SECTION 33 08 19
MICROTUNNELING AND PIPE-JACKED TUNNELS

PART 1 – GENERAL

1.1 DESCRIPTION

A. The work covered by this Section includes all labor, materials, and equipment necessary for trenchless installation of utility pipe using an appropriate tunnel boring machine combined with pipe-jacking techniques. All work shall comply with the Standard Construction Specifications of the Metropolitan St. Louis Sewer District. This section is applicable if alternative trenchless methods are approved.

1.2 RELATED WORK

A. Maintenance of Existing Utilities: Section 01 00 00, GENERAL REQUIREMENTS.

B. Excavation, Trench Widths, Pipe Bedding, Backfill, Shoring, Sheeting, Bracing: Section 31 20 00, EARTH MOVING.

C. Temporary Construction Fence: Section 01 00 00, GENERAL REQUIREMENTS.

D. Section 33 30 00, SANITARY SEWERAGE UTILITIES

E. Section 33 08 17, JACKED AND BORED PIPE

1.3 CONTRACTOR'S QUALIFICATIONS

Qualified Contractors will have actively engaged in the installation of pipe using trenchless methods for a minimum of 5 years, during which time the Contractor shall have completed at least 25,000 linear feet of installations.

1.4 SUBMITTALS

In accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA AND SAMPLES, furnish the following:

1. Qualifications: Submit documentation showing that the Contractor and personnel meet the minimum required qualifications stated in this specification. Information must include date and duration of work, location, pipe information (length, diameter, depth, pipe material, etc.) project owner and pipe contents.
2. Tunneling Methodology:
   A brief description of proposed tunneling methodology for review. The description should be sufficient to convey the following:
   a. Proposed method of tunnel construction and type of face support.

b. Manufacturer and type of tunneling equipment proposed. Describe lighting and ventilation systems.
c. Number and duration of shifts planned to be worked each day.
d. Sequence of operations.
e. Locations of access shafts and work site arrangement. Describe method of construction of tunnel shafts.
f. Method of spoils transportation from the face, surface storage and disposal location.
g. Capacity of jacking equipment and type of cushioning.
h. Identify critical utility crossings and special precautions proposed.
i. Slurry injection system details.

3. Tunnel Shafts:
Submit shaft construction drawings together with calculations. As a minimum the submittal shall include:
a. Shaft dimensions, design criteria, and details for ground support system, such as sheeting, shoring, bracing, and stabilization, protection of the excavations, special requirements for shaft penetrations, tunnel "eye", starter and back tunnels, and seal slabs. Allowable surcharge loads and any restrictions on surcharge capacity, including live loads, shall be clearly shown on the shaft construction drawings. Thrust blocks or other reactions required for pipe jacking shall be shown, if applicable.
b. Location of shafts by station and limits of working sites.
c. Description of site security arrangements in conformance with Section 01 00 00 GENERAL CONDITIONS, Operations and Storage Areas.
d. Description of method of protecting shaft from surface runoff.
e. Any geotechnical/boring work undertaken by the Contractor for purposes connected to the work.
f. Shaft design submittals by the Contractor shall be signed and sealed by a Professional Engineer registered in the State of Missouri.

4. Drawings and Calculations:
Submit for record purposes, all drawings and calculations for any tunnel support system designed by the Contractor. Drawings shall be

adequate for construction and include installation details. Show pipe and pipe joint details. Documents must be signed and sealed by a Professional Engineer registered in the State of Missouri. Calculations shall include clear statement of criteria used for the design. Review by Owner's Engineer of all drawings and calculations is for information purposes and overall conformance only and does not relieve the Contractor of any liability for the safety and performance of their design.

5. Quality Control:
   a. Method and frequency of survey control.
   b. Example of tunnel daily log.
6. Geotechnical Investigation:
   When geotechnical investigations are conducted by the Contractor, results of such investigation shall be submitted to the Engineer for record purposes.
7. Structure Assessments:
   Pre-construction and post-construction assessment reports shall be provided for critical structures, namely those located within 20 feet on either side of all tunnel alignments and all structures within 50 feet of active excavation areas. Photographs or video of any existing/pre-construction damage to those structures in the vicinity of the tunnel alignment shall be included in the assessment reports.
8. Traffic Control Plan:
   Access to the cemetery must be maintained at all times during operating hours. After hours road closures must be coordinated with the Cemetery Director and Project Manager. If changes to normal traffic flow are proposed, Contractor shall submit a traffic control plan. The plan shall include an outline of the permit acquisition procedure for lane closure (for work on Sheridan Road) and methods for proper signing and barricades, which complies with local requirements and the MUTCD.
9. Documentation that pipe and/or casing pipe material including the standard to which it is manufactured, outside diameter, wall thickness, joint configuration, and certificate of compliance certifying that the pipe and/or casing pipe meets these specifications.

