the method and difficulty of the working conditions. Stratigraphy layers should be defined in a GBR, or within this specification to properly inform the Contractor's means and methods. It is strongly recommended that tunneling projects follow the ASCE guidelines and recommendaitons for a Geotechnical Baseline Report and Geotechnical Data Report.

****

The drilling equipment must be proven capable of drilling a borehole at the required angle from vertical, to the required drill depth, and produce grout hole suitable for accepting grout. Furnish equipment with the capability to maintain an alignment within a tolerance of [1][2][4] percent or less of the depth drilled.[All drilling equipment used must be of a type, capacity, and mechanical condition sufficient to advance through the stratum indicated without delays, as submitted in the work plan approved by the Contracting Officer.] List equipment capabilities, including anticipated production rates based on the expected working conditions. Supplies must include all coring and non-coring bits, drill rods,[core barrels,] piping, pumps, tools, water, power, and other miscellaneous equipment required to complete the work without schedule delays. All drilling rigs and pumps must be equipped with[floating needle pressure gages].

****

NOTE: There is a wide range of equipment available that will be sufficient to advance holes for contact grouting. For concrete lines the holes can be cored or drilled. For steel liners the holes should be pre-fabricated or drilled.

****

[Contact Grouting Drilling: For drilling tunnel contact grout drill holes, the use of handheld equipment or jacklegs is permitted and must consist of drill or core type bits of sufficient diameter to facilitate grouting.]

****

NOTE: Add or remove the following sections as applicable to your project.

Air is compressible and can damage foundations through hydrofracture and/or jacking. In addition, air can clog fractures with moist cuttings. Air should be avoided where there is concern about nearby structures or overburden. Regardless of structure type, sensitive structures should consider adherence to USACE's Engineering Regulation ER 1110-1-1807.

****

[[The use of air as circulating medium is prohibited.][All drilling equipment must be in accordance with ER 1110-1-1807.]]

[
Drilling equipment that adversely impacts the installation of rock reinforcement elements is not permitted.]

[
The use of hand-held equipment, such as jackhammer percussion-type drills, is not permitted for drilling holes above the horizontal.]

3.1.1.1 Drilling Equipment

****

NOTE: Please note that no sample or core is required for rock drilling equipment. Destructive drilling is cheaper than core drilling and is recommended for heavy production work. Choose the brackets that best describe the work to be performed with your project. Combinations of brackets can be tailored into the specification, but authors should be cautious to ensure consistency throughout the spec.

****

Grout hole drilling for [production holes][drain holes][exploratory holes][verification holes] must be advanced in rock with [water-actuated down-the-hole hammers][top-hole hammers][standard rotary drills]. Submit the proposed drilling equipment to include: 1) manufacturer and model number of the drill rig, 2) the manufacturer, model, designation, and diameter[s] of the drill rods, and 3) the bit type, bit manufacturer, bit model, and diameter proposed to complete the work. Use [water][air] for removing cuttings from the hole during drilling operations.[Do not use air drilling if near a [dam][levee].]

[3.1.1.2 Coring Equipment

****

NOTE: Rock Coring is not strictly necessary for grouting jobs, unless core samples are required. Samples obtained from coring should be considered for all exploratory and verification holes. If the grouting series requires split spacing through succeeding series of advanced holes (Primary, Secondary, Tertiary), consider the benefit vs costs for coring primary holes. It is cheaper to drill a destructive hole. Typically for tunnels the core size/diameter is NQ or smaller. Choose either double-tube or triple tube: 1) for rock that is

partially or all soft, a triple-tube coring system is recommended; 2) for hard rock, a double-tube coring system may suffice. The triple tube system has a second inner barrel that is split, allowing the core not be disturbed during removal. Spilt barrel may be considered for the double-tube to improve recovery of material that may be substandard. See EM 1110-1-1804, or other standards, on geotechnical investigations for more information on rock coring equipment and uses.

Consider requiring a wire line system for downward inclined holes that are 7.5 meters 25 feet or greater in depth.

Coring bits for exploratory holes and drain holes should be NW or NQ sized. PQ and HQ may have situational benefits on certain projects. Capabilities vary by Contractor. Allow reasonable variations to be submitted and approved in the work plan.

****

[Coring is required for [exploratory holes][verification holes][primary holes][as indicated in the Contract drawings][as proposed in the work plan].]Standard [triple-tube][double-tube] coring equipment must be utilized for coring rock[concrete]. Coring bits must be [NQ][PQ][HQ] sized. The core barrel must be of a length, generally[1.5 or 3 meters 5 or 10 feet for tunnels,] appropriate for the working space and the type of material being drilled. Rock coring must be performed using fresh water as the drilling fluid, with no air utilized. Submit the proposed drilling equipment to include: 1) manufacturer and model number of the drill rig, 2) the manufacturer, model, designation, and diameter[s] of the drill rods, and 3) the coring bit type, bit manufacturer, bit model, and diameter proposed to complete the work.

[Utilize coring equipment for drilling reinforced concrete, unless written proof of the successful use of non-coring equipment for drilling through reinforced concrete can be submitted and is approved. Either coring bits, or full face diamond-coring bits are acceptable.][Do not use air drilling if near a [dam][levee].]

][3.1.2 Hole Washing Equipment

****

NOTE: The hole should be washed immediately before grouting. If grouting proceeds immediately after drilling, washing may be conducted with the drilling equipment. This washing cost should be incidental to drilling, and not separate payment made for washing. A separate dedicated hole washing piece of equipment is required when clay infilling and other material is present in the borehole with the potential to reduce the effectiveness of grouting. This may require additional payment. Choose the appropriate requirements for washing and coordinate with the measurement and payment sections. It may be prudent to require washing via both methods.

****

[Wash holes with the approved drilling equipment until the return fluid runs clear prior to moving off the hole. This hole washing is incidental to the cost of drilling.]Water pressures used in the hole must be [less than the maximum grouting pressure][less than 90 percent of the hydrofracture pressure][as submitted in the Contractor's Work Plan].

Immediately prior to grouting, provide a separate piece of equipment that is used for washing the grout hole. The equipment must be capable of spraying the hole in 360-degrees through [spiral] holes that are required to emit a pressure [less than the maximum grouting pressure] [less than 90 percent of the hydrofracture pressure] [as directed.] [The tooling must contain centralizers to keep it in the center of the hole.] The equipment is required to measure the depth washed from the surface of the hole. In the submittal, include photos of the hole washing equipment, manufacturer cut sheets if applicable, or design details if custom made, and any output pressures, pressure monitoring, and pressure control devices.

]3.1.3 Cement Grouting Equipment

****
NOTE: Recommendations for a typical grout job include: Minimum capacity of 15 gpm/57 lpm, max pressure 200 psi/1400 kPa per active hole, and the number of simultaneous holes will vary by the job from one to as many as needed.
****

Submit a plan of the proposed grouting equipment types and layout for approval. Furnish grout plant capable of supplying, mixing, stirring, and pumping the grout as specified and approved in the work plan. The capacity must be sufficient to support all proposed concurrent hold grouting operations. Maintain equipment in first-class operating condition at all times. 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 equipment that meets the requirements for the following sections:

3.1.3.1 Grout Mixer

****
NOTE: Colloidal mixers are vastly superior to paddle mixers for mixing grout. Colloidal mixers have been around for nearly a century (in 2023). The use of paddle mixers for mixing balanced and stable grout should not be approved for use. Most equipment is designed based on metric units. Select a mixer with a minimum 250 L capacity for most small jobs where concurrent grouting operations are not occuring.

Consultants and Contractors have both expressed concerns with specifications requiring mixer capacities that end up directing means and methods. It is recommended to select the lowest minimum capacity and to allow the Contractor to propose larger sizes if needed, based on proposed means and methods.
****

Grout mixers must be high-speed colloidal mixers or high-speed mechanically driven shear-type tub mixers having a vertical or horizontal drum. Provide mixers that are capable of effectively mixing grout at a capacity of at least 250 [500] [750] liters 65 [130] [200] gallons of grout per batch. The grout mixers must be equipped with a tangential return line and capable of effectively mixing the full suite of grout mixes at the w/c ratio established in the mix design. The mixing time must be a minimum of [45] seconds to a maximum of [90] seconds, or as submitted and approved in the work plan. Equip the mixer with a suitable volume-measuring water metering device that measures water for batching. Utilize either 1) A water meter graduated in cubic meters feet and tenths having a direct reading totalizer, and capable of being conveniently set back to zero or 2) A water scale measuring in kilograms pounds with tenths and hundredths.

[If using bentonite, a separate colloidal mixer for mixing and hydrating bentonite is required. Pre-hydrate bentonite prior to mixing.]

3.1.3.2 Grout Pump

****

NOTE: For tunnels or shafts near dams or levees, piston pumps should generally not be permitted due to risks for hydrofracture and foundation damage. Progressive cavity pumps provide a constant output pressure. They are considered superior to piston pumps, which have variable output pressures. Pumps are addressed in USACE's Engineering Manual EM 1110-2-3506 entitled "Grouting Technology" in section 10-5, on pages 10-7 to 10-8, and in the book "Dam Foundation Grouting" by Bruce and Weaver (2007) in section 9.3 on pages 274-276. The use of piston pumps are predominately excluded from this specification. There may be circumstances where piston pumps are needed or preferred by the Contractor, such as when grouting at high pressures in tight formations. Piston pumps may also be advantageous for pumping sanded grout mixes.

