SP-120219
(New)

Iowa Department of Transportation

**SPECIAL PROVISIONS**
**FOR**
**PIPE JACKED SHIELDED TUNNELS**

**Pottawattamie County**
**IM-NHS-29-3(102)48--03-78**

**Effective Date**
**December 16, 2014**

**THE STANDARD SPECIFICATIONS, SERIES 2012, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.**

## 120219.01 GENERAL.

### A. Summary.

**1.** The construction method involves jacking pipe following a tunnel excavation operation using a tunneling shield. The pipe jacked in place may not serve as the final carrier pipe after completion of construction. This Specification is intended to be primarily functional in nature and to define in general terms the work to be accomplished.

**2.** The primary method for tunnel excavation addressed by this Section is by the use of a tunneling shield such that the Contractor has full direct access to the tunnel face. The shield must be capable of having a closed face in the event that the excavated tunnel face is running or is raveling at a rate that is faster than the Contractor can remove the material and advance the shield.

**3.** Contractor shall be responsible for the final constructed product, materials, and tools used, and for furnishing the labor and qualified superintendents necessary for the method of construction.

**4.** The Contractor must demonstrate that the chosen method will control flow of water, prevent loss of soil into the tunnel, provide stability of the face under anticipated conditions, and have the ability to fill all voids that develop around the pipe.

**5.** The Contractor shall furnish all items, including but not limited to, the shield with excavation equipment, spoil transportation systems, hoists, signal systems, ventilation safety equipment, and survey controls necessary to excavate and advance the tunnel by the selected method.

### B. Quality Assurance.

**1. Referenced Standards.**

The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by the abbreviation only.

**a.** American Railway Engineering Association (AREA):
Manual for Railway Engineering, applicable sections.

**b.** American Association of State Highway and Transportation Officials (AASHTO).

**c.** American Society for Testing and Materials (ASTM).

**1)** C76, Standard Specification.

**2)** A139, Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over).

**d.** Occupational Safety and Health Administration (OSHA).
Particular attention is called to Subpart S of the OSHA Standards (29 CFR 1926/1920), published as U. S. Department of Labor Publication 2207, Revised October 1, 1979. Second revision dated August 1, 1989. See Federal Register dated June 2, 1989 for revised standard and commentary.

**2.** All tunneling work shall be performed by an experienced Contractor or Contractors having at least 5 years of experience in performing pipe-jacked shielded tunneling and have completed at least three similar projects involving at least a 300 feet shielded tunnel having an excavated diameter of at least 72 inches on each project. The project superintendent shall have at least 5 years of experience supervising shield bored tunneling operations. The equipment operator(s) shall have technical training in the operation of the proposed pipe jacking and shield boring equipment and shall have completed, as a primary operator, at least three similar shield bored tunneling projects involving at least a 300 feet long installation having an excavated diameter of at least 72 inches on each project. The supervisor(s) shall be present on site at all times during shield bored tunneling operations. The supervisor shall be knowledgeable in all aspects of shield bored tunneling.

**3.** Contractor shall comply with all applicable laws, regulations, ordinances, and with the requirements of the applicable railroad, highway or street department, or other utilities that will be crossed.

**C. Definitions.**

**1.** Pipe-jacked tunnels shall be defined as a construction method by which the Contractor's pipe serves as initial construction lining and tunnel support, installed by the Contractor for stability and safety during construction. The pipe is of a diameter to permit access to the tunnel face at all times and to allow physical inspection of the installed pipe.

**2.** Tunneling Work Plan shall be defined as written descriptions, together with sketches, drawings, schedules, and other documents defining Contractor's plans and procedures for tunneling. "Contractor's construction drawings" shall be defined as drawings by which the Contractor proposes to furnish, construct, install and operate the referenced item. The submission of Tunneling Work Plans, including Contractor's drawings, shall be required for the sole purpose of providing the Engineer sufficient details to verify that the Contractor's planned work and work in progress is in accordance with the intent of the Project design and Specification requirements.