10. Details of casing spacers, including manufacturer's recommended spacing.
11. Details of end seals for casing.
12. Dewatering Plan.

1.5 DESIGN CRITERIA

1. Pipe:
   a. Contractor is responsible for selection of the appropriate pipe and pipe joints to carry the thrust of any jacking forces or other construction loads in combination with overburden, earth and hydrostatic loads. Design of any pipe indicated on the Contract Documents considers in-place loads only and does not take into account any construction loads. The criteria for longitudinal loading (jacking forces) on the pipe and joints shall be determined by the Contractor, based on the selected method of construction. Approval of pipe for Microtunneling will be required by Engineer and MSD prior to installation. This approval may require more than 2 weeks. Contract time shall not be extended due to this review.
   b. The jacked pipe shall be designed to withstand the thrust from the jacking equipment and pipe advance without damage or distortion. The propulsion jacks shall be configured so that the thrust is uniformly distributed and will not damage or distort the pipe.
   c. Take into account loads from handling and storage.
   d. The criteria to be used for truck loading shall be HS-20 vehicle loading distributions in accordance with AASHTO.
   e. Provide pipes of diameter shown on the Contract Documents. Substituion of pipe with larger diameter to suit jacking equipment available will only be permitted if the Contractor can demonstrate to the Engineer's satisfaction that design flows and velocities can be achieved.
2. Tunnel Shafts:
   a. Shaft design must include allowance for contractor's equipment and stored material and spoil stockpile as appropriate. Design must also allow for HS-20 highway loading if located in the vicinity of a paved area.

b. The shaft shall be designed to withstand full hydrostatic head without failure.
c. Shaft cover, shall not be used in lieu of shaft perimeter security fencing.
d. Steel plate deck, if such is required, shall be designed for HS-20 loading.

PART 2 - PRODUCTS

2.1 SEWER PIPE

A. Contractor shall be responsible for selecting appropriate pipes and pipe joints to safely carry the loads imposed during construction, including jacking forces. The Contractor shall select approved pipe materials conforming to Section 33 30 00, SANITARY SEWERAGE UTILITIES and MSD requirements for trenchless method used.
B. Use pipe that is round with a smooth, even outer surface, and has joints that allow for easy connections between pipes. Pipe ends shall be designed so that jacking loads are evenly distributed around the entire pipe joint and such that point loads will not occur when the pipe is installed. Pipe used for pipe jacking shall be capable of withstanding all forces that will be imposed by the process of installation, as well as the final in-place loading conditions. Protect the driving ends of the pipe and joints against damage.

2.2 SLURRY

A. Slurry will be a mixture of water and bentonite clay. The fluid will be inert. The fluid should remain in the tunnel to ensure the stability of the tunnel, reduce drag on the jacked pipe, and provide backfill within the annulus of the pipe and tunnel.
B. Disposal of excess slurry and spoils will be the responsibility of the Contractor who must comply with all relevant regulations, right-of-way, workspace, and permit agreements. Excess slurry and spoils will be disposed at an approved location. The Contractor is responsible for transporting all excess slurry and spoils to the disposal site and paying any disposal costs. Excess slurry and spoils will be transported in a manner that prevents accidental spillage onto roadways. Excess slurry and spoils will not be discharged into sanitary or storm drain systems, ditches or waterways.

C. Mobile spoils removal equipment capable of quickly removing spoils from the machine face will be present during drilling operations to fulfill the requirements of item B. above.

D. The Contractor will be responsible for making provisions for a clean water supply for the mixing of the slurry.

2.3 GROUTING MATERIALS:

Prepare mixes that satisfy the required application. Materials used in grout mix shall meet the following standards:

A. Cementitious Material:

1. Portland Cement: ASTM C 150, Type II, unless the use of Type III is authorized by the Engineer; or ASTM C 595, Type IP. For concrete in contact with sewage use Type II cement.
2. When aggregates are potentially reactive with alkalis in cement, use cement not exceeding 0.6 percent alkali content in the form of Na2O + 0.658K20.

B. Water: Clean, free from harmful amounts of oils, acids, alkalis, or other deleterious substances, and meeting requirements of ASTM C 94.

C. Fine Aggregate: ASTM C 33. Determine the potential reactivity of fine aggregate in accordance with the Appendix to ASTM C 33.

D. Fluidifier: Use a fluidifier meeting ASTM C 937 that holds the solid constituents of the grout in colloidal suspension and is compatible with the cement and water used in the grouting operations.

