



# DENVER

## THE MILE HIGH CITY

CITY AND COUNTY OF DENVER  
DEPARTMENT OF PUBLIC WORKS | ENGINEERING DIVISION

## Storm Drainage and Sanitary Sewer Construction Detail and Technical Specifications

---

### 7.2 Micro Tunneling

#### 7.2.1 General

Where indicated on the Drawings, or where field conditions dictate that open trenching for the pipeline across railroad tracks, highways, or other obstructions is prohibited, the pipe shall be installed by jacking, tunneling, boring and casing methods, or micro tunneling.

Should the General Contractor, in the process of Project construction, elect to propose that a portion of the pipe be installed by micro tunneling, rather than by jacking, boring or trenching operations, the subject cost shall not total more than the aggregate sum of the removal and replacement costs that such an activity would replace.

#### 7.2.2 Shop Drawings

Detailed shop drawings will be required for all pipe jacking, tunneling and boring installations.

#### 7.2.3 Construction

Work specified in this Section describes the construction of sanitary sewers by jacking fiberglass reinforced polymer mortar (RPM) behind a remotely operated, steerable, micro-tunneling boring machine (MTBM), with RPM serving as both the primary tunnel liner during construction and sanitary sewer pipe (secondary tunnel liner) after completion of construction. The General Contractor shall select and utilize methods and equipment compatible with the selected dimensions of the tunnel and with the anticipated geologic conditions described in the Geotechnical Report (GR).

The micro-tunneling boring machine (MTBM) may be either of the following:

**1. Slurry Shield**

An MTBM in which the tendency of soil at the excavation face to run or flow uncontrollably into the MTBM is prevented by the counterbalancing force of bentonite slurry contained at the face of the MTBM. During boring, the excavated material is mixed with the bentonite slurry and pumped through a pipe for disposal.

**2. Earth Pressure-Balance Shield**

An MTBM in which the tendency of the soil at the excavation face to run or flow uncontrollably into the MTBM is prevented by the counterbalancing force of the excavated material which is contained, under pressure, at the face of the MTBM. During boring, the excavated material is mixed with water or bentonite slurry and pumped through a pipe for disposal or by a balanced screw auger or screw conveyor system.

During tunneling and construction operations, the following shall be followed:

- a. Control groundwater in accordance with specified requirements during all micro-tunnel excavation.
- b. Perform micro-tunneling operations in a manner that will minimize loss of ground and minimize settlement of the ground surface, structures, and utilities above and adjacent to the tunnel.
- c. The General Contractor shall perform pre-construction and post-construction surveys of all structures, residences, and other facilities adjacent to the areas of the tunnel.
- d. Maintain clean working conditions at all times inside the tunnel and pits. All muck, slush, grout spills, ponded water, and any other material not required for tunneling shall be removed from the excavations in a timely manner.
- e. All work of excavating, lining, grouting and construction of the jacking operation shall be so executed that ground settlement or loss will be minimized; the completed sewer pipe shall have full bearing against earth, and no voids or pockets will be left in any portion of the Work. The peripheral space between the support elements and the excavated surface (i.e., the diameter of the excavated hole is no larger in diameter than 3/4 inch more than the pipe outside diameter) shall be filled with the bentonite lubricating material. If the diameter of the excavated hole is greater than 3/4 inch more than the outside diameter of the pipe, it shall be promptly filled with suitable material, such as grout, as accepted by the Project Construction Engineer. This may require jacking or the pipe be discontinued and additional access pits installed at no extra cost to the City.
- f. The General Contractor shall be aware that various existing soil borings, piezometers or instrument wells coincide with the proposed sewer pipe alignment. These may or may not have been backfilled with grout and therefore caution should be used in

tunneling through these existing borings. General Contractor shall take mitigating measures at no additional cost to the CITY to counter any effect these bore holes, piezometers or instrument wells may have on tunneling operations.

- g. All excavations shall remain within the easements and rights of way indicated on the Drawings, to the lines and grades designated on the Drawings, and use methods which include due regard for safety of workmen, adjacent structures, utilities, and the public. Methods of excavation shall be at the General Contractor's option, subject to the review of the Project Construction Engineer. Shape the excavation to fit the sewer pipe section and of sufficient size to allow the construction of the sewer pipe to the lines and grades indicated on the Drawings.

