Stretto di Messina

Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia e il Continente Organismo di Diritto Pubblico
(Legge n° 1158 del 17 dicembre 1971, modificata dal D.Lgs. n°114 del 24 aprile 2003)

EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

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Opera - tratto d'opera - parte d'opera	Longitudinal and transverse restraint
Titolo del documento	Performance Specification - Buffers.

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INDICE

1 Introduction

1.1 The Project

The Messina Strait Bridge will span the Messina Strait between Calabria on the Italian mainland and the island of Sicily. The suspension bridge crossing comprises a 3,300 m main span, which will be longest in the world when constructed.

The bridge carries four marked vehicle lanes, two emergency lanes and two rail lines. The bridge superstructure comprises three separate orthotropic deck steel box girders, one for each of the Sicily and Italy bound roadways and one for the railway. The three box girders are connected by transverse steel box cross girders spaced at 30 m. The superstructure is supported by pairs of hanger cables connected to each cross beam end. The hangers are connected to pairs of main cables on each side of the bridge (four main cables), with each main cable having a diameter of 1.24 m. The main cables are anchored at each bridge end in massive reinforced concrete anchor blocks. The main cables are supported by two steel main towers, each with a height of 399 m above mean sea level. The main towers are founded on reinforced and post-tensioned concrete footings, which are supported on underlying rock formations.

1.2 Scope

This performance specification specifies the requirements for the design, manufacture, installation and testing of the hydraulic buffers and associated interfaces to be provided between towers/terminal structures and bridge decks.

The scope of works can be summarized as follows:

- Design: detailed design of the buffers and appurtenant parts, including the submission of design calculations, shop and installation drawings and details to the supervision.
- Integration of the buffer systems into the overall bridge design, considering interface requirements from other parts of the bridge structure. The interfaces to be considered will include, but are not limited to:
  - Support of hydraulic dampers to bridge structures
  - Monitoring system

  - Airtight sealing around piston rods
  - Access facilities

- Manufacture and testing: manufacture, assembly, works inspection and prototype trials under simulated running conditions; dismantling, inspection and re-inspection of the prototype.
- Installation and trial running: installation on the Messina Bridge, connection to running tracks, site trials and adjustments.
- Post-installation: provision of spare parts, operation and maintenance instructions, as built records, and personnel training.

Each hydraulic buffer system shall comprise:

- Hydraulic buffers including piping system, valves, accumulator arrangement and tank
- All steel mountings and connecting hardware that is integral with the buffers between cross girder diaphragm and tower. This includes spherical bearing, pin towards the tower and spherical bearing, pin towards the cross beam.
- Instrumentation, electrical work and junction boxes for monitoring system
- Fluid charge
- Cover of stainless steel and canopies above buffers
- Casing under buffers and pipelines for protection of the bridge structure from oil waste

1.3 References

1.3.1 Design Specifications

1 CG.10.00-P-RG-D-P-GE-00-00-00-00-00-02 "Design Basis, Structural, Annex," COWI 2010

2 GCG.F.05.03 rev. 1. Technical specifications for the definitive and the executive project of the bridge - Design development requirements & guidelines. Stretto di Messina, 2004 October 22.

3 GCG.G.03.02. Technical specifications for the construction of the suspension bridge - Structural steel works and protective coatings, Stretto di Messina, 2004 July 30.

1.3.2 Material specifications

4 EN ISO 12944:2000. Paints and varnishes - Corrosion protection of steel structures by protective paint systems

5 EN 10025-1:2004 Hot-rolled products of structural steels

6 EN 10025-2:2004 Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels

7 EN 10164:2005 Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions.

8 EN ISO 898-1:2009 Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs.

9 EN 20898-2:1994 Mechanical properties of fasteners – Part 2: Nuts with special proof load values – coarse thread (prEN ISO 898-2:2010).

