9 TRENCHLESS PIPELINE CONSTRUCTION

9.1 GENERAL

9.1.1 Scope

1 This part includes the specification for the construction of pipelines by microtunnelling, pipejacking or other trenchless methods approved by the Engineer.

9.1.2 Related Sections and Parts

This Section
Part 1, ... General
Part 2, ... Earthworks
Part 3, ... Pipes and Fittings Materials
Part 4, ... Pipe Installation

Section 1, General
Section 5, Concrete
Section 23, Ground Investigation.

9.1.3 References

1 The following standards and other documents are referred to in this Part:

BS 2494, ...Materials for elastomeric seals for joints in pipework and pipelines

BS 5228, ...Code of practice for noise control on construction and demolition sites

BS 6164, ...Code of practice for safety in tunnelling in the construction industry.

9.1.4 Definitions

1 Pipejacking: technique for constructing pipeline by thrusting pipes or other permanent lining of preformed units progressively into the ground by means of jacks or similar equipment while excavation proceeds at the leading end.

2 Microtunnelling: small diameter tunnelling technique employing mechanical excavation methods usually within a non-man entry guided tunnel boring machine with primary lining inserted behind by jacking.

3 Shaft: excavated thrust and reception pits used for tunnelling operations.

9.1.5 System Description

1 The Contractor shall be responsible for the design of the pipes including joints to meet the requirements of the method of construction.

9.1.6 Submittals

1 The Contractor shall submit complete data and details for the trenchless pipeline construction for the Engineer's approvals follows:

(a) Structural design calculations for the trenchless pipeline and temporary works:

(i) the description and specification of pipes and design calculations.

(ii) details of the permitted angular deflection and draw for the proposed pipes.

(iii) the Contractor shall submit full details of the pipes together with details of previous works undertaken using similar pipes.

(iv) details of proposed manufacturer of pipes with relevant literature and details of manufacturer's Quality Control system.

(v) anticipated jacking loads.

(vi) structural design of thrust walls.

(b) Shop drawings.

(c) Materials Specifications.

(d) Method statements which shall include:

(i) details of the specialist sub-contractor's qualifications and experience in micro-tunnelling together with project references including previous employers' names and current contact details and a curriculum vitae of the proposed tunnelling machine operator including details of relevant experience in Qatar and the Middle East.

(ii) detailed procedure for the Works.

(iii) a description of tunnelling equipment with relevant literature and a statement from the tunnelling machine manufacturer detailing a delivery schedule for spare parts and consumables for the proposed tunnelling machines.

(iv) preconstruction activities (geotechnical investigations including test pits).

(v) safety procedures.

(vi) handling and fixing of the inner pipe in the case of pipe jacking with larger diameter pipes.

(vii) programme of work, including proposed production rates.

(viii) bentonite injection system details.

(ix) detailed method statements for all other aspects of micro-tunnelling work.

(x) where appropriate for the size of machine proposed, details of man access into the tunnel and tunnel boring machine.

(e) Designs of thrust and reception shafts and detailed drawings.

(f) Dewatering arrangements and disposal of groundwater.

(g) Methods for dealing with different ground conditions.

(h) Equipment layout at the thrust and reception shafts.

(i) Details of sleeving system.

(j) Ventilation.

(k) Lighting and communications.

(l) Disposal of surplus excavated material:

(i) details of the spoil separation process to produce clean slurry for recirculation to the tunnel boring machine.

(ii) details of the containment of the excavated material to prevent water and slurry draining from the Contractor's designated working area or wagons. Lagoons for storage and settlement of slurry from the micro-tunnelling process will not be permitted.

(iii) details of the purpose made tanks for settlement of slurry shall be provided.

(iv) details of the solid waste disposal procedure to an approved tip in a manner which does not cause spillage of slurry, mud or any other solid or liquid waste on the carriageway.

(v) disposal of surplus water, once all solids have been removed, to an approved surface/ground water outfall, if locally available, or removed by tanker to an approved point of disposal.

(m) Pilot bore.

(n) Plan at 1:50 scale showing working plant positions, spoil removal faculties, materials storage facilities, launch and reception shafts, fencing, offices, discharge lines, ground water removal facilities, etc.

2 The Contractor shall not procure materials or begin construction of the Works until the Engineer has approved all submittals. The Engineer's approval shall not relieve the Contractor of his obligations under the Contract.

9.1.7 Specialist Subcontractor

1 The Contractor shall employ an approved specialist subcontractor experienced in trenchless methods for the pipeline construction.

9.1.8 Quality Assurance

1 The Contractor shall employ an approved prequalified specialist subcontractor as designated in the contract specific documentation. All personnel in the employment of the subcontractor shall be experienced and competent in their respective tasks and shall work only under the control of a qualified supervisor.

9.1.9 Site Conditions

1 The Contractor shall carry out additional geotechnical site investigations which he considers necessary. The results of such investigations and laboratory testing together with the factual and interpretive reports shall be submitted to the Engineer for approval. The Engineer's approval shall not relieve the Contractor of his obligations under the Contract.

9.2 TRENCHLESS PIPELINE CONSTRUCTION GENERALLY

9.2.1 Scope

1 Where a pipeline is designated in the Contract documents to be constructed by a trenchless method, the Contractor shall not be permitted to adopt open trench methods and shall confine his surface operations to working shafts and the area immediately adjacent to such shafts. In locations where construction of pipelines is not indicated to be by trenchless method, the Contractor may elect to construct additional lengths of pipelines by a trenchless method in accordance with this specification, subject to the Engineer's approval.

9.2.2 Surveys and Setting Out

1 Before commencing the excavation of any shafts for pipejacking or microtunnelling, the Contractor shall

(a) establish at least four adequately protected bench marks comprising steel pins embedded in a block of concrete adjacent to the shaft to facilitate the setting out of the underground works

(b) record the initial levels for pipelines beneath or across roads and submit a copy of these to the Engineer

(c) record and report with supporting photographs of the condition of structures, roads, footpaths and other paved areas that are located over and beside all jacking or microtunnelling routes.

2 During construction of a drive between any two working shafts, the Contractor shall observe levels on predetermined cross-section points at regular intervals to determine if there is any subsidence.
Temporary benchmarks shall be set up along the centre of the pipe at 15 metre intervals between the shafts and at 5 and 10 metres offsets. Levels shall be taken along the centre of the pipeline and at offsets of 5 metres and 10 metres each side of the pipeline at 15 metre intervals between shafts. Levels shall be taken and recorded on all of the above points at daily intervals during micro-tunnelling works, again one week before issue of a Completion Certificate, and finally at the end of the 400 day period of maintenance.

3 Immediately following completion of the drive between any two working shafts, the Contractor shall

(a) repeat the level survey of the ground surface along the centreline of the drive as described above

(b) record and report to the Engineer with supporting photographs any changes to the condition of roads, footpaths and other paved areas.

4 Before the completion of the whole of the Works and again before the expiry of Period of Maintenance, the Contractor shall repeat the surveys and inspections as described above for all of the trenchless pipeline construction.

5 The Contractor shall determine the location of all working shafts having due regard to existing services, minimising disruption to traffic and pedestrian movements and achieving the required system layouts, as approved by the Engineer. The Contractor shall prepare suitably scaled working drawings for the setting out of the Works, including the location of existing services and all other relevant details and submit these for the Engineer's approval.

6 As-built surveys of each micro-tunnel drive shall be undertaken. For all micro-tunnel drives of internal diameter 800 mm or more, including any permitted sleeves of this size, the Contractor shall employ an approved independent survey company to undertake an as-built survey of the drive. Coordinates and levels shall be provided for every pipe joint. For steel sleeves, coordinates and levels shall be provided at 5 metre intervals. Each completed drive shall be surveyed immediately after completion of the drive. No further micro-tunnel drives may be commenced until the survey results have been submitted to and approved by the Engineer. No pipes may be installed within sleeves until the survey results have been submitted to and approved by the Engineer.

9.2.3 Monitoring Lines and Levels

1 A laser guidance system shall be used for the control of the pipe alignment. The shield/tunnel machine shall be fitted with a calibrated laser target, robustly constructed and rigidly secured to the shield/tunnel machine.

2 The setting of the laser and target and the alignment of the tunnel relative to the laser beam shall be checked frequently at intervals as directed by the Engineer. In addition, the Contractor shall verify the accuracy of the laser guidance system by conventional theodolite and level control methods to the approval of the Engineer.

3 The invert level of the finished pipeline at the drive shaft shall be within ±10mm of the required level shown on, or interpolated from, the Contract drawings.