### **7.2.3.1 Casing Pipe Installation Method**

The General Contractor shall have the option to select the method of micro-tunneled casing pipe installation, subject to approval by the Project Construction Engineer.

The excavated size of the tunnel shall be determined by the General Contractor based on construction requirements for the secondary lining system, and is subject to the limitations shown on the Drawings.

### **7.2.4 References**

All work shall be performed in accordance with applicable regulations of all federal, state, and local regulations, codes, and standards.

### **7.2.5 Existing Conditions**

#### **7.2.5.1 Restrictions**

The General Contractor shall comply with all restrictions set as conditions under which the easement or permission was granted to the Owner to perform the work of this Contract. These restrictions are included with these Specifications. The General Contractor is presumed to have fully determined all special requirements that pertain to each length of sewer in tunnel constructed under this Section.

#### **7.2.5.2 Preliminary Inspections**

The General Contractor shall inspect the locations where the access pits and tunnels are to be built to familiarize himself with the conditions under which the Work will be performed and with all necessary detail as to the orderly prosecution of the work in conformance with Instructions for Bidders. The omission of any details necessary for the satisfactory prosecution of the WORK in its entirety, which may not appear herein, shall not relieve the General Contractor of his full responsibility.

#### **7.2.5.3 Soil, Rock and Groundwater**

The General Contractor acknowledges that certain soils reports, borings, and other Geotechnical data, more particularly described or referenced in the Technical Specifications of the Contract, have been made available for inspection and review. The borings were made

for the use of the City in the design of the Project and are not intended to be interpreted for use in temporary construction facilities designed by the General Contractor.

#### **7.2.5.4 Utilities**

The General Contractor shall be responsible for the protection of all utilities encountered during the Work of this Contract. The known utilities are shown on the Contract Drawings and the General Contractor shall take every precaution when working near the utility to locate and protect these utilities. All damage to the existing utilities shall be the sole responsibility of the General Contractor. The General Contractor shall replace, repair, remedy, or compensate for all damages at no additional cost to the Owner.

#### **7.2.5.5 Structures**

The General Contractor shall be responsible for the protection of all structures, roads and railroads above or adjacent to the tunnel, within the framework and criteria set forth in the Contract Documents.

### **7.2.6 Definitions**

#### **1. Micro Tunneling**

Shall be defined as a method of installing pipe, by jacking the pipe behind a remotely controlled, steerable, guided articulated Micro-Tunneling Boring Machine (MTBM). The MTBM, which is connected to and followed by the pipe being installed, shall ensure that the soils being excavated are fully controlled at all times.

#### **2. Jacked Pipe**

Shall be defined as the General Contractor's sewer pipe that serves as initial construction lining and tunnel support, installed by the General Contractor for stability and safety during construction, and as the sewer line or permanent secondary liner.

#### **3. Jacking System**

A system of jacks which pushes the sewer pipe. Capacity of jacks and extension rate is synchronized with excavation rate of the machine.

#### **4. Intermediate Jacking Station**

Hydraulic jacks installed at intermediate locations in the pipe string to allow selective shoving of discrete segments of the total pipe.

#### **5. Slurry System**

Transportation of excavated material in slurry flow matched to excavation rate. System balances groundwater pressures and separates soil from slurry at end of process. Soil separation methods are not limited to mechanical means. Soil separation method may be chemical in nature.

#### **6. Laser**

An optical system projecting a beam to a target to provide guidance for the micro-tunnel excavation.

## **7. TV**

A television system which monitors the progress and alignment of the micro-tunneling machine and pipe.

## **8. Controls**

The system which synchronizes excavation, removal of the excavated material, and jacking of pipe to maintain overall balance to provide complete and adequate ground support at all times.

### **7.2.7 Quality Assurance**

#### **7.2.7.1 General Contractor**

The General Contractor must provide proof of successful experience with micro tunnel excavation and support at the depths shown, in the soil and groundwater conditions expected, with the lining systems shown and with the General Contractor's proposed equipment.

#### **7.2.7.2 Project Superintendent**

The project superintendent shall have at least five years of tunneling experience and shall have worked on at least two micro-tunneling projects in similar ground conditions using equipment similar to the equipment required for this project. The machine operator shall have at least three years of micro-tunneling experience and shall have worked on at least one tunnel project using the same equipment required for this project.