E. Admixtures:

1. Use admixtures meeting ASTM C 494 and ASTM C 1017 as required, to improve pumpability, to control time of set, to hold sand in suspension and to reduce segregation and bleeding.
2. For cellular grout, do not use foam or admixtures that promote steel corrosion.
3. Ensure that admixtures used in a mix are compatible. Provide written confirmation from the admixture manufacturers of their compatibility.

F. Water Reducers: ASTM C 494, Type A.

1. Water Reducing Retarders: ASTM 494, Type D.
2. High Range Water Reducers (Superplasticizers): ASTM C 494, Types F and G.

G. Prohibited Admixtures: Admixtures containing calcium chloride, thiocyanate, or materials that contribute free chloride ions in excess of 0.1 percent by weight of cement.

H. Grout Type Applications.

1. Grout for pressure grouting and back grouting: Sand-cement mortar mix.
2. Grout for annular grouting: Low density (cellular) grout or sand-cement mortar mix.
3. Ground stabilization: Sand cement mortar mix.

I. Do not include toxic or poisonous substances in the grout mix or otherwise inject such substances underground.

J. Provide grout that meets the following minimum requirements:

1. Minimum 28-day unconfined compressive strength: 1000 psi for sand- cement mortar grout; 300 psi for cellular grout.
   a. Determine strength by ASTM C 942.

PART 3 - EXECUTION

3.1 CONSTRUCTION OPERATIONS CRITERIA

A. Use methods for microtunneling and pipe-jacked tunneling operations that will minimize ground settlement. Select a method which will control flow of water and prevent loss of soil into the tunnel and provide stability of the face under anticipated conditions.

B. The Pilot Tube Microtunneling system shall utilize a two or three phase system as described below:

1. Three Pass System
   a. Phase 1:

      A rigid steel pilot tube in approximately one-meter lengths shall be installed through the ground from the drive shaft to the receiver shaft by earth displacement with the jacking frame. The alignment of the pilot tube shall be established with a theodolite mounted at the rear of the drive shaft and accurately set to the desired line and grade. The theodolite shall view a lighted target in the lead or steering pilot tube. A camera shall be fitted to the theodolite and shall transmit the image of the crosshair and the target onto a monitor screen to be viewed in the drive shaft by the operator. As the operator

advances the pilot tube through the earth the center of the target will drift from the crosshair as a result of the biased or slanted leading tip of the pilot tube. The operator shall rotate the pilot tube as required to orient the slanted steering tip toward the crosshair and continue to advance the pilot tube until it reaches the receiver shaft.

b. Phase 2 :

An enlargement casing with an outside diameter up to 1 ½" larger than the product pipe shall be rigidly connected to the final pilot tube and advanced into the earth behind the pilot tube. An auger shall be used inside the enlargement casing to remove the material being excavated. The auger shall be contained inside the limits of the enlargement casing as it progresses along the proposed alignment. A train of temporary steel casings with an outside diameter very similar to the enlargement casing and used to move the enlargement casing from the drive shaft to the receiver shaft. The enlargement casing will cut a bore hole from the drive shaft to the receiver shaft and the temporary casings will case the hole as it is cut. Each temporary casing shall be fitted with an internal auger to transport the excavated material to the drive shaft where it shall be removed from the shaft and disposed of at an approved location. The pilot tubes shall be recovered in the receiver shaft as the temporary casings are installed.

c. Phase 3:

The product pipe shall then be installed directly behind the final temporary casing pipe with the jacking frame. The casing pipes and augers shall be recovered in the receiver shaft as the product pipe is installed.

2. Two Pass System

a. Phase 1:

The pilot tube shall be installed in the same manner described Phase 1 of the Three Pass System.

b. Phase 2:

The enlargement casing shall be installed in the same manner described in Phase 2 of the Three-Phase System. Each product pipe shall be fitted with an internal protective-casing pipe to house the auger and prevent damage to the product pipe. The product pipe shall be installed directly behind the enlargement casing with the internal casing rigidly connected to the auger chamber of the enlargement casing. The internal casing shall be manufactured such that the excavated material does not leak excessively into the product pipe. The internal casing shall be fitted with a protective shoe to protect the product pipe from damage and to support the casing and auger at the centerline of the pipe. The product pipe shall be advanced along the proposed alignment with the jacking frame thus progressing the enlargement casing from the drive shaft to the receiver shaft with the pilot tubes being recovered in the receiver shaft. The excavated material shall be funneled into and conveyed through the internal casing to the drive shaft where it shall be removed from the shaft and disposed of at an approved location. Upon reaching the receiver shaft the enlargement casing shall be removed and the internal casings and augers retracted and recovered at the drive shaft.