10 EN 14399-3:2005 High-strength structural bolting assemblies for preloading - Part 3: System HR - Hexagon bolt and nut assemblies

11 EN ISO 14555:2006 Welding-Arc stud welding of metallic materials.

12 ISO 6124-3:1982 Spherical plain radial bearings, joint type -- Boundary dimensions -- Part 3: Dimension series C

13 EN 20286-2:2010 ISO system of limits and fits - Part 2: Tables of standard tolerance grades and limit deviation for holes and shafts

14 ANSI/IEC 60529-2004 Degrees of protection provided by enclosures

- EN 1088 + A2:2010: Safety of machinery - Interlocking devices associated with guards - Principles for design and selection
- EN ISO 6743-4:2001Lubricants, industrial oils and related products (class L) - Classification - Part 4: Family H (Hydraulic systems)

1.3.3 Drawings

The basic requirements and principle for the hydraulic systems are shown on the drawings listed below:

CG1000-P-AX-D-P-CG-S5-AM-00-00-00-01	Articulation system - General arrangement
CG1000-P-AX-D-P-SS-A0-00-00-00-00-02	Articulation system - Support of suspended deck at towers
CG1000-P-BX-D-P-SS-A0-00-00-00-00-01	Articulation system - Longitudinal supports
CG1000-P-BX-D-P-SS-A0-00-00-00-00-02	Articulation system - Transverse supports (1)
CG1000-P-BX-D-P-SS-A0-00-00-00-00-03	Articulation system - Transverse supports (2)
CG1000-P-BX-D-P-SS-A0-00-00-00-00-05	Articulation system - Hydraulic systems

2 Design by supplier

2.1 General

In order to transfer transverse loads from the main and side span girder to the tower and to reduce stress from bending in the railway girder a structure consisting of two triangles and a rigid connection to one of the tower legs is used in the design. The connection to the tower is equipped with a seismic isolator by means of hydraulic buffers which reduces the maximum forces transferred between the bridge girder and the tower leg during a severe seismic event.

Further to reduce movements of the bridge girder in the longitudinal direction to acceptable level hydraulic buffers are installed longitudinally at the towers. In the event of an earthquake the buffers will also hydraulically limit the force transferred between the towers and the bridge girder.

The system of buffers adds up to the following

- Buffers for longitudinal support: A system of four hydraulic buffers is installed on both sides of the girder at the towers (D2);
- Buffers for transverse support: A system of two hydraulic buffers is installed in the transverse support at each tower (D1).

2.2 Requirements

In the design particular attention shall be paid to the following points:

- Materials and systems shall be designed to function as required outdoors in an aggressive marine environment. The buffer systems shall, when installed, be capable of operating system temperature from -5°C to +80°C.
- The buffer systems shall essentially operate at sea level pressure (760 +/- 50 mm mercury).
- The buffer systems shall be designed to withstand a relative humidity up to 100 percent, including condensation due to temperature change.
- The buffer systems shall be designed to withstand any of the probable combinations of the following atmospheric elements: rain, snow, sleet, hail, ice, fog, smoke, wind, ozone, sunshine, sand, dust and salt.
- The buffers shall be arranged to stop longitudinal and transverse movements of the girder and shall serve as a braking device restraining movements.
- All equipment shall be installed in such a way that future maintenance and repair can be performed in a safe and ergonomically correct way.
- Repairs and replacement can be undertaken without affecting the essential operation of the system
- Ability to withstand the local extreme climate conditions at site
- Lifetime of the hydraulic dampers shall be 50 years for cylinders and 25 years for moveable components
- The lifetime of the spherical bearings shall be minimum 25 years.
- The stiffness factor has to be extremely high to avoid abrasion on the bridge elements caused by fast pulsating movements when trains cross the bridge or due to dynamic wind.
- Ease of inspection and maintenance
- Freedom from undue vibrations
- Reliability and continuity in service

- In general, all installations shall be arranged in such a way as to repairs and replacement can be undertaken without affecting the essential operation of the system

2.2.1 Tower - Buffers for longitudinal support, D2

The buffer arrangement D2 shall act as a combination of a damper and a spring according to the characteristic shown in Figure 2-1.