### **7.2.8 Quality Control**

General Contractor shall establish and maintain quality control for operations under this Section to assure compliance with contract requirements and maintain records of his quality control for materials, equipment, and construction operations including but not limited to the following:

#### **7.2.8.1 Preparatory Inspection**

Preparatory inspection shall be conducted prior to commencing work and should include the following as a minimum requirement:

1. Check pipe for conformance to approved certified tests.
2. Check pipe for proper storage and handling.
3. Discuss and review pipe installation procedure with the Project Construction Engineer. Discussion shall include placement of pipe, joint preparation and application of each pipe used.

#### **7.2.8.2 Initial Inspection**

Initial inspection shall be conducted after a representative sample of the work is complete and should include the following as a minimum requirement.

1. Check for proper depth and grade for pipe.

2. Check method of joining pipes.
3. Check the pipe for proper alignment.

### **7.2.9 Tolerances**

Excavation and jacking of the sewer pipe shall be controlled by the General Contractor to allow construction of the sewer to a true circular shape and to within 1.5 inches on line and 1 inch on grade. Variations from line and grade tolerances listed herein may be allowed provided the line and grade variation is regular and only in one direction, and that the final grade of flow line is in the direction indicated on the Drawings. When the excavation is off line and grade, the General Contractor shall make corrections to plan line and grade at the rate of 3 inches per 100 feet.

The General Contractor shall survey the sewer at 50-foot intervals or a minimum of once per tunnel drive to ensure the alignment is within the tolerances specified. The survey shall be conducted immediately behind the tunnel excavation to allow immediate correction of misalignment. Tunnel excavation shall not precede surveyed verification of the alignment by more than 100 feet, or more frequently if line and grade tolerances have been exceeded. The tunnel guidance system may be used; however, the General Contractor shall select times to measure and record this information after the air temperatures have stabilized throughout the pipe to ensure accurate readings.

If the General Contractor is unable to maintain these tolerances, he shall bear full responsibility and expense for correction (redesign, easement acquisition, etc.) If these tolerances are exceeded and redesign of structures is required, the General Contractor shall obtain the services of an independent professional engineer registered in the State of Colorado for the redesign. Plans showing the changes shall be submitted to the Project Construction Engineer for review.

### **7.2.10 General Contractor Submittals**

The Project Construction Engineer will base the review of submitted details and data with consideration of requirements for the completed work, utilities, and the possibility of unnecessary details in the execution of the work to be constructed under this Contract. Review of the General Contractor submittals by the Project Construction Engineer shall not be construed in any way as relieving the General Contractor of his responsibilities under this Contract.

The General Contractor shall submit the following to the Project Construction Engineer for approval and/or examination:

#### **1. Working Drawings**

Complete working drawings showing details of the proposed method of construction and the sequence of operations to be performed during construction shall be submitted. Working drawings shall show the method of micro-tunneling, including the micro-tunneling system to be used, location of access pits including method of excavation, shoring and bracing appurtenance installation, and dewatering techniques that are

proposed to be used. The following shall be included as the minimum level of detail required:

- a. A detailed description of the micro tunneling procedure including construction techniques to provide the access required to install pipe in conformance with the Contract Documents.
- b. Manufacturer's literature describing in detail the micro-tunneling system to be used. Detailed description of projects on which this system has been successfully used including the names, addresses and telephone numbers of owner's representatives for these projects as well as length, diameter, and pipe material used.
- c. Calculations and drawings indicating limits of access pits and any ground support to be utilized.
- d. Method of spoils disposal.
- e. A groundwater stabilization scheme covering the excavations for starter and receiver pits. Verify this plan to stabilize anticipated unstable soil conditions. Such verification shall include all calculations and detail drawings for methods of controlling groundwater.
- f. Certification by the machine manufacturer of the thrust, torque, condition, and operational characteristics of all equipment to be used for installing the specified pipes. The micro-tunneling equipment shall employ a spoil removal system with a pressure balance system that is capable of equalizing pressures between the tunnel face and the micro-tunneling machine head in order to prevent caving beyond the outside diameters of the pipe.
- g. Layout of tunneling and ancillary equipment at each jacking and receiving (access) pit location.
- h. Tunnel machine shop drawings including configuration of cutter head and over cut.
- i. Ventilation system details.
- j. Pipe lubrication system details.
- k. Electrical system and lighting details.
- l. Grade and alignment control system details.
- m. Tunneling machine groundwater control provisions.
- n. Gas monitoring system.
- o. Details of mucking system and soil separation methods including proposed slurry formulations and calculations of the system capacity to handle flows at all distances and changes of elevation to and from the tunnel machine.
- p. Details of jacking system, intermediate jacking stations and their proposed spacing, method of operation, and thrust capacity. Include calculations of anticipated jacking forces required to advance the pipe. Include sleeve details and supporting gasket compression calculations for joints and gaskets used with intermediate jacking