The invert level and line of the pipeline shall at no point deviate from the design by more than the following:

Pipe Bore D mm	Vertical mm	Horizontal mm
D < 600	± 20	± 25
600 ≤ D ≤ 1000	± 25	± 40
1000 < D ≤ 1400	± 30	± 100
D > 1400	± 50	± 200

4 The pipe manufacturer's stated permitted draw or angular deflection shall not be exceeded at any individual joint.

5 If the line and levels of any section of pipeline deviates from the design alignment within the tolerances the shield/tunnel machine shall be steered in a manner that ensures a gradual return to the correct alignment.

6 If the deviation in the lines and levels exceeds the tolerance specified above, the Contractor shall stop work and immediately inform the Engineer. The Contractor shall submit proposals to rectify the deviation. Work shall be resumed only on the written instruction of the Engineer.

7 Where micro-tunnelled sewers are required to connect into existing pipelines or pipelines previously completed under this project, due allowance for the tolerance shall be made prior to commencing the drive to ensure that the finished pipeline profile does not require the pipe contents to flow uphill.

9.2.4 Temporary Site Facilities

1 In addition to the provisions of Section 1, the Contractor shall provide the following at each thrust shaft as a minimum:

(a) air-conditioned mobile office
(b) telecommunication between the mobile office and the work crews
(c) adequate ventilation
(d) approved gas detectors and oxygen meters
(e) first aid kit.

9.2.5 Safety Requirements

1 The Contractor shall adopt safe working practices for tunnelling in accordance with BS 6164. Only authorised personnel shall be allowed access to the Site.

2 The Contractor shall ensure that a suitably qualified safety officer is present during tunnelling operations.

9.3 MATERIALS

9.3.1 Pipes

1 Pipe material and the lining and coating shall be as designated in the Project Specification. If the use of other pipe material or lining and coating is proposed, technical details and justification shall be submitted for the Engineer's approval.

2 Pipes shall be designed to withstand the maximum axial thrust with a factor of safety of four based on the full effective area of the pipe and the ultimate compressive strength of the pipe material. For reinforced concrete pipes the full effective area at the joint shall be used. The pipe design shall take into account both permanent service loads and temporary loads encountered during installation.

3 Where GRP or similar material pipes with concrete surround are proposed the concrete shall be regarded as sacrificial. The concrete surround shall be designed to withstand the maximum jacking force. The design shall also ensure that the GRP or similar material pipe is not subjected to forces during installation. Vitrified clay pipes shall be in accordance with Clause 3.2 of this Section.

4 The Contractor's submittals shall describe the measures to be taken to avoid the development and transfer of grout shrinkage and expansion stresses to the pipe and to avoid any adverse chemical reaction between the pipe and the concrete, grout or other materials comprising the pipeline. The pipe manufacturer shall guarantee that the crushing and beam strength of the pipe are sufficient for their intended use.

5 Joints in pipes shall be designed to avoid projections which could obstruct the travel of the pipe. Joints shall be watertight under axial loading and at the permissible deflection of the pipes. Quality control tests at the factory shall include subjecting the pipe joints, at maximum permissible deflection, to a hydrostatic pressure of 0.2 MPa.

6 Standard pipes shall generally be of 2.0 m in length. Where required, pipes shall incorporate lubricant injection holes spaced equally around the circumference. Concrete pipes with a liner shall only be permitted to have lubricant injection holes in the concrete. Lubrication holes shall be clear of joints and shall be plugged on completion of the work. Pipes may incorporate lifting holes and fixing holes for securing temporary apparatus; all such holes shall be threaded to enable plugs to be screwed into the sockets to withstand external water pressures.

7 Joints which shall be used in conjunction with a resilient packing and shall be capable of accepting repeated angular deflections as recommended by the pipe manufacturer without

(a) damage to pipe or loss of structural integrity

(b) the ingress or egress of water or lubricant under the maximum test pressures

(c) the ingress of either or both soil or groundwater onto the bearing surfaces.

8 Unless otherwise directed by the Engineer the joint design for concrete pipes shall be such that areas available for transmitting the maximum permitted thrust force will be sufficient to ensure that with an angular deflection of 1 ° and with resilient packing material in place, the maximum pressure applied to the joint bearing surface will not exceed 23.5 MPa for drives up to 100 m in length and 21.0 MPa for drives in excess of 100 m in length.

9 Unless Authenticated independent test results acceptable to the Engineer are available, two consecutive axial load tests incorporating a 1 ° angular deflection with the application of double the maximum permissible thrust force (or, if greater, of the greatest thrust force that the proposed thrust equipment can apply) shall have been successfully conducted without visible crushing, cracking or spalling of the pipe being evident, before pipes will be accepted for use. The tests shall be extended to record the loading at which visible signs of failure become evident, and shall be carried out in an approved manner to simulate actual working conditions. Pipes which have been submitted to the proof load test will not be permitted in the Works.

10 Where the Contractor elects to construct certain sections within larger diameter pipes and grout the annular space, the external pipe may be of steel. The difference between the external face of the inner pipe and the internal face of the outer pipe shall not be less than 150 mm. The steel pipe and the grout shall be regarded as sacrificial and the inner pipe shall be designed as a stand alone pipe, capable of withstanding installation forces and soil, traffic and groundwater loads.

11 Where the Contractor elects to construct certain sections not within larger diameter pipes, pipe installation by trenchless methods shall continue until at least one additional length of pipe beyond the limit of trenchless construction is exposed. The condition of the exposed pipe and its exterior coating will be inspected by the Engineer. Where in the opinion of the Engineer the pipe or coating has been excessively damaged during installation, the Contractor shall submit a proposal for review by the Engineer, for demonstrating the adequacy of the pipeline installed by trenchless methods and for rectifying defects. The proposal shall also include jacking out of defective pipes.

12 Concrete jacking pipes shall comply with the provisions of EN 1916 and BS 5911-1.

13 Collars shall be manufactured from weldable stainless steel plate Grade 316 Ti (EN 1.4571). They shall be provided with suitable stainless steel lugs or anchors to enable them to be cast into the body of the pipe, if applicable.

14 Joints in concrete jacking pipes shall be in-wall flexible joints of the fixed collar type. They shall be designed to include one or more joint seals. All joint surfaces which will transmit load during installation shall be plane and free from irregularities that could cause high local concentrations of stress.

15 The nominal internal bore of the micro-tunnelling pipes shall be as indicated on the Drawings or as specified by the Engineer. The Contractor shall select an appropriate external diameter for the pipe which shall be submitted to the Engineer for approval.

16 The design of the jacking pipes and determination of acceptable pipe fabrication tolerances shall be the responsibility of the Contractor. Maximum compressive stresses applied to the pipe shall not exceed 33% of the design compressive strength of the pipe and shall not exceed the pipe manufacturer's recommended allowable stresses.

17 Pipes for installation by micro-tunnelling shall be fit for purpose and shall be one of the following:

(a) Concrete designed specifically for jacking to EN 1916:2002 and BS 5911-1:2002+A2:2010 with a GRP pipe lining in accordance with Section 8 Part 3 Clause 3.4. . The GRP lining pipe shall incorporate watertight joints between adjacent pipes and shall accept no longitudinal load during jacking. The joint between adjacent pipes shall be designed to ensure concentricity of adjacent pipes and shall prevent application of any lateral forces to the GRP pipe. The coarse aggregate used in the manufacture of the pipes shall be crushed Gabbro rock. The external surface of the pipe shall be coated with at least 300μ DFT abrasion resistant epoxy. Pipes shall be factory manufactured by an approved experienced manufacturer. Pipes shall not be manufactured on-site.

(b) Concrete designed specifically for jacking to EN 1916:2002 and BS 5911-1:2002+A2:2010 with a polymer lining as described in Section 5 Part 14 Clause 14.6. The coarse aggregate used in the manufacture of the pipes shall be crushed Gabbro rock. The external surface of the pipe shall be coated with at least 300μ DFT abrasion resistant epoxy. Pipes shall be factory manufactured by an approved experienced manufacturer. Pipes shall not be manufactured on-site.

(c) Direct jack GRP pipes to ISO 25780:2011 shall be in accordance with Clause 3.4 of this Section.

(d) The joint between adjacent jacking pipes shall be designed to ensure concentric alignment of adjacent pipes and uniform transfer of jacking forces from one pipe to the next. The pipe joint shall consist of a substantial external stainless steel guide ring to achieve this requirement. The joint shall also incorporate one or more EPDM or other approved elastomeric sealing gaskets.

