12 VACUUM SEWERAGE SYSTEM

12.1 GENERAL

12.1.1 Scope

1 This Part includes the specifications for the design and provision of vacuum sewerage systems.

2 Related Sections and Parts are as follows:

This Section

Part 1..... General
Part 2..... Earthworks
Part 3..... Pipes and Fittings Materials
Part 4..... Pipe Installation
Part 5..... Valves, Penstocks and Appurtenances
Part 6..... Miscellaneous Metalwork
Part 8..... Protective Coatings and Painting

Section 1, General
Section 9, Mechanical and Electrical Equipment
Section 10, Instrumentation, Control and Automation
Section 21, Electrical Works
Section 22, Air Conditioning, Refrigeration and Ventilation.

12.1.2 References

BS 5500, welded pressure vessels

European Standard CEN/TC 165, Vacuum sewerage system outside buildings.

12.1.3 Definitions

1 The following definitions of vacuum sewerage system apply to this Part:

(a) Batch Volume: volume discharged from a collection sump during one normal cycle of the interface valve and is equivalent to the volume of the sump within the operating range of the sensor.

(b) Collection Chamber: interface between the vacuum sewerage system and the collection sewers consisting of a collection sump and interface valve pit.

(c) Collection Sump: storage capacity provided to store flows of sewage until sufficient volume has accumulated to activate the interface valve. Storage may also be provided to reduce the risk of flooding if there is a system failure.

(d) Controller: device which, when activated by the sensor, opens the interface valve and, after the passage of sewage and air, closes the valve.

(e) Forwarding Pumps: pumps installed at the vacuum station to pump the sewage from the vacuum system to the trunk sewer.

(f) Interface Valve: valve which admits the flow of sewage and air into the vacuum sewer through the service connection.

(g) Isolation Valve: valve installed to isolate a particular section in the vacuum sewer network.

(h) Lift: up-grade section between two down-grade sections of a vacuum pipeline. The lift height is the difference in sewer invert levels between two successive down-grade sections. The static lift is the increase in the hydraulic grade line at a lift and is generally the increase in invert level minus the internal diameter.

(i) Sensor: device which senses the presence of sewage in the collection sump and activates the controller to open the interface valve.

(j) Service Connection: that part of the vacuum pipeline which connects a single collection
chamber to the vacuum sewer.

(k) Vacuum Generator: equipment installed at the vacuum station to generate a vacuum.

(l) Vacuum Pipeline: pipeline under negative pressure.

(m) Vacuum Pump: pump that creates the vacuum in the vacuum pipeline.

(n) Vacuum Recovery Time: time taken after the operation of an interface valve for the negative pressure at the valve to be restored to its original value.

(o) Vacuum Sewer: the major part of the vacuum pipeline into which the service connections discharge.

(p) Vacuum Station: vacuum generators, vacuum vessel (or sewage sump), forwarding pumps and system controls.

(q) Vacuum Vessel: negative pressure vessel connected to the vacuum pump. The vacuum sewer discharges into the vacuum vessel and the forwarding pumps pump sewage from the vessel. The vacuum pumps maintain a negative pressure in the vessel. When the vacuum generator is an ejector pump, the vacuum vessel is replaced by a sewage sump at atmospheric pressure.

12.1.4 System Description

1 The Contractor shall be solely responsible for the design and construction of the system to meet the specified requirements.

2 The design of the system shall conform generally with European Standard CEN/TC 165, except as otherwise specified in this Part.

3 The vacuum sewerage system shall be required to operate under very low flows but it shall provide effective transfer of sewage to the sewers under all conditions and not cause flooding or overflow of sewage from the collection vessels.

4 The maximum noise level at the vacuum station and elsewhere in the system shall not exceed 65 dbA.

12.1.5 Submittals

1 The Contractor shall submit complete data and details of vacuum sewerage systems for the Engineer's approval as follows:

(a) method statement which shall include:

(i) name and experience of specialist

(ii) detailed procedure for the works

(iii) list of all construction plant and tools

(iv) safety procedures

(b) hydraulic, structural, mechanical, and electrical calculations used in the preparation of the shop drawings.

(c) shop drawings for all components and the complete system.

(d) certificates that all components and equipment to be provided are suitable and made of such materials to withstand the prevailing climatic conditions of Qatar and the corrosive environment. Details of proposed corrosion protection systems shall be provided.

(e) complete justification for any proposed changes in materials.