- stations. Describe controls to prevent the maximum jacking force from being exceeded.
- q. Details of grouting the annulus space after pipe has been installed including injection pressure and method of controlling grout pressures.
  - r. Grouting techniques to be used for over excavation if any, including equipment, pumping procedures, pressure grout types and mixtures.
  - s. Procedures for measuring excavation quantities versus forward progress during the tunneling operation.
  - t. Calculations demonstrating that the pipe selected has been designed to support the maximum anticipated earth loads and superimposed live loads, both static and dynamic, which may be imposed on the pipe. Determine the additional stresses imposed on the pipe during jacking operations and upgrade the quality and strength of the pipe and pipe joints to the extent necessary to withstand the additional stresses imposed by the jacking operation. The details shall be submitted for approval.
  - u. Complete information on General Contractor's safety plan for personnel conducting the micro-tunneling operations and appurtenance installation. The plan shall include provisions for lighting, ventilation, and electrical safeguards.
  - v. Keep and maintain at the construction site a complete set of field drawings for recording as-built conditions. It shall have marked or noted thereon all field information, properly dated, recording as-built conditions. This set of field drawings shall be kept up to date.
  - w. Pipe certification of compliance.
  - x. Pipe jointing methods and details.
  - y. All General Contractor submittals requiring structural design shall be signed by a professional civil or structural engineer registered in the State of Colorado.
  - z. Written documentation summarizing the qualifications of the project superintendent, machine operators, and site safety representative.

## 2. Log of the Jacking Operations

The General Contractor shall submit a log of jacking operations; the log shall be taken at intervals of no more than 10 minutes apart and a minimum of four readings per pushed 10 foot and accomplished by a VHS video recording of the TV image at the operator's console. Video shall show a real-time clock that matches the time scale used in the log. Indicators in the tunneling machine being viewed by the VHS recorder shall indicate when the tunneling machine is excavating and the number of the pipe joint that is being pushed. The log shall be submitted to the Project Construction Engineer each day. The videotape shall be submitted to the Project Construction Engineer each week. As a minimum, the log shall consist of the following:

- a. The position of the tunneling machine in relation to the design line and grade.

- b. The jacking forces exerted on the pipe at each jacking station.
- c. The date, the starting time, and the finish time.
- d. The position of the steering jacks.
- e. Inclination.
- f. Cutter head torque.
- g. Slurry flow rates in both the supply and return lines (if slurry is used).
- h. Face pressure.
- i. Hydraulic pressure (on hydraulic motor machines).
- j. LEL gas readings.

### **3. Pipe Lubricant**

Submit a separate log tracking pipe lubricant used in gallons, its viscosity, and pumping pressure. Log shall be submitted to the Project Construction Engineer each day

### **4. Muck Removal**

Submit a separate log tracking the volume of muck removed from the site. Log shall be submitted to the Project Construction Engineer each day.

### **5. Survey Records**

Submit survey records of the horizontal and vertical positions of surface control points and other instrumentation within 24 hours of measurements as required herein.”

### **6. Inclinometer Data**

Inclinometer data shall be plotted on a cumulative time-deflection plot, using commercial software from the manufacturer, with past readings shown together with most current so that trends can easily and quickly be established by the Project Construction Engineer and General Contractor.

## **7.2.11 Products**

### **7.2.11.1 Equipment**

No gasoline powered equipment shall be permitted in the tunnel operation. 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 jacking in free air. Provide compressed air and electricity for General Contractor’s operations from a source outside the pipe.