C. Conduct tunneling operations in accordance with applicable safety rules and regulations, OSHA standards and Contractor's safety plan. Use methods, which include due regard for safety of workmen, adjacent structures, utilities, and the public.

D. Maintain clean working conditions on the project site.

3.2 LOCATION OF TUNNEL SHAFTS:

A. The number of tunnel shafts shall be kept to a minimum and shall be typically sited at proposed manhole locations.

B. When shaft sites are indicated on the Contract Documents, the Contractor may alter locations of shaft sites as needed for construction operations. Relocation shall be subject to the Engineer’s approval.

C. Locate shafts and associated work areas to avoid blocking traffic, and to minimize disruption to Cemetery operations and visitors.

D. Locate shafts and associated work areas to avoid any major utility relocations. Any required utility relocations for shaft construction shall be coordinated by Contractor with the utility owner and are incidental to the work. Contractor shall include all costs associated with utility line conflicts (additional support, relocations, and coordination with utility) in their base bid.

E. The Contractor shall verify all existing utilities, pipelines, and structures in the project area, and take all precautions and measures to protect them during the installation, subsequent tunneling and backfilling of the shafts after completion of sanitary sewer installations. Relocation of any and all utilities for the construction of temporary shafts are considered incidental to shaft construction and shall be included in the Contractor's base bid.

F. Plan shaft locations to minimize interference with storm drainage channels, ditches, water mains, sanitary sewers, storm water sewers or culverts, which, if damaged, could result in ground washout or flooding of shafts and tunnels.

3.3 CONTROL OF GROUNDWATER

Provide groundwater control measures in conformance with Section 31 20 00, EARTH MOVING, when necessary to the work. Contractor shall maintain tunnel shafts in a dry condition so as to not cause project delays or additional stresses within the shaft.

3.4 EQUIPMENT:

A. Full directional guidance of a shield, TBM, or MTBM is a prerequisite of this method of construction.

B. The Contractor shall be responsible for selection of tunneling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils to be encountered.

C. The Contractor shall employ tunneling equipment that will be capable of handling the various anticipated ground conditions and is capable of minimizing loss of soil ahead of and around the machine and shall provide satisfactory support of the excavated face.

D. The TBM used for pipe-jacking shall conform to the shape of the tunnel with a uniform perimeter that is free of projections that could produce over- excavation or voids. An appropriately sized overcutting head may be provided to facilitate steering. In addition it shall:

1. Be capable of full face closure.

2. Be equipped with appropriate seals to prevent loss of bentonite lubricant.
3. Be capable of correcting roll by reverse drive or fins.
4. Be designed to handle adverse ground conditions including ground water inflow.
5. Be equipped with visual display to show the operator actual position of TBM relative to design reference.

E. If a hand shield is used for pipe-jacked tunneling (with or without attached mechanized excavating equipment), the shield must be capable of handling the various anticipated ground conditions. In addition, the shield shall:
1. Conform to the shape of the tunnel with a uniform perimeter that is free of projections that could produce over-excavation or voids. An appropriately sized overcutting head may be provided to facilitate steering.
2. Be designed to allow the face of the tunnel to be closed by use of gates or breasting boards without loss of ground.

F. In the case of MTBM, use a spoil transportation system which:
1. Either balances the soil and ground water pressures by the use of a slurry or earth pressure balance system; system shall be capable of adjustments required to maintain face stability for the particular soil condition and shall monitor and continuously balance the soil and ground water pressure to prevent loss of slurry or uncontrolled soil and ground water inflow, or, in the case of a slurry spoil transportation system:
   a. Provides pressure at the excavation face by use of the slurry pumps, pressure control valves, and a flow meter.
   b. Includes a slurry bypass unit in the system to allow the direction of flow to be changed and isolated, as necessary.
   c. Includes a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with sediment content within the limits required for successful tunneling can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
   d. Uses the type of separation process suited to the size of tunnel being constructed, the soil type being excavated,

and the workspace available at each work area for operating the plant.

e. Allows the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

2. In the case of a cased auger earth pressure balance system, the system shall be capable of adjustments required to maintain face stability for the particular soil condition to be encountered. Monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.

   a. In a cased auger spoil transportation system; manage the pressure at the excavation face by controlling the volume of spoil removal with respect to the advance rate. Monitor the speed of rotation of the auger flight, and the addition of water.

3. Provide an MTBM which includes a remote control system with the following features:

   a. Allows for operation of the system without the need for personnel to enter the tunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force, and cutter head torque; rate of advance and installed length.

   b. Integrates the system of excavation and removal of spoil and its simultaneous replacement by pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.