9.3.2 Joint Packing

1 Packers shall be incorporated into each joint in concrete jacking pipes in order to distribute the jacking pressure and avoid point loads and to prevent damage to the ends of the pipes during the jacking process. The packers shall not extend over the full joint width, a gap to the inside surface should be left to prevent localised spalling, in accordance with the manufacturers recommendations.

2 The material used for packing shall withstand all imposed loadings applied during the installation of pipes for each completed length without showing signs of deterioration or distress. The initial thickness of the packing shall be such that the final joint gaps achieved upon completion of the pipeline are a normal width of 8 mm.

3 The material proposed for the joint packing and its mechanical properties shall form part of the pipe design submission from the Contractor.

9.3.3 Lubricant

1 Lubricant shall always be used. Lubricant shall be polymer or bentonite-based slurry approved by the Engineer. It shall be stored and mixed in a manner recommended by the supplier and tested before use. Sufficient quantity of the lubricant material shall be kept available at Site.

9.3.4 Joint Sealant

1 The joint sealant for the jacking pipe shall be of the elastomeric ring type complying with BS 2494. Joint sealants shall be stored in a manner recommended by the supplier.

9.3.5 Grout

1 Grout used for slurry replacement shall

(a) consist of either ordinary or sulphate-resisting cement and water as determined by geotechnical data and directed by the Engineer

(b) have nominal strength at least equivalent to the requirement for Grade 20 concrete.

(c) have admixtures only if tests have shown to the satisfaction of the Engineer that their use improves the properties of the grout, such as by increasing workability or slightly expanding the grout.

Full details of the proposed grout mix including admixtures shall be submitted to the Engineer for approval.

2 Grout used for annular space filling shall

(a) be a low-strength foam concrete placed at low pressures.

(b) have a mix density in the range 900-1200 kg/m^3

(c) have free water/cement ratio not greater than 0.6.

The internal pipe shall be filled with water to avoid floatation forces, hydration temperatures and to resist forces during grouting. A 5 m high free vented standpipe shall be used. A free venting standpipe of not less than 100 mm diameter shall be installed on the grout injection feed to restrict grouting pressures to a maximum of 0.1 MPa. GRP carrier pipe and joints shall be protected from the possible adverse physical or chemical effect of grout, and compressible material shall be wrapped around the pipe.

9.4 THRUST AND RECEPTION SHAFTS

1 The dimensions of thrust and reception shafts shall be the minimum necessary to construct the Works.

2 Excavations shall comply with the requirements in Part 2 of this Section. Dewatering, if necessary, shall be conducted at a rate which will minimise the inducement of settlements at the ground surface. The shafts shall be kept dry at all times.

3 The thrust wall of the thrust shaft shall be normal to the proposed line of thrust. The thrust wall shall be sufficient to accept repeatedly the maximum permitted thrust force without movement. The Contractor shall not thrust directly from permanent parts of any shaft, or walls of other structures. The thrust wall shall not be joined to the jacking rig base concrete.

4 Shaft base slabs shall be capable of withstanding external uplift pressure from groundwater, if any, in addition to other imposed loads.

5 Any tail tunnel which has been used as a reaction surface shall pass the designated watertightness test at a time not less than 14 days after the load has been removed.

6 The design of the thrust wall and any other associated temporary works shall be such as to prevent damage to any part of the permanent works.

7 Any void between the soil face used to provide a reaction to the thrust force and the thrust wall shall be grouted up.

8 Where the excavation is in water-bearing ground, the Contractor shall provide means of checking whether any solids are being removed with the water from excavation. Regular checks shall be made to compare the volume of solids removed with the calculated volume as a safeguard against excessive loosening or loss of material beyond the shaft dimensions.

9 The Contractor shall select the location of the drive and reception shafts. These locations shall be submitted to the Engineer for approval. These shafts may be incorporated as part of the permanent works. All modifications to the shafts converting them into access manholes shall be completed at the Contractor's own expense. Details of the modifications shall be submitted to the Engineer for approval and shall conform to those shown on the Contract drawings.

10 Prior to commencing work at a shaft, the Contractor shall provide details of the shaft support system, working plant position, spoil facilities, material storage facilities, dewatering arrangements, etc. The details shall include a sketch of all the working facilities at the head of the shaft.

11 Access down into the shaft for personnel and equipment shall be approved by the Engineer. Hand railing set at a height of 1 100 mm above ground level together with toe boards and protective netting to prevent equipment falling into the shaft shall be provided at each shaft. Fencing shall be erected around each shaft site establishment to prevent the entry of unauthorised persons.

12 The dimensions of shafts shall be the minimum necessary to safely construct the Works.

13 Backfilling of shafts shall be undertaken in accordance with Section 8 Part 2 Sub-Clause 2.3.3.

9.5 PIPEJACKING

9.5.1 General

1 The maximum lipping between edges of adjacent jacked pipes shall not exceed the maximum tolerance given in Clause 9.2.3 of this Part.

2 The horizontal drive rate shall be maintained equal to the excavation rate throughout the operation.

3 Where dewatering is required it shall incorporate standby facilities and shall have been in operation sufficiently in advance to attain stable groundwater levels before beginning tunnelling. If, during the course of the work, the shaft face becomes unstable through water ingress, it shall be immediately sealed and made safe.

4 Damaged pipes shall be replaced either by pushing through to the end of the line or broken out and replaced by pushing up adjacent pipes.

5 The Contractor shall ensure that oil and lubricant spillage is minimised. Any spillage of oil or lubricant shall be cleared as soon as is practicable and the inside of the pipes shall be cleaned on completion of the pipejacking.

9.5.2 Tunnelling Shields for Pipejacking

1 Where considered necessary, the Contractor shall provide and maintain a shield suitable for excavating in the ground conditions as envisaged by him and in accordance with his chosen method of excavation. In determining the type of shield and method of excavation to be used, the Contractor shall take account of the need to ensure that the face of the excavation is adequately secured at all times such that ground loss is kept to a minimum and is controlled to prevent excessive ground loss. The shield shall be removed on completion of the tunnelling operation.

2 Rotating excavating heads fitted to shields shall be capable of rotating clockwise and counter-clockwise.

3 The shield shall be equipped with steering jacks and such beads, ploughs and copy cutters as may be required for adjusting the alignment of the pipes.

4 Multiple lubricant injection points shall be provided within the shield in order to provide immediate ground support when necessary.

9.6 MICROTUNNELLING

9.6.1 General

1 Micro-tunnelling shall be defined as a method of installing pipe or casing by jacking the pipe or casing behind a remotely controlled, laser guided, steerable, guided tunnel boring machine which fully supports the excavated face with fluid and/or earth pressure balance at all times.

2 Micro-tunnelling pipe is defined as pipe or casing capable of withstanding installation jacking and any other construction loads in addition to permanent live and dead loads.

3 The method to be employed for micro-tunnelling shall be selected by the Contractor to suit ground conditions and ground water pressure. The Contractor shall submit a detailed method statement which shall be approved by the Engineer prior to commencing micro-tunnelling.

9.6.2 Contractor Responsibilities

1 The Contractor shall carry out, and be responsible for, the detailed design of:

(a) The micro-tunnel;

(b) All associated works (including shafts, connections, etc.).

2 The design shall be prepared by qualified design engineers or other professionals who comply with the criteria stated in the Specifications. The Contractor warrants that he, his designers and design sub-contractors have the experience and capability necessary for the design. The Contractor undertakes to ensure that the designers shall be available to attend discussions with the Engineer at all reasonable times.

3 The Contractor shall satisfy himself that he has sufficient geotechnical details before commencing the detailed design. If available, a copy of existing geotechnical investigation reports shall be provided to the Contractor. These reports are provided for information only and the Contractor is advised to corroborate the details provided and commission any additional site investigation works he deems to be necessary.

4 The Contractor shall be responsible for ensuring that he avails himself of all necessary utilities information, existing and proposed, prior to commencement. Where available, a copy of existing utilities information shall be provided by the Engineer. These reports are provided for information only and the Contractor shall be responsible for ensuring that the information collected is the most recent and factual record of existing and proposed services in the project area. The Contractor shall utilise appropriate equipment and methods to aid him in the determination of the line and level of existing utilities apparatus. This may be undertaken either by the Contractor's own staff or by specialist sub-contractors.

5 The Contractor shall be responsible for obtaining all approvals/consents required for the disposal of excavated material/spoil that is surplus or unsuitable for incorporation in the permanent works. The Contractor may propose, subject to the approval of the Engineer, remedial measures to be taken for the improvement of earthwork arisings, which are not suitable in the as-dug condition, for use in the permanent works.