#### **1. Micro Tunnel Boring Machine (MTBM)**

The General Contractor shall employ MTBM that is capable of handling the various anticipated ground conditions. In addition, the MTBM shall:

- a. Have a “closed” face which is capable of minimizing loss of ground ahead of and around the machine and providing satisfactory support of the excavated face at all

- times and shall have the capability of setting a calculated earth balancing pressure and positively measuring the earth pressure at the face.
- b. Provide a system to indicate whether the amount of earth material removed is equivalent to that displaced by the advance of the machine such that the advance rate may be controlled accordingly.
  - c. Conform to the shape of the tunnel with a uniform perimeter that is free of projections that could produce over excavation or voids.
  - d. Be articulated to enable remote steering of the system.
  - e. Have a display available to the operator, at an 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 and valve positions.
  - f. Incorporate a seal in the tail of each MTBM shield to prevent leakage of lubricating liquid or grout, into the tunnel space, between the MTBM shield and lining.
  - g. Have a cutter head powered by electric or hydraulic motors and have motors and operating controls protected against water inflows.
  - h. Provide a bi-directional drive on the cutter head wheel.
  - i. Provide means for maintaining the tunnel face under wet and adverse soil conditions. Use closure doors on the cutter wheel or other means acceptable to the Project Construction Engineer.

## **2. Automated Spoil Transportation**

The General Contractor shall provide a MTBM which includes an automated spoil transportation system which shall:

- a. Match the excavation rate to the rate of spoil removal thereby maintaining settlement or heave within tolerances specified.
- b. Balance ground water pressures by the use of a slurry pressure balance system which shall be capable of any adjustment required to maintain face stability for the particular soil condition encountered on the Project and shall monitor and continuously balance the ground water pressure to prevent loss of slurry and or ground water.
  - In a slurry spoil transportation system the ground water pressure shall be managed by use of the slurry pumps, pressure control valves, and a flow meter.
  - A slurry bypass unit shall be included in the system to allow the direction of flow to be changed and isolated, as necessary.
  - A separation process shall be provided when using the slurry transportation system which shall be designed to provide adequate separation of the spoil

- from the slurry so that the clean slurry can be returned to the cutting face for reuse. Spoil shall be appropriately contained at the site prior to disposal.
- The type of separation process used shall be dependent upon the size of the tunnel being constructed, the soil type being excavated, and the work space available at each work area for erecting the plant.
  - The composition of the slurry shall be carefully monitored for specific gravity and viscosity.
- c. Balance ground water pressures by the use of an auger earth pressure balance system which shall be capable of any adjustment required to maintain face stability for the particular soil condition to be encountered on the Project and shall monitor and continuously balance the ground water pressure to prevent loss of ground water.
- If an auger spoil transportation system is utilized, the ground water pressures shall be managed by controlling the volume of spoil removal with respect to the advance rate (Earth Pressure Balance Method) and the application of compressed air. The speed of rotation of the auger flight, the addition of water, and/or compressed air shall be monitored.
  - The Project Construction Engineer's approval will be required where an auger soil transportation system is proposed for use by the General Contractor in the presence of ground water. Such approval will be based on an evaluation of the equipment's ability to balance soil and water pressures at the face, stability of the soils, and the significance of the ground water present.

### 3. Pipe Jacking Equipment

The General Contractor shall provide a MTBM which includes a pipe jacking system which shall:

- a. Have the main jacks mounted in a jacking frame located in the starting pit.
- b. Have a jacking frame which shall successively push the MTBM along with a string of connected pipes toward a receiving pit.
- c. Have sufficient jacking capacity to push the MTBM and the string of pipe through the ground.
  - Calculations shall be made to determine the face excavation forces, frictional factor, and weight of the MTBM and pipes.
  - The jacking equipment installed must have a capacity at least 20 percent greater than the calculated theoretical jacking load.
- d. Have hydraulic cylinder extension rates which are synchronized with the excavation rate of the MTBM, which shall be determined by the soil conditions.
- e. Have intermediate jacking stations which shall be provided when the calculation of the total jacking force needed to complete the installation exceeds 80 percent of the

- capacity of the main jacks or the designed working compressive loads (including safety factor) allowed for the pipe.
- f. Develop a uniform distribution of jacking forces on the end of the pipe by use of spreader rings and packing.
  - g. Provide for a pipe lubrication system which shall be used if the calculated jacking forces are expected to exceed the pipe design strength (including the 2.5 to 1 safety factor) or if the actual jacking forces encountered exceed 80 percent of the pipe design strength (including the 2.5 to 1 safety factor). Should either of these conditions occur, an approved lubricant shall be injected to lower the friction developed on the surface of the pipe during jacking.

#### **4. Remote Control System**

The General Contractor shall provide a MTBM which includes a remote control system which shall:

- a. Allow for the operation of the system without the need for personnel to enter the micro-tunnel. In man entry sized pipes, intermittent entry of personnel will be permitted for maintenance and removal of equipment once the pipe installation is complete, provided that all safety precautions specified elsewhere and required by law are in place and functional.
- b. Integrate the system of excavation and removal of soil 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.
- c. Provide complete and adequate ground support at all times.