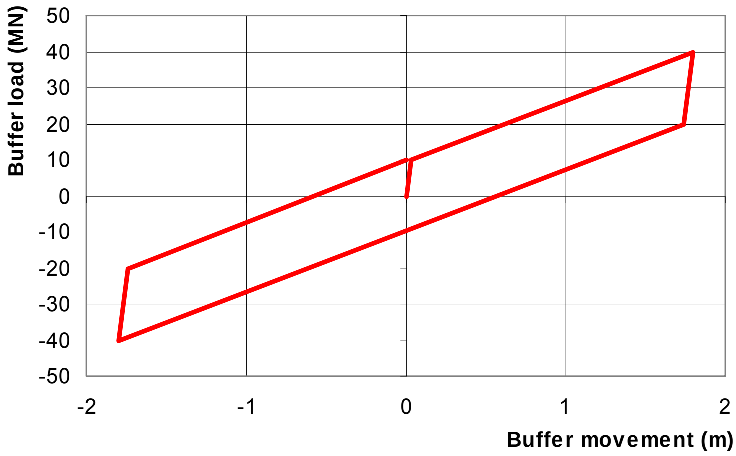

Figure 2-1: Characteristic of buffer D2 (each tower leg)

The figure shows the load-displacement curve for the buffer at one tower leg. Under the threshold value of 10 MN the buffer systems should act as a passive element.

The buffer systems should be coupled hydraulically between the east leg and the west

leg of each tower in order to allow rotation of the bridge girder relative to the tower.

The buffers should be equipped with spherical bearings in both ends.

Each buffer shall have stability for transmitting a force up to 10 MN on piston impact against buffer bottom in ULS.

2.2.2 Tower - Buffers for transverse support, D1

The characteristic of the buffer arrangement D1 is shown in Figure 2-2.

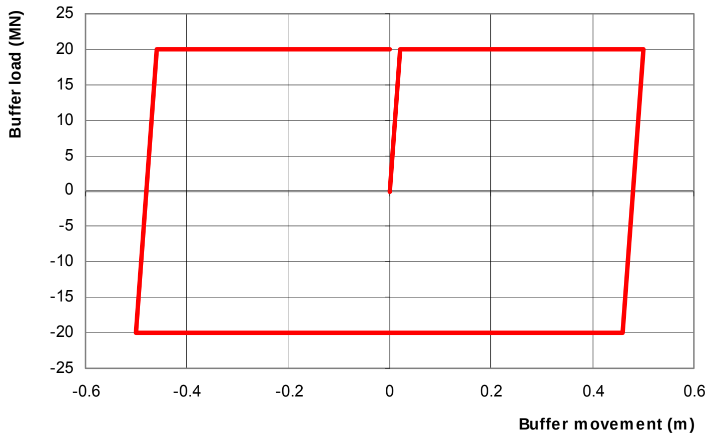

Figure 2-2 Characteristic of buffer D1

Under the threshold value of 20 MN the buffer system should act as a passive element.

The buffers should be equipped with spherical bearings at one end and rigidly attached to the transverse member of the transverse support at the other end to allow for the movements.

Each buffer shall have stability for transmitting a force up to 10 MN on piston impact against buffer bottom in ULS.

The two buffer arrangement may be replaced by a simple buffer arrangement if considered beneficial.

2.3 Principles of the system

The buffer arrangement shall restrain longitudinal and transverse movement of the girder and must not introduce forces in the bridge structures due to other movement of the girder, e.g. torsion around a vertical axis.

The movement of the buffers shall be a function of the load acting on the piston, independently of the origin of the load, according to the characteristics given in Figure 2-1 and Figure 2-2. The system shall be double acting and when a movement pulls or pushes the piston, the valve system shall restrain the piston.

In normal operation the stop function must give an immediately stop and not give a longer stroke than the actual compression of oil in the buffer chambers.

In normal operation for traffic and wind movements (damping) the buffer systems shall be designed for a relative volume change of 0,004 or less according to Figure 3-1.

The compressibility has to be extremely high to avoid abrasion on the bridge elements caused by fast pulsating movements when trains cross the bridge or the bridge oscillates.

Longitudinal pulsing and transverse pulsing:

- The buffers of system D1 (traverse) shall be able to withstand 1 x 10^6 cycles of 2.5 MN shock-like loads per year.
- The buffers of system D2 (longitudinal) shall be able to withstand 1 x 10^6 cycles of 5 MN shock-like loads per year.
- The buffer system has to make sure that pulsating movements of the bridge caused by wind, traffic etc. are stopped.
- The flow control valve shall control the girder velocity.
- The flow control valve shall be adjustable within a range of 0.1 meter /24 hours to 2.0 meter / 24 hours for the velocity of the girder.
- The flow control valve shall be widely pressure and temperature independent.