(f) Training program

(g) operation and maintenance methods manual which shall include:

(i) complete information of the system illustrated in detailed drawings.

(ii) detailed procedures for correct operation and maintenance of all system components.

(iii) reprogramming manual

2 The Contractor shall not procure materials or commence installation of the Works until the Engineer has approved his submittals.

12.1.6 Quality Assurance

1 The vacuum system shall be provided by approved, specialist manufacturers, suppliers and installers designated in the contract Project Specification.

2 All supervisors and technicians employed shall be fully competent in the installation methods.

12.1.7 Warranty

1 The control equipment shall be provided with a satisfactory performance warranty.

2 In addition to the warranty requirements of Part 1 of this Section, the vacuum sewerage system supplier shall warrant that the system and its components will meet the performance for a period of 24 months from the date of startup. The vacuum system supplier shall be solely responsible for the warranty. The warranty shall be in the form of a letter and report which shall be submitted to the Engineer, for review. Within the warranty period, any remedies necessary to bring the vacuum sewerage system into compliance with the specifications shall be the sole responsibility of the vacuum system supplier.

3 The Contractor shall furnish the Employer with manufacturer's warranty and guarantee certificates for all equipment.

12.1.8 System Operation

1 On satisfactory completion, the Contractor shall operate and run the vacuum system for a period of 400 days during which time he shall be totally responsible for all maintenance including spares.

12.1.9 Commissioning

1 The Contractor shall submit instruction manuals in draft to the Engineer four weeks prior to the commissioning.

2 The Contractor shall demonstrate to the Engineer that all equipment functions to meet the design criteria and specifications.

12.1.10 Maintenance

1 The Contractor shall provide any special tools and equipment needed to operate and maintain the system and provide spare parts for two years operation and an additional 400 days for the maintenance, all at his expense.

12.2 SYSTEM DESIGN AND PERFORMANCE

12.2.1 General

1 The vacuum system shall be supplied by a manufacturer approved by the Engineer.

2 The general location of the vacuum sewerage system including the locations of collection chambers, vacuum pipelines, vacuum station and pressure pipeline discharging to the trunk sewer which forms part of the gravity sewerage system shall be as shown on the Drawings.

3 The Contractor shall be responsible for carrying out any additional site investigations, for the design, and for provision of a complete system including supply of all materials and equipment, testing, startup and commissioning.

12.2.2 Design of the System

1 The design of the system shall satisfy either of the two conditions:

(a) outline design of the sewerage system provided by the Engineer

(b) as an alternative option proposed by the Contractor to avoid deep sewers in the Contract in which case the design will be based on the Contract Drawings

2 The Contractor shall not procure materials, equipment or begin construction of the Works until the Engineer has approved the design and all other submittals.

3 The vacuum sewerage system shall intercept sewage flow and convey the flow to collection chambers. Collection chambers, interface valves and vacuum pipelines shall be located so that they do not interfere with or obstruct existing services and access thereto.

4 Sewage from the collection chambers shall be drawn into the system through interface valves and conveyed by the vacuum pipelines to a collection vessel located in the vacuum station, equipped with vacuum pumps.

5 Sewage from the vacuum station shall be pumped through the pressure pipeline to the gravity sewerage system. All necessary pipework shall be included from the vacuum station to the point of discharge to the gravity sewer.

12.2.3 Design of Vacuum Station

1 The Contractor's design shall optimise the number and locations of the vacuum stations. Where more than one station is required, the size of the collection vessels, vacuum pumps and other equipment shall be standardised as far as practicable.

2 Vacuum stations shall comprise all civil works; mechanical and electrical works including pipework, vacuum vessel, vacuum pumps, cooling systems, forwarding pumps, odour control equipment; motor control centre; instrumentation including vacuum data loggers, and valve telemetry display and telemetry outstation and connection to the control centre; lighting and all other work necessary in accordance with Sections 9 and 21 to make the vacuum station complete in all respects.

3 Forwarding pumps shall be controlled by level probes installed in the collection vessel; two sets of probes shall be installed, an upper set to run on normal day operation and a lower set to empty the vessel under extreme low flow conditions. The pump control station shall include automatic timer, indication and alarm in accordance with Sections 9 and 21.