4. Provide an MTBM that includes an active direction control system with the following features:

   a. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference (e.g., by a laser beam transmitted from the jacking shaft along the pipe to a target mounted in the shield).

   b. Provides active steering information that shall be monitored and transmitted to the operating console.

c. Provides positioning and operation information to the operator on the control console.

5. Use generator which is suitably insulated for noise reduction in residential or commercial areas. Use of generator must be in accordance with City noise ordinance.

G. In the case of PTMT the following are minimum major components required:

1. Line and Grade Control System – The control system shall include but not be limited to a theodolite, lighted target, camera, and monitor screen. The equipment must be capable of installing the pipe to the desired line and grade with a tolerance described in Section 33 30 00.
2. Jacking Frame – The jacking frame shall possess adequate strength to advance the pilot tube, the enlargement casing and the string of product pipe from the drive shaft to the receiver shaft. The jacking force shall be easily regulated down to the safe working load rating of the pipe. The frame shall develop a uniform distribution of jacking forces on the end of the pipe. The auger motor shall possess adequate torque to steer the pilot tube and adequate torque and speed to effectively auger the excavated material from the face of the bore to the drive shaft.
3. Pilot Tube – The pilot tubes shall be constructed of steel in rigid but short sections to accommodate the small drive and receiver shafts. The tubes shall rigidly connect to each other, the steering tip and the enlargement casing and have a clear inside diameter large enough to adequately view the lighted target. The tubes shall withstand the torque encountered in the steering process.
4. Enlargement Casing – The enlargement casing shall be constructed of steel to a diameter just larger than the product pipe and have a leading connection compatible with the pilot tube. The leading face of the casing shall possess several large openings for the soil to enter as it advances along the proposed alignment. An internal auger chamber shall funnel the excavated material into the temporary full diameter casings of the Three-Phase Process or into the internal auger casings of the Two-Phase Process.

Structural members shall connect the leading edge of the casing to the pilot tube connections.

5. Soil Transportation System – The soil transportation system shall consist of an auger train operating inside the full diameter temporary steel casings of the Three-Phase System and an internal casing and auger train operating inside the product pipe. The internal casings of the Two-Phase Process shall be manufactured to minimize leakage of the excavated material into the product pipe.
6. Soil Removal – A soil removal system shall be provided to safely remove the excavated material from the drive shaft to the surface.
7. Hydraulic Power Unit – The hydraulic power unit shall rest on the surface and be connected to the jacking frame by hoses. The unit shall meet all applicable noise standards.
8. Lubrication System – A lubrication system shall be employed to minimize pipe friction to insure that pipe can be installed from the drive shaft to the receiver shaft within the safe working load rating of the pipe. The system may also be required to minimize the torque required to transport the excavated material to the drive shaft.

H. Provide a pipe jacking system with the following features:

1. Has the main jacks mounted in a jacking frame located in the starting shaft.
2. Has a jacking frame which successively pushes a string of connected pipes following the tunneling excavation equipment towards a receiving shaft.
3. Has sufficient jacking capacity to push the tunneling excavation equipment and the string of pipe through the ground. Incorporate intermediate jacking stations, if required.
4. Develops a uniform distribution of jacking forces on the end of the pipe by use of spreader rings and packing, measured by operating gauges.
5. Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.

I. Use thrust reactions for pipe jacking that are adequate to support the jacking pressure developed by the main jacking system. Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

J. Provide equipment to maintain proper air quality of manned tunnel operations during construction in accordance with OSHA requirements.

K. Enclose lighting fixtures in watertight enclosures with suitable guards. Provide separate circuits for lighting, and other equipment.

L. Electrical systems shall conform to requirements of National Electrical Code – NFPA 70.

3.5 PIPE-JACKED TUNNELING DATA

A. Maintain shift logs of construction events and observations. The Engineer shall have access to the Contractor's logs with regard to the following information:

1. Location of boring machine face or shield by station and progress of tunnel drive during shift.
2. Hours worked per shift on tunneling operations.
3. Completed field forms for checking line and grade of the tunneling operation, showing achieved tolerance relative to design alignment. Steering control logs will generally be acceptable.
4. Maximum pipe jacking pressures per drive.
5. Location, elevation and brief soil descriptions of soil strata.
6. Ground water control operations and piezometric levels.
7. Observation of any lost ground or other ground movement.
8. Any unusual conditions or events.
9. Reasons for operational shutdown in the event a drive is halted.

3.6 TUNNEL SHAFT CONSTRUCTION

A. Ground support systems shall be in accordance with the following:

1. Liner elements, bracing and shoring structural members shall be installed at the locations and in the method sequence and tolerances defined on shaft construction drawings as the excavation progresses.
2. The bracing and shoring shall be in contact with the liner to provide full support as shown in shaft construction drawings. Any modifications to liner, bracing and shoring shall be evaluated,

checked and approved by Contractor's Professional Engineer, and submitted to the Engineer.