6 The Contractor shall allow the Engineer full access to real time micro-tunnelling data any time during construction.

9.6.3 Safety and Environment

1 The Contractor shall carry out all works to the requirements outlined in all current appropriate Regulations, Codes of Practice. The following recognised documents shall form the basis for guidance and development of the safety plan and site procedures:

(a) UK Health and Safety at Work Act including the provisions of BS 5228, Parts 1 and 2;

(b) BS 6164: Safety in Tunnelling (Code of Practice);

(c) Guide to Best Practice for the Installation of Pipe-jacks and Micro tunnels.

2 The Contractor shall develop a safety plan to encompass all aspects of safety and environmental requirements prior to commencement of the work. This plan shall be a working document and be subject to continuous review throughout the period of the contract.

3 All machinery, including hoists shall be suitable for quiet and efficient operation and shall be installed and maintained to an acceptable safety standard.

4 A site safety culture shall be instigated on-site prior to work commencing and be developed throughout the course of construction. The culture will comprise of the use of key management tools by the site management (and outlined in the site safety plan) in educating the site operatives in all aspects of best safety practice and awareness in their work. An induction session shall be given to all operatives and staff irrespective of their discipline and experience. This should, in particular outline all local requirements relating to the contract, actions to be taken in event of emergencies, and an overview of the Site and its personnel. The content of the induction may be varied to suit the recipients. Each operative shall receive training, together with any appropriate examination or documentation, to ensure he is completely aware of the requirements of each aspect of his job and the hazards which are inherent in its execution.

5 The Contractor shall produce a risk/hazard analysis of the key elements of the pipe-jacking operation and utilise the results of the analysis in reducing such risks that remain to a minimum. Such hazards shall be communicated to workers through induction, tool box talks and the like.

6 The Contractor shall develop and implement a plan for immediate underground evacuation in the event that the presence of toxic/inflammable gas is identified in the excavation. In such case the Contractor shall identify and take appropriate action to rectify such hazard prior to allowing work to recommence.

7 Appropriate training and certification shall be given to all operators of plant. This shall be carried out only by engineering staff competent in the use and hazards associated with the particular item of plant concerned.

9.6.4 Performance Requirements

1 The micro-tunnelling system shall be selected by the Contractor to suit local ground and groundwater conditions. The Contractor shall submit a detailed method statement for approval by the Engineer prior to starting micro-tunnelling work.

2 Micro-tunnelling operations shall be carried out in a manner that minimizes ground movement in front of and surrounding the pipeline. Settlement of the ground surface shall be minimized. Damage to structures and utilities above and in the vicinity of the underground operations shall be prevented.

3 The ground shall be continuously supported in a manner that prevents loss of ground and maintains the stability of the tunnel face and perimeter at all times.

4 A full work force shall be maintained on a continuous basis (24 hours per day) during any emergency or work stoppage that could endanger the tunnel excavation, sub-surface infrastructure and surface facilities.

5 Dust, noxious gasses or other atmospheric impurities shall be actively controlled in accordance with the relevant Qatar occupational health and safety legislation. Approved instrumentation for monitoring air quality in work areas and pipelines accessed by personnel shall be provided. This environmental control and associated procedures to be followed in monitoring shall be fully documented in the Contractor's Safety Plan.

6 All micro-tunnelling and underground construction work shall be performed in accordance with the relevant Qatar occupational health and safety legislation and the approved Contractor's Safety Plan. This Plan shall include safe procedures to mitigate risks associated with the work, including identification and logging of any and all visitors into and out of the underground works and prevention of unauthorized entry. Safe procedures shall also be established for personnel entering the tunnel to carry out maintenance or for other purposes.

9.6.5 Micro-tunnel Design Elements

1 Tunnel Pipe Design

(a) The watertight lining pipe shall be installed by single pass pipe jacking using a remote controlled tunnelling operation to the alignments and grades shown on the drawings. Remote controlled tunnelling operations apply to trenchless pipe installation by micro-tunnelling where the carrier pipe is installed directly behind the tunnelling machine and the machine provides support to the excavation face at all times.

(b) All jacking pipes, including special designs, shall be sufficiently reinforced with steel to withstand all stresses induced by handling, jacking, earth and water pressures and all working loads at the depths at which they are to be used without cracking, spalling or distortion. A load factor of not less than 1.5 shall be used in the calculations to determine the strength of the pipes required. The clear cover to any steel reinforcement shall not be less than nominal 50 mm. The pipes are designed and calculated in according ATV 161 (Technical Standard of pipe jacking).

(c) The strength of the pipes shall be tested by a three edge bearing test. When subjected to the design load in such a test, the maximum crack developed on the pipe shall not exceed 0.25 mm. If this test not possible an equivalent quality control and security system has to be developed.

(d) All pipes shall be manufactured by a supplier approved by the Engineer. The process of manufacture may be by centrifugal or vertical casting subject to submission and approval by the Engineer. All pipes shall be cast with a minimum of 3 grout holes equally spaced around the pipe wall. A steel threaded insert (¾ to 1 BSP minimum dimension) shall be cast in each hole. All pipes shall be of spigot and socket design with an integral steel collar cast on the socket or trailing end. The collar shall be suitably and securely fixed to the reinforcing cage of the pipe prior to the pipe being cast. Each pipe shall have a 75 mm dia lifting hole or lifting anchor cast in the top centre to facilitate a lifting device. All pipes shall have their date of manufacture clearly and indelibly marked on them. All pipes shall be fully cured and have reached the designed concrete strength prior to delivery.

(e) The Contractor shall submit full details of his proposals for the pipes, giving detailed drawings showing sizes, reinforcement and jointing arrangements, all cast in items and concrete design including specifications for all component materials. A full set of design calculations including the parameters adopted for the design shall also be submitted.

(f) The name of the manufacturer, place of manufacture and manufacturing process shall be identified at an early stage and provision made for inspection of such facilities by the Engineer for his approval.

(g) The jacking equipment including any required intermediate jacking stations shall have a capacity of not less than 20 per cent greater than the calculated theoretical maximum jacking load.

(h) The design of the tunnel shall take into account the required life span, the proposed use, the ground conditions, the sequence and timing of construction and the local existence of adjacent structures. Relaxation of stresses in front of boring machine and excavation, installation and water-tightness of lining pipe should be considered. The required life span is 100 years. 100-year durability design shall meet the requirements of BS 8110.

(i) Numerical methods shall be used to evaluate the loading on the lining pipe. Results of the numerical calculations shall be used to assess surface settlements. The Contractor shall specify, justify and explain the model he intends to use. The Contractor shall also submit two licensed English versions of the software including all manuals, to the Engineer.

(j) The Contractor shall be solely responsible for the accuracy of the numerical model and the assumptions necessary to fully simulate the anticipated ground and the tunnel excavation within it, the installation of any support measures and the construction of the permanent tunnel lining system. The Contractor shall provide in his Design Submission numerical simulations which are applicable to and reflect the work and construction stages proposed by him. State of the art modelling techniques, material properties, simulation procedures and material definition, shall be applied. In addition the Contractor shall at least consider the requirements as outlined below for the modelling process:

2 Tunnel Access Shaft

(a) The positions of the micro-tunnel shafts and tunnel are shown on the Contract Drawings. The Contractor may suggest alternative positions to suit his equipment and works programme. The final depth and position of the shafts and tunnel however shall be subject to the approval of the Engineer.

(b) The working shaft shall be designed to withstand the force applied by the main jacking station and of adequate dimensions to fully cater for the underground installation of all necessary pipe-jacking equipment. This will include the jacking frame and thrust ring assembly, slurry pumping equipment, electrical isolation box and guidance system. Consideration must also be given to safe access and working space for the pit bottom crew. The design of the shaft base shall incorporate the requirements of a thrust block for the jacking frame to bear upon and a tunnel launching eye and sealing ring through which the TBM is launched. The design of these structures will depend on the type of ground and jacking pressures envisaged. They are normally considered to be temporary structures, being removed on completion of the drive, but consideration may be given to incorporating them in the permanent works wherever possible.

(c) Requirements for launching the TBM assembly, which may comprise multiple units of varying length, shall also be taken into consideration when deciding upon the overall size of the shaft base.

(d) Micro-tunnel shafts shall be placed at main road intersections to take drainage from the surrounding areas.

(e) Micro-tunnel shafts shall be built to Employer's standards and requirements. The Contractor may propose alternative designs subject to the approval of the Engineer.