**D. Submittals.**

**1.** Submittals shall be made in accordance with the required submittal procedures. The Engineer will review submitted plans, details and data for compliance with the requirements of this Section. Such review shall not be construed to relieve the Contractor in any way of his responsibilities under the Contract. Contractor shall not commence work on any items requiring a Tunneling Work Plan or other submittals until the submittals have been reviewed by the Engineer. All structural designs and other engineered components shall be signed and sealed by a Professional Engineer registered in the State of Iowa.

**2.** Pipe Jacked Tunnel Operations.
- **a.** Submit for review a Tunneling Work Plan with complete Contractor's construction drawings and written description identifying details of the proposed method of construction and the sequence of operations to be performed during construction, as required by the method of tunneling. The drawings and descriptions shall be sufficiently detailed to demonstrate to the Engineer whether the proposed materials and procedures will meet the requirements of this Section.
- **b.** Depending on the Contractor's method of construction, the Tunneling Work Plan, including drawings, shall be submitted on the following items:
  - **1)** If the use of mechanized excavating equipment is proposed, Contractor shall submit arrangement drawings and technical specifications of the machine and associated equipment (including any modifications), experience record with this type of equipment, of Contractor experience and training records for the equipment operator, and a copy of the manufacturer's operation manual for the shield.
  - **2)** The Contractor may elect to use a tunnel shield that is separate from mechanized excavation equipment or for use with hand excavation. If the use of a separate tunnel shield is proposed, Contractor shall submit arrangement drawings, design criteria, dimensional data, and method of excavation and operation of the shield, including acceptable method for supporting, controlling, and closing face of heading.
  - **3)** Method of controlling line and grade of tunneling operation.
  - **4)** Method and details of spoil removal, including equipment type and numbers, surface storage, processing, and disposal.
  - **5)** Ventilation system, lighting layout, and electrical system.
  - **6)** Proposed contingency plans for critical phases and areas of tunneling.
  - **7)** Grouting techniques to be used for over excavation, if any, including equipment, pumping and injection procedures, pressure grout types, mixtures, and means to fill voids that develop around the casing during and after installation.
  - **8)** Details of the pipe jacking method and operation including jack setup, for jack thrust reaction bearing, and pipe lubrication system.
  - **9)** Details of method proposed to cushion and distribute jacking forces at pipe joints.
  - **10)** Plans for storage and handling of pipe.
  - **11)** Ground water control system per requirements in the Contract Documents.
- **c.** Submit for review, the layout and design of proposed tunnel work areas.
- **d.** The following specific submittals are required for the jacking pipe:
  - **1)** Design calculations for the proposed pipe.
  - **2)** Properties, definition of strength criteria, and properties required by the referenced design standards for the pipe and joints.
  - **3)** Casing pipe fabrication drawings, including joint details.
  - **4)** Details of the pipe and casing installation.
  - **5)** Test reports certifying that the pipe has been tested in accordance with and exceeds minimum specified requirements.

**3.** At least 30 days prior to the start of tunneling, the Contractor shall submit to the Engineer a description of the quality control methods proposed for tunneling operation. The submittal shall include:
- **a.** Supervisory control to ensure that work is performed in accordance with the contract documents, Tunneling Work Plan, and drawings.
- **b.** Procedures for surveying, controlling and checking line and grade, including field forms.
- **c.** Procedures for preparing and submitting daily logs of tunneling operations, including field forms.
- **d.** A plan for testing and submittal of test results to demonstrate compliance with the Specifications and Contractor's criteria for permanent products, materials, and installations. The plan shall identify all applicable standards and procedures for testing and acceptance.
- **e.** Monitoring Plan to meet the requirements of the Contract Documents:
  - **1)** Name of instrument installation Contractors.

**2)** Layout of instrumentation points.
**3)** Procedures forms and schedules for periodic submittals of readings.

**f.** Settlement Survey Plan, to meet the requirements of the Contract Documents. This plan may be submitted as a part of the Monitoring Plan.

**g.** Grouting techniques to be used for contact grouting of over excavation, if any, including equipment, pumping and injection procedures, pressure grout types, and mixtures.

**4.** The results of geotechnical and environmental investigations performed by Contractor as relevant to tunneling shall be included in the Tunneling Work Plan.