The hydraulic buffers shall be buffers with a through going rod leading to identical piston areas on both sides. The buffers shall be connected to the girder by spherical bearings to allow for some misalignment and angular movement.

The hydraulic buffers, their mounting system and connecting parts shall be designed to resist static break down on a pressure 3 times the pressure necessary to produce the force.

In case of failure of the hydraulic system by leakage, pipe burst or breakdown in the connecting pipelines, the buffer chambers shall be shut off by pilot operated depressurization valves to ensure that the hydraulic fluid stays in the buffers.

Normally the depressurization valves are opened by the hydraulic controlled pressure established from the accumulator basic pressure. The valves shall close if the pressure decreases below the limit. In case of pipe burst or similar (pressure = 0), the depressurization valves shall be closed.

The buffer system shall be provided with high pressure safety valves which prevent the build-up of excessive pressures.

Open at pressure: ≥ 75 MPa
Closed at pressure < 75 MPa

The safety valves shall function even if the depressurization valves are closed if maximum pressure limit is exceeded.

System for longitudinal movements: The chamber in each cylinder shall be arranged in parallel connection to the corresponding chamber in the opposite tower leg. The system shall be double acting.

Each cylinder including valves and components will be a self-function unit arrangement connected with simple pipelines.

The hydraulic system shall contain provision to allow thermal expansion and contraction of the fluid medium to prevent excessive build up of internal high pressure or vacuum pressure. Further, it shall be equipped with an accumulator arrangement for taking up volume variations caused by temperature variations.

The hydraulic system shall establish basis pressure for opening the fracture valves through the accumulator system.

The hydraulic system shall function independently of viscosity in the hydraulic fluids within the specified temperature range.

The spherical bearings must enable the rotations of the buffer presented above.

The dampers shall be equipped with flexible tightening diaphragms around the piston rod.

2.4 Numerical simulation of the buffer arrangement

A dynamic numerical simulation of the mechanical-hydraulic system of the buffer shall be performed using a proper software or a “multi-physical environment” software.
Among the most important parameters, the following shall be taken into consideration:

- Inertial response of fluid and mechanical elements

- Volume deformation of the fluid
- Elastic deformation of mechanical elements
- Deformation of pipes systems
- Activation procedure and response of the mechanical (e.g. valves) or electronic control system elements.

Analyses can be carried out using time histories of imposed displacements that are obtained from analyses performed on a finite element global model of the bridge. Service limit states, ultimate limit states, and possible malfunction conditions of the system must be taken into consideration.

2.5 Monitoring

The functional behaviour the hydraulic buffer systems shall be monitored continuously by means of instrumentation installed by the manufacturer.

Signals shall be connected to and monitored from a monitoring system (SCADA):

- Pressure in buffer chambers
- Pressure at accumulator tank
- Position of the piston buffers
- Temperature in the hydraulic oil in chambers
- Alarm for leakage of the system (pressure at accumulator tank = 0)

3 Materials

3.1 General

All materials for the hydraulic damper systems shall be of a recognised and well-known make and be available in Italy as standard components.

Replacement of components in the hydraulic damper system with a short service life shall be confirmed by the contractor to be achievable with the time frame which will be acceptable to the engineer and the employer. Components to be regularly inspected and maintained shall be easily accessible and removable.

3.2 Hydraulic cylinders

The hydraulic cylinders shall be designed by the supplier as a double-acting cylinder for working in a closed (passive) system for maximum reliability.

A same size piston area in both chambers shall be ensured by a single continuous through piston rod.

The cylinder shall be equipped with a position monitor to indicate the position of the piston.

The material for cylinder lining mountings and connecting hardware shall be of carbon steel, heat treated by normalisation and examined ultrasonically or radiographic X-ray methods for defects. The material shall be in accordance with [6] - S355J2G3.

The material for the steel bar shall be of carbon steel hot rolled and peeled. The material shall be in accordance with [6] - S355J2G3. The general design requirements for the hydraulic cylinders are:

Design pressure:	30 MPa
Test pressure:	50 MPa
Static break down pressure:	90 MPa
Working temperatures:	-5°C to + 80°C

The steel bar shall be normalised and examined by ultrasonic testing and the surface cover shall consist of 100 μm nickel, hardness min. 500 HV and 50 μm hard chrome plated, hardness min. 860 HV, RA $\leq$ 0.2 μm.