3. A seal slab shall be installed as soon as final depth and stable bottom conditions have been reached and accepted by the Engineer. The seal slab shall be capable of withstanding the full piezometric pressure, either by pressure relief using under drains, or in the case of more permeable ground condition, by the use of a structural reinforced slab. In either case, the seal slab shall be constructed in accordance with the design provided by the Contractor’s Professional Engineer.
4. The entire shaft shall be designed and constructed to appropriate factors of safety against yield, deformation, or instability as determined by Contractor's Professional Engineer, and shall withstand a full hydrostatic head without failure.
5. Special framing, bracing or shoring required around tunnel "eyes" or other penetrations shall be in-place according to shaft construction drawings before the liner or any bracing or shoring at the penetration is cut or removed.
6. Conduct annular space grouting in accordance with Paragraph 3.8

B. Install suitable thrust or reaction blocks as required for pipe jacking equipment.

C. Provide drainage from shafts while work is in progress and until adjacent pipe joints have been sealed and the shaft is backfilled. Conform to the requirements with Section 31 23 19.

D. Divert surface water runoff and discharge from dewatering system away from the shaft. Protect the shafts from infiltration or flooding.

E. Each surface work site is to be surrounded by a security fence, which shall be secure at any time the site is unattended by Contractor’s personnel.

F. In addition to the above, the shaft, when not in use shall be protected by a second security fence at the perimeter of the shaft, or alternatively by a cover designed in accordance with Paragraph 1.6.

G. A shaft which is constructed more than 60 days in advance of its intended use shall be covered by a steel plate deck designed by the Contractor’s Professional Engineer, and the surface restored to permit full traffic flow during the time the shaft is not in use. All other Contractor’s material including portable concrete traffic barriers,

traffic control system, fencing and other materials and equipment must be removed from the site and reinstalled at the time the shaft is re-opened for use.

H. Backfill and compaction of the shaft shall be provided in accordance with Section 31 20 00, EARTH MOVING. Grouting of manhole or structure annular space in accordance with Paragraph 3.8, will be permitted in cases where insufficient workspace exists.

I. Remove the shaft liner above the level of 8 feet below ground surface, unless otherwise indicated on the Contract Documents. Maintain sufficient ground support to meet excavation safety requirements while removing the shaft structure.

3.7 EXCAVATION AND JACKING OF PIPE:

A. Tunnel Excavation

1. Keep tunnel excavation within the servitudes and rights-of-way indicated on the Contract Documents and to the lines and grades designated on the Contract Documents.
2. Perform tunneling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel. Prevent damage to structures and utilities above and in the vicinity of the tunneling operations.
3. Open-face excavations:
    a. Keep the face breasted or otherwise supported and prevent falls, excessive raveling, or erosion. Maintain standby face supports for immediate use when needed.
    b. During shut-down periods, support the face of the excavation by positive means; no support shall rely solely on hydraulic pressure.
4. Closed-face excavation:
    a. Carefully control volume of spoil removed. Advance rate and excavation rate to be compatible to avoid over excavation or loss of ground.
    b. When cutting head is withdrawn or is open for any purpose, keep excavated face supported and stabilized.
5. Excavated diameter should be a minimum size to permit pipe installation by jacking with allowance for bentonite injection into the annular space.

6. Whenever there is a condition encountered which could endanger the tunnel excavation or adjacent structures, operate without intermission including 24- hour working, weekends and holidays, until the condition no longer exists.
7. The Contractor shall be responsible for damage due to settlement from any construction-induced activities. Replacement of all damaged areas shall be the responsibility of the Contractor at no additional cost to the Owner.

B. Pipe Jacking

1. Cushion pipe joints as necessary to transmit the jacking forces without damage to the pipe or pipe joints.
2. Maintain an envelope of bentonite slurry around the exterior of the pipe during the jacking and excavation operation to reduce the exterior friction and possibility of the pipe seizing in place.
3. If the pipe seizes up in place and the Contractor elects to construct a recovery access shaft, approval must be obtained from the Engineer. Coordinate traffic control measures and utility adjustments as necessary prior to commencing work.
4. In the event a section of pipe is damaged during the jacking operation, or joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe. Any pipe damaged or misaligned shall be removed and replaced by the Contractor at no additional cost to the Owner.
5. Overcutting shall be remedied by grouting along the entire length of the installation.
6. All tunneled pipes 36-inches in diameter or larger shall have grout injection ports built into the pipe at the 12 o’clock position for pumping slurry during the pipe installation and for grouting the annular space once the tunneling is complete.