#### **5. Active Direction Control**

The General Contractor shall provide a MTBM which includes an active direction control system which shall:

- a. Control 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 pit along the center line of the pipe to a target mounted in the shield).
- b. Be capable of maintaining grade to within plus or minus one inch and line to within plus or minus 1.5 inches.
- c. Provide active steering information which shall be monitored and transmitted to the operation console.
- d. Provide minimum steering information available to the operator on the control console which includes the position relative to the reference, role, inclination, attitude, rate of advance, installed length, thrust force, and cutter head torque.

## **6. Ventilation and Monitoring**

Equipment shall be provided to adequately ventilate the entire micro-tunneling operation at all times during construction.

- a. Portable testing equipment shall be provided for carbon monoxide gas, hydrogen sulfide gas, oxygen deficiency and explosive gases.
- b. An automatic gas alarm to detect explosive gases shall be provided on the Micro-Tunnel Boring Machine. The audible alarm shall be located in the jacking pit and shall be active at all times.

## **7. Electrical Systems**

All electrical systems utilized on the Micro-Tunnel Boring Machine shall be equipped with appropriate ground fault systems. All electrical systems are to be insulated, not permitting any bare wire exposures. Motors and controls shall be equipped with an automatic shutoff such as MSA Methane Monitoring System VI or equal.

## **8. Additional Safety Equipment**

Necessary equipment for tunnel excavation shall include signal systems, fire extinguishers, safety equipment, and other equipment required by the General Contractor's method of construction. Such equipment shall be maintained in good repair.

### **7.2.11.2 Jacked Pipe**

Pipe for jacking shall be designed to carry all jacking loads. Refer to individual pipe specification sections.

### **7.2.11.3 Pipe Joints**

The outside walls shall be straight without bell modifications. All joints shall be watertight.

### **7.2.12 Design**

The General Contractor shall be responsible for the design of the fiberglass reinforced polymer mortar pipe to carry the loads imposed on it during construction, including the jacking forces.

### **7.2.13 Excavation**

#### **7.2.13.1 General Tunnel Requirements**

Tunnel excavation shall not begin until:

- a. The work Plan and all required submittals have been submitted by the General Contractor and reviewed and returned approved by the Project Construction Engineer.
- b. The required Pre-Construction Surveys have been completed.

- c. All instrumentation along the tunnel alignment is in place, stable, and baselines have been established.
- d. All pre-job safety meetings required by OSHA and/or General Contractor's Safety Plan have been held.

#### **7.2.14 Micro-Tunneling**

The General Contractor shall conduct all micro-tunneling operations in accordance with all applicable safety rules and regulations. The following shall apply to micro tunneling operations:

1. No work shall commence until the design and construction procedure has been approved in writing by the Project Construction Engineer. The General Contractor is totally responsible for the performance of the equipment and methods selected for this phase. The Project Construction Engineer's approval signifies only that the construction process is compatible with the overall objectives of the project.
2. The pipe used for jacking shall be round, have a smooth, even outer surface, and have joints that allow for easy connections between pipes. Pipe ends shall be square and smooth so that jacking loads are evenly distributed around the entire pipe joint and such that point loads will not occur when the pipe is jacked in a reasonably straight alignment. Pipe used for 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. The driving ends of the pipe and intermediate joints shall be protected against damage.
3. The pipe, insofar as practical, shall be micro-tunneled from the downstream end.
4. A jacking frame shall be provided for developing a uniform distribution of jacking forces around the periphery of the pipe. Special care shall be taken by the General Contractor to ensure that the thrust reaction backstop is properly designed and constructed. The backstop shall be square with the proposed pipe alignment and shall be designed to support the maximum obtainable jacking pressure with a factor of safety of at least 2.0. The jacking system shall be capable of continuously monitoring the jacking pressure and rate of advancement. Special care should be taken when setting the pipe guard rails in the pit to ensure correctness of the alignment.
5. The General Contractor shall 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 the possibility of the pipe freezing in place. Water jetting of the pipe bedding or backfill shall not be permitted.
6. The pipe freezes and the General Contractor is unable to move it again, the General Contractor may be permitted to construct an intermediate access pit, with the location subject to review by the Project Construction Engineer. The General Contractor shall be solely responsible for making arrangements for such an intermediate pit and shall be solely responsible for any and all costs associated with the location and construction of the pit and for maintaining traffic in the area.