NOTE: Keep in mind that injection pressures and pump pressures are two different requirements. The maximum pressure used for the pump must overcome line losses and be sufficient to push the grout to the point of injection. The capacity of the pump should be sized to match the batching volume, including the volume of material required to charge the grouting lines. Ensure an adequate batch volume is available. If in doubt, leave these as performance requirements and revise this section to be as submitted by the Contractor in the Work Plan.

****

Provide an air or electric powered progressive cavity pump free of surging. Provide a pump capable of providing [40] [55] [75] [_____] liters per minute[10] [15] [20] [_____] gallons per minute (cfm) at a maximum pressure of [690] [1380] [_____] kPa [100] [200] [_____] pounds per square inch (psi) for each production hole, or as submitted in the work plan. Keep a minimum of one spare grout pump and spare pump parts available on site during all grouting operations. The distance from the grout pump to

the grout header must never exceed the capabilities of the equipment to deliver grout to the hole. [Do not exceed [200] [_____] meters[500] [_____] feet of grout line from the header of a hole being grouted without adding an intermediate holding tank and grout pump.] Alternate configurations and distances may be submitted for consideration but are subject to approval by the Contracting Officer.

3.1.3.3 Holding Tank and Sump

****
NOTE: After the grout is mixed in the colloidal mixer, it is transferred to the distribution tank. This tank contains paddle agitators and is connected to the pump for distribution out the grout header. Grout that is not injected into the hole is returned to the distribution tank in the grout 'loop'.
****

Holding tank(s), sump(s), and grout distribution tanks of the mechanically agitated type are required to provide a high volume and continuous injection of grout. Grout distribution tanks must have paddles capable of rotating at a minimum of 100 rpm, and be properly baffled to prevent vortex formation. Each tank is required to be equipped with two 0.45mm No. 16 screens such that all grout arriving from the mixer and returning from the grout hole return line is screened. The sump must be capable of holding the solids of the mix in suspension and have a capacity three times the capacity of the mixing system. Utilize a water storage tank or suitable source of clean auxiliary water for use in washing, [water pressure testing] and flushing operations.

[Separate tanks are required for hydrating bentonite and storing hydrated bentonite, if bentonite is utilized. The tanks should be fitted with agitators to prevent settlement or separation.]

3.1.3.4 Supply and Pressure Control

****
NOTE: For low flow rates, the inner diameter of the hoses will need to be reduced. Double line systems are the general requirement. If piston pumps are proposed by the Contractor, a return circuit is not required and the bracketed version of paragraph 1 will apply. Unless specifically requiring piston pumps, delete the brackets in paragraph 1.
****

Valves, pressure gauges, grout lines, header arrangements, and accessories are required as necessary to provide a continuous supply of grout and accurate pressure control. 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. Convey grout between the pump and the hole using a 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, or as submitted by the Contractor. 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.[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 as submitted by the Contractor. 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.]

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. The gauge accuracy must be to within [2] percent for the range of the gauge. An accurately NIST-calibrated, high precision pressure gage is required for use to check the accuracy of all gages used in the grouting.[Test gauges for accuracy [daily] during the work by cross comparison with a standard set of oil-filled gauges.] When defects are found, grouting operations must be stopped until calibration of gages has been obtained. Protect the moving parts of all gauges from dust, grit, and direct contact with grout. Maintain a ready supply of pneumatic packers and other accessories for [water pressure testing and] grouting. Provide a sufficient supply of mechanical packers for the purpose of preventing debris from entering or grout escaping the grout holes, stop grout or water from flowing between holes that are hydraulically connected.

3.1.3.5 Grout Header(s)

Each grout header must have two valves that control flow both 1) down the hole, and 2) back to the grout plant. These valves must be capable of being controlled by hand. Each grout header must have a sufficient length of hose to reach the bottom of the deepest hole in the work area. The hose must be marked minimally every 1-meter (with no English markings) 5-feet, in feet (with no metric markings). Each hose must be supplied with and be capable of rapidly attaching either a single-packer or double-packer. Each grout header must be fitted with a pressure transducer, and a flow meter, each having a readout that is visible at the header itself. Each grout header is required to have a visible air pressure gauge for inflation of the packer(s). Each grout header must be capable of having a reference pressure gauge and reference flow meter attached to it for calibration. Grout headers must be capable of using all mixes submitted; if thick mixes require larger diameter hoses and a separate grout cart, then provide it for that setup at no additional cost to the Government.

[3.1.3.6 Instrumented Packer Equipment

****
NOTE: The 2 percent accuracy listed below may not be appropriate for all situations, especially where pressures are relatively low (2 percent of 10 psi is 0.2 psi). For lower-risk or low-pressure situations, it may make sense to decrease the accuracy requirement (to 6 percent).
****

Procure an instrumented packer system. The Instrumented packer must measure the fluid pressure below the packer seal, or between the packers for a double-packer assembly. Packer diameters must be compatible with borehole diameters drilled. Use pressure transducers with a pressure range appropriate for the pressures encountered, accurate to ± 2 percent. The sensor must work in temperatures between 1 to 32 degrees degree Celsius 33 to 90 degrees Fahrenheit.

Procure a length of casing for calibration ("Calibration Casing"), with an external and replaceable pressure gauge that senses the inside of the casing. This external pressure gauge must allow comparison with the instrumented packer pressure gauge. The calibration casing external gauge is required be a test gauge accurate to ±0.25 percent full scale or better with NIST certificate and a sensitivity, range, and scale appropriate for anticipated pressure for respective operations. The calibration casing and pressure gauge location must be compatible for either single or double packer assemblies and the calibration casing must have a minimum burst strength of 5500 kPa 800 psi. The Contractor is required to procure sufficient extra packers, pressure sensors, accessories, and spare parts as not to cause delays. The system must include the wiring, wireless-or-wired transmitter and receiver, processor/computer, and display monitor necessary to show the data in real-time and record the data for record. The Contractor must include a plan for sensor calibration. Perform calibration weekly, or more frequently when anomalous readings are observed.

Conduct operator's checks on equipment at the beginning of each shift of operation to verify gauges are reading zero during no pressure and no flow conditions. Conduct a check of manually measured flow and pressure versus equipment readout daily or at any time as directed by the Contracting Officer. The mid-range of the gauges used for testing should be close to the anticipated gauge pressures for this work. Record these checks in QC documentation.

****
NOTE: Use of an instrumented packer will normally also require the incorporation of an Automated Grouting Data Collection System (AGDCS). The use of instrumented packers and AGDCS systems are limited to the most complex jobs of a highly sensitive nature.
****

The systems must include all items required for monitoring and data collection during production pressure grouting. The Contractor is required to devise a system such that the down hole sensor is readable in-real-time within the AGDCS.

][3.1.4 Chemical Grouting Equipment

****
NOTE: Delete the following section if chemical grouts are not required.
****

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 accordance with the submitted work plan. Submit a plan of the proposed chemical grouting equipment types and layout for approval. Furnish a grout plant capable of supplying, mixing, stirring, and pumping the grout as specified and approved in the work plan. Maintain equipment in first-class operating condition at all times. 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 equipment that meets the requirements for the following sections:

a. Provide chemical grouting equipment having the capacity and mechanical

capability to do the specified work while remaining compatible with the chemical to be handled. The Contractor is responsible for all necessary equipment, packers, lines, headers and materials, including but not limited to; electric generators, compressors, heaters, hoses, containers, valves, clamps, connections, and gauges to safely and efficiently conduct and control the work [and minimize the impact to the existing structure]. Maintain equipment in functioning operating conditions at all times. Monitor and record constituent components and final mix volumes and pressures. Injection pumps must meet the grout manufacturer's recommendations per the selected grouting products. [Alternative equipment and methods are permitted to be submitted as part of the work plan, subject to approval by the Contracting Officer.]

****
NOTE: The capacity of the grout plant and pump required will vary by application.
****

b. Chemical Grout Plant - The grout plant must be a continuous mixing type capable of proportioning and mixing to provide a continuous supply of pumped grout with a gel time established in paragraph "CHEMICAL GROUT MIX DESIGN". Batch-type systems are not permitted. Equip main pumps with positive displacement meters, capable of recording data, constructed of materials that are non-corrodible for the intended products and that operate independently of the viscosity of the fluid. Provide a pumping unit with the capability to vary the rate of pumping while maintaining the component ratios constant.

c. Pumping Unit - Equip with piping [and][or] hoses of adequate capacity to carry the base grout and reactant solutions separately from the point of mixing or batching to the point of placement.[Provide a pump capable of providing [40][55][75][_____] liters per minute [10][15][20] [_____] gallons per minute (cfm) at a pressure not greater than [690] [1380][_____] kPa [100][200][_____] pounds per square inch (psi) for each production hole.] The pumping unit must be capable of varying the flowrate without changing the mixture proportions of the materials. The hoses must contain check valves to prevent backflow. Provide a sampling valve beyond the point of mixing and the baffling chamber, easily accessible for sampling mixed grout. Distribute proportioned grout under pressure, to the grouting locations monitored by separate, automatic real-time display, flow rate indicators and gauges. Place a water flushing connection or valve in the line to facilitate flushing the grout between grouting sessions.
****
NOTE: Keep in mind that injection pressures and pump pressures are two different requirements. The maximum pressure used for the pump must overcome line losses and be sufficient to push the grout to the point of injection. The capacity of the pump should be sized to match the batching volume, including the volume of material required to charge the grouting lines. Ensure an adequate batch volume is available. If in doubt, leave these as performance requirements and revise this section to be as submitted by the Contractor in the Work Plan.
****

d. Recording Instruments - Each main pump must be equipped with recording instruments and gauges to document continuous pressure, flow, and injection rate. 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. The gauge accuracy must be to within [2 percent] for the range of the gauge. An accurately NIST-calibrated, high precision pressure gage is required for use to check the accuracy of all gages used in the grouting. Test gauges for accuracy [daily] during the work by cross comparison with a standard set of oil-filled gauges. Pressure gauges must be supplied by the Contractor at the pump and at the grout pipe head. Grout injection is not permitted without fully operational recording instrumentation and gauges in place. When defects are found, grouting operations must be stopped until calibration of gages has been obtained. Protect the moving parts of all gauges from dust, grit, and direct contact with grout.

e. Provide, at the site, the required quality control testing apparatus including hydrometers, balance scales, graduates, viscometers, and other devices required to conduct acceptance tests, proportioning tests, and grout quality tests.

f. Provide redundant equipment to include but not be limited to hoses, headers, fittings, pumps, gauges, sensors, and instrumentation systems to ensure work can commence without interruption.

g. Any grout hole that is lost or damaged due to mechanical failure of grouting equipment or inadequacy of grout supply must be replaced by another hole, provided and installed by the Contractor at no cost to the Government.