4 The vacuum station shall be of cavity wall construction. The Contractor shall design the station building and submit detailed design drawings for the Engineer's approval. The station building shall incorporate the following minimum requirements:

(a) minimum internal floor area 12 m^2

(b) external cement, sand or concrete blocks

(c) aluminium doors and window frames

(d) black PVC-U rainwater drainage connected to surface water drainage conduits if available, otherwise to a gargoyle and soakaway

(e) sufficient wall area for telemetry outstation

(f) QGEWC supply meters to be mounted in external box (QGEWC supply)

(g) a connection point to the incoming vacuum sewer, fitted with an isolation valve, for independently testing vacuum valves

(h) a separate room housing a single water closet and hand basin with both hot and cold running water

(i) water supply to a 200 l GRP header tank above the roof

(j) external washdown tap with concreted splash area below, draining to the on-site vacuum collection chamber

(k) activated carbon type exhaust air filter

(l) a collection chamber shall be constructed at the site which shall receive the flows from the water closet, hand basin, external washdown tap, and coolant water from the liquid ring vacuum pumps.

5 The vacuum station shall include all pipework necessary for satisfactory performance, operation and maintenance.

12.2.4 Design of Collection Chambers

1 Collection chambers shall be designed such that in each case the lowest invert of the incoming gravity sewer is above the high operation sewerage level of the interface valve to avoid surcharging the gravity sewers during normal operation.

2 Collection chamber sumps shall be sized to give a 4 h retention capacity at average flow below the level of the incoming sewers. The Contractor shall account for the probability of power failure and its consequences. Provision shall be made in the control panel and cabling for connecting mobile standby power generation.

3 Collection chambers shall be fitted with a level sensing devices and local and remote alarms as designated, and shall be so located and fitted with access openings to enable clearing of sewage using pumping or vacuum tankers. In no case will the provision of facilities for discharge of sewage to the surface water drains be permitted.

4 Collection chambers shall incorporate an intermediate platform within the chamber to facilitate easy access to the vacuum interface valve. The area of the platform must be at least equal to half the plan area of the chamber. Access to the lower part of the chamber below the intermediate platform shall be provided with a minimum 600 mm diameter clear opening. Where the intermediate platform is provided by means of a concrete slab, the access hole into the lower chamber shall be provided with a galvanised open mesh cover as specified in Clause 6.5.7 of this Section permitting viewing of the lower part of the chamber from the top of the chamber.

5 Vacuum interface valves in collection chambers shall incorporate an auxiliary suction pipe such that if the valve fails the chamber can be emptied into the vacuum pipeline. The auxiliary suction pipe shall be positioned within 100 mm below the cover level and shall be operable from ground level outside the chamber.

6 Interface valve assemblies shall incorporate isolating valves such that the interface valves can be easily removed without necessitating loss of vacuum in the vacuum pipeline.

7 Where breathers are used on vacuum interface valves they shall not exceed 5 m in length. Where the breather head is not against a structure to which it can be securely fixed the breather head shall be protected by a 50 mm by 50 mm galvanised steel angle cast in concrete, the head being fixed into the angle with plastic cable ties or similar. Where any double valve collection chambers are used each valve shall have a dedicated breather.

8 The sump shall be vented to allow the intake of air. The sump may be vented by the gravity system provided that the operation of the vacuum system does not unseal the traps on the internal sewerage system and that the internal sewerage system is vented to atmosphere.

12.2.5 Design of Vacuum Pipelines

1 Pipeline profiles shall be as follows:

(a) the size of individual lifts shall be kept as small as possible to maximise vacuum transport efficiency and many small lifts shall be provided instead of one large lift. The minimum horizontal distances between profile changes shall be 6 m for vacuum sewers and 1.5 m for service connections

(b) except at lifts, vacuum sewers shall have a minimum gradient of 1:500 in the direction of flow. Profile changes shall be made where necessary to ensure that the pipeline depth does not become excessive

(c) where the ground surface has a gradient of 1:500 or more in the direction of flow, vacuum sewers may be laid parallel to the surface. Stagnation of sewage shall be avoided at locations followed by an uphill section

(d) lifts shall generally not be more than 1.5 m, but where conditions are such that a lift exceeds 1.5 m special care shall be taken in the design of pipelines by taking into consideration the flow capacity and total lengths of the vacuum pipeline.

2 Air Flow. The total average air/liquid ratio shall not be less than 1.5:1. The Contractor shall identify in his calculations the average air liquid flows for which the system is designed.

3 Minimum Negative Pressure. The system design shall achieve a minimum negative pressure of 25 kPa (gauge) under no flow conditions at each interface valve.