3.8 GROUTING

A. Preparation

1. Notify the Engineer at least 24 hours in advance of grouting operations.
2. Select and operate grouting equipment to avoid damage to new or existing underground utilities and structures.

3. In selection of grouting placement consider pipe flotation, length of pipe, length of tunnel, depth from surface, and type of sewer pipe, type of pipe blocking and bulkheading, grout volume and length of pipe to be grouted between bulkheads.
4. The Contractor is to ensure there is no water in the annular space between the carrier pipe and the tunnel liner prior to pumping the cellular grout into the annular space.
5. Operate any dewatering systems until the grouting operations are complete.

B. Equipment

1. Batch and mix grout in equipment of sufficient size and capacity to provide the necessary quality and quantity of grout for each placement stage.
2. Use equipment for grouting of a type and size generally used for the work, capable of mixing grout to a homogeneous consistency, and providing means of accurately measuring grout component quantities and accurately measuring pumping pressures. Use pressure grout equipment, which delivers grout to the injection point at a steady pressure.

C. Pressure Grouting for Jacked or Pulled Pipe

1. For jacked pipe 60 inches in diameter or greater, pressure grout the annulus after installation, displacing the bentonite lubrication. Jacked or pulled pipes less than 60- inch diameter may be left ungrouted unless the excavated diameter exceeds the external pipe diameter by more than one inch.
2. Inject grout through grout holes in the sewer pipe. Drilling holes from the surface or through the carrier pipe walls is not allowed. Perform grouting by injecting it at the pipe invert with bentonite displacement occurring through a high point tap or vent.
3. Control ground water as necessary to permit completion of grouting without separation of the grout materials.

D. Limit pressures to prevent damage or distortion to the pipe or to keep flexible pipe within acceptable tolerances.

1. Pump grout until material discharging is similar in consistency to that at point of injection.

E. Pressure Grouting for Shaft Liner:

1. If required, perform grouting operations to fill voids outside of the shaft liner.
2. For nonexpendable primary liners installed by hand mining or in shafts, grout once every 4 feet or more frequently if conditions dictate.
3. Control grout pressures so that shaft liner is not overstressed, and ground heave is avoided.
4. For liner requiring grout, perform back grouting once each shift, or more often if required to ensure that all voids are filled.

F. Ground Stabilization Grouting:

1. Completely fill voids outside the limits of excavation caused by caving or collapse of ground. Fill with gravity or pressure injected sand-cement grout as necessary to fill the void.
2. Take care in grouting operations to prevent damage to adjacent utilities or public or private property. Grout at a pressure that will not distort or imperil any portion of the work or existing installations or structures.
3. Verify that the void has been filled by volumetric comparisons and visual inspection. In the case of settlement under existing slabs, take cores as directed by the Engineer, at no additional cost to the Owner, to demonstrate that the void has been filled.

G. Field Quality Control:

1. Pressure Grouting for Shaft Liners. For each shaft, make one set of four compressive test specimens for each 30-foot depth and one set for any remaining portion less than a 30-foot increment.
2. Pressure Grouting for Jacked Pipe. Make one set of four compressive test specimens for every 400 feet of jacked pipe pressure grouting.
3. Pressure Grouting for Pulled Pipe. Make one set of four compressive test specimens for every 400 feet of pulled pipe pressure grouting.
4. Ground Stabilization Grouting. Make one set of four compressive test specimens for every location where ground stabilization grouting is performed.

3.9 CONTROL OF LINE AND GRADE:

A. Construction Control

1. Contractor shall check baselines and control points at the beginning of the Work and report any errors or discrepancies to the Engineer.
2. Use the baselines and control points indicated on the Contract Documents to establish and maintain construction control points, reference lines and grades for locating tunnel, sewer pipe, and structures. These control points are given to assist the Contractor and if deemed necessary the Contractor should establish additional control points or benchmarks in order to perform the work accurately.
3. Establish construction control points sufficiently far from the work so as not to be affected by ground movement caused by pipe-jacked tunneling operations.

B. Bench Mark Movement

The Contractor shall ensure that if settlement of the ground surface occurs during construction which affects the accuracy of the temporary benchmarks the Contractor shall detect and report such movement and reestablish temporary bench marks.

C. Line and Grade

1. Check and record the survey control for the tunnel against an above-ground undisturbed reference at least once for each 250 feet of tunnel constructed.
2. Record the exact position of the MTBM, TBM, PTMT or shield after each shove to ensure the alignment is within specified tolerances. Make immediate correction to alignment before allowable tolerances are exceeded.
3. When excavation is off line or grade, make alignment corrections to avoid reverse grades in gravity sewers. A belly in the tunnel which will hold water is not acceptable and shall be replaced at no additional cost to the Owner.
    a. The sewer pipe shall not vary more than plus or minus one inch (1) in elevation or plus or minus six inches (6) horizontally from the established line and grade (as shown on the Contract Documents) at any point between manholes,

including the receiving end. The installed pipe shall not hold water.

b. Pipe installed outside tolerances and subsequently abandoned shall first be fully grouted.