**5.** Procedures to meet all applicable OSHA requirements. These procedures shall be submitted for record purpose only and will not be subject to review or approval by the Engineer. As a minimum provide for:

**a.** Protection against soil instability and ground water inflow.
**b.** Safety for tunnel and shaft access and exit including ladders, stairs, walkways, and hoists.
**c.** Protection against mechanical and hydraulic equipment operations, and for lifting and hoisting equipment and material.
**d.** Ventilation, lighting, and communication system.
**e.** Monitoring for hazardous gases.
**f.** Protection against flooding, and means for emergency evacuation and self-rescue.
**g.** Protection of shaft including traffic barriers, accidental or unauthorized entry, and falling objects.
**h.** Emergency protection and self-rescue equipment.
**i.** Safety supervising responsibilities.

**E. Design Criteria.**

**1.** The determination shall take into account, as a minimum, any loading criteria; long-term earth and hydrostatic loads; construction loads, such as erection and jacking forces; loads from handling and storing; and space necessary to install permanent structures.

**2.** The criteria to be used at railroad crossings shall be Cooper E-80 locomotive loading distributions in accordance with AREA specifications for culverts. Account for additive loadings for multiple tracks in the design.

**3.** The criteria to be used for truck loading in all cases, except for railroad crossings, shall be HS-20 vehicle loading distributions in accordance with AASHTO.

**4.** 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.

**a.** Calculations shall be made to determine frictional forces and, if the TBM or shield is advanced by the pipe jacks, the face excavation forces.
**b.** The pipe jacking equipment installed must have a capacity at least 20 percent greater than the calculated maximum theoretical jacking load.
**c.** Number, location and capacity of any intermediate jacking stations.

**5.** The Contractor shall be responsible for selection of the appropriate pipe and pipe joints to carry the thrust of the jacks. Unless otherwise noted, any design indicated on the contract documents considers in-place loads only and does not take into account any construction loads.

**6.** Compatibility of Methods:

**a.** The methods of tunneling, pipe jacking, ground and ground water control shall be compatible.
**b.** The jacked pipe shall be designed to withstand the thrust from the shield and pipe

advance without damage or distortion. The propulsion jacks on the shield and at any intermediate jacking stations shall be configured so that the thrust is uniformly distributed and will not damage or distort the pipe.

**c.** The tunneling method shall be compatible with possible restrictions on the work such as influence on existing installations, or potential ground water contamination, if any.

**F. Job Conditions.**

**1. Safety Requirements.**

**a.** Perform work in a manner to maximize safety and avoid exposure of men and equipment to hazardous and potentially hazardous conditions, in accordance with applicable safety standards and Contractor's safety procedures.

**b.** Whenever there is an emergency or stoppage of work which may potentially endanger the tunnel excavation, adjacent structures, or other facilities such as roads and utilities, operate a full work force for 24 HRS a day, including weekends and holidays, without intermission until the emergency or potentially hazardous conditions no longer jeopardize the stability and safety of the Work.

**c.** Perform tunneling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel. Minimize subsidence of the surface. Prevent damage to structures and utilities above and in the vicinity of the tunneling operations.

**d.** Support the ground continuously in a manner to prevent loss of ground and keep the perimeters and faces of the tunnel and bottoms of the shafts stable.

**2. Surveillance of Headings.**

If Contractor is not able to close the face of the machine because of maintenance requirements, maintain qualified personnel on duty to observe conditions that might threaten the stability of the heading whenever tunnel excavation is suspended or shut down. Such personnel shall be equipped with an approved contingency plan to take appropriate action to prevent or limit damage should conditions which threaten the stability of the heading occur.

**3.** Conduct operations by methods and with equipment which will positively control dust, fumes, vapors, gases, or other atmospheric impurities in accordance with OSHA, Federal, State, and City requirements. Provide approved instrumentation for testing the quality of the air in tunnel and shaft work areas. Obtain samples under working conditions at prescribed intervals in accordance with the above-referenced requirements. Submit the results of the air quality tests to the Engineer each week.