][3.1.5 Automated Grouting Data Collection System (AGDCS)

****
NOTE: It may not be practical to use AGDCS for small projects, contact grouting, or other applications where there is little benefit for the additional costs or data generated.
****

Provide, set up, maintain, and operate the AGDCS. Utilize the system during all grouting operations for grouting holes in rock, verification holes, [contact grouting] and backfilling of holes. Provide the Government unlimited access to the system for monitoring purposes. Include in the AGDCS all necessary equipment, materials, computer hardware, and software to direct grouting operations in accordance with these specifications and collect and display digital data in real-time. Ensure the system is capable of producing data in hard copy and digital formats.

Include the following information about the automated grouting data collection program in the submittal:

a. System name and manufacturer.

b. The calculations for producing total and effective pressure.

c. Describe the process for data input to the system.

d. Describe the process for data storage for all generated data,

including but not limited to grouting, testing, or other required processes.

e. Describe the data visualization (e.g., GIS mapping, CAD profiles, and plots) methodology, including any data transformations.

f. Describe methodology used for export of data to [Excel Spreadsheets][Enterprise Database].

g. Capability to backup data to ensure no data loss occurs.

h. Screenshots of raw data format and typical plots.

i. Example normal water-pressure-testing log.

k. Example grout log with a change in mix type.

3.1.5.1 AGDCS Equipment Capabilities

The AGDCS must have the following capabilities:

[a. Monitor and record all water pressure testing including but not limited to pressures, flow rates, and Lugeon values.]

b. Monitor and record all grouting including but not limited to mix type, [line losses], hold/target pressure, gage pressure, total volume, flow rates, and apparent lugeon values at the midpoint of each stage.

c.Calculated maximum total pressures from the specified pressure criteria

****

NOTE: Please ensure that only one of the two (1 of 2) choices for paragraph "d" (below) are picked, depending upon whether the designer is specifying instrumented packers or not. The second choice of 'd' is for use with instrumented packers.

****

[d. Downhole effective grouting pressure must be calculated based on pressures measured at the grout header, considering in-situ water pressure, weight of grout column, and estimated head losses.

][d. Measure effective pressure in the ground with an instrumented packer. Calculate effective grouting pressure based on 1) pressures readings in the grouting zone, from the instrumented packer, minus 2) the pressure provided by the local water table.

]

e. The automated system must have the ability to continuously monitor the grouting operation without interference or interruption to the grout injection process while grouting a stage when a mix change is warranted.

f. List of cumulative drilling and grouting issues including lost tooling, hole communications, rod drops, fluid loss, leaking packer, and others as directed by the Contracting Officer.

g. Correct and reduce the collected data to account for correction

factors and field parameters (pressure head losses, pressure measurements, actual depth of the stage being grouted, groundwater influence, mix batching/cycling).

h. Export raw data files into a non-proprietary file format and produce tabular digital records as specified in section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION, paragraph "DATA REQUIREMENTS".

i. Capable of producing graphs in Microsoft Excel format. Other formats must be proposed and approved within this submittal.

j. Graphically display in real-time, the following at a minimum:

1) Total volume of grout [or water] placed in the stage;

2) Gauge pressure, holding pressure, [total pressure,] and [effective pressures,] [and measured total pressure from the instrumented packer,] at active zone being grouted.

3) Start and stop times of grout injection;

4) A continuous dotted line showing the holding pressure;

5) Rate of injection (volume per time);

6) Apparent Lugeon value;

7) The time, type and volume of a particular grout mix for the full duration of the grouting;

8) Plots for Time History of flow, pressure, Apparent Lugeon.

9) The entire grouting record for the stage versus time;

10) Do not distort the time axis on real-time plots

]3.2 HOLE SEQUENCES

****

NOTE: Tailor the following sections to clarify prescribed hole sequences. Engineering and geologic judgment is required to establish the designed spacing between grout holes, which partially depends upon the discontinuity spacing. It is recommended to sequence the grouting procedures in the order you intend for work to progress during production. Include sequences for grouting multiple stages, verification holes, and exploratory holes as required to complete the scope.

If grouting for seepage or structural stability, split spacing may be required. There should also be thought given to the desired primary hole spacing. Permeable horizontal discontinuities usually provide the means for hole-to-hole hydraulic connections. In general, two adjacent primary holes should not be drilled and grouted concurrently. All grout should be set before drilling the adjacent hole.

For typical grouting, most holes will be upstage grouted unless caving holes, fluid loss, or other geologic conditions necessitate the need for downstage grouting. Clarify what conditions may necessitate downstage grouting. Conditions with a high likelihood of encountering these conditions should clarify or prescribe when downstage grouting is required.

****

The drilling and grouting sequence for tunnel and shaft grouting must be submitted and approved in the work plan. All planned holes, including verification holes, are required to be executed by upstage grouting, see paragraph "UPSTAGE GROUTING SEQUENCE". Any rock drilling/coring [and water pressure testing] must not occur adjacent to any hole where grouting is ongoing until after grout stage has reached the final set time [after the grout stage has set for a period of 24 hours.] The maximum [water pressure testing and] grout stage length is [1.5][3][6][10] meters [5][10][20][30] feet.

[Drilling and grouting sequences for tunnel liner grouting must be submitted in the work plan. The approach must ensure 100 percent coverage around the liner, and provide a means for verification.]

3.2.1 Upstage Grouting Sequence

Upstage grouting is a method whereby each hole is drilled to a final depth in one step, and then grouted by stages through an expansion plug or packer which is set at successively shallower depths, starting at the bottom and working inward. It involves the placement of grout by drilling and grouting per the following general procedure:

a. Drill hole to the full depth and wash as specified in paragraph "DRILLING PROCEDURES".

b. As directed, the drill holes must be washed [and water pressure tested] as specified in paragraphs "GROUT HOLE WASHING PROCEDURES"[and "WATER PRESSURE TESTING PROCEDURES"].

c. The packer must be placed in the hole at the top of the interval to be grouted, blocked off the outer portion of the hole, and grouted.

d. After placing the grout at the pressure and mix required, the expansion plug, or packer, must be left in place until the grout pressure drops for the next higher stop, or as directed by the Contracting Officer. The packer must then be moved to the next higher stop and grout placed as required. The procedure is repeated until the hole is completed.

****

NOTE: Delete Section e if split-spacing is not required.

****

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

directed.]

[3.2.2 Downstage Grouting Sequence

****
NOTE: Delete this section is not required.
****

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

a. The drilled holes must be washed [, water pressure tested as required,] and then grouted.

b. After the grouting of any hole, the grout within the hole must be allowed to set and subsequently the holes must be re-drilled.

c. The hole is then regrouted via upstage grouting.

d. The primary holes can then be drilled, washed, [pressure tested,] and grouted in stages until the hole is completed.

]3.3 DRILLING PROCEDURES

****
Select the brackets that appropriately define the work to be completed. Delete other brackets if not needed. Contact grouting for liners may have special provisions that must be coordinated with other elements of the specification.

Drilling and grouting in rock in contact with overburden soil must be completed in accordance with specification 31 33 10 Foundation Grouting in Rock.
****

Locate holes to be placed [through shotcrete][through the concrete/steel liner] into the surrounding rock in accordance with the geometries [shown in the Contract drawings][as approved in the work plan]. For liners, [form holes by embedding pipe in the concrete or shotcrete during placement][drill holes through concrete, shotcrete or rock after placement]. Drill all grout, drainage, and exploratory holes per the requirements of paragraph "EQUIPMENT".

[3.3.1 Exploratory Hole Drilling

****
Stages for grouting are limited by the diameter of the tunnel or opening you are working in. It is recommended for the minimum stage length be set to 5 feet. Exploratory holes should either be cored or drilled and water pressure tested. Delete paragraph 2 if coring is not required.
****

Complete exploratory holes as required to determine the existing conditions and properties within the bedrock. This includes borehole logging, [water
pressure testing] and classifying the [RQD][RMR]of the bedrock prior to

drilling and grouting. Exploratory drilling is required at any inclination [in advance of the excavation face] [along the perimeter of the tunnel or shaft]. The depth and number of exploratory drill holes [are indicated on the plans][as approved in the work plan] [must not exceed a maximum of [15][_____] m [50][_____] feet].