3.10 MONITORING

A. Instrumentation Monitoring. Instrumentation specified shall be accessible at all times to the Engineer. Readings shall be submitted promptly to the Engineer.

1. Install and maintain an instrumentation system to monitor and detect movement of the ground surface and adjacent structures. Establish vertical control points at a distance from the construction areas that avoids disturbance due to ground settlement.
2. Installation of the instrumentation shall not preclude the Engineer, through an independent contractor or consultant, from installing instrumentation in, on, near, or adjacent to the construction work. Access shall be provided to the work for such independent installations.
3. Instruments shall be installed in accordance with the Contract Documents and the manufacturer’s recommendations.
4. Monitoring locations given on the Contract Documents are not inclusive and are given to assist the Contractor. Additional locations may need to be established by the Contractor. The Contractor is responsible for all construction induced ground movement and the monitoring thereof.

B. Surface Settlement Monitoring

1. Establish monitoring points on all critical structures.
2. Minimum monitoring points are indicated on the Contract Documents.
3. Record location of settlement monitoring points with respect to construction baselines and elevations. Record elevations to an accuracy of 0.01 feet for each monitoring point location. Monitoring points should be established at locations and by methods that protect them from damage by construction operations, tampering, or other external influences.
4. Ground surface elevations shall be recorded on the centerline ahead of the tunneling operations at a minimum of 100-foot

intervals or at least three locations per tunnel drive. For sewers greater than 60-inch diameter, also record similar data at approximately 20 feet each side of the centerline. Settlement monitoring points must be clearly marked by studs or paint for ease of locating.

5. Monitoring points to measure ground elevation are required at a distance of 0 feet, 10 feet and 20 feet from the perimeter of the shaft on each of four radial lines, the radial lines being at 90 degrees to each other.
6. Railroads. Monitor ground settlement of track subbase at centerline of each track.
7. Utilities and Pipelines. Monitor ground settlement directly above and 10 feet before and after the utility or pipeline intersection.
8. Reading Frequency and Reporting. The Contractor shall submit to the Engineer, records of readings from the various instruments and survey points.
    a. Instrumentation monitoring results to be read at the frequency specified and unless otherwise specified, shall be started prior to the zone of active excavation reaching that point, and shall be continued until the zone of active excavation has passed and until no further detectable movement occurs.
    b. Surface settlement monitoring readings shall be taken:
        I. Prior to the zone of active excavation reaching that point,
        II. When the tunnel face reaches the monitoring point (in plan), and
        III. When the zone of active excavation has passed and no further movement is detected.
    c. All monitoring readings shall be submitted promptly to the Engineer.
    d. Immediately report to the Engineer any movement, cracking, or settlement which is detected.
    e. Following completion but prior to final acceptance, make a final survey of all monitoring points.

3.11 DISPOSAL OF EXCESS MATERIAL

Remove spoils in accordance with Section 31 20 00, EARTH MOVING and Section 02 45 00, DEMOLITION AND SITE CLEARING.

3.12 ACCEPTANCE TESTING

Acceptance testing and inspection is to be carried out by methods described in Section 33 30 00, SANITARY SEWERAGE UTILITIES.

3.13 SITE RESTORATION

All surfaces affected by the Work shall be restored to their preconstruction conditions. Performance criteria for restoration work will be similar to those employed in traditional open excavation work as described in Section 31 20 00, EARTH MOVING.

3.14 POST CONSTRUCTION EVALUATION

A. The Contractor shall provide a set of Field Record Drawings including both alignment and profile to the Engineer. Drawings should be developed from actual field readings. Raw data should be available for submission at any time upon request. As part of the Field Record Drawing, the Contractor shall specify the tracking equipment used, including method of confirmatory procedure used to ensure the data was captured. Field Record Drawings having survey data shall be stamped by a Professional Land Surveyor registered in the State of Missouri.

B. All fittings, valves, manholes, connections, etc., including all critical structure monitoring points as shown on Contract Documents, shall be located by GPS and based on the Missouri State Plane - East coordinate system as shown on Contract Documents and shall be provided on the Field Record Drawings. No landmarks shall be used. The record drawings shall be stamped by a Professional Land Surveyor registered in the State of Missouri.

3.15 FINAL CLEAN-UP

Remove all debris, rubbish and excess material from the site.

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