(f) Shaft openings shall be located within the central reservation or footway areas. No openings shall be accepted within the highway carriageway.

(g) The design of the tunnel shafts shall take due account of the following:

(i) Need to provide a structurally sound and stable reinforced concrete shaft wall and superstructure that shall comply with all relevant BSI standards. Design calculations and materials shall be submitted for approval to the Engineer prior to any construction work being undertaken.

(ii) All shafts shall be watertight.

(iii) All shafts for sewerage applications shall be full lined internally with GRP in accordance with Part 4, Clause 4.4.1.

(iv) All shafts for surface water / ground water applications shall have a combination of GRP lining and epoxy protective coating internally in accordance with Part 4, Clause 4.4.2. .

(v) Where practical, the underside of the base slab and external faces of the walls shall be protected by a membrane tanking system. Where this is not possible, the Contractor shall propose a protection system for approval by the Engineer.

(vi) All ladders, platforms and handrails, where shown on the Contract Drawings, shall be to QCS Section 8, Part 6, Clauses 6.4.1 to 6.4.7. Platforms shall be provided at maximum distances of 6 metres and shall be positioned to allow maintenance equipment to be lowered unhindered to the base of the shaft. Ladders shall terminate at platforms and be staggered between platforms.

(vii) Down-pipes shall be secured by stainless steel brackets to the inside of walls.

9.6.6 Design Checking

1 All drawings and calculations intended for incorporation into the design package shall be checked by an approved Independent Checker. Evidence of the extent and scope of checking carried out on each set or subset of calculations shall be provided either in the form of parallel calculations or by marking up the calculation sheets or by providing a summary on the cover sheet.

2 All drawings shall be checked with due consideration for the following:

(a) completeness;

(b) compliance with the relevant requirements of the Contract Documents;

(c) consistency between calculations, schedules, reports, drawings, specifications;

(d) compliance with standards, codes, regulations and statutory requirements;

(e) dimensional accuracy and presentation.

3 With his approval the Independent Checker confirms that the relevant documents are in compliance with the Employer's requirements, relevant local and international standards and designed correctly.

9.6.7 Finite Element (FE) and Finite Difference (FD) Models

1 A numerical analysis shall be carried out and fulfil the following geometrical requirements:

(a) Notwithstanding the requirements as listed below the mesh layout shall be such that numerical accuracy is guaranteed. If required, the Contractor shall perform sensitivity studies with different levels of mesh refinement.

(b) Width of mesh shall extend at least two tunnel diameters beyond the limits of the tunnel lining.

(c) The model used for the design at the ground sections of the tunnel shall be capable of considering the joint system and joint properties of the ground strata, by either explicitly modelling joint systems or applying suitable models with equivalent properties.

2 Element size around excavation contours shall not be larger than those elements that correspond to an angle of 10 degrees along the arch. Infinite elements shall be used along the border of the mesh or a suitably large mesh shall be proposed so that the influence of boundary of mesh is negligible for FE models: The practical limit of the aspect ratio of zones should be kept to approximately 1:4 or less in order to achieve reasonable solution accuracy. The practical limit for FD models of the aspect ratio of zones should be kept to approximately 1:1 or less in order to achieve reasonable solution accuracy.

3 Each computation shall be accompanied by a report that shall at least include a description and interpretation of:

(a) definition of the mesh;

(b) selection of design sections;

(c) definition of geological strata;

(d) selected input parameters;

(e) material models used;

(f) results including surface settlements and expected deformations in the tunnel;

(g) dimensioning of the tunnel lining.

9.6.8 Verification of Results

1 Numerical calculations for the design of the lining shall be verified using different analytical methods.

9.6.9 Design Parameters for the Calculations

1 Parameters required for the design and not defined in this document shall be established by the Contractor. All details on these parameters shall be provided by the Contractor in his Design Basis Report subject to the consent of the Engineer.

2 The results of site investigations carried out are to be summarised in the Data Reports and the Contractor shall conduct supplementary site investigations within the project area as designated and/or where considered appropriate. The interpretation of all site investigation data, including the interpretation of the Data Reports and of the bore logs shall be the responsibility of the Contractor. The Contractor shall justify and explain the derivation of all his geotechnical parameters in his geotechnical interpretative report. The geotechnical parameters used for the design require the consent of the Engineer. The worst credible ground parameters as identified in the site investigation data shall be used to check the micro-tunnel lining (at the ultimate limit state).

9.6.10 Design Loadings

1 The Contractor shall include for the following loads in his calculation of the stresses and strains induced in the installed pipeline:

(a) Ground/Rock Loads;

(b) Water Loads: Groundwater levels with sufficient safety margins for the design shall be determined from groundwater observations. The design calculations shall be carried out both for an upper bound and a lower bound of the ground water level subject to the consent of the Engineer;

(c) Live Loads: For underground structures under a roadway, a live load as defined in BS 5400, Part 2 for highway bridges considering type HA loading combined with 45 units HB loading shall be allowed for in the design;

(d) Surcharge Loads: For all underground structures and in locations where live loads as specified above do not apply, a surcharge load of 22.5 kN/m² applied at ground level shall be allowed for in the design;

(e) All other loads.

2 The Contractor shall take into account any other loading criteria which may be applicable to achieve the full performance of the micro-tunnel, including water pressures under operational conditions within the lined tunnel.

3 In addition to the design sections as defined above the Contractor shall carry out case studies of all relevant and possible combinations of geological, hydrogeological and geometrical conditions as necessary for his design and construction. The Contractor shall also provide calculations in accordance with the soil /rock classification proposed by the Contractor and based on the Contractor's geotechnical interpretation. The Contractor's calculations shall cover all possible geotechnical conditions anticipated over the entire tunnel length. Notwithstanding the calculations as requested above, the Contractor shall consider within his design submissions one numerical simulation of the tunnel construction of at least every 400 m of the bored tunnel section. Within the Preliminary Design Submission the Contractor shall propose these calculation sections which shall be subject to the consent of the Engineer.

9.6.11 Design Submissions

1 The Contractor shall submit his proposed detailed design report to the Engineer for approval, not less than four weeks prior to his intended construction start date for this element of work, or as specified by the Engineer. The submission should include, but not be limited to, the following :

(a) Summary of all subjects addressed in the design stages;

(b) Summary of the design criteria adopted in the design stages;

(c) Final hydraulic model for overall drainage system including all input and output data;

(d) Final hydraulic design and calculations for overall drainage system including connections;

(e) Final hydraulic design and calculations for the temporary pumping station if required.

2 For the purpose of obtaining all necessary approvals on completion of the detail design stage, the Contractor shall submit to the Engineer the following:

(a) 4 no. complete sets of detail drawings-paper prints (A1) to include:

(i) The modified positive surface water drainage system and micro-tunnel plans at 1:1000 scale based on survey sheets and incorporating coordinate grid, proposed sewers connections, access and maintenance shafts, invert, cover and ground levels. Key plan of the proposed system plans including coordinate grid, contract area, sewer connections, main building and road/street names, and layout plan of the temporary pumping station sites at 1:100 or 1:50 scale if required.

Sections of micro-tunnel and the modified positive surface water drainage system at 1:1000 horizontal and 1:100 vertical scales. Sections are to be related to each the system plan and include chainages, access and maintenance shafts number, invert, cover and ground level, tunnel diameter, gradient, terrain crossed, major service crossings and any connecting branch sewer details.

Standard drawings for the modified positive surface water drainage system, micro-tunnel cross section, access and maintenance shafts and miscellaneous details to appropriate scales based on Employer's standards.

(b) 4 no. complete sets of the detailed construction specification;

(c) 4 no. Bills of Quantities, containing the principal items;

(d) The submittal of the detail design for approval shall also be accompanied by 4 copies of a comprehensive “Engineering Report” including the design calculations, which will detail revisions and amendments to the design subsequent to the approvals given for design. The report shall include copies of the comments made on the design and corresponding actions taken;

(e) Drawings, designs, documents and reports submitted for approval will not be accepted if there is no evidence of internal, qualified, checking; or if the quality of the contents of the Drawings and documents clearly indicate that they have not been checked thoroughly;

(f) Partial submittals will not be accepted.

If significant changes are required to the above original document submissions, the Contractor shall re-submit to the Engineer.

9.6.12 Certification Procedure

1 The entire design of the Bored and any Cut and Cover Tunnels (layout design, structural design and geotechnical design) shall be checked by the Accredited Checker. On completion of the design and check the respective certificates shall be submitted to the Engineer in accordance with the UK DMRB BD 2/02.