[

Exploratory holes must be cored with tooling as required in paragraph "CORING EQUIPMENT". Perform core drilling by competent and experienced drillers meeting the requirements from paragraph "QUALIFICATIONS". Take special care to obtain cores in as good condition as possible. Core logging must be performed by Contractor in the presence of the Government. Suitable wooden core boxes must be furnished by the Contractor for core storage in an approved location on site. The core boxes must have the project name, Contract number, project location, hole ID, alignment station, and offset [coordinates], and drilling information to include drill footages, voids, RQD. 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. Protect core boxes from the weather upon completion of an exploratory hole. Transport core boxes to the storage area upon completion of each drill hole.]

][3.3.2 Embedded Pipe

Provide all metal pipe and fittings required for constructing grout holes, grout hole connections, and air vents. Cut, thread, fabricate, and install all pipe required for the work as required. Thoroughly clean dirt, grease, grout, and mortar from pipe sections and fittings immediately before embedment into concrete. Firmly hold the pipe in position and protect the pipe from damage or displacement while the concrete is being placed. Take care to avoid premature clogging of pipes and clean out any pipe that becomes clogged or obstructed before completion of operations. Replacement of clogged pipes is incidental to completion of the work.

]3.3.3 Grout and Vent Hole Drilling

****

Tailor the following section based on the scope of work for your project. Clarify if the project drawings specify inclination, hole spacing and depth, or if the contractor is required to submit this information in the work plan, or if the Government will direct the operation. Include the last bracketed sentence for grouting programs that intend to split-space grout holes.

****

Grout and drain holes must be advanced as required in paragraph "DRILLING EQUIPMENT". All holes for grouting and drain holes must be drilled at the orientations and inclinations [as indicated on the Contract drawings][as submitted and approved in the work plan][as assigned in the field by the Contracting Officer]. Locate grout and vent holes [on the liner][on the exposed rock surface][on shotcrete][prior to drilling]. Drill grout holes through [shotcrete][concrete/steel liner][rock] 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 within a tolerance of 6 mm 0.25 inch and at least 35 mm 1-3/8 inch in diameter at the point of the drilled hole. Alternative hole diameters, pipe sizes, and tolerances may be submitted by

the Contractor in the work plan. Check the size of completed grout holes frequently during the work to assure proper hole diameters are achieved. Advance drilled holes to the required stage to facilitate grouting. It is anticipated that the required total depth for any [ring][tunnel][shaft] grout hole will not exceed [15][_____] m [50][_____] feet.[Hole spacing for succeeding series holes must be submitted as part of the work plan for approval.]

Protect each hole drilled from becoming clogged or obstructed by means of a cap or other suitable device on the collar. The use of grease, "rod dope," or other lubricants on the drill rods or in the grout holes is not permitted. 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.

[3.3.4 Contact Grout Drilling

Contact grouting is performed through an array of holes at the crown and at positions located 30-degrees above springline of the tunnel or as submitted and approved in the work plan. Space rows of holes one tunnel diameter apart along the tunnel alignment. Field adjust hole spacing based upon encountered rock/soil conditions. Holes are drilled [cored] a minimum of [7][15] centimeters [3][6][_____] inches into native material. Measure and record any void space between the tunnel liner and the excavation, and wash the holes with water until the return is clear. If no water returns, wash for 5 minutes. In either instance, observe and record water flow from adjacent holes during washing and grouting.

][3.3.5 Drain Hole Drilling

****
Tailor the following section based on the scope of work for your project. Clarify if drain holes are shown on the plans, submitted by the Contractor as part of the work plan, or field located based on encountered conditions.
****

Locate drainage holes as indicated on the contract drawings [as submitted in the work plan][as directed by the Contracting Officer]. Drill through the permanent liner after all grout holes within [60][_____] m [200][_____] feet have been completed. Drain hole diameters must be at least [50][_____] mm [2][_____] inches with a tolerance of 6 mm 0.25 inch for the full length.

]3.3.6 Verification Hole Drilling

****
Verification holes should either be cored or drilled and water pressure tested. Delete paragraph 2 if coring is not required.
****

Perform verification hole drilling as required to assess the effectiveness of the post grouting operations via [_____] holes assigned by the Contracting Officer. Verification hole drilling may be required at any inclination along the perimeter of the tunnel or shaft. The depth of verification holes must not exceed the depth of production holes.

Verification holes must be washed [and water pressure tested] in accordance with GROUT HOLE WASHING PROCEDURES [and WATER PRESSURE TESTING PROCEDURES].

[Verification holes must be cored with tooling as required in paragraph "CORING EQUIPMENT". Perform core drilling by competent and experienced drillers meeting the requirements from paragraph "QUALIFICATIONS". Take care to obtain cores in good condition. Core logging must be performed by Contractor in the presence of the Government. Suitable wooden core boxes must be furnished by the Contractor for core storage in an approved location on site. The core boxes must have the project name, Contract number, project location, hole ID, alignment station, and offset [coordinates], and drilling information to include drill footages, voids, RQD. 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. Protect core boxes from the weather upon completion of an exploratory hole. Transport core boxes to the storage area upon completion of each drill hole.]

3.3.7 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 in accordance with paragraph DISPOSAL OF DRILL CUTTINGS, WASTE WATER, AND WASTE GROUT.

3.4 GROUT HOLE WASHING PROCEDURES

****

NOTE: Pressure washing of boreholes has created controversy for a long period of time. It has previously been included as a) both incidental to drilling and b) a separate cost item.

The two (2) ways to wash holes are 1) cleaning hole with extra water pumped through the drill rods, and 2) using a separate tool as a separate step. An effective separate washing tool produces jets of water in a 360-degree spiral pattern at moderate pressure and is raised or lowered (or both) though the hole at a moderate speed.

While pumping water through the drill rods (e.g., flushing the hole) can be made incidental to drilling, separate hole washing should be a separate line item or incidental to water pressure testing.

Select the appropriate brackets based on your scope of work and anticipated geologic conditions. Hole washing using the drill tooling and separate equipment may also be selected.

Hole washing is not necessary for contact grouting and this paragraph should be deleted for jobs that only consist of contact grouting."

****

Wash the hole thoroughly with clean water under pressure after completion of drilling and before the injection of grout for any hole drilled.[Wash the hole with separate hole washing equipment fitted with brushes immediately before grout injection.] All hole washing must be completed for [10][15] minutes until the return water runs clear. The maximum pressure at which air and water are introduced for hole washing must be less than the pressures required to complete grouting operations. The hole washing must be documented with a washing log. See the paragraph HOLE WASHING LOG for details.[Do not wash contact grout holes.]

[3.5 WATER PRESSURE TESTING PROCEDURES

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Note: Water pressure testing should generally not exceed the target grouting pressure, adjusted for Lugeons vs Apparent Lugeons.

Water pressure testing is also required in exploratory/verification holes for the purpose of either assessing the grout take potential or the imperviousness of a grouted area.

At the end of paragraph 1, utilize the requirements for electronic and paper copies of records if the AGDCS is not used. If the AGDCS is used delete the brackets and add that AGDCS requirements.

****

Provide the necessary fittings, a gauge for measuring hydraulic water pressure up to [690][_____][1380]kPa [100][200][_____] psi and a meter large enough to measure flows required in accordance with paragraph ["CEMENT GROUTING EQUIPMENT"]["CHEMICAL GROUTING EQUIPMENT"]. After the waterline or header has been secured to the collar of the hole, pump water into the system. Test drill holes as directed with clean water and maintain the pressure by control of a bypass valve. Test grout holes until the stage has reached holding pressure and the rate of take and permeability has stabilized for at least two minutes. Do not exceed the holding pressure, as required in paragraph TARGET HOLD GROUTING PRESSURE. If no flow occurs, shut in the pressure and hold for 5 minutes and record any 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. Measure all pressures by a pressure transducer and gage and readout at both the top of the hole. Generally, water pressure testing must be conducted at the same intervals as stage grouting. The Contractor must compute the lugeon values for each test. The plots in electronic and paper copies must be furnished along with the water pressure testing data. In addition, the summary data from the water pressure test must be recorded in the "Database of Water Pressure Testing and Pressure Grouting Results". [The Automated Grouting Data Collection System must be used to collect and record data, and calculate and display the 1) gauge pressure, 2) target vs actual effective pressure, 3) flow, and 4) the Lugeon value in real time during testing.]

After completion of water pressure testing the holes must be temporarily capped and sealed to prevent material or debris from entering the holes prior to grouting. 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.

]3.6 GROUTING PROCEDURES

Perform grouting in the presence and under the direction of the Contracting Officer. Remove cement grout from the mixer, sump, and supply line before initial set [gel time] is reached.

3.6.1 Protection to Work and Cleanup

****

Note: Include the second bracketed paragraph when working next to drainage features that are at risk of being impacted by grouting operations.

****

During drilling and grouting operations, the Contractor must keep the work area clean, and continually clean any areas where grout is placed near permanent project features. The Contractor must take such precautions necessary to prevent drill cuttings, equipment exhaust oil, equipment hydraulic 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 is required to furnish any pumps necessary to care for wastewater and grout generated from operations. Upon completion of these operations, clean up all waste. Any damage to project features from drilling and grouting operations must be repaired at the Contractor's expense.

[Except as otherwise specified, no grouting is permitted within [_____] feet meters 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 detect any fugitive grout. 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.]

[3.6.2 Contact Grouting

****

Note: Contact grouting is grouting performed to fill voids between the tunnel face/foundation and the liner. It may be performed to distribute loads evenly over the liner or to reduce inflow/outflow from the tunnel, or both. In cast-in-place tunnels, contact grouting is performed above the springline, as the concrete conforms to and makes complete contact with the surrounding excavation before it sets. Where precast liner or steel liner sections are used, it is likely that there will be voids between the upper and lower portions of the liner and the surrounding ground, because the liner is rigid and cannot conform to irregularities in the excavation faces. Tailor the following section based on these considerations as needed.