The seals shall be of a recognised make and shall be capable of resistance to the oil type and to the marine environment. The sealing in buffers around the piston and the piston rod must not have any form of stick/slip problems caused by deflection in the buffer construction or similar.

The type of sealing must be extremely tight and shall be able to withstand the pulsation movements stated in section 2.3.

3.3 Spherical bearings

The piston rod mounting and the basic mounting at the cylinder lining shall be equipped with spherical bearings. The spherical bearings shall be delivered according to [12].

The spherical bearings and pin shall be able to withstand cycles of shock-like loads, alternating between tension and compression in the bearing plane according to section 2.3.

The cylinder lining shall be equipped with flanges for pipe connections.

3.4 Pipes tubes and fittings

The pipes shall be of stainless steel of high pressure type according to AISI 316L or similar.

3.4.1 Pipes

Design pressure:	30 MPa
Test pressure:	50 MPa
Static break down pressure:	90 MPa

The pipes shall be delivered in accordance with the best control class.

3.4.2 Hoses

The hoses shall be of the high pressure wire braid hose type:

Design pressure:	30 MPa
Test pressure:	50 MPa
Static break down pressure:	90 MPa

3.4.3 Fittings

Fitting system (AISI 316L) elbow, tee, reducing, clams etc. shall be of the same type as manufactured by GS- Hydro or products having equivalent functions or performance as approved by the engineer.

All pipes and component connections must be of a flanged flared type.

The flanges shall be as SAE high pressure flange for flared tubes.

Pipes, hoses and fitting shall be manufactured in accordance with the approved UNI/EN/ISO standards.

3.5 Valves

Valves will be leak free according to current standards.

Design pressure: 30 MPa
Test pressure: 50 MPa
Static break down pressure: 90 MPa

The valves shall be manufactured in accordance with the approved UNI/EN/ISO standards.

3.6 Accumulators

Design pressure: 30 MPa
Test pressure: 50 MPa
Static break down pressure: 90 MPa

The accumulator in the buffer system will be designed for taking up all volume variations caused by temperature variations (-5°C to +80°C) of the hydraulic oil.

The accumulators shall be manufactured in accordance with the approved UNI/EN/ISO standards.

3.7 Hydraulic fluid

The hydraulic oil shall be a fluid with low pour points to ensure fluidity at low temperatures. High viscosity index shall limit the change of viscosity if change of temperature. The fluid shall be blended with selected additives that contain anti-oxidant, anti-rust, anti-wear and anti-foam additives.

The fluid shall have low intake of air and good release of air. The compressibility shall be as shown in Figure 3-1.

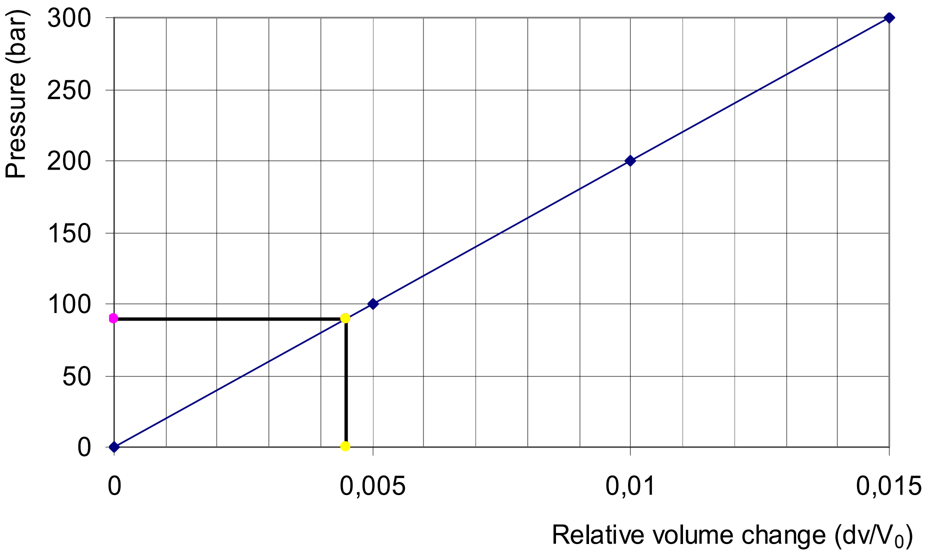

Figure 3-1 Isentropic compressibility - Hydraulic oil

The requirement for the hydraulic oil shall be in accordance with the typical standards:

- Hydraulic oil based on mineral oil
- Viscosity, Index accordance with current standards
- Low intake of air and good release of air
- Non-toxic and non-flammable

Hydraulic fluid shall be in accordance with the approved UNI/EN/ISO standards.