7. In the event a section of pipe is damaged during the jacking and excavation operation, one of the following procedures shall be used to correct the damage, as directed by the Project Construction Engineer.
  - a. Slightly damaged pipe which passes leakage test and maintains pipe barrel and joint structural integrity shall be repaired in place with a method approved by the manufacturers.
  - b. Severely damaged pipe shall be removed from the excavation by jacking it through the excavation and removing it at an access pit.
8. The joints shall be made watertight by using rubber gaskets.
9. The pipe joints shall be cushioned by a plywood ring between the joints, or by other methods, to transmit the jacking forces without damage to the pipe or pipe joints.
10. After the pipe is in place and the jacking and excavation operation is complete from one access pit to the next; any over excavation greater than the pipe outside diameter plus 3/4 inch shall require the pipe to be grouted in place.

#### **7.2.15 Grouting**

The General Contractor shall furnish and operate suitable equipment for all grouting operations.

After completion of the jacking operation, the lubricate material shall be displaced from between the pipe exterior and surrounding ground by a cement grout. Pressure and the amount of grout shall be controlled by the General Contractor to avoid pipe damage and displacement of the pipe and soil beyond specified tolerances. Grouting shall be accomplished as soon as possible after pipe installation has been completed to prevent any surface settlement due to movement of soil material into the void space or loosened zone around the pipe.

All voids outside the limits of the excavation created by caving or collapse of earth cover over the excavation, or by other cause shall also be completely filled with pea sized gravel or sand cement grout. Pressure-injected grout shall be placed at the same frequency as required when placing grout behind the pipe.

Pressure-injected grout used in conjunction with pea gravel shall be placed behind the pipe if required to minimize ground loss. General Contractor shall provide seals on the tail of the tunnel boring machine which will prevent the pea gravel or grout from moving into the shield.

#### **7.2.16 Jacking Pits**

Construction techniques required to provide access for micro-tunneling shall be such as to ensure the safety of the work. Acceptable excavation methods include the use of interlocked steel sheetpiling or open excavation. Final dimensions of access pits selected by the General

Contractor shall conform as a minimum with dimensions required to permit installation of the work.

The General Contractor shall be required to properly support all excavations and to prevent all movement of the soil, pavement, utilities or structures outside of the excavation. All pits shall conform to applicable Local Safety Standards, OSHA Standards, trenching, and shoring standards.

If at any time the method being used by the General Contractor for supporting any material or structure adjacent to any excavation is not safe in the opinion of the Project Construction Engineer or applicable federal, state or local inspection authorities, the Project Construction Engineer may require and the General Contractor shall provide additional bracing and support necessary to furnish the added degree of safety required by the Project Construction Engineer. The General Contractor shall provide such added bracing and support by such method approved by the Project Construction Engineer as he may elect to use but the taking of such added precautions shall in no way relieve the General Contractor of his sole final responsibility for the safety of lives, work, and structures. The use of such additional bracing and support shall be without additional cost to the City. The absence of an order from the Project Construction Engineer for the aforementioned additional bracing shall in no way relieve the General Contractor of his sole final responsibility.

Pits shall be constructed to accommodate the installation of pipe casings, slurry shield, and jacking device. Install thrust block as required and consolidate the ground where the casings enter and exit the ground.

All work of excavating shoring and bracing shall be so executed that settlement is minimized, the in-place casing shall have full bearing against earth, and no voids or pockets are left in any portion of the work.

Before beginning construction, the General Contractor shall adequately protect existing structures and other permanent objects. The repair of or compensation for damage to permanent facilities due to negligence or lack of adequate protection on the part of the General Contractor will be at no cost to the City.

The General Contractor shall provide surface drainage during the period of construction to protect the work. Provide all dewatering and test any groundwater discharges. All discharge limits and reporting requirements shall be the responsibility of the General Contractor.

Size and locate pits and their work areas so as to avoid interference with traffic.

Blasting will not be permitted.

### **7.2.17 Line and Grade**

The Project Construction Engineer has established the baselines and benchmarks as indicated on the Contract Drawings. The General Contractor shall check these baselines and benchmarks at the beginning of the contract period and report any errors or discrepancies to the Project Construction Engineer.