4 Vacuum Recovery. The system shall be designed so that the vacuum recovery will be fast enough to ensure that temporary surcharging of collection chambers does not occur under normal flow conditions.

5 Length of Vacuum Sewers. Lengths of vacuum sewers shall be such to enable the system to restart automatically and recover vacuum following rectification any breakdown.

6 Service Connections. Service connections shall slope away from the interface valve and shall connect into the top sector of the vacuum sewer contained within the angle of +60 ° about the vertical axis.

7 Branch Connections. Branch connections to vacuum sewers shall be by junctions connected to the sewer above the horizontal axis, and the angle of the junction shall ensure that the flow towards the vacuum station is generated and backflow is minimised. No connection shall be made within 2 m of a lift.

8 Isolating Measures. Adequate means of isolating lengths of vacuum sewer to permit maintenance shall be provided by isolating valves or appropriate inspecting pipes. Isolating valves shall be suitable for service under vacuum and pressure and shall be capable of sustaining a differential vacuum of 80 kPa.. Buried valves shall be provided with extension spindles and surface boxes.

12.3 PRINCIPAL SYSTEM COMPONENTS

12.3.1 General

1 All materials used in the manufacture of collection chamber, interface valve and controller shall be capable of resisting corrosion from soils, groundwater, sewage and sewage gases.

12.3.2 Vacuum Pipelines

1 Vacuum sewers shall have a minimum diameter of 80 mm and service connections shall have a minimum diameter of 50 mm.

2 All vacuum pipes and fittings shall be of MDPE as specified in Part 3 of this Section. The minimum pressure rating for plastic pipes shall be 0.6 MPa but higher ratings shall be employed if the pipe has an initial ovality or if progressive deformation is likely to occur.

3 Pipelines and components shall be designed to withstand the stresses arising from earth cover, traffic and cyclic loads, particularly at connections to structures and the range of negative pressures arising during operation and testing.

12.3.3 Collection Chamber

1 The chamber shall be watertight and shall be protected against floatation in waterlogged areas. The internal surface of the sump shall be smooth and the sump shall be designed to be self-cleansing.

2 Access to the chamber shall be through a manhole cover and frame as specified in Part 4 of this section. The size of chamber shall be similar to inspection chamber on the Contract Drawing.

12.3.4 Interface valves

1 Interface valves shall be all ABS construction and shall be capable of performing sufficient cycles to evacuate 3000 m3 without attention. All materials shall be serviceable at 50 °C ambient temperature and 100 % humidity conditions except if the valves are exposed to the sun where the temperature could reach 80oC. The valve mechanism shall be explosion proof.

2 Interface valves shall:

(a) be minimum of 80 mm diameter and capable of passing solids with a maximum size of 65 mm diameter with a visual flow through area of not less than 60 %

(b) be complete with controller, sensor pipework, fittings and telemetry connections

(c) be vacuum-operated in opening and spring-assisted in closing

(d) be controlled by sump liquid level and by vacuum

(e) fail safe in the closed position

(f) prevent backflow to the collection sump

(g) evacuate the batch volume on each cycle.

3 Batteries shall not be used in valve actuating or control elements.

4 Valve opening initiation level and valve opening times shall both be adjustable.

5 Configurations shall be such that the vacuum ensures positive valve seating.

6 When the valve is open, the flow stream shall not be obstructed by the valve plunger. The valve may be protected from obstruction by the installation of constriction in the suction lift pipework.

7 The internal diameter of the suction pipe shall not be greater than the internal diameter of the interface valve which shall not be greater than the internal diameter of the service connection.

8 Valves installed in sumps shall be capable of operating when submerged in sewage.

9 Valves shall be designed to allow easy access for maintenance. Fixing arrangements shall enable the valve and control system to be readily replaced.

12.3.5 Controller

1 Controllers shall

(a) be explosion proof

(b) open the interface valve only if there is a minimum vacuum of 15 kPa available

(c) maintain the valve fully open until the sump has been fully emptied

(d) be adjustable so that a range of air to sewage volume ratios can be obtained.

2 If the introduction of air is allowed after the sewage has been fully emptied, the controller shall maintain the valve in the open position for a further period.

12.3.6 Sensor

1 The interface valve shall be provided with a sensor to determine the level of sewage in the collection sump. The sensor shall be designed to be fouling resistant. Where level sensor pipes are employed they shall not be less than 45 mm diameter.