2 The Contractor shall provide a certificate of assurance from a reputable TBM manufacturer or refurbisher to warranty that the proposed TBM is fit for purpose to carry out the intended works.

3 At least four weeks before the commencement of any tunnel excavation works, the Contractor shall submit to the Engineer test certificates concerning all material properties and characteristics as defined in the relevant sections herein and/or used for tunnel design purposes from an independent and acknowledged source.

9.6.13 Contractor’s Documents

1 The Contractor’s Documents shall comprise, but not be limited to the following:

(a) Safety Procedure Manual (Project Specific Safety Plan);

(b) Risk mitigation plan;

(c) Contingency plan;

(d) Pre-construction inspection reports of adjacent properties and utilities;

(e) List of drilling team (Names, qualifications, experience, training, etc.) and management control.

2 Full details of the micro-tunnelling system shall be supplied with the above submittals, including:

(a) Type(s), number(s) and model reference of proposed micro-tunnelling system. If not from single source, detail main elements of the system.

(b) Written confirmation from manufacturer (with company seal) that the machine configuration is suitable for the external diameter of pipe proposed.

(c) Cutter face details, including tooling and face port opening dimensions.

(d) System of alignment control and steering control and activation.

(e) Full details and justification for excavation and spoil disposal method(s).

(f) Hydraulic jacking system maximum capacity and method of limiting to maximum jacking pipe capacity.

(g) Details of any intermediate jacking stations.

(h) Electrical system and on-site power supply.

(i) Proposed communication system between the MTBM (Micro-Tunnel Boring Machine) and operating personnel on the surface.

3 Full and comprehensive details of the procedures and resources that will be used to perform the work shall be provided, including;

(a) Machine launch and reception;

(b) Pipe handling and connections;

(c) Supplementary alignment surveying;

(d) Excavation and spoil disposal;

(e) Closure of any intermediate jacking stations;

(f) Emergency procedures;

(g) Ventilation of tunnel, including gas monitoring.

(h) All materials, including slurry, lubricants;

(i) Location of approved spoil disposal facility;

(j) Drawings showing layout, temporary equipment locations and complete jacking set-up in typical jacking shaft.

4 Daily logs shall be used to record the micro-tunnelling work and any associated delays. The log shall be submitted to the Engineer for record purposes on a weekly basis. The basis of the log shall be the electronic data recorder that operates with the micro-tunnelling system. The log shall include:

(a) MTBM alignment deviation data and applied jacking load shall be recorded at intervals;

(b) Alignment deviation shall not exceed 0.3 m in 5 minutes;

(c) The commencement and completion of jacking of each pipe section;

(d) The operating pressure if pressure balanced system is used;

(e) Quantities of lubricant injected;

(f) Air quality monitoring results;

(g) Unusual events.

9.6.14 Construction Responsibilities

1 During construction, the Contractor shall be responsible for:

(a) Providing a temporary and secured drainage system for the Works (N.B. restricted access, safe and dry working environment, etc.);

(b) Taking all necessary precautions to protect the tunnel and/or adjacent properties from flooding (e.g. groundwater may be problematic in the area);

(c) Provision of a temporary wall, if required, to enable the executed tunnel section to serve as temporary storage.

2 The Contractor shall provide temporary pumping facilities to the extent required to avoid delays to the construction programme and quality of the work. The Contractor shall also indicate any EFA sites (Emergency Flood Area) if required for flood alleviation works during the construction works and confirm the availability of the land. The Contractor shall be responsible for the fencing, safety and security of any temporary EFA areas. Any fuel and/or power sources shall be provided as appropriate. All facilities/connections in this respect shall comply with standard regulations regarding their storage and/or use.

3 The Contractor however shall be responsible at his cost for providing temporary submersible pumps to evacuate any flooded tunnel sections and discharge to an acceptable outfall point.

9.6.15 Quality Assurance/Control

1 All pipes delivered to site shall be the subject of inspection and approval by the Engineer before they can be incorporated in the Works. Any and all rejected pipes shall be immediately removed from site and replaced with pipes acceptable to the Engineer. Pipes and pipe gaskets shall be stored or stacked on-site in accordance with the manufacturer's recommendations.

2 Every jacking shift shall be supervised by at least one person with previous experience of micro-tunnelling work. Operators of the micro-tunnelling system shall have prior knowledge and ability in its proper operation and shall run test the system after set-up and before starting the drive. The Contractor shall follow manufacturers' instructions when operating the complete system and operational manuals shall be available to site operational personnel at all times.

3 The installed pipeline shall be subject to visual inspection. Visible leaks (flowing or dripping water) in pipes, pipe joints, manholes and structures shall be repaired even if leakage test requirements are satisfied.

9.6.16 Materials

1 Pipe repair materials shall be supplied by the pipe manufacturer as suitable for the intended purpose and applied strictly in accordance with the pipe manufacturer's instructions. Water used for lubricant or grout shall be of neutral pH and shall be clean, fresh and free from oil, organic or other deleterious matter. Polymers shall be non-toxic and grout for filling voids outside the installed micro-tunnel pipeline shall be designed by the Contractor and submitted for approval. The pipe material shall be reinforced concrete (RC) or GRP subject to the approval of the Engineer.

2 The Contractor shall also submit a sample of the pipe wall section, joint band and gasket seal. This wall section shall be completely fitted with the proposed grout bush and flush fitting plug to be watertight.

3 The Contractor shall obtain the pipe manufacturer's warranty that the pipe conforms to the specifications and shall be free from defects in materials and workmanship.

9.6.17 Temporary Works

1 The Contractor shall develop his temporary works design taking into account all site constraints identified elsewhere in the Contract Documents. The Contractor shall provide clear method statements detailing all stages of the temporary works including supporting calculations for the temporary works. These method statements shall be issued to the Engineer before works can commence. Calculations shall be included where relevant, e.g. as part of settlement checks on adjacent structures. A "Detailed Safety Plan" identifying hazards and mitigating measures shall also be included in the Temporary Works Method Statements.

9.6.18 Construction Preparation

1 The Contractor shall be responsible for:

(a) the means and methods of micro-tunnelling and pipe jacking operations and shall be solely responsible for and shall ensure the safety of the work, his site personnel, the public and adjacent property (public and private);

(b) maintenance of clean working conditions at all locations at all times;

(c) control and implementation of safety precautions for personnel entering pipeline;

(d) organizing equipment in all areas to ensure safe operation at all times;

(e) providing safeguards to prevent leakage of fuel or lubrication oils from micro-tunnelling system equipment. Hydraulic oils used by the Contractor's plant shall be bio-degradable and non-flammable.

9.6.19 Pipeline Installation

1 The pipeline shall be placed within 50 mm of the vertical and 200 mm of the horizontal alignment shown on the Drawings. Steering corrections shall be made to the pipeline so that the joint to joint angle of any two adjacent pipes does not exceed 0.5 degrees. The Contractor shall submit daily records of deviations.

2 Each section of pipe shall be jacked forward as the excavation progresses in such a manner that complete and adequate ground support is provided at all times and such that joints maintain their integrity and the pipe train continuity is maintained.

3 The Contractor shall ensure that jacking loads do not exceed the manufacturer's safe jacking capacity by effective management of the pipe jacking alignment and pipe lubrication controls (intermediate jacking stations).

4 No damaged pipes shall be permitted to be used in the permanent works. Pipes damaged in the casting and handling process in the factory shall not be permitted on-site. Repairs to cast pipes, either in the factory or on-site shall be confined to minor cosmetic repairs only. All repairs shall be subject to the approval of the Engineer and carried out to an approved procedure. Any pipes identified as being unfit for use in the tunnel shall either be removed from site and destroyed or clearly marked and quarantined for later inspection and possible repair.

5 A proprietary seal of rubber or EPDM shall be incorporated in each pipe joint, including joints between pipes and inter-jacks / TBM. The design of the seal shall be commensurate with the detailing of the pipe joint. Seals may be fitted either at the place of manufacture or on-site prior to placing of the pipe below ground. In either case the seals shall be fitted in accordance with the manufacturer's instructions. Seals shall be inspected for damage by the surface crew immediately prior to pipe use and any damaged seals replaced. Pipe seals shall be suitably lubricated with a soap solution or other such compound in the pit bottom immediately prior to closing the joint with the jacking frame.

6 A minimum of 30 mm thick Medium Density Fibreboard (MDF) packer shall be fitted to the socket face of each pipe prior to the pipe being used in the tunnel. The packer, comprising several segments to form the 360% annulus, shall be firmly glued to the socket end and in such manner as to be 25 mm inset from the intrados of the pipe. These packers may be fitted on either at the factory or on-site, however it should be noted that in wet weather conditions suitable protection may be required in cases of lengthy exposures.