The General Contractor shall use the baselines and benchmarks to furnish and maintain all reference lines and grades for the micro-tunnel construction. These lines and grades shall be used to establish the exact location of all micro-tunneling, excavations and structures.

The General Contractor shall establish and be fully responsible for the accuracy of his own control for the construction of the entire project, including access shaft locations, structures, excavation, pipe alignment and grade. The General Contractor shall submit copies of field notes used to establish all lines and grades.

The General Contractor's control points shall be established sufficiently far from the tunnel operation not to be affected by ground movement.

The General Contractor shall maintain daily surveying records of alignment and grade and shall submit three copies of these records to the Project Construction Engineer . The General Contractor, however, remains fully responsible for the accuracy of his work and the correction of it, as required.

The General Contractor shall check his control for his excavation against an above ground undisturbed reference at least once each week and once for each 250 feet of tunnel constructed, or more often as needed or directed by the Project Construction Engineer .

After installation of the sewer pipe, the General Contractor shall provide the Project Construction Engineer with access to the tunnel for visual inspection of the line and grade of the completed in place sewer pipe.

Guidance laser system shall be mounted in a manner that isolates it from effects of movement by the jacking forces.

### **7.2.17 Earth Movement**

The General Contractor shall be responsible for all damages due to settlement from any construction induced activities or occurrences.

The General Contractor is advised of the proximity of buildings, structures, roads, and utilities to the work. Precautions shall be taken to avoid damage or settlement to any of these. Such precautions shall include the use of construction methods and equipment to minimize loss of earth at the excavation face and settlement of earth around the sewer pipe.

In the event any movement of earth is detected, the Project Construction Engineer may order the work stopped and secured. Before proceeding, the General Contractor shall correct any problems causing or resulting from such movement.

The General Contractor should be aware that if settlement of the ground surface should occur during construction, which will affect the accuracy of the temporary benchmarks established by the Project Construction Engineer, it shall be the General Contractor's responsibility to detect and report such movement. The locations of the permanent City monumentation benchmarks (BM) and temporary benchmarks (TBM) are indicated on the Drawings; the General Contractor may use these to verify temporary benchmark accuracy. Advise the

Project Construction Engineer and the City of any settlement affecting the permanent monumentation benchmarks. Upon completion, the field books pertaining to monitoring of the permanent monumentation benchmarks shall be submitted to the City.

### **7.2.18 Excavated Material**

Remove and dispose of all excavated materials from jacking pit and tunnel excavations in accordance with the requirements of State of Colorado.

### **7.2.19 Infiltration Leakage Test**

The tests shall be performed by the General Contractor under the observation of the Project Construction Engineer. A test section is defined as the length of tunnel between manholes or structures.

Leak testing shall be by television inspection after dewatering operations have been discontinued a minimum of 48 hours and until groundwater has been allowed sufficient time to reach its natural elevation. Any leakage found during this operation shall be corrected.

Each joint shall also be tested in place by exerting a pressure of 11.2 psi absolute on it in accordance with ASTM D 3754 Paragraph 8.7.2. The internal test pressure, which is 3.5 psi lower than normal atmospheric pressure, shall be in addition to the normal external hydrostatic pressure exerted on the pipe by the groundwater above the pipe. Each joint when tested in this manner shall exhibit no infiltration of groundwater into the pipe. The General Contractor may at his option, test sections of the sewer using this method instead of individual joints. If this method is selected each section shall exhibit no infiltration of ground water into the section. The General Contractor shall isolate any joints which are found to leak during this test and jack such joints through until all joints between manholes are found to be watertight under these conditions.

One hundred percent of the sewer and sewer joints shall be tested.

The General Contractor shall repair all visible leaks in manholes, structures, and joints even if the leakage test requirements are met.

Adequate bulkheads, or plugs, shall be installed at each end of the sewer pipe in preparation for testing. The General Contractor shall submit the type of bulkhead, or plug, to be used to the Project Construction Engineer for review. After testing, the bulkheads or plugs shall remain in place until the sewer is put into service, at which time the General Contractor shall remove the bulkheads or plugs.

### **7.2.20 Restoration**

The General Contractor shall promptly restore to their original condition any streets, curbs, sidewalks, or any other facilities which are damaged, moved or disturbed as a result of tunneling operations or jacking pit construction. Any surface or subsurface settlement shall be restored to pre-construction conditions.