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EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

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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 3,300m 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 cross beams spaced at 30m. 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 1.24m. 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 399m 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 of works

The dehumidification systems scope of works includes the supply, construction, completion, testing and handing over of the following dehumidification systems for corrosion protection of steel elements inside the following structural elements, according to this document and the associated drawings, see the drawing list in chapter 5 Appendices.

- The main cables
- The suspended deck, road and railway box girders and cross beams
- The terminal structures
- The tower saddles
- The towers
- The anchor block chambers

The dehumidification systems will be optimised for lowest life cycle cost. This means an integrated system with each plant covering as many elements as feasible, which gives the best economy, i.e. lowest construction, operation and maintenance costs.

The dehumidification systems will be designed to allow easy and efficient maintenance avoiding any kind of interference with the steel structures or distribution of traffic.

The dehumidification systems will be installed in easily accessible areas through hatches to facilitate maintenance or replacement.

The structural elements will be utilised as ducts, minimising the use of normal ducts, e.g. troughs.

The Works will include all materials necessary to form complete systems of the various installations including design, programming, coordination, drawings, samples and equipment submissions, supply, installation, tests, adjustments, commissioning, and maintenance manuals.

Complete execution of the works and proper operation of the installation in co-operation, co-ordination, programming, planning of the sequence of design, installation, testing and commissioning, etc. between all concerned parties responsible for the works.

The works will also include the delivery to the site, erection, connecting up, site testing, balancing, provision of drawings/manuals and spare parts, liaison with relevant authorities for obtaining stamps, permits or the like, etc. for all the systems.

2 Concept description

2.1 General

The purpose of the dehumidification systems in the bridge is to dehumidify the air inside the bridge structures and thereby protect the interior surfaces of the structures from corrosion. To ensure this the bridge will be equipped with dehumidification plants with ventilation fans for circulation of the dehumidified air, with an average year round value of 40% relative humidity as a maximum and with an extreme value over 1 hour/day of 50% relative humidity. This will prevent corrosion of the internal steel surfaces.

The preset limit value for the relative air humidity shall not be higher than 40% and the relative air humidity shall not exceed 50% for more than one hour per day. These values are determined for

operation of the systems and are verified by data from operation and maintenance of dehumidification systems in existing large bridge structures.

The dehumidification plants dehumidify the air in the bridge structures as well as the ambient air entering for equalisation of pressure in the structures, which will occur because of climate conditions.

The systems will consist of a minimum number of dehumidification plants with low electrical consumption and all plants will be easily accessible.

The systems will require some ductwork, but the use of ductwork will be minimised due to utilisation of the structural elements as ducts.