## 120219.02 MATERIALS.

**A.** Steel casing pipe for direct jacking or tunneling installation shall be manufactured with integral grout ports with removable plugs that allow for the injection of bentonite lubricating fluid during jacking operations and for contact grouting of the pipe in its final location after installation. Grout ports and plugs shall be manufactured of a material resistant to corrosion in a sewer environment. Grout ports and plugs shall be located so that when installed, there will be one line of grout ports on each side of the pipeline and one at the crown; the lower line of grout ports on each side of the pipe shall be not more than 12 inches above the pipe invert. The grout ports in each line shall be not more than 8 feet apart and shall be staggered.

**B.** Contractor shall be responsible for increasing the casing pipe wall thickness as required to safely carry the loads imposed during construction, including jacking forces. Pipe shall have a minimum safety factor of 2.5 for all installation loadings, with calculations submitted by the Contractor to Engineer.

**C.** Pipe joints shall be flush with the outside pipe face when the pipes are assembled.

**D. Welded Smooth Steel Casing Pipe.**

1. All pipe shall be new material with a minimum yield stress of 35,000 psi.

2. All casing shall have machine-cut, beveled ends that are perpendicular to the longitudinal axis of the casing.

3. The minimum diameter and wall thickness shall be as indicated on the contract documents.

4. Contractor shall be responsible for increasing the casing pipe wall thickness as required to withstand all installation loadings and to increase the casing pipe diameter as required to facilitate carrier pipe installation and casing fill materials.

5. All joints shall be fully seal welded prior to installation of the casing.

6. Conform to ASTM A139, Grade B.

## 120219.03 CONSTRUCTION.

### A. Preparation.

1. The Contractor shall be responsible for means and methods of tunneling and pipe jacking operations and shall ensure the safety of the Work, the Contractor's employees, the public, and adjacent property, whether public or private.

2. Tunneling and pipe jacking operations shall be so executed that ground settlement or loss will be minimized. The completed casing pipe shall have full bearing against earth; no voids or pockets shall be left in any portion of the Work. Fill the peripheral space between the installed casing pipe and the ground with bentonite lubricating material during the jacking of the casing pipe into its final location. Contact grout all pipe jacked casing pipe. If loss of ground occurs, fill the resulting void with suitable material, such as grout, as accepted by the Engineer.

3. Maintain clean working conditions inside the tunnel excavation and jacking operation area and remove spoil, debris, equipment, and other material not required for operations.

4. For tunneling under railroad embankments, highways, or streets, perform the installation so as to prevent interference with the operation of the railroads, highways, or streets.

### B. Ground Water Control and Ground Stabilization.

1. The Contractor shall provide the necessary ground water control measures to perform the work and to provide safe working conditions. Contractor shall prevent excessive inflow of water into the excavation during construction of the tunnel. Contractor's ground water control method shall provide means to prevent piping of fines into shafts or tunnel and other adverse effects due to ground water inflow.

2. Portions of the excavation may be below the ground water table and in cohesionless soils, even if not indicated on the soil borings, and in conditions which may require a ground water control system for the tunneling operations. Use eductors, well pointing, deep well pumping, or other means to remove water and to achieve stable conditions. If dewatering is the sole means of ground water control, draw water level down below the elevation of the invert of the casing pipe.

3. Tunneling operations for which ground water control is necessary shall not proceed until monitoring data show that it is safe to do so.

4. The dewatering method used shall not cause damage to adjacent structures or property due

to lowering of the water table and subsequent ground settlement. Contractor's dewatering method shall provide means for controlling water inflows to prevent inflow of fines and other adverse effects due to ground water. In the event damage does occur, the Contractor shall be fully responsible for correction of damage and settlement of any claims arising from such damage.

**5.** Install and maintain an instrumentation system to monitor the water level and to detect any movement in adjacent structures and property. Monitor the water level by recording the initial water level before dewatering is started and thereafter on a weekly basis. Remove water monthly from the piezometers to demonstrate that they are operable. Submit weekly reports of the water levels to the Engineer. The Engineer will have access to the piezometers at all times to perform his own measurements.

**6.** If eductors, well points, or deep wells are used, space them adequately to provide the necessary ground water control. Sand packing and other means shall be used to prevent pumping of fine sands or silts from the subsurface and to minimize ground subsidence. Ensure that subsurface soil is not being removed by the dewatering operation or subsurface drainage into the shafts.

**7.** Keep sufficient pumping equipment and other machinery available at the site to assure that the operation of the dewatering system can be maintained.