When using cast-in-place lining, calculate expected concrete volume for liner segments ahead of placement. Compare expected volumes with actual

volumes of concrete. If significantly less concrete is used than anticipated, there may be excessive voids developed due to inadequate vibration or settlement of the concrete or due to trapped air. Highly irregular surfaces can result in significantly greater concrete volumes, and still result in voids due to shrinkage or pinching geometries that obstruct flow. Either of these conditions may result in excessive voids in the liner that require contact grouting.

Paragraph 2 only applies to new liners and should be removed if grouting through an existing liner. Coordinate with drilling requirements if a new liner is being grouted. For existing liners, delete paragraph 2 and adjust paragraph 3. Paragraphs 5 and 6 may be added as needed based on scope requirements.

****

Contact grouting is defined as the injection of grout to fill voids [reduce inflows] between the [tunnel][foundation] and [cast-in-place concrete lining][shaft [and][or] tunnel][, or grouting behind the initial support system,] to achieve continuous contact between the liner and the surrounding rock or soil. Contact grouting is performed with multiple holes open to prevent applying excessive pressures on the liner.

[

Leave cast-in-place concrete final lining in place at least [7][28-days][_____] days before grouting commences. Contact grouting in pre-cast liners or steel liners is performed through holes that are arranged or installed during fabrication of the liner system.

][Provide vent pipes, for the release of air and water during grouting of crown overbreak cavities [as indicated on the Contract drawings][as included in the approved work plan][as directed by the Government]. The installation requirements of paragraph EMBEDDED PIPE applies to vent pipes.

]

Grout must be in accordance with paragraph [CEMENTITIOUS GROUT MIX DESIGN][CHEMICAL GROUT MIX DESIGN]. 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 are filled with grout. Initiate grouting from the lower end and at the invert of a tunnel and the grout behind the liner displaced upward to the crown holes. Open holes not being grouting must be fitted with packers that are left open while grout is being injected. [If][When] grout communicates to an open packered hole, it is closed off, to allow grout to fully fill the void resulting in the connection. Apply a maximum target pressure that does not exceed 80 percent of the design load bearing capacity of the liner at [7-day][28-day] strength. The minimum target pressure must not be lower than 10 psi above the total pressure at the point of injection. Do not terminate grouting on any hole until all voids have been filled and the grout hole reaches refusal. If refusal is not met, terminate grouting once the theoretical volume is exceeded by a factor of 1.3 or grout has communicated to the adjoining grout holes in the row. The Government may direct the Contractor to stop grouting as required.

[

Grouting in the tunnel crown area requires secondary grouting to completely fill all the void space due to overbreak. Perform secondary grouting after the initial contact grout has been injected and set up.

Secondary grouting must be completed with approved grouting mixtures [expansive chemical grouts].

][

For shaft linings, radially locate grout holes or grout nipples so grout can initiate from inside the shaft. Split spaced grout injection holes or nipples may be necessary in shaft liner grouting.

]

][3.6.3 Grouting Behind a Steel Liner

This type of grouting consists of placing grout in the annular space surrounding a steel liner or "can" to fill the void between the steel liner and achieve continuous contact with the surrounding [rock][liner][soil]. Positive displacement pumps and equipment that causes sudden surges in pressure are not permitted. Contact grouting is performed with multiple holes open to prevent applying excessive pressures on the liner. Grout must be in accordance with paragraph [CEMENTITIOUS GROUT MIX DESIGN][CHEMICAL GROUT MIX DESIGN]. 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 are filled with grout. Initiate grouting from the lower end and at the invert of a tunnel. Grout behind the liner to displace grout upward to the crown holes. Provide grout holes and sealing plugs in the steel liner plates during fabrication. Provide pattern [as shown in the Contract drawings][as submitted and approved in the work plan]. Holes into which grout is not being pumped are fitted with packers that are left open while grout is being injected. [If][When] grout communicates to an open packered hole, it is closed off, to allow grout to potentially fill voids beyond it. Apply a maximum target pressure that does not exceed 80 percent of the design load bearing capacity of the liner at [7-day][28-day] strength. The minimum target pressure must not be lower than 10 psi above the total pressure at the point of injection. Do not terminate grouting on any hole until all voids have been filled and the grout hole reaches refusal. If refusal is not met, terminate grouting once the theoretical volume is exceeded by a factor of 1.3 or grout has communicated to the adjoining grout holes in the row. The Government may direct the Contractor to stop grouting as required. Grind grout hole plugs flush with the steel liner and finish smooth. 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.

]3.6.4 Tunnel, Shaft, and Ring Curtain Grouting

****

NOTE: Tunnel, shaft, and ring curtain grouting may occur ahead of the tunnel or shaft face, along any reach of tunnel or shaft to control water flows, or to aid in stabilization/void filling in the formation.

In relatively stable rock tunnels, water-bearing features may be assessed and considered for grouting if they produce enough water to cause issues with liner construction (either cast-in-place or pre-cast systems). A criterion such as gallons per minute of water flow (estimated by the COR) or maximum joint width may be used.

Ground stabilization grouting occurs either in

advance of the tunnel excavation or soon after excavation in unstable ground. When it occurs ahead of tunnel advancement, some of the grouted rock or soil mass is sacrificial. This material is more readily excavated because it is less variable. When performing ground stabilization grouting after excavation, temporary support is necessary for safety of workers and to maintain the excavation faces. Both grouting to control groundwater inflow and ground stabilization may be performed ahead of the advancing face by drilling a pattern/array of holes based upon geologic discontinuities or water-bearing features.

****

Accomplish tunnel[,shaft] [and] [ring curtain] grouting at [the locations shown on the Contract drawings][as approved in the work plan][as directed by the Contracting Officer.] The Contractor must replace any grout hole that is lost or damaged due to failure of equipment, inadequate grout supply, or Contractor error at no additional cost to the Government.

****

NOTE: For grouting intended to control inflows into the excavation, use the following sections. Select the pargraph most appropriate for your job. Delete the other paragraph.

****

For joints or shear zones in rock where water is still flowing,[drill holes offset from the feature such that they are in stable rock and are angled to intersect the water-bearing feature no less than 15 centimeters 6 inches 6-inches into the native rock nor more than 45 centimeters 18 inches into the native rock.]

[drill holes into the water-bearing feature deep enough to divert water from the surface exposure to the holes. Drill sufficient holes such that the flow from the water-bearing feature is diverted from the intersection of the feature with the tunnel face and flows from the drain holes, and space holes no greater than 50 centimeters 20 inches apart along the water-bearing extent of a feature.]

After water flow is diverted, clean loose material from the feature and seal it using expansive hydraulic cement mortar. Use dental concrete in cases of features greater than 8 centimeters 3 inches. [The Contractor may seal the feature with approved approved caulking material.] After surface sealant has set, begin sequentially grouting each hole starting at the bottom. Fit each open hole not yet grouted with a packer. Grout each hole in succession until grout communicates to the next higher hole. Close the packer in the closest hole when grout begins to exit and continue until grout exits the next open hole up the feature. Close the packer in that hole, and repeat the process moving further away. When grout has communicated to the last hole up the feature, stop grouting and close all packers in all holes, and disconnect the header from the bottom hole. Immediately close the packer in the bottom hole. Move the header and connect to the next hole up the feature. Leave packer in the bottom hole closed. Open the packer in the hole above the hole connected to the header. Begin grouting again, and apply the same sequencing for all holes with closed packers until each hole has been set-up on and grouted. Again, when grout is exiting the last hole upward in the sequence, close the packers and stop grouting. Repeat the process up sequence until the

feature and the overall inflow into the excavation in this area is [within the acceptable tolerances submitted and approved in the work plan][less than [_____]].

When tunnels are advanced through existing grout curtains, install arrays of grout holes radially around the tunnel at least one tunnel diameter into native ground to restore the integrity of the grout curtain. Upon completion, holes remain sealed by packer or plug to prevent loss of grout until the grout sets.

3.6.4.1 Grout Injection (Cement Grout)

The procedure for selecting the initial grout mix, and the thickening procedure, must be executed as submitted and approved in the work plan. Based on geologic/other considerations, the Government may require the Contractor to start at a thicker mix or thicken mixes faster or slower than is required in the work plan. In no instance is the flow rate allowed to exceed 10[20] gpm. Do not increase the pressure or rate of pumping suddenly, because either may produce a water-hammer effect which may damage the bedrock or grouting equipment.

a. Start grouting with Grout Mix A until the holding pressure is reached. Maintain the hold pressure as required until refusal for the hole[stage] is met. Maintain the pressure by means of a stopcock or other suitable device until the grout has set to the extent grout remains in the grout hole.

b. When the hold pressure is not reached, use progressively thicker grout mixes until the required hold pressure has been reached. For an open hole condition, select Grout Mix C or a thicker grout mix with the grout pump operating at constant speed at all times. If the hold pressure is still not reached after cycling through the suite of grout mixes, batch the thickest grout mix [sanded grout] and evaluate if the hold pressure is obtained. Proceed to refusal.

c. If the hole still does not reach refusal, reduce the flow rate or utilize intermittent grouting to allow sufficient time between grout injections for the grout to stiffen. Intermittent grouting must not allow grout to set in the lines. If the hole does not reach refusal discontinue grouting in the hole.

d. The hole must be cleaned and the grout allowed to set. Split space the hole distance to the nearest hole in at least 4 directions. Upon drilling and grouting those holes, redrill the hole and grout the hole until refusal is met. If refusal is not met, split space the holes again and repeat the process until all holes reach refusal.