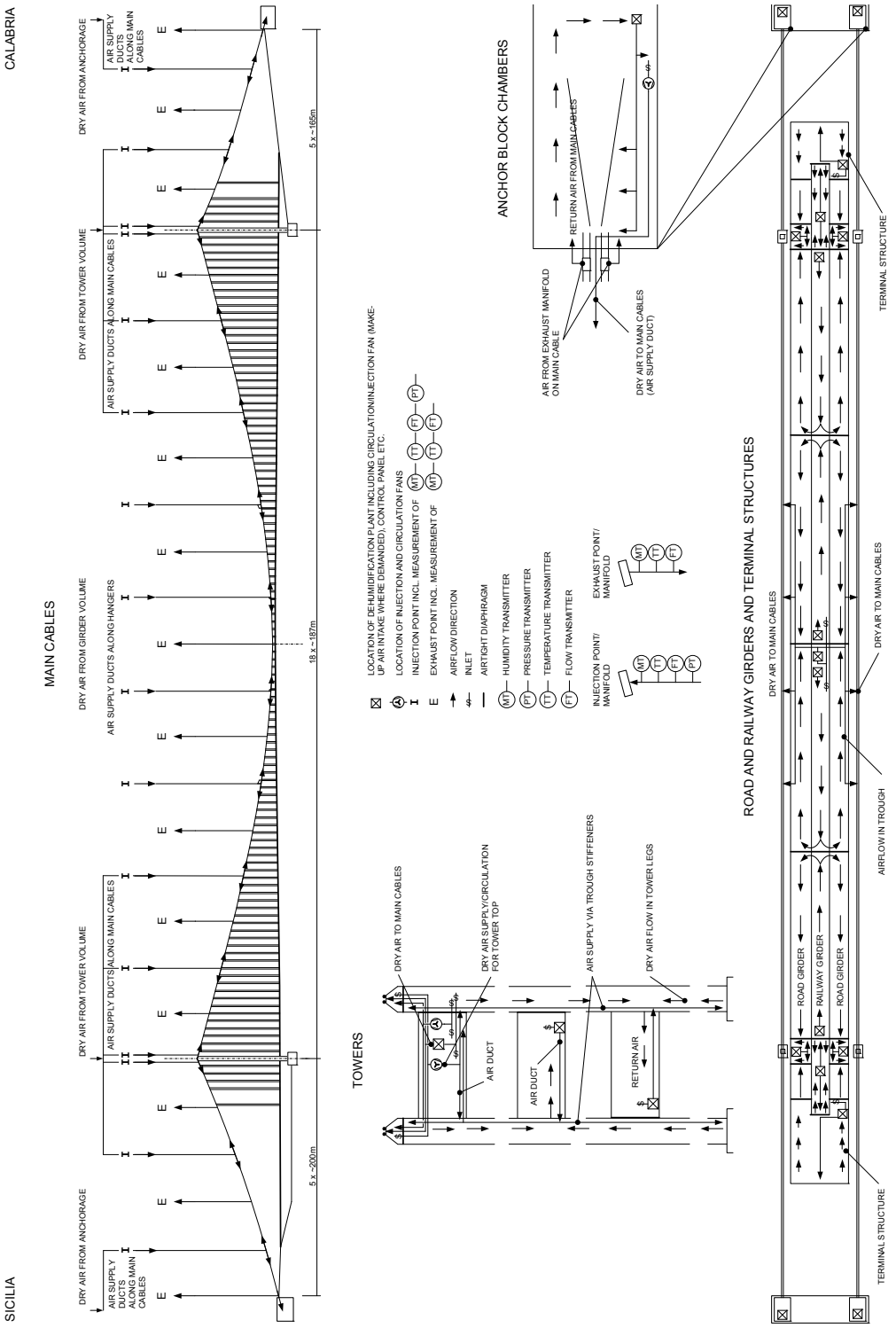
The structures shall be as airtight as possible to minimize the infiltration of ambient air.

The dehumidification systems will be designed for unmanned and unattended operation, 24 hours a day, 7 days week. They will be durable and require a minimum of maintenance.

Ventilation fans for circulation of air and for dry air supply to main cables will run continuously. The dehumidification units will not run continuously but automatically start and run when necessary to dehumidify the air inside the bridge structures and stop when the relative air humidity is brought down to the acceptable limit.

General maintenance is normally required once every year and should be performed during spring or autumn, i.e. outside the summer period. Any unexpected acute maintenance during summer can be carried out at night or early morning. The structures must as far as possible be kept closed during inspections and maintenance.

2.2 Dehumidification concept



2.3 Main cables

Corrosion protection of the main cables is based on a controlled volume of dry air surrounding the cable strands. There will be a continuous flow of dry air inside the main cables, supplied from a number of dehumidification plants.

In general it is not regarded feasible to recirculate air from the cables. The system will be designed to operate with a certain leakage rate from the cables to the ambient air and a slight overpressure is maintained in the cable to prevent intrusion of air and moisture from the outside. The maximum pressure inside the cable will be limited to reduce stress on the wrapping and limit injection fan power consumption.

The air flow resistance along the main cables, combined with the leakage, will require multiple injection points along the cables with air flow up and down in a number of sections. Each injection point serves a section of the main cable, and air is flowing from the injection point in both directions to the nearest exhaust points. Dry air will be supplied via ducts from the main box girders, tower legs and anchor block chambers connected to a number of injection points located along the cables. The system is therefore based on air supply from other dehumidified structure volumes, which will act as a buffer tank and minimise electrical consumption.

To limit the extension of the external ducts, dry air is supplied from the box girder below via ducts along the hangers to the injection points at the main cables. The dry air is supplied from the tower legs and anchorage block chambers via ducts along the main cables to the injection points at the main cables. Generally one fan can supply several injection points. The full box girders, towers and anchor block chambers volumes serve as dry air buffers and the dehumidification units will be designed for the additional load associated with the main cables. A supplementary dehumidification plants dedicated to the main cables are located at the middle of the main span and at the tower top cross beams. These plants will further dry the air supply to the main cables as necessary.