**8.** The dewatering system shall remain in operation until the final carrier pipe is installed.

**C. Equipment.**

**1.** Any method or equipment which the Contractor can demonstrate, based on past experience, will produce the specified results for the ground conditions will be considered, provided it complies with all relevant requirements. However, the tunneling method used, whether hand or machine, shall have full-face closure capabilities.

**2.** No gasoline-powered equipment shall be permitted in the tunneling operation or shafts. Diesel, electrical, or air-powered equipment will be acceptable, subject to applicable Federal and State regulations. Diesel engines equipped with scrubbers are acceptable only when tunneling in free air, and with adequate ventilation.

**3. Tunnel Shield.**

The Contractor shall employ a shield that will be capable of handling the various anticipated ground conditions. In addition, the shield shall:

**a.** 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 bead or taper along the length of the shield may be provided to facilitate steering. The shield shall be continuous around its full perimeter; an open bottom shield is not acceptable. Although it is recognized that a capability to over excavate beyond the perimeter of the shield may be necessary under certain conditions, provisions to prevent accidental over excavation shall be provided.

**b.** Have a hood, poling or breasting plates, shelves and breast jacks, breast tables, and combinations of these and such other bracing as necessary to fully support the face of the tunnel excavation without loss of ground.

**c.** Depending upon Contractor's selected equipment, the shield shall conform to either of the following:

**1)** Have a propulsion system moving the shield in a forward direction, while maintaining the construction tolerances with respect to line and grade, without damage to previously-installed pipe. Design the propulsion system so that in the event of failure of any element of the system, there is no movement backward and there is no overstressing of the pipes.

**2)** Be moved forward by the pipe jacking equipment (see Article 120219.03, C, 4) while

maintaining the construction tolerances with respect to line and grade, with steering jacks in the shield.

**d.** Have survey controls showing the location of the shield in relation to the design references.

**e.** Have motor and controls protected against water inflow.

**f.** Incorporate a suitable seal between the shield and the leading pipe to prevent loss of bentonite.

**4. Pipe Jacking Equipment.**

Provide a tunneling operation which includes a pipe jacking system with the following features:

**a.** Has the main jacks mounted in a jacking frame located in the starting shaft.

**b.** Has a jacking frame which successively pushes a string of connected pipes following the tunneling excavation equipment toward a receiving shaft.

**c.** Has sufficient jacking capacity to push the tunneling excavation equipment and the string of pipe through the ground. Incorporates intermediate jacking stations, if required.

**d.** Has hydraulic cylinder extension rates which are synchronized with the excavation rate of the shield, as determined by the soil conditions, if advanced by the pipe jacks.

**e.** Develops a uniform distribution of jacking forces on the end of the pipe by use of spreader rings and packing, measured by operating gauges.

**f.** Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.

**5. Air Quality.**

**a.** Provide equipment to adequately ventilate the entire tunnel operation during construction.

**b.** Provide portable testing equipment for carbon monoxide gas, hydrogen sulfide gas, oxygen deficiency, and explosive gases.

**c.** Provide an audible automatic gas alarm to detect explosive gases. The alarm shall be located near the tunnel face.

**d.** Equip motors and controls with an automatic shutoff methane monitoring system.

**6.** Equip all electrical systems utilized on the shield with an appropriate ground fault system. Insulate electrical systems, and do not permit any bare-wire exposures.

**7.** Provide adequate lighting with lights at 50 feet, maximum. Enclose fixtures in watertight enclosures with suitable guards. Provide separate circuits for lighting, and other equipment.

**8.** Provide necessary safety devices for locomotives or cars used for personnel transport.

**9.** Uses generators which are suitably insulated for noise (“hospital” type) in developed areas.

**10.** Necessary equipment for tunnel excavation shall include signal systems, fire extinguishers, safety equipment, and other equipment required by the Contractor's method of construction. Maintain such equipment in good repair and have readily available at the place of work.

**D. Shafts.**

**1.** Contractor shall have sole responsibility to design tunneling shafts to suit his selected method of construction and equipment.