12.3.7 Vacuum Vessel

1 Flows from vacuum pipelines discharged to vacuum stations shall be collected in a vacuum vessel. The vessel shall be manufactured of steel and be in accordance with the requirements of BS 5500 or other corrosion resistant material such as GRP. The steel shall be corrosion protected in accordance with Clause 8.4.2 of this Section.

2 Vessel capacity shall suit vacuum generator and forwarding pump capacities and the vacuum rate of inflow and storage volume.

3 Vessels shall

(a) be fabricated and tested for a working vacuum of 70 kPa and rest vacuum of 90 kPa

(b) be fitted with the required number of correctly sized sewage inlet and outlet pipes which shall be integral with the vessel. No inlet pipes shall be connected below the system emergency stop level. The inlet and outlet pipes shall be located such that solids do not accumulate in the vessel

(c) be provided with a suitable flanged manhole access cover to permit entry for internal inspection and maintenance

(d) be fitted with a level control system which is suitable for operation in vacuum and easily removed for adjustment or replacement

(e) be fitted with suitable galvanised mild steel cradles for bolting to the concrete floor of vacuum station.

4 The pump manufacturer's advice on the need to install equalising lines connecting the discharge side of the pumps to the vacuum vessel shall be sought. If required by the pump manufacturer, a suitably sized and valved equalising line from each pump to the vessel shall be provided

5 The steel vessel shall be internally and externally protected from corrosion with a suitable protection system in accordance with Part 8 of this Section. Details of the proposed protection method shall be submitted as required by Clause 12.1.5 of this Section. The protection system shall take account of accessibility for inspection and maintenance.

12.3.8 Vacuum Pumps

1 Two vacuum generators such as liquid ring or rotary vane pumps or ejector pumps shall be provided each having sufficient capacity to serve the system.

2 Vacuum pumps shall be capable of continuous operation and shall be designed for a minimum of 12 starts per hour. Pumps of equal capacity shall be installed such that one pump can act as standby.

3 Vacuum pumps shall be operated by pressure switches attached to the vacuum vessel. The pumps shall operate on the liquid ring principle and shall exhaust air from the vacuum vessel. One duty and one standby vacuum pump shall operate in conjunction with a common tank containing the operating liquid, normally water, and associated pipework connecting the pumps to the tank so that the water level is maintained at all times. The service liquid shall be maintained at 30 °C by a refrigerated cooling unit, circulating the liquid through the tank. Ambient air temperatures up to 50 °C shall not limit the functioning of this equipment or cause the vacuum pumps to trip on high circulating water temperature.

4 Each pump shall be provided with a rotary seal comprising a rubber seal, spring loaded and rotating against a carbon face. Suitable non-return valves shall be provided to prevent the exhausted air from returning into the vacuum system. The pressure switches shall control the operation of the vacuum pumps to maintain the vacuum within the system.

12.3.9 Forwarding Sewage Pumps

1 Forwarding pumps or pressure vessels used to forward the sewage shall have sufficient capacity to serve the system. Forwarding pumps shall be as specified in Section 9 except as modified below.

2 Forwarding pumps shall be unchokeable sewage pumps suitable for operating under negative pressure without cavitations. They shall be suitable for a maximum of 12 starts per hour. The motor speed shall be 1500 rpm.

3 A 25 mm connection of swept flanged tee shall be provided on each pump delivery, with hand hole incorporated in the impeller casing or duckfoot bend under the pump and reversible wear plate fitted under the impeller. Pumps shall be fitted with lip seals to prevent loss of vacuum from the shaft when pumping from the sewage vessel.

12.3.10 Motor Control Centre

1 The motor control centre for the operation of all pumps shall be as specified in Sections 9 and 21.

2 The operation of pumps shall be controlled by a programmable logic controller and shall prevent simultaneous starting of the vacuum and sewage pumps to prevent surges.

3 The controls shall permit the manual or programmed selection of duty and standby pumps and shall provide for automatic start of the standby pumps in the event of duty pump failure.

4 The vacuum pumps shall be controlled by monitoring the vacuum in the vacuum vessel with adjustable pressure switches set to the desired operating range. Additional pressure devices shall be provided to indicate and record both high and low vacuum.

5 The level control system shall respond to the following sewage levels in the vacuum vessel or the sewage sump:

Emergency stop level (High Level)		-	stops vacuum generation
		-	forwarding pumps operate
Start level		-	starts forwarding pumps
Normal stop level	(Low Level)	-	stops forwarding pumps.