3.8 Tanks

The material shall be of stainless steel AISI 316L and supplied with a filter. The tank's volume shall be 200 litres and installed in order to pick up or indicate any leakage from safety valves etc.

3.9 Corrosion protection

All mechanical installations for the hydraulic dampers not specifically noted above shall be painted or otherwise protected so that they will sustain without further maintenance for a period of minimum 20 years in the surroundings and environmental conditions that are present in the

Messina area. Due attention shall be paid to the effects of mechanical wear, grease or other liquids inside as well as outside.

Attention shall be paid to the marine environment when selecting materials and components. Environment class C5 M according to [4] applies.

During the detail and workshop design the contractor shall give requirements for acceptable approved standards. Corrosion protection treatment for different materials used in the environment shall be current classes according to corrosion protection. The class applies to surfaces in outdoor ambient air.

Steel structures and mounting connecting the buffer to the tower and cross beam shall be painted with the same system as for externally exposed structural steel.

4 Submission

4.1 Documentation

The following documentation shall be submitted by the contractor:

Detail design package:

- Quality plan for the hydraulic damper system scope of work
- Operating and functional principles
- Systems description
- Material data
- Equipment data
- Design procedures
- Schedule of works
- Workmanship for the installation
- Preliminary details of the O&M Manual (including demonstration of method to replace buffers when required) and the training program

- Programme for tests and investigations
- Layout drawings and outline diagrams for the systems
- Interface documentation/description
- Preliminary quality records
- Preliminary commissioning records
- Vendor drawings
- Details of manufacturer's name and place of manufacture

Final documentation and completion activities:

- Update of the detail design package to "As-built" status
- Provide operation and maintenance manuals in Italian and English languishes for the hydraulic buffer systems
- Provide training for the employer’s staff relating to the operation and maintenance of the hydraulic buffer system
- Testing and commissioning of the hydraulic buffer systems

5 Fabrication

5.1 General

All installation work shall be carried out by skilled personnel.

Documentation for proposed work procedures, quality procedures, testing procedures, qualifications of welders etc. shall be made during the detail and workshop design. The procedures shall be submitted to the engineer for approval and personnel shall conform to these approved procedures.

All items of plant and equipment and all fabricated items shall be manufactured in parts small enough to be transported and installed through the designed bridge structure.

The hydraulic buffer systems shall fulfil the current standards for the working environment, applicable for the intended type of operation. All work performed at site during installation and testing etc. shall also fulfil these standards.

The design of the buffer systems shall be elaborated so that all possible source of danger to personnel or equipment during assembly, disassembly, testing, operation and maintenance is minimized.

The buffers, including all steel mounting and connecting hardware, shall be constructed and finished in a thorough workmanlike manner.

Particular attention shall be paid to neatness and thoroughness of soldering, wiring, making of parts and assemblies, welding, brazing, plating, finishes, riveting, machining and screw assemblies.

All parts shall be free of burrs and sharp edges and damages, defects or foreign material which might detract from the intended operation, function or appearance of the buffer systems.

Welding on buffers and mounting parts shall follow all proposed and used standards and shall be submitted to the engineer for review and approval. Welding of steel structures connecting the buffer to the tower and cross girder shall follow the requirements for welding in the steel section.

The buffer arrangement shall be design in such way that in case of break down of one buffer a spare buffer shall be reinstalled within 24 hours.

5.2 Hydraulic buffers

The buffers shall be assembled at site after installation of steel bridge elements.

The design of the total packing system in the hydraulic buffers shall be approved by the engineer.

All sealing bearing rings etc. shall be secured against "Stick slip" problems.

All O-rings and sealing's shall withstand the used hydraulic oil so that a long lifetime can be obtained.

All bolts shall be checked for the right size, length and type so that damages to the buffers system can be avoided.