**2.** Use thrust blocks for pipe jacking that are properly designed and constructed. Position thrust blocks normal to the proposed pipe alignment. Use thrust blocks designed to support the maximum obtainable 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. If a concrete thrust block or treated soil zone is used, do not jack the shield until the concrete or other materials have attained the required strength.

**E. Excavation and Jacking of Pipe.**

**1. Tunnel Excavation.**

**a.** Conduct tunneling operations in accordance with applicable safety rules and regulations and use methods which include due regard for safety of workmen, adjacent structures, utilities, and the public.

**b.** Keep tunnel excavation within the easements and rights-of-way indicated on the contract documents, to the lines and grades designated on the contract documents. Methods of tunnel excavation are at the Contractor's option, subject to review by the Engineer.

**c.** Locate equipment powered by combustible fuels at suitable distances from shafts and protect equipment to prevent the possibility of explosion and fire in shafts or the sanitary sewer pipe.

**d.** During open-face excavation:

**1)** Excavate the face commencing at the crown and proceed down to the invert. Keep the hood buried in the soil ahead where soils include sands and silts. Excavate the heading so that both sides of the heading are excavated simultaneously.

**2)** Keep the face breasted or otherwise supported; employ other means as necessary to maintain face stability and prevent falls, excessive ravelling, or erosion. At all times maintain standby face supports to allow for immediate use when needed.

**3)** During shut-down periods, support the face of the excavation by positive means; no support shall rely solely on hydraulic pressure. In all cases when the face is untouched for more than 24 hours, fully breast the face and shove the shield tight against it.

**e.** During closed-face excavation:

**1)** Carefully control and monitor volume of spoil removed. Balance spoil removed with advance rate and excavation rate to avoid over excavation.

**2)** When cutting face is withdrawn for any purpose, keep excavated face stabilized by means necessary.

**f.** During forward movement of the shield, provide sufficient support at the excavation face to prevent loss of ground.

**g.** Make the excavation of a minimum size sufficient to permit pipe installation by jacking with allowance for bentonite injection into the annular space.

**h.** For jacking, 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.

**i.** Maintain an envelope of bentonite slurry, or other similar material, 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. Water jetting of the ground to advance the pipe shall not be permitted.

**j.** If the pipe seizes in place and the Contractor is unable to move it again, the Contractor shall be solely responsible for any remedial measures, obtaining approvals for such remedial measures, and shall be solely responsible for costs associated with the remedial measures required.

**k.** 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, use one of the following procedures to correct the damage, as directed by the Engineer.

**1)** Slightly damaged pipe which passes leakage test and maintains pipe barrel and joint structural integrity, may, if access is possible, be repaired in place with a method approved by the pipe supplier, and subject to review by the Engineer.

**2)** Severely damaged pipe, or pipe where structural pipe barrel or joint failure is evident, shall be removed from the excavation by jacking it through the excavation and removing it at receiving shaft, or by surface access, subject to review by the

Engineer.

**2. Grouting.**

**a.** Contact grout casing pipe after it is installed in its final location. Contact grouting shall completely fill voids outside the limits of the excavation created by caving or collapse of earth cover over the excavation.

**b.** Furnish and operate suitable equipment for any required grouting operations depending on the condition of the application.

**c.** Take care in grouting operations to prevent damage to adjacent utilities or other properties. Grout at a pressure that will not distort or imperil any portion of the work or existing installation or structures.

**F. Jacking Operation Data.**

Shift logs of construction events and observations shall be submitted within 24 hours of the operations on at least the following:

- Location of shield by station and progress of tunnel drive during shift.
- Hours worked per shift.
- Completed field forms for checking line and grade, with achieved tolerance relative to design alignment. Copies of steering control data will generally be acceptable.
- Maximum pipe jacking pressures per shove and rams used.
- Location, elevation and brief soil descriptions of significant soil strata.
- Ground water control operations and piezometric levels.
- Observation of lost ground or other ground movement.
- Indications of damaged pipe joint or pipe.
- Any unusual conditions or event.
- Operation shut-down periods or other interruptions in the work and reasons.

**G. Control of Line And Grade.**

**1. Construction Control.**

**a.** The baseline and benchmarks are indicated on the contract documents. Contractor shall check baseline and benchmarks at the beginning of the Work and report any errors or discrepancies to the Engineer.