6 All power, control and instrumentation cabling shall be provided as required for the complete system.

7 The following alarms with appropriate remote signalling shall be provided:

(a) low vacuum alarm indicating that system vacuum is below the minimum preset level

(b) high sewage alarm indicating that sewage level in the vacuum vessel or sewage sump is at the high level mark.

12.3.11 Telemetry Outstation

1 Telemetry shall be designed and installed in accordance with Section 10.

12.3.12 Discharge Pipelines

1 All pipes, fittings and valves on the discharge side of the forwarding pumps shall be as specified in Parts 3 and 5 of this Section.

12.4 INSTALLATION OF THE SYSTEM

12.4.1 Pipelines

1 Vacuum and pressure pipelines shall be installed in accordance with Part 4 of this section and valves shall be installed as specified in Part 5 of this Section, except where modified herein.

2 Vacuum pipelines shall be jointed as specified herein.

12.4.2 Pipe Joints for Vacuum Pipelines

1 Pipeline components shall be connected in such a way that the pipeline is sealed and accommodates static and dynamic stresses.

2 Where mechanical joints are employed they shall comply with the requirements of Part 3 of this Section and be suitable for vacuum service.

3 Pipelines shall be securely anchored or bedded to resist thrust arising from internal vacuum. Precautions shall be taken against flotation where necessary.

4 Welded joints shall only be made by suitably trained personnel using approved welding equipment.

12.4.3 Pumps, Motors and Instrumentation

1 Pumps shall be installed as specified in Section 9.

2 Motors shall be installed as specified in Sections 9 and 21.

3 Instrumentation shall be installed as specified in Section 10.

12.5 TESTING

12.5.1 General

1 The Contractor shall prepare and submit his proposed testing program for the approval of the Engineer.

2 The Engineer shall be notified 24 hours in advance of testing.

3 Pipelines and equipment shall be adequately restrained before testing.

4 On satisfactory completion of testing, the Contractor shall submit a report describing the tests undertaken and the test results.

12.5.2 Testing of Interface Valves, Controllers and Sensors

1 Interface valves, controllers and sensors shall be tested to demonstrate that they function correctly to meet specified duties.

2 Where new valves or controllers are introduced or significant changes are made to proven valves, laboratory tests shall be undertaken under simulated working conditions and test certificates provided. The tests, using water and air, shall demonstrate that the complete valve mechanism can comply with the preceding performance requirements.

12.5.3 Testing of Pipelines

1 Pipelines shall be pressure and vacuum tested.

2 Pressure tests shall be carried out in accordance with Clause 4.5.3 of this Section.

3 Before carrying out a vacuum test, the Contractor shall ensure that the test equipment is calibrated, is in working order and correctly fitted to the pipe.

4 The permitted loss of vacuum in pipeline tests shall be corrected to allow for changes in temperature and atmospheric pressure. Pipe temperatures atmospheric pressure shall be recorded at the start of the test and at hourly intervals.

5 Regular vacuum testing and final vacuum testing shall be carried out as specified herein. In the event of failure under either test, the leaks shall be located and repaired, and the tests redone.

6 Regular vacuum testing of all service connections and vacuum sewers shall be carried out on the pipelines before backfilling and in sections as approved by the Engineer. The test duration shall be 1 h. Open ends of pipeline shall be capped and a vacuum of 80 kPa applied and allowed to stabilise for 15 min after which time the fall in vacuum shall not exceed 1.0 % over the 1 h test.

7 Final testing of service connections, vacuum sewers and vacuum vessels shall be tested before the installation of the interface valves. The test duration shall be 4 h. A vacuum of 80 kPa shall be applied using the vacuum pumps in the vacuum station. Instrumentation shall be provided to record system vacuum during testing. After the vacuum has stabilised, the fall in vacuum shall not exceed 1.0 %/h for each hour of the test.

12.5.4 Testing of Pumps, Motors and Instrumentation

1 Testing of pumps shall be in accordance with Section 9.

2 Testing of motors shall be in accordance with Sections 9 and 21.

3 Testing of instrumentation shall be in accordance with Section 10.

12.6 TRAINING OF EMPLOYER'S PERSONNEL

1 The Contractor shall prepare and submit a training program and manual for the approval of the Engineer. The training shall cover system installation, operation and maintenance, and record keeping and interpretation.

2 On-site training shall be provided by the system manufacturer specialist staff for a minimum period of 90 days.

3 The Contractor shall provide facilities required for implementation of the training program.

END OF PART