7 Pipes shall only be lifted on-site using the cast in lifting hole or lifting anchor and a purpose made lifting device. Such device shall be fully tested and carry relevant certification. Pipes shall be stored in an orderly fashion in a designated area, not more than two pipes high and on purpose made timber supports.

8 Pipes shall be power lowered by crane or gantry down the working shaft and set on a purpose made cradle comprising the base of the jacking frame assembly. The cradle shall have been set true to line and level prior to commencement of the jacking and secured to the shaft bottom. The thrust wall assembly behind the jacking frame shall also be set at right angles to the line of drive to ensure that no misalignment occurs at the pipe joint on closure. The lifting device shall be removed from the pipe prior to the joint being closed and jacking of the pipeline recommenced. The lifting hole shall be sealed with a precast concrete plug and rapid setting mortar prior to the hole location passing through the eye seal. Jacking of the pipeline shall be carried out in such manner as to limit any deflection at a joint to the manufacturer's recommended maximum. Pipe loadings shall normally be limited to 50% of the design load (or similar as agreed) whereupon an inter-jack assembly shall be installed.

9 On completion of a drive the line shall be fully inspected for damage or leaking joints. The Contractor shall propose remedial works in such cases. Holes used for injection of lubricants shall be filled with an approved mortar to a smooth finish at the intrados of the pipe.

9.6.20 Construction Execution

1 All excavation works shall be properly set out to the line, level, curve or slope required within accepted tolerances. Survey stations, centre lines, bench marks and grade lines shall be clearly marked in paint on the tunnel walls. Chainages at 10 metre intervals shall also be clearly marked by appropriate permanent means.

2 Internal tunnel marking shall be done prior to jacking any “lining” pipes. This method can be used to mark the exact location of any problem areas during the jacking operation.

3 The Contractor shall establish and maintain reference control lines and grades for the Works, which shall be used to exactly locate the pipeline and structures. The primary control for the micro-tunnelling system shall be checked at least once per week or not more than 60 metre intervals of constructed pipeline.

9.6.21 Working in Compressed Air

1 Provisions shall be made on the tunnelling machine to facilitate entry into the face of the machine under compressed air for inspections and maintenance. These provisions shall comply in all respects with all relevant statutory regulations governing work in compressed air. The airlocks and other equipment fitted to the machine shall comply with the requirements of CENprEN12110.

2 All equipment and personnel necessary to perform such interventions for inspection or maintenance shall be available throughout the pipe-jacking operations.

3 The Contractor shall submit details of the compressed air installation for the Engineer’s approval, along with details of the qualification and previous experience of lock attendants, medical lock attendants, compressor attendants and supervisory staff.

4 In highly permeable ground where air losses might be excessive, arrangements shall be made to inject thick bentonite slurry into the face prior to an intervention to form a cake on the exposed face in order to limit air loss.

5 Air compressors shall have a standby capacity of at least 50% and be powered by an independent power source.

6 All essential parts of the compressed air system, including pipelines carrying compressed air to the face, shall be duplicated. All pipework, valves, gauges, etc. must be protected from impact damage. Where flexible hoses are used to carry the compressed air through the pit bottom jacking arrangement they shall also be protected from entrapment. In the event of failure of one part of the system it should be possible to isolate that part without interrupting the air supply.

7 A safety valve shall be fitted to free air side of the pressure bulkhead of the tunnelling machine. This safety valve shall be set to relieve at marginally above the working pressure and shall be of adequate size to match the installed capacity of the air compressors. Prior to any work in compressed air the system should be tested to working pressure.

8 Any airlock fitted to the tunnelling machine shall be at least 1.5 meters diameter. The air lock should be designed as a pressure vessel, subjected to a hydraulic test and issued with an appropriate test certificate. Air lock doors should be at least 500 millimetres by 400 millimetres. Doors should normally be kept closed by the air pressure but the door opening to the front of the tunnelling machine should also be able to be locked shut whilst persons are being decompressed in the lock. The airlock should be comprised of two chambers to allow access into the working chamber in case of emergency. For use at pressures above one bar the lock should be fitted with seating for the persons being decompressed. Where the working pressure is above 0.7 bar a medical lock shall be provided which shall be manned by a medical lock attendant whenever work in compressed air is in progress and for twenty four hours afterwards. If necessary the quality of the compressed air supplied to the working chamber shall be improved by coolers and filters to ensure compliance with the specified requirements. The supply of compressed air to the working chamber shall be sufficient to ensure that the level of any contaminant shall not exceed 10% of the short term exposure level when measured at atmospheric pressure. Air quality should be monitored at least once per day.

9 The Contractor shall appoint a registered medical practitioner experienced in compressed air work to advise on decompression methods to be adopted and on all other aspects of health relating to the work in compressed air. All employees will be medically examined prior to working in compressed air. Records will kept of all medical examinations and details of each compressed air exposure including working pressure, working time, decompression procedures, etc. No person shall be allowed to work in compressed air if the Contractor has reason to suspect that person is under the influence of drink or drugs such that his capacity is impaired. No one shall be allowed to enter the compressed air working chamber alone.

10 An experienced lock attendant shall be on duty at the free air side of the air lock at all times when there are persons in the compressed air working chamber. All valves gauges and controls at the lock attendant's station shall be clearly marked with their function and method of operation.

11 Smoking shall be banned in compressed air and no person shall take smoking materials into compressed air. As far as is practicable no combustible material shall be taken into the air locks and or the working chamber. The use of burning or welding equipment should be strictly limited and shall be subject to a permit to work system. Fire extinguishers shall be provided in the air locks and the working chamber whenever work in compressed air is in progress.

9.6.22 Ground Pre-treatment

1 Pre-treatment of the ground, where applicable, shall be applied in advance of the tunnel excavation to provide sufficient stability of the excavated area. Execution of such works shall not commence before consent has been given to the design of such works by the Engineer. The surface settlement monitoring shall be installed, initialised and baselined prior to any ground modification work.

9.6.23 Drainage During Construction

1 The Contractor shall supply, install, operate and maintain sufficient pumps and pipe work to control and remove water from any part of the underground works. Standing water shall not be allowed. The capacity of pumps installed where required, including at launch/reception pits, shall always be at least twice the normal volume of the inflow of water plus the volume of flushing water if drilling equipment is used. The minimum capacity of the pumps shall be 20 l/s.

2 The Contractor shall store or immediately have available standby pumps in good working conditions of the same capacity. This equipment shall be maintained properly and tested frequently.

3 The Contractor shall provide settlement tanks or other decontamination facilities before the water is discharged. The Contractor shall submit his design for these facilities as part of his method statement. The Contractor shall remove all accumulated slurry, silt or other debris from the Works on an ongoing basis.

9.6.24 Disposal of Tunnel Seepage and Waste Water

1 Tunnel seepage and wastewater arising from the Works shall be collected and discharged via a settlement tank. Seepage and wastewater shall not be discharged into the public drainage system unless it meets the standards listed below. Where necessary, the water shall be treated to achieve these standards.

2 The Contractor shall comply with BS 6031:1981 Code of Practice for Earthworks or equivalent, regarding the general control of site drainage and the requirements of the Relevant Authority. The Contractor shall ensure that water which may have come into contact with contaminated material shall be disposed of in an appropriate manner. The Contractor shall have to apply for consents and approvals as follows:

(a) obtain and complete standard “permit application form” for proposed discharge into a PWA system.

(b) before any discharges can be permitted into a PWA pipeline, written approval shall be obtained from the relevant department of the PWA. Failure to obtain the permit can result in immediate closure of the Works.

3 The Contractor shall make provisions that all hazardous substances including oil drums or containers on-site are controlled in accordance with the relevant legislation and are properly stored so that no oil or their contaminants are allowed to reach watercourses or groundwater.

9.6.25 Testing

1 The Contractor shall provide all apparatus, assistance, documents and other information, electricity, equipment, fuel, consumable, instruments, labour, materials, and suitably qualified and experienced staff, as are necessary to carry out the specified tests efficiently. The Contractor shall agree, with the Engineer, the time and place for the specified testing of any plant, materials and other parts of the Works.

2 The Engineer may vary the locations of details of specified tests, or instruct the Contractor to carry out additional tests. If these varied or additional tests show that the tested Materials or workmanship is not in accordance with the Contract, the cost of carrying out this Variation shall be borne by the Contractor, notwithstanding other provisions of the Contract.