**b.** The Contractor shall use the baseline and benchmarks to furnish and maintain reference control lines and grades for the casing and final carrier pipes construction. Use these lines and grades to establish the exact location of the tunnel excavation, casing and final carrier pipes, and structures.

**c.** The Contractor shall establish and be responsible for accuracy of control for the construction of the entire Project, including access shaft locations, structures, excavation, pipe alignment, and grade.

**d.** Establish control points sufficiently far from the tunnel operation not to be affected by ground movement.

**e.** Maintain daily surveying records of alignment and grade. Submit three copies of these records to Engineer within 24 hours of the operation. The Contractor, however, shall remain fully responsible for the accuracy of the work and the correction of it, as required.

**f.** Check the primary control for the excavation against an above-ground undisturbed reference at least once each week and once for each 50 feet of tunnel constructed, or more often as needed or directed by the Engineer.

**2. Earth Movement.**

**a.** The Contractor shall be responsible for damage due to settlement from any construction-induced activities.

**b.** Contractor shall take precautions to avoid damage or settlement to buildings, structures, roads, railroad tracks, and utilities in proximity to the work. Construction methods and equipment to minimize loss of earth at the excavation face and settlement of earth

around the casing pipe shall be used.

**c.** In the event any movement of ground is detected, before proceeding, the Contractor shall correct any problems causing or resulting from such movement.

**d.** The Contractor shall be aware that if settlement of the ground surface should occur during construction which will affect the accuracy of the temporary benchmarks, it shall be the Contractor's responsibility to detect and report such movement. Advise the Engineer of any settlement affecting the benchmarks. Upon completion, the field books pertaining to monitoring of the benchmarks shall be submitted to the Engineer.

**3. Line and Grade.**

**a.** Contractor shall continuously monitor the line and grade of the tunnel excavation using a laser in the jacking shaft and a target in the shield.

**b.** Record the exact position of the shield at each shove to ensure the alignment is within specified tolerances. Make the survey immediately behind the excavation face to allow immediate correction of misalignment before allowable tolerances are exceeded.

**c.** When excavation is off line or grade, make alignment corrections as required by the Engineer.

**d.** Perform a verification survey of the installed casing pipe from shaft to shaft after removal of the tunneling equipment. Document measured conformance to design line and grade of the pipe together with locations and deviation (distance and direction) of any out-of-tolerance locations.

**e.** Acceptance criteria for the casing pipe shall be ±6 inches in horizontal alignment from the theoretical at any point between manholes, including the receiving end, and ±2 inches in elevation from the theoretical.

**f.** If allowable tolerances are exceeded, the Contractor shall bear full responsibility and expense for correction (redesign, reconstruction, easement acquisition, etc.). If redesign of structures is required, the Contractor shall obtain the services of a Professional Engineer registered in the State of Iowa for the redesign. The installed pipe must be capable of meeting the purpose of the casing pipe as shown on the contract doucments. Plans showing the changes shall be submitted to the Engineer for review.

**g.** Casing pipe installed outside tolerances or which are outside of right-of-way or permanent easement shall be backfilled (grouted) and reconstructed to be within tolerances if directed by the Engineer.

## H. Tunnel Connections, Terminations, and Temporary Bulkheads.

**1.** Connect new tunnels to existing structures by removing existing bulkheads, if necessary, and sealing the junction as shown on contract documents.

**2.** Seal terminations of tunnels, which are not connected to permanent structures, by a temporary bulkhead.

**3.** Design temporary bulkheads where and when required. Provide bulkheads capable of resisting the lateral earth and hydrostatic pressures, waterproof, and capable of being removed without damaging the sanitary sewer pipe or plastic liner.

## I. Monitoring.

**1.** This establishes minimum instrumentation requirements for tunneling work. Additional instrumentation requirements for critical areas may be specified elsewhere in the Specifications or on the contract documents. The Contractor shall install a more extensive system at Contractor's expense, if required due to Contractor’s operations. The instrumentation specified shall be accessible at all times to the Engineer.

**a.** The Contractor shall submit for review, prior to construction, a Monitoring Plan including instrument installation design, instrumentation points location and layout, manufacturer's catalog literature, and installation reports formats.