[3.6.4.2 Stage Grouting

Stage grouting is the procedure by which a grout hole or a ring curtain hole is drilled 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. After the grout has achieved an initial set, wash, clean and deepen the hole and then grout to the bottom of the next stage. 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. The target grouting pressure for each grout stage must be as submitted and approved

in the work plan for successively deeper stages. 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 succeeding series of split spaced holes in stages as required.

][3.6.4.3 Grout Injection (Chemical Grout)

Perform chemical grouting to produce a continuous mass of chemically grouted ground outside the excavation perimeter for the tunnel or shaft to increase the strength and reduce permeability of the material. Grout must be chemically stable and nontoxic for the environment after gelling. 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. 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. Do not commence excavation through grouted areas until the grouting work has been completed and approved by the Government. Perform split spacing and additional grouting if the required degree of waterproofing [and][or] stabilization is not achieved with the first application.

]3.6.5 Split-Spacing and Closure Procedures

3.6.5.1 Target Hold Grouting Pressure

****

NOTE: Select the appropriate bracket based on the subsurface conditions to define the most appropriate hold pressure for your application. Items 1 and 3 may be used to support a DIPP for USACE projects. Item 2 must be verified by site specific conditions to ensure it will not result in harm. Item 4 has criteria from USACE EM 1110-1-2902. For liners, Items 4 and 5 can be paired to bound performance criteria.

****

The hold pressure is a site specific determination based on local geology, project scope, and impacts to nearby structures. The target hold pressure is determined by one of the following:

1. The target hold pressure must be 90 percent of the site specific hydrofracture pressure.

[

2. USACE Dams and Levees. The target hold pressure must be 12 kPa per meter 0.5 psi per foot of depth of overburden and 24 kPa per meter 1.0 psi to per foot of [rock][concrete].]

[

3. The target hold pressure must be less than 24 kPa per meter 1 psi per foot of depth of overburden and 48 kPa per meter 2.0 psi to per foot of [rock][concrete].]

[

4. For liners, increase the pressure by 10 psi above the total pressure acting on the stage.]

[

5. For liners, grouting pressures used are no more than 80 percent of the design load of the liner system.]

[

6. Alternative methods submitted by the Contractor and approved by the Contracting Officer, backed by a comprehensive numerical analysis, that does not result in hydrofracture or deformation.]

3.6.5.2 Refusal

****

NOTE: Select a refusal time at 30 minutes or 10 minutes. Note that slower production times will result for the longer time that is required to reach refusal. Grouting in sensitive areas may require longer times for refusal to ensure better grout coverage.

****

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 30 minutes][0.005 cubic meter 0.16 cubic foot of solids (cement) per 10 minutes] at whatever grout mixture and hold pressure being used.

3.6.5.3 Split-Spacing Procedures

When a primary hole does not meet refusal, it must be split spaced with secondary holes in the succeeding series. If a secondary hole does not reach refusal, it must be split spaced with a tertiary hole of the succeeding series, and so forth. Each succeeding series requires a minimum of 4 holes installed around the hole that did not reach refusal; one hole split spaced to the left, right, above, and below the hole.[For seepage control grouting, all holes in a section must reach refusal for the area to reach closure, see paragraph CLOSURE CRITERIA.]

Split-spaced holes must only be drilled to the depth of the lowest failed stage.[Split-spaced holes must be drilled to full depth.]

[3.6.5.4 Closure Criteria

****

NOTE: Closure is only required for projects with an objective of controlling groundwater inflows and reducing seepage. As the work progresses the Contracting Officer reserves the right to establish closure based on apparent Lugeons measured during the grouting or the Lugeons from water pressure tests.

NOTE: Grouting effectiveness is limited for foundations with a permeability less than 1 Lugeon. Weaver and Bruce (2007) state that attempting to grout below one (1) Lugeon is not feasible or practical. One (1) Lugeon is considered nearly impervious and is required for combined sewer

overflow (CSO), sanitary sewer, and potable water supply applications.

NOTE: A value of three (3) Lugeons is considered "tight". Grouting to this level of closure may not be cost effective depending on the application considered.

NOTE: A value of five (5) Lugeons is recommended for general applications.

****

All stages must meet the following closure criteria:

a. All holes in the section must reach meet the target objective of the grouting, reach refusal, and satisfy split spacing criteria.

[

b. [1][5][_____] Lugeons as calculated by water pressure testing for production and verification holes.]

[

c. [1][5][_____] apparent Lugeons as calculated during grouting for production and verification holes.]

Based on In-situ ground conditions, the Contracting Officer reserves the right to require additional grout holes including but not limited to changing spacing, offsets, drilling angles, sequence, staging, mix designs, pressures, and volumes as needed to achieve closure as defined by paragraph CLOSURE CRITERIA.

]3.6.5.5 Verification Holes

****

NOTE: The purpose of a verification hole is to verify that the goals of the grouting program have been met. Verification holes are typically advanced between two production grout holes. Coring is not required for verification holes unless deemed necessary for the evaluation of grouting effectiveness or stability. Verification holes should utilize existing measurement and payment items.Determine if the number of verification holes will be defined per hole, or per foot. Select brackets as appropriate.

NOTE: As part of the verification program, closure will be realized by permeability testing at each verification hole. The designer must consider the goal of the grouting job and local geologic conditions to determine closure criteria. The specification for closure should be adjusted to each job site specific requirements.

****

Grouting verification holes must be drilled[, and pressure tested,] within the completed grout area to verify effectiveness for the grouting to fill void space behind the liner [reduce permeability and water inflows][ensure stability of the grouted area]. Drilling, washing, and grouting procedures must be the same as production grout holes. The Contracting Officer determines locations for verification holes, which may

be along the grout line[s] or between successive grout lines.[For estimating purposes, the Contractor must assume a quantity of [_____] verification holes of which [_____] must be angled at [_____] degrees from vertical advanced to the production depth.][For estimating purposes, the Contractor must assume meters feet of drilling.]

3.6.6 Waste Water and Grout

During the progress of the work, provide for adequate disposal of all wash and waste water and remove all waste grout in accordance with paragraph [DISPOSAL OF DRILL CUTTINGS, WASTE WATER, AND WASTE GROUT][and][PERMITS, CERTIFICATIONS, AND LICENSES][as submitted and approved in the work plan].

3.7 GROUT QUALITY CONTROL TESTING

Establish and maintain quality control to assure that:

a. The laboratory 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 submitted and approved][as recommended by the manufacturer or supplier].

g. Only approved materials are used that are properly protected from moisture and contamination after delivery and transportation to the site.

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

i. Install and monitor all structural monitoring equipment required, including ground movement monitoring devices.

3.7.1 Cementitous Grout Production Grout Testing

****

In choosing between frequency of testing for the language below, it will depend upon the amount of grout planned to be mixed, as well as the risk of the job. It would make more sense to test grout twice a shift when thousands of gallons of grout are anticipated being produced daily versus just a few batches daily.

NOTE: For very large jobs, quality control testing of the grout mixes, specifically temperature, viscosity, specific gravity, bleed, pressure filtration, initial set, final set, and 28-day unconfined compressive strength, will start with 100 percent of the batches for each mix being tested on

every shift for at least the first 75 of each test being performed. If the process is not in control and/or has greater than or equal to 10 percent failure, then the 100 percent testing is continued until it can be proven the batching process is under statistical control. If a process that was good goes out of control or has greater than or equal to 10 percent failure rate for any test, then 100 percent testing must resume until the process is again under statistical control." The designer must consider what statistical method (e.g, regression, ANOVA, T-test, or other methods) would be best for the job and specify the statistical method.

****

All requirements from paragraphs TRIAL BATCH LABORATORY TESTING and TRIAL BATCH FIELD TESTING apply, except as modified below:

a. Temperature (production grout). Test temperature anytime other field testing is performed. If other field testing is not being performed, test grout for temperature at least [once][twice] per shift on each mix type utilized that shift in accordance with ASTM C1064/C1064M. Each mix type utilized on that shift must be tested each shift, specifically the first time that mix type is batched.

b. Viscosity (production grout). Testing must be performed [once][twice] per shift on each mix type utilized that shift. Marsh Funnel testing must be performed in accordance with ASTM D6910/D6910M. Flow Cone testing must be conducted in accordance with ASTM C939/C939M. Test results must meet the established thresholds established during trial batching.

c. Specific Gravity (production grout). Testing must be performed [once][twice] per shift on each mix type utilized that shift in accordance with the ASTM D4380. Test results must meet the established thresholds established during trial batching.

d. Bleed (production grout). Grout bleed must be performed once per week on each mix type utilized that week in accordance with ASTM C940, and meeting the thresholds established during trial batching.

e. Pressure Filtration (production grout). Pressure filtration must be performed once per week on each mix type utilized that week, per the methods and thresholds established during trial batching.

f. Setting time (production grout). Setting time testing, obtaining both initial set and final set, must be performed once per month on each mix type utilized that month in accordance with ASTM C191, Method A. Test results must meet the established thresholds established during trial batching.

****

NOTE: Testing at 28 days is necessary, other intervals are optional. While it is traditional to test grout samples for strength at 3, 7, and 14 days, those tests are typically 'for information only', and may not be always necessary. Only 28 day samples are typically used for compliance. For example, it could make sense to test at 3 and 28

days, to ensure proper initial set and then final strength.