The system means a limited number of plants, but a more complex interaction between the different elements of the bridge. The operation of the system requires conscientious monitoring because it must be controlled that flow and pressure in each of the sections are adequate to secure permanent protection at any time without dead points along the cable.

At all injection and exhaust points, monitoring instruments are installed for permanent monitoring of system operation and documentation for corrosion protection. Temperature, humidity, flow and pressure at injection points and temperature, humidity and flow at exhaust points.

2.4 Suspended deck, road and railway box girders and cross beams

Corrosion protection of the inner surface of the box girders is based on drying and circulating the air volume contained inside the structures.

The requirement for distribution ductwork is minimized by utilizing the structural elements. For the dehumidification system, the suspended deck box girders can be regarded as three large parallel steel pipes, connected by the cross beams.

The bridge box girder is divided in 8 dehumidification sections, each with its own dehumidification plant, except at the towers where there are two plants, one for each road box girder volume, giving a total of 12 plants. For each section, dried air is supplied from the plant to the central railway box girder. The air flows forward through the railway box girder and flows back to the plant through the two road box girders. A small amount of air will flow through each cross beam along the dehumidification section. The main flow at each end of a section is through the last cross beam.

The dehumidification sections will be separated by airtight diaphragms and doors/hatches will be designed airtight.

The structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight, be able to stand the specified differential pressure, and be equipped with switches for remote signal in case they are not closed.

The cross beams are provided with airtight diaphragms, except the last cross beam in each end of the dehumidified section, where the air can flow from the railway box girder and circulate back to the plant through the two road box girders. As air exchange to the outside will be limited, effective protection is possible with low air circulation rate.

For each section, the dehumidification plant, including dehumidification unit, air circulation fan, air filters, dampers and the control panel are located in the cross beam, except at the towers where the plants are located in both road box girders.

Air pressure in the structure varies with the temperature. To reduce inflow of humid air from outside, and consequently also reduce operation cost, air pressure in the box girders will be allowed to fluctuate within certain limits. This is controlled by a damper arrangement connected to two pressure switches (high and low limit respectively). If the differential pressure, relative to outside, exceeds the preset value, the damper will open to equalize the pressure. For safety reasons, the damper will also open in case of power failure to prevent excessive pressures, which may stress the structure.

The pressure control damper arrangement is located at the upstream (low pressure) side of the dehumidification plant to let the humid air entering from the damper pass the plant before circulating in the structure.

Dry air from the box girders is used for supply of dry air to some of the injection points on the main cables and the dehumidification unit will be designed according to the additional inflow of ambient air. A make-up air intake will be provided with balancing damper, instruments, etc.

2.5 Terminal structures

Corrosion protection is based on drying and circulating the air volume contained inside the structures.

The dehumidification plant is located in one side of the structure and dried air is supplied to the opposite side via one main air supply duct. The duct branches out and blows air in all longitudinal bulkhead chambers, which flows back to the extraction duct at the plant side of the structure.

The structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight, be able to stand the specified differential pressure, and be equipped with switches for remote signal in case they are not closed.

As air exchange to the outside will be limited, effective protection is possible with low air circulation rate.

Air pressure in the structure varies with the temperature. To reduce inflow of humid air from outside, and consequently operation cost, air pressure in the structure will be allowed to fluctuate within certain limits. This is controlled by a damper arrangement connected to two pressure switches (high and low limit respectively). If the differential pressure, relative to outside, exceeds the preset value, the damper will open to equalize the pressure. For safety reasons, the damper

will also open in case of power failure to prevent excessive pressures, which may stress the structure.

The pressure control damper arrangement is located at the upstream (low pressure) side of the dehumidification plant to let the humid air entering from the damper pass the plant before circulating in the structure.

2.6 Tower saddles

Corrosion protection is based on supply of dry air to the volume contained inside the saddle structure.

The saddle structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight and equipped with switches for remote signal in case the door does not close.

For each saddle, dried air is supplied from the plant located in the tower top cross beam via air supply duct and the air is returned to the plant via extraction duct.

Due to the limited volume to the structure, no pressure control system is required.

2.7 Towers

Corrosion protection is based on drying and circulating the air volume contained inside the structure. The requirement for distribution ductwork is minimized by utilizing the structural elements. For the dehumidification system, the tower legs structure can be regarded as a number of parallel steel channels.