**b.** Install and maintain a system of instrumentation to monitor the tunneling operation and to detect movement in the soil and adjacent structures. Instruments shall consist of no less than a sufficient number of inclinometers and crack monitors at bridge and adjacent structures and sufficient piezometers. Use monuments sufficiently removed from the construction to avoid errors in readings due to ground settlement.

**c.** Soil instruments such as piezometers, inclinometers, extensometers, and crack monitors shall be installed by a qualified Contractor specializing in geotechnical work.

**d.** Extensometers shall be installed to a depth of 5 feet above the crown of the tunnel to measure vertical movements in the soils during and subsequent to tunneling. The extensometer consists typically of a three-prong anchor, a 1/4 inch standard stainless steel inner pipe, and a 1 inch standard Schedule 80 PVC outer pipe. The pipes are assembled in sections and fastened together with standard couplings to the required anchor depths. The top of the extensometer shall be located within a flush-mounted handhole cover capable of withstanding H-20 truck loading. The geotechnical instrumentation installation Contractor shall provide procedures for installation of the extensometers as a part of the Monitoring Plan.

**2.** The Contractor shall submit for review prior to construction, a Building and Structures Assessment Plan. Preconstruction and post-construction assessment reports shall be provided for buildings and structures located within a distance equal to the depth of tunnel but at least 50 feet in plan from the proposed tunnel centerline and shafts. Photographs or a video of any existing damage to structures in the vicinity of the sanitary sewer alignment shall be included in the assessment reports.

**3.** This establishes minimum settlement survey requirements for structures and ground surface monitoring points.

**a.** Submit a settlement surveying and monitoring plan for review prior to construction. The plan shall identify the location of settlement monitoring points, reference benchmarks, survey schedules and procedures and reporting formats.

**b.** Locate survey points on all structures within a distance equal to the depth of the tunnel but at least 50 feet in plan from the tunnel centerline.

**c.** Record the horizontal coordinates and elevations (with an accuracy of 0.01 feet) for each survey point location. Reference survey points so that they may be accurately re-established if lost or destroyed.

**d.** Unless otherwise specified, record the ground surface elevations on the centerline ahead of the shield at a minimum of 100 feet intervals or at least three locations per tunnel drive. Record cross-sectional points on the centerline and 20 feet each side of the centerline of the tunnel. Starting 100 feet ahead of the shield and continuing until the shield is 100 feet beyond the measurement point or until no further movement is detected, unless otherwise directed by the Engineer.

**e.** Locate survey points at crossings under other installations as follows:

**1)** Roads: Centerline and each shoulder.

**2)** Railroads: Track subbase at centerline of each track.

**3)** Utilities and Pipelines: Directly above and 10 feet before and after the intersection.

**4.** Measure and maintain records of deformation of any non-rigid pipe at locations spaced no farther than 50 feet apart. The vertical and horizontal diameters shall be measured and reported.

**5. Reading Schedule and Reporting.**

**a.** The Contractor shall submit readings from the various instruments and survey points weekly to the Engineer. Readings shall be daily or as required by the Engineer when construction is approaching or near critical structures (structures, bridge piers, pipelines, etc., partially or entirely located within a distance equal to the depth of tunnel but at least 50 feet in plan from the tunnel centerline). Initial readings of surface points shall be taken before any excavation or construction is started.

**b.** Immediately report to the Engineer any movement, cracking, or settlement which is detected and take immediate remedial action. The Contractor shall be fully responsible for such damage to adjacent structures, pavements, or other improvements or installations.

**c.** At the end of construction (after the casing pipe is installed, contact grouted, and dewatering is discontinued), make a final survey of control points established for instrumentation and observation. The final readings shall be submitted to the Engineer. Make a visual inspection of structures adjacent to the casing pipe and report to the Engineer the condition of the structures, any damage incurred during construction, and corrective action taken.

**J. Disposal of Excess Material.**
Remove spoil from the job site and dispose in accordance with the contract documents.

**120219.04 METHOD OF MEASUREMENT.**
Trenchless Construction will not be measured for payment.

**120219.05 BASIS OF PAYMENT.**
All items of work contained in this section are incidental to the underground utility pipe being installed and will not be paid for separately.