Typically, 2 samples are prepared for each test interval, but it could make sense to utilize 3 samples if lesser amounts of testing will be performed, to

****

g. Grout strength sample collection and testing (production). [Cubes][or][cylinders] must be taken once a week for each mix type utilized. Test samples at [3][7][28] days with a minimum of [2][3] samples tested per day to establish an average strength. Strength tests and samples must comply with the methods and thresholds established during trial batching.

Submit the received results of all laboratory testing as part of the Weekly Grout Test Results submittal.

3.7.2 Failing Grout Tests

Grout mixes failing the viscosity and specific gravity quality control criteria must be considered unacceptable mixes and be wasted. When mixes fail either quality viscosity or specific gravity tests, every subsequent mix batched must be tested for both viscosity and specific gravity until [six][_____] tests pass in a row. If grout mixes fail bleed, pressure filtration, initial set time, final set time, or unconfined compressive strength tests, then the Contracting Officer must be notified immediately and the Contractor must resume 100-percent testing until that property has passed [six] tests in a row. The Contracting Officer will determine if the 100-percent testing is just for the failed test or all the quality control tests. The Contractor must also propose, in writing, the steps to be taken to remedy the situation. If QC test failures continue for more than [7][15] days, the Contractor must submit a written plan to get back within tolerances.

3.7.3 Testing Laboratory

The Contractor must have a dedicated, sheltered space and equipment for conducting Quality Control fresh property tests on the grout. The Contractor is required to provide the Government space and separate equipment of equal grade, quality, precision, and accuracy as used for QC activities to conduct Quality Assurance testing of the grout in the same working space.[Both spaces must be accredited in accordance with ER 1110-1-8100.]

[3.7.4 Chemical Grout Production Grout Testing

****

NOTE: Delete strength requirements if seepage control and permeability requirements are the intent the goal of the scope of work. Final permeability can be tested by water pressure testing via verification holes, and are omitted from this section.

For structural support, the strength should be equivalent to support a safe geometry for the excavated soil/rock. Strengths greater than 500 psi

are likely not required. For contact grouting, consider using a strength that will be strain compatible to the liner and stratum the liner contacts.

****

a. Batch weight of each solid component and weight of water on a per [liter][cubic meter] [gallon][cubic yard] basis daily.

[

b. Strength Testing. Once per week, test [2][3] samples for each mix used for the [7][and][28]-day compressive strength in accordance with ASTM D4219.]

c. Test the gel and cure time [once per shift][daily][as submitted and approved in the work plan][in accordance with manufacturer's recommendations][for every 946 liters 250 gallons of grout].

d. Viscosity of the chemical grout must be checked daily for each mix [per the manufacturer's recommendations][as submitted and approved in the work plan].

]3.8 PATCHING AND RESTORATION

****

NOTE: Reinforced concrete liners and steel liners must be patched with compatible materials of similar strength. Strain compatibility for materials must be considered. For shotcrete or unfinished excavations, mortar patches are acceptable. Choose paragraph 2 for concrete liners and pargraph 3 for steel liners.

****

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 [liner][concrete][shotcrete]. The liner must be patched with strain compatible materials of similar composition and strength. Patch and restore holes and depressions for the full length of the liner. Thoroughly [tamp][tremie][pump] [concrete] [grout] into the hole as [submitted and approved in the work plan][required in the Contract drawings]. Patch in a neat workman like manner to provide a surface smoothness at least equal to undisturbed areas of the final lining.

[

Patch holes or depressions thus formed with[an approved grout mix] a damp-pack mortar composed of water, one part hydraulic cement to two parts sand. 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.]

[

If ports are cut into the steel liner, the cut must be cleaned squared off and ground smooth prior to patching. Patches must have welds approved by a certified welding inspector. Large patches over 12 inches across the smallest dimension must be validated by geophysical methods submitted by the Contractor for approval.]

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.

3.9 HOLE RECORDS

Submit raw data records within [one][two] days of hole completion. All record keeping and submission is incidental to the work. No additional payment will be made for keeping or providing records. Provide records within the stated turnover times, and provide digital records within [six][_____] hours of a request by the Contracting Officer.

3.9.1 Drill Logs

****

NOTE: USACE uses USACE Form 1836 and 1836 Continuation Form. For other agencies, utilize the agency-specific drilling form.

****

Drill logs must[use the USACE Form 1836 and 1836 Continuation Form. Complete drill logging in accordance with EM 1110-1-1804]. The Government may choose to log holes in parallel, however, complete drill logging as specified is still required. Logging may be performed on paper logs or, if approved in writing by the Contracting Officer in advance, using a digital device such as a tablet. If any data associated with a hole is lost through no fault of the Government, the log must be reproduced, or the entire zone where data is missing must be redrilled and logged, at no cost to the Government.

3.9.1.1 [Paper][Digital] Drill Logs

****

NOTE: Select whether you want paper logs or digital logs using a tablet. Delete brackets as required. For projects utilizing AGDCS should require a tablet.

****

[If using a paper form, then the logger must keep no separate log. The log must contain all relevant information collected, including any verbal comments made by the driller. The paper log must be legible, and available for a quality assurance check by any Government representative at any time. Photograph or scan paper logs at the end of each day, and back up electronically[in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION].]

[If using a digital logging device such as a tablet[, the program utilized must be approved in advance by the Contracting Officer, and] it must produce a[USACE Form 1836] formatted drill log. Back up the logging data via cloud synchronization at the conclusion of every run while drilling. In remote sites without Internet connectivity, use device and external storage in tandem as redundant backups to protect against data losses.[Print any drill log or partial drill log within 1 hour of any Contracting Officer request.]]

[3.9.1.2 OpenGround Cloud

****

NOTE: OpenGround Cloud is the authoritative data

source location for all USACE boring data. In addition to the requirements above, this section should be used by all USACE projects where recovered core is logged. Other agencies can delete this section. If used, verify that this language is up to date with the HQUSACE OpenGround Cloud point of contact.

****

Provide all drilling data in OpenGround Cloud configured for the [_____] project. The Government will provide necessary permissions to enter data. Provide a list of users with name and emails for the Government to grant access. OpenGround Cloud (OGC) named user or concurrent licensing are required for use. For data entry into OGC, utilize fields with dropdown lists where applicable. Only use additional descriptions for text entry of data when a dropdown list for that feature does not exist. Verify there is no applicable field for a feature before using the Comments/Remarks fields in any table to enter material classification.

The field [geologist][geotechnical engineer] who logged the core must perform the data entry of the log into OGC. A separate [geologist][geotechnical engineer] must perform a 100 percent QC check of the data entered into OGC. Enter logs into OGC within 48 hours of hole completion, or as directed by the Contracting Officer.[Complete QC of the log entry to OGC within 72 hours of hole completion.] The Contracting Officer may request a photograph or scanned copy of a drill log (paper log) or electronic copy of the drill log (tablet log) at any time more than [72][_____] hours after the completion of the drilling, and an electronic copy must be provided to the Contracting Officer at no additional cost, within 24 hours.

][3.9.2 Hole Washing Log

****

NOTE: This section may be deleted if hole washing utilizes the drilling equipment, as notes can be added to the boring log before removal of tooling.

****

A hole washing log must be submitted with the tool used for washing, the date and time of washing, the discharge rate, the pressure used, the total amount of water used, the color of discharge water, as well as any notes. The Contractor must submit a [paper][and][electronic] copy of the hole washing record within [48][72] hours.

][3.9.3 Water Pressure Testing Reports

Provide a separate water pressure testing report that contains all the required water pressure testing records and information required for each water pressure test stage. The report must include a time history of the stage information, packer air pressure, water inflow, flow versus time, pressure versus time (including hold pressure), any communication between stages or instrumentation, any observed new water flow at the surface, lugeon value versus time and any comments recorded by the [Contractor][requested by the Contracting Officer]. Provide the report in .doc or .docx format readable by the Microsoft word processing software, and in Adobe PDF formats. Submit final records within [7][_____] calendar days of stage completion.

]3.9.4 Grouting Reports

Provide a separate grouting report for each grout stage. The report must be a time history of the stage, along with any comments. The report must include: stage information, packer air pressure, water inflow, flow versus time, pressure versus time (including hold pressure), grout mix[es], apparent lugeon value versus time. In addition, the cumulative flow, interpreted single lugeon value, and any comments by the [Contracting Officer][Contractor] recorded, including any communication between stages or instruments, or observed grout at the surface. The comments must include any comment directed to be added to that specific stage report by a Contracting Officer. Provide the report in .doc or .docx format readable by the Microsoft word processing software, and in Adobe PDF formats. Submit final records within [7][_____] calendar days of stage completion.

[3.9.5 AGDCS Records

****
NOTE: If this option is used, delete select sections from above if recorded using AGDCS records.
****

The AGDCS must be capable of producing outputs that include the following information:

a. Type of data (Grouting versus Water-Pressure-Testing).

b. Hole stations, offsets, and Northing Easting coordinates.

c. Testing interval or zone data (as appropriate)including depth, and elevation.

[
d. Initial water pressure and calculation for each stage.]

[
e. Water pressure testing results from each zone in [Lugeons][modified Lugeons].]

f. Grout takes for each mix used in each stage.

g. Grouting time for each stage (hr:min:sec).

h. Graphs displaying injection rates, all pressures, and apparent Lugeon values from the grouting.

i. The system must be able to reduce monitoring data to account for correction factors and field parameters, such as pressure head losses, actual depth of the stage being grouted, and pressure measurements.

j. Show time horizontally on graphs.

k. Produce separate graphs for pressures, flow, lugeon, and (for grouting only) mix-type all measured on the vertical axis.