3 The Contractor shall promptly forward to the Engineer duly certified reports of the tests. When the specified tests have been passed, the Engineer shall endorse the Contractor's test certificate, or issue a certificate to him to that effect.

9.6.26 Grouting

1 As soon as each section of pipeline has been installed, its periphery shall be grouted using a cement based grout with a minimum 48 hour compressive strength of 345 kPa (50psi) and minimum 28 days compressive strength of 1380 kPa (200psi). Every effort shall be made by the Contractor to place the grout even when it is known that the periphery contains polymer or other lubricant and shall demonstrate that grout is not being taken before the grouting operation is terminated.

2 The grouting pressure shall be sufficient to move the grout to fill the annulus along the pipe but shall not be greater at the injection nozzle than the pressure limit set by the pipe manufacturer. The injection points shall be placed at not more than 6 metre intervals along the pipeline. Grouting shall be carried out around pipelines at launch and reception shafts as soon as the pipeline is placed at these locations to prevent water and soil from entering the shafts. Additional grouting shall be carried out at the Contractor's expense, if required to ensure that the joints are watertight.

3 The micro-tunnel shall be adequately lit and ventilated for safe access, egress and for working. If open flames are to be used where combustible gasses may enter the air, tests for combustible gas shall be conducted continuously during the work. The tunnel workers shall carry a gas meter that automatically records the level of combustible gas. Particular care shall be taken that pipe repairs are carried out in accordance with approved ventilation and safety procedures.

4 Infiltration Acceptance Test of the installed pipe, which shall be witnessed by the Engineer, shall be in accordance with ASTM C969. The internal inspection of the completed pipeline shall be the subject of approval by the Engineer.

9.6.27 Surface and Building Settlement Monitoring

1 The Contractor shall submit, for the consent of the Engineer, the detailed proposal for positioning of ground and building monitoring points and other instruments and the frequency of the measurements. Excavation works shall not start until the consent of the Engineer to that submission has been obtained. During construction the Contractor shall review monitoring frequencies depending on settlement trends, the extent of construction activity in an area and the behaviour of the structures.

2 The monitoring data shall be copied to the Engineer on the same day that the readings are taken, followed by hard copies with analysis within 24 hours. In addition to carrying out all the normal surveying requirements for carrying out a pipe-jack the Contractor shall set-up surface settlement monitoring points at suitable intervals along the projected pipeline. The spacing of such points may be as close as 10 metres in sensitive areas however may vary according to the depth and location of the jack.

3 In addition to monitoring over the centre line of the drive readings shall be taken at suitable lateral distances to the centreline at each monitoring chainage. In roads these cross sections shall extend the full width of the road corridor.

4 Settlement monitoring points shall also be installed at the corner of each building or structure within a recognised distance from the tunnel centreline. The distance shall normally be equivalent to the depth to invert of the proposed pipeline with a minimum of 20 metres.

5 A full record of existing ground and structure levels shall be taken and agreed prior to commencement of pipe-jacking operations.

6 A photographic record of existing damage and faults to all adjacent surface structures shall be made by the Contractor and agreed prior to commencement of pipe-jacking operations.

7 During the jacking operation between any two shafts the Contractor shall survey the levels of the appropriate monitoring points on a daily basis.

8 Monitoring shall be carried out on any particular section of points when the tunnel face is within 20-50 metres of that section dependent on the tunnel depth and ground conditions. Monitoring shall continue at each section until the tunnel drive has been completed or in the case of excessive settlement until the settlement has ceased or the rate of settlement becomes acceptable.

9 If during jacking operations the actual movement of the ground reaches 90% of the predicted value the Contractor shall immediately review his predictions and if appropriate revise his operational procedures accordingly. Where such movement occurs suddenly and adjacent to the tunnel face the Contractor shall not proceed with the jacking operation until a revised method has been agreed with the Engineer.

9.6.28 Contractor's Obligations

1 The Contractor shall carry out the Tests on Completion in accordance with this Clause after providing the "As-Built" documents for the part to be tested.

2 Unless otherwise stated in the Particular Conditions, the Tests on Completion shall be carried out in the following sequence:

(a) Pre-commissioning tests per stage, which shall include the appropriate inspections and pressure tests to demonstrate that each item of the stage is acceptable and that the Works can safely proceed to the next stage

(b) Commissioning tests, which shall include the specified operational tests to demonstrate that the Works or Section can be operated safely and as specified, under all available operating conditions.

3 For all tests described in sub-paragraph (a) and (b) the pipe and joints shall be considered watertight if water infiltration is so low that it can only be detected as damp patches without flowing or dripping water. Likewise, the tests described in sub-paragraph (a) and (b) shall be used to confirm that the pipeline remains equally watertight throughout the leak testing.

4 As soon as the Works, or a Section, have passed each of the Tests on Completion described in sub-paragraph (a) and/or (b), the Contractor shall submit a certified report of the results of these tests to the Engineer.

9.6.29 Microtunnelling Machine

1 A remote control tunnelling machine shall be used and it shall include a closed circuit television (CCTV) camera which transmits a picture of the laser beam on the target together with other machine information (such as jacking force, face pressure, length, roll, pitch, steering attitude, temperature valves open or closed) to a microprocessor console on the surface from where the system is operated.

2 The tunnelling machine shall be steerable, incorporating hydraulic rams to move the articulated cutting head. The line and level control shall be achieved by a laser beam transmitted from the jacking shaft to a target mounted in the tunnelling machine

3 The design of the tunnelling machine shall ensure no rotation or rolling during installation.

4 The tunnelling machine shall be capable of operating under groundwater conditions where encountered. The hydrostatic balance shall be not less than 3 m head of water.

9.7 THRUST SYSTEM

1 The thrust system shall distribute the force to the pipes through a thrust ring and packing. The jacks shall be capable of applying the thrust symmetrically to the thrust ring. Intermediate jacking stations may be used at the discretion of the Contractor where frictional resistance or obstructions result in unacceptable thrust forces.

2 A purpose made compressible packer of hard board or other approved material shall be included between the thrusting surfaces. Pushing blocks shall not be in direct contact with the pipe or preformed unit, which shall be protected by means of a steel ring, template or other approved method. Damaged pushing blocks shall not be used.

3 Spacer blocks, if used, shall be true and free of distortion.

4 Thrust rings shall be free from distortions and sufficiently stiff so as to transfer the load from the jacks uniformly to the packing.

5 Except at the shield, each group of jacks shall be interconnected hydraulically to ensure that the load is evenly distributed to the thrust ring. Each jack shall incorporate a load cell.

6 At the rig and at intermediate station, automatic thrust recording equipment monitoring load cells incorporated in each jack shall be provided together with a pressure metering device. Other continuous records, including cutter torque, rate of progress, slurry pressure, slurry flow, pitch, roll, and earth face pressure shall be provided. Copies of these records shall be submitted daily to the Engineer.

7 The thrusting force shall not exceed the maximum permissible force stated in the method statement. Thrust pressure shall be monitored and controlled to ensure that the pipe joint deflection does not exceed the maximum permitted angular deflection of 1 °.

9.8 LUBRICATION HOLES

1 Lubrication holes shall be threaded to enable plugs to be screwed into the socket and to withstand external pressure. A non-return valve shall be fitted where opening a lubrication hole would permit ground loss. Upon completion of grouting, the plugs shall be covered with material similar to that of the pipes. The pressure of the lubricant shall be maintained until it is replaced by grout.

9.9 RECORDS

1 The Contractor shall maintain and submit to the Engineer after each day a log which records the following information:

(a) location of drive, between manholes
(b) strata encountered
(c) position and orientation of the pipes
(d) thrusting pressure used on both main and interjack rams during driving of each pipe
(e) line and levels of pipeline constructed including details of angular deflection at joints
(f) roll of pipejacking shield

(g) average length of pipeline constructed per shift

(h) thrust from ground on face of machine

(i) readings of oxygen, methane and hydrogen sulphide gas at the excavating face

(j) volume of excavated materials removed

(k) volume of grout used, the points of injection and pressure at the points of injection

(l) Contractor's operating personnel.

9.10 TESTING

9.10.1 General

1 Upon completion of the permanent construction of the pipeline, it shall be tested for watertightness, alignment, condition and soundness, and all other designated requirements.

2 In the event of the Works failing a test, the Contractor shall take such remedial action as is necessary, subject to the Engineer's approval of the methods proposed. The Works shall then be retested until such time as the Works pass the test.

9.10.2 Watertightness

1 Leakage tests shall be carried out in accordance with Clause 4.5.4 of this Section.

END OF PART