All screw threads to be controlled and if necessary cleaned for burrs before the main items as, e.g. Rod End Eyes incl. spherical bearings are assembled.

All air has to be ventilated out of the hydraulic system after the buffers system has been assembled.

Particular attention shall be given to a careful assembly of the different parts to the buffers.

ISA-tolerances in accordance with [13] and other instructions for the installation shall be fulfilled when installing the spherical bearings.

5.3 Hydraulic pipe installations

Piping runs shall be laid with due consideration to expansion, venting and drainage.

The piping systems will be provided with supports which shall be specified in the detailed design.

Generally, all pipes shall be joined with flanges for flared tubes.

All piping systems shall be subjected to internal surface treatment in order to ensure that the piping system in question has been cleaned to the necessary extent.

Hoses shall be installed without any form of tension in the runs and follow all accepted rules for installation.

5.4 Pipe supports

Clamps shall be installed in such a way that pipelines are safely fixed.

5.5 Marking

Marking of all components with a designation and numbering system shall be made to ensure a safe and rational operation and maintenance of the hydraulic buffer system.

The component number shall be indicated on labels in the plant and in documents, e.g. lists of fixtures, drawings and diagrams.

All equipment shall be marked prior to commencing test runs on the component or system.

5.6 Labels

A list of labels shall be prepared by the supplier during the detail/workshop design.

Labels shall be fixed by screws or if required in label holders. Fixing of labels shall not decrease the degree of protection; sealing shall be made if necessary.

6 Electrical works

6.1 General

The electrical work covered in the hydraulic buffer system scope of work is as follows:

- Electrical work between components as part of the hydraulic buffer system and the local junction box

All electrical components for the hydraulic buffer system shall satisfy requirements specified in this Section.

The following list is an example of electrical components which have their requirements in above particular specifications:

- Distribution boards and all components for installation inside distribution boards
- Cables, cable ways and electrical accessories
- Terminals, row with the required potential free signals and measurements.
- Earthing and equipotential bonding

6.2 Instrumentation

All instruments shall produce analogue output signal of 4-20 mA (for piston position, for pressure and temperature indication).

The equipment shall be suitable for local conditions and marine environment, when installed on the bridge.

The quality of instruments, sensors and installations shall be designed to produce accurate measurements, be resistant against influence from environmental impact and be of a rugged construction selected in materials suitable for installation on the bridge.

All external input circuits shall be protected against induced transients and over voltages.

Calibration of instruments will be possible within a junction box, control cubicle or other cubicle containing the transducer for the measurement circuits.

Protection classes shall be accordance to [14]

6.3 Pressure transmitter

Pressure measurement range:	0-3 MPa (basis pressure)
Pressure measurement range:	0-65 MPa (cylinder pressure)
Accuracy:	Class 1
Protection class:	IP 65

6.4 Temperature transmitter

Working temperature	-5°C to + 80°C
Accuracy:	± 0.5% of full scale
Protection class	IP 65

6.5 Position transmitter

The position transmitter shall be a linear displacement transducer system with analogue output 4-20 mA.

The component shall be constructed for operation in a corrosive environment and the sensor housing shall be of stainless steel.

Accuracy:	± 0.5% of full scale

6.6 Installation of instruments

Installation of instruments shall be in accordance with the manufacturer's recommendation. This includes cable selection but the following requirements shall be followed where applicable:

- Signal Transmission cables for connection of sensors shall be individually screened armoured multi-pair cables

The documented tests shall include but not be limited to the following:

- Functional test of each system
- Birth and calibration certificate test

6.7 Monitoring system

The monitoring of the bridge shall be supervised from a central control room with computer facilities.

The monitoring system shall be provided with the following signals for communication with the control and monitoring system, SCADA.

6.8 SCADA interface

Each buffer system shall, in the local junction box, be equipped with the following input/output signals to the SCADA system:

Potential free contacts (hydraulic damper control system output signals) for:

- Pressure in cylinder chambers (analogue 4-20 mA)
- Pressure at accumulator tank (analogue 4-20 mA)
- Alarm for leakage of the system (pressure = 0) (potential free contact)

Analogue signals shall be an independent potential free signal of 4 - 20 mA.