]3.10 PERIODIC RECORDS

****
NOTE: Depending on the needs of the project, the designer may change frequency of reporting periods

listed.
****

3.10.1 Weekly Grout Test Results

On a weekly basis, submit a project-cumulative table with all daily, weekly, and monthly Contractor Quality Control field and laboratory grout tests in electronic[, EXCEL360,] spreadsheet. Submit the spreadsheet starting the week after the first test is conducted.

Display each batch as separate records, and test results as fields. Display all testing records. The spreadsheet must contain the following columns: batch date, batch time, combined batch date and time, test date, test time, which batch plant the sample was taken from, ASTM standard utilized, Pass/Fail (with 0 and 1 used for pass and fail, respectively), and each test title (e.g., Viscosity, Density, etc.). The actual numerical test result must be posted, "Passed", "Within Spec", or "<0.09" are unacceptable. Include all failing and passing tests.

3.10.2 Monthly Grouting Red Line Drawings

****
NOTE: If grouting is part of a larger project, then this submittal need not be required monthly, only months that work is occurring. On grouting-only jobs, delete the last paragraph.
****

In accordance with paragraph AS-BUILT DOCUMENTS, prepare red-line drawings each month, with red-lines showing changes from the award drawings, and as many new drawings as necessary showing the drilling[, water pressure testing,] and grouting work completed to date. Include all of the grout holes authorized to date in plan (map) view. The drawings must be in [MicroStation][AutoCAD][GIS] format.

[
Monthly Grouting Red Line Drawings need only be submitted when drilling or grouting work is underway or when drilling or grouting information is still being processed after completion.]

[3.10.3 Monthly Drilling and Grouting Photographs

Provide a set of at least [10][_____] photographs showing the operation of drilling and grouting. All photographs must be a minimum of [10 megabytes][10 pixels per inch]. Include photograph digital files in a lossless image format, and in annotated PDFs describing the date, location, orientation, and feature of work in the photo.

]3.11 DRILLING AND GROUTING CLOSEOUT RECORDS

3.11.1 As-Built Drilling and Grouting Drawings

Provide As-Built drawings in accordance with Section 01 78 00 AS-BUILT DOCUMENTS. As-Built drawings are not limited to the sheets in the Contract drawings. Add as many sheets as necessary to show the work completed. Include the three new views for the entire grouting work. The color and binning symbology for pressure, grout volume, and drilling issues will be provided by the Government. Make changes to symbology, binning, and color representations as directed by the Contracting Officer.

a. The first view is drilling results. Include every grout hole as a line, with the ground surface and top-of-rock noted for each hole. Display voids, an interpreted top-of-rock line, and interpreted connections between voids. Show any lost tooling at the presumed lost depth. Show all casings with top and bottom depth.

[

b. The second view is water pressure testing results. Show each grout hole as a line, with each water pressure testing stage depicted by a color-coded box with the Lugeon value printed on it.[The Government will provide color symbol binning for Lugeons.]]

c. The third view is grout volumes. Show each grout hole as a line, with each grouting stage shown with a color-coded box with the grout volume printed on it. Depict annular-space grout volumes for overburden stages separately.

3.11.2 Drilling and Grouting Final Report

****

NOTE: The final report is a necessary submittal and provides the government a thorough and useful final record of the contractor's work that will provide critical information to meet the requirements of completion reports (For USACE, see Engineering Regulation (ER) 1110-2-1901).

The requirement to reduce references without full-text incorporation is necessary to prevent submission of final reports of an inferior quality and detail. Reports which simply reference job submittals and do not present a final aggregate record with digestible analytical findings, and supporting data should be avoided. Utilize specific and descriptive language that is enforceable to get the desired final product.

****

Prior to the Contract completion, prepare and submit a drilling and grouting final report that describes all activities throughout construction in detail. Include any narrative about issues encountered and technical resolution. Submit the complete report with [three][five] hard copies and a digital copy of the report including but not limited to: forms, sketches, drawings, tables, graphs, and color photographs as necessary to provide a full understanding of how the work was accomplished and any difficulties, problems, or unusual conditions which were encountered. The report must 'standalone' and not reference other material to the maximum extent as possible, except for the As-Built drilling and grouting drawings.

Submit the final report no later than [30][60] days after completion of grouting of the final hole.[Submit an outline of the report for approval when 50 percent of the construction is completed.] The report must contain the following minimum content:

a. Average drilling time and drilling depths of holes broken down into overburden,[concrete,] and bedrock.

b. Drilling records including depths and locations of holes.

c. A list of all drilling,[water pressure testing,] and grouting equipment used on the project, type of equipment used on each element, and depth of excavation for each type.

d. A minimum of twenty-five annotated color photographs of all phases of construction and equipment.

e. A discussion of the grout mix[es] used and quality control procedures for maintaining the grout mixes.

f. A descriptive list of any lost tooling including type of tooling, length, depth, batter, and location (station and offset).

g. Discussion of any deviations from the Work Plan submittals.

h. Discussion of the refusal criteria[closure analysis] and any stages that [did not refuse][were not closed] by the split-spacing method.

i. Discussion of all[water-pressure-testing stage[s]] or grouting stage[s] that appeared to have induced either dilation or hydro-fracture based upon the trend plots. The specific trend plots must be included in the report.

j. Instantaneous and Industrial Production rates for drilling[, water pressure testing] and grouting. Compare production rates achieved with the production rates forecast in the baseline schedule; note any actual rate that is 25 percent different from the forecast in the baseline schedule. Include an interpretation of why forecast and actual were different.

k. Summary statistics of each test for each grout mix during the Contract period. Include: Mean, Median, Mode, Standard Deviation, and 95-percent Confidence limit.

l. For compressive strength data, only evaluate the 28-day strength. Also plots of each test, for each mix, showing results versus time, with specifications limits clearly delineated.

[
m. A discussion of the Computer Grouting System to include the formulas used for calculating effective pressure of water testing and grouting.]

[
n. A discussion of issues encountered, including but not limited to, cross hole communication, water losses, excessive takes, surface grout emergence, hole collapses, excessive infill materials encountered leading to hole stability problems, signs of connectivity, instrumentation responses, any signs of structural distress that appeared or changed during grouting - related to the area grouted at the time.]

3.11.3 Database of [Water Pressure Testing and] Pressure Grouting Results

****

NOTE: A database is an essential tool for analysis and quality assurance review by engineering for grouting projects. The database will facilitate data research, analysis, and visualization. It can be incorporated into a project Geographic Information System (GIS) - including profile views of the grout lines. For all dam safety or

large-scale grouting jobs, an enterprise database is recommended. Smaller projects could utilize a Microsoft Access database. It is a best practice to develop the database format based on the project quality management and reporting requirements and provide this to the Contractor. Alternatively, the Contractor could propose a format for approval by the project's data manager in conjunction with the grouting engineer. Projects should ensure data requirements are complete enough that they facilitate needed reporting and evaluation required throughout the contract

For any database utilized, it is imperative that all values have a content definition and that any calculations, variables and constants involved in creating values reported in the database are clearly defined in human-readable database documentation.

For all geospatial and database regulations and best practices, refer to applicable guidance. For USACE this includes Engineering Manual 1110-1-2909 Geospatial Data and Systems.

For all data products, ensure minimum data quality, turnover time, and format requirements are in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATIONUFGS, and included in that section.

****

Develop an [Enterprise][Microsoft Access] database in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION that contains all data generated over the course of the project - including but not limited to drilling, grouting[, water pressure testing,] and verification drilling and testing. Minimum data requirements include but are not limited to:

a. Hole ID
b. Hole surface station[or substitute latitude for station]
c. Hole surface offset[or substitute longitude for offset]
d. Hole series
e. Hole top (ground surface) elevation
f. Hole bottom elevation
g. Hole inclination (vertical =90, non-vertical as built)
h. Hole azimuth (999 for vertical, as measured for non-vertical)
i. Hole total grout volume for the hole
j. Hole top-of-rock elevation
k. Hole top elevation of casing
l. Hole bottom elevation of casing
m. Hole top elevation of casing (if applicable)
n. Hole bottom elevation of casing (if applicable)
o. Hole drilling issues including hole collapse, voids, drill water loss.
p. Stage ID
q. Stage top elevation
r. Stage top station
s. Stage top offset
t. Stage bottom elevation
u. Stage bottom station

v. Stage bottom offset
w. Stage Lugeon value
x. Stage grout volume in [liters][gallons] of each mix
y. Stage geologic formation
z. Stage hold pressure
aa. Stage target gauge pressure
ab. Stage grouting issues including cross hole communication, bypass or leaking of a packer, unintended grout emergence, or others as requested by the Government.
ac. Hole ID of corresponding communicating hole
ad. Stage ID of corresponding communicating stage
ae. Comments

[
A data dictionary detailing the specific data tables, fields, and relationships of the database required for use[is provided as an addendum to the Contract][will be provided by the Government upon issuance of the notice to proceed]. See Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION for additional database requirements.[The database must contain metadata cin accordance with ISO 19115.][The database must be in accordance with with SDSFIE Standards.]]

3.12 COMMUNICATIONS

Install a communications system that links (at a minimum) the grout plants, grout injection stations, water-pressure-testing stations, the Automated Grouting Data Collection System and all other operations on site as necessary.[Furnish two devices per shift to the Contracting Officer that communicate on the Contractor's frequency or line for monitoring and coordination of grouting operations. These must be returned to the Contractor at the end of grouting operations, subject to normal wear and tear.]

-- End of Section --