The towers are dehumidified by two plants, each serving one leg. The structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight, able to stand the specified differential pressure, and equipped with switches for remote signal in case they are not closed. Between the legs, at the one end of the cross beams the beams are sealed by airtight diaphragms.

For each leg, dried air is supplied from the plant to a trough stiffener, which functions as a duct. In the top and bottom of the leg, openings are provided, where the air can flow from the supply air corner and circulate back to the plant through the other channels.

As differential pressures are likely to vary considerably with the height of the structure, the air circulation rate is maximum 6 hours.

The dehumidification plant, including dehumidification unit, air circulation fan, air filters, dampers and the control panel are located in the low cross beam.

Air pressure in the structure varies with the temperature. To reduce inflow of humid air from outside, and consequently the operating costs, the air pressure in the tower will be allowed to fluctuate within certain limits. This is controlled by a damper arrangement connected to two pressure switches (high and low limit respectively). If the average differential pressure, relative to outside, exceeds the preset value, the damper will open to equalize the pressure. For safety reasons, the damper will also open in case of power failure, to prevent excessive pressures, which may stress the structure.

The pressure control damper arrangement is located at the upstream (low pressure) side of the dehumidification plant; to let the humid air entering from the damper pass the plant before circulating in the structure.

Dry air from the towers is used for supply of dry air to some of the injection points on the main cables and the dehumidification unit will be designed according to the additional inflow of ambient air. A make-up air intake will be provided with balancing damper, instruments, etc.

2.8 Anchor block chambers

Corrosion protection of the main cable strands and other steel elements in the anchor block chamber is based on drying and circulating the air volume contained inside the structure.

The chambers will be sealed airtight to the ambient air; doors/hatches will also be designed airtight and be equipped with switches for remote signal in case the not is door closed.

For each chamber, dried air is supplied from the plant placed above the back wall of the chamber. A duct from the plant carries dray air to the upper end, and the air flows back to plant from here.

The dehumidification plant, including dehumidification unit, air circulation fan, air filters, dampers and the control panel are located in the lower end of the chamber.

The temperature variations inside the chambers will be very slow. Due to the slow pressure fluctuations, no pressure control damper system is required.

Dry air from the chambers is used for supply of dry air to some injection points on the main cables and the dehumidification unit will be designed according to the additional inflow of ambient air. A make-up air intake will be provided with balancing damper, instruments, etc.

The air from the main cables is discharged through an exhaust manifold just outside the anchor blocks for measuring the air humidity, temperature and flow. The exhaust air is lead via a duct into the anchorage. The rest of the air from the main cables is discharged where the cables spread in the chamber. This will reduce the mount of makeup air needed for the main cables to a minimum.

3 Technical specification

3.1 Design requirements

3.1.1 Code, Standards and general documents

The design and construction of the dehumidification systems will be in accordance with applicable European standards or code of practice.

Special attention will be paid to standards or code of practice for the following areas:

- Ventilation, Safety, Materials, Vibration, Acoustics
- Machinery Directive 2006/42/EF
- Low Voltage Equipment Directive 2006/95/EC
- Electromagnetic Compatibility (EMC) 89/336/EEC.
- CE Mark
- EN 779 Particulate air filters for general ventilation - Determination of the filtration performance.
- EN 1506 Sheet metal air ducts and fittings with circular cross-section - Dimensions.
- EN 1507 Sheet metal air ducts with rectangular section - Requirements for strength and leakage.

- EN 1751 Ventilation for buildings - Air terminal devices - Aerodynamic testing of dampers and valves.
- EN 1822-1 High efficiency air filters (HEPA and ULPA) - Part 1: Classification, performance testing, marking.
- EN 1822-2 High efficiency air filters (HEPA and ULPA) - Part 2: Aerosol production, measuring equipment, particle counting statistics.
- EN 1886 Air handling units - Mechanical performance.
- EN 12097 Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems.
- EN 12220 Ductwork - Dimensions of circular flanges for general ventilation.
- EN 12236 Ductwork hangers and supports - Requirements for strength.
- EN 12237 Ductwork - Strength and leakage of circular sheet metal ducts.
- EN 12599 Test procedures and measuring methods for handing over installed ventilation and air conditioning systems.
- EN 12792 Symbols, terminology and graphical symbols.
- EN ISO 5801 Industrial fans - Performance testing using standardized airways.
- EN ISO 11204 Acoustics - Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a work station and at other specified positions applying accurate environmental corrections.
- EN ISO 14122-3 Safety of machinery