7 Test and investigations

7.1 General

The hydraulic buffer systems shall be tested and adjusted by the supplier to ensure that operational data and functional requirements, as indicated in the specification and on the drawings, are met.

It shall in particular be ensured that all functions and functional contexts, e.g. in connection with control and monitoring, are tested and that a record is prepared.

All test result shall be filed and checked within four weeks after finishing the test.

The following basic schedule for tests shall be applied but not limited to:

- Factory tests (incl. performance test)
- Site cold tests
- Performance tests on site

Works inspections and testing shall be carried out in accordance with the relevant codes and standards and the following clauses.

All specialist test equipment shall be supplied by the contractor for the purpose of the test. All test equipment shall have a current test/calibration certificate.

Utilizing a horizontal hydraulic test bench, the buffer system shall be tested in tension and compression in accordance with characteristics and the below described tests.

Forces, displacement and time measurements shall be accurately obtained and recorded.

7.2 Factory testing

7.2.1 Tests of hydraulic buffer

The tests shall comprise the following:

- Stiffness test

- Static pressure test
- Static loading test
- Dynamic loading test
- Chrome/nickel thickness test
- Ultrasonic and radiographic X-ray examination

Stiffness test: Measurement of the compressibility of the hydraulic cylinder loaded up to design pressure with the valves closed. The value of the deformation of oil shall be ≤0,4 % at pressure ≤90bar of the total stroke. The measurement of force and deformation shall be read during the course of the test and the graph directly recorded.

Static pressure test: The hydraulic cylinder shall be tested with a static pressure on both chambers at test pressure for 24 hours, simultaneously.

The piping system including cylinders, valves and other accessories shall be kept constant in pressure at test pressure for 24 hours.

The pressure shall be read during the course of the test and at the end of the test the piping system shall be examined by the contractor and the engineer.

Dynamic loadng test: Testing of the hydraulic cylinder shall be carried out in order to verify the durability of the components of the cylinder. Special attention shall be given to the internal and external seals in the cylinder.

7.3 Performance tests of the complete system in factory

The whole of the plant shall be tested for compliance with the specifications.

7.3.1 Static loading test

The test shall determine the system resistance to the thermal displacement. The load shall be applied in both directions.

The measurement of the reaction shall be read during the course of the test and the graph directly recorded.

7.3.2 Dynamic loading test

The test shall determine the spring system and simulate the characteristic according to the figures shown in section 2.2.

The measurement of the reaction shall be read during the course of the test and the graph directly recorded.

The system shall be tested at flow valve set points between 0.002 mm/s and 0.2 mm/s.

The test is conducted by applying a constant translation velocity to the device in the order of 2mm/s. and at the same time reading the resulting reaction for the displacement.

The thrust shall be maintained constant at maximum load for approximately 5 seconds.

The test shall be conducted in two positions of the stroke of the piston rod, i.e. central and ±250 mm off-axis. The load shall be applied in both directions at each test position.

The measurement of the thrust and the displacement shall be read during the course of the test and the graph recorded.

7.3.3 Chrome/nickel thickness test

Measurement of the surface covers thickness (100 μm nickel and 50 μm chrome).

7.3.4 Ultrasonic and radiographic X-ray examination

Test of weldings to be approved by the works supervision.

7.3.5 Influence of the temperature on the test results

The static loading test and the dynamic loading test shall be performed simulating the following temperatures:

- -5°C
- +20°C (workshop temperature)
- +80°C

All tests shall be carried out at normal workshop temperature. In order to simulate the buffer performance at -5°C and +80°C, the tests described above shall be performed using different oil types with a viscosity identical to the original oil at these temperatures (this compatibility shall be proven by the supplier).

7.3.6 Certificates

- Heat treatment certificate (to be approved by the works supervision)
- Test certificate of materials (to be approved by the works supervision)
- Works certificate of materials (to be approved by the works supervision)

7.4 Site cold tests

All plant parts shall be subject to site cold tests carried out by the supplier.

The tests shall comprise:

- Visual inspection
- Test of continuity of electrical connections
- Test of valves by injection of an external supply
- Test of I/O points.
- Pipe pressure test
- Accumulator test of nitrogen pressure

7.5 Performance test on site

The whole of the plant shall be tested for compliance with the specifications.

8 Warranty

A five year warranty for the hydraulic buffer system shall be provided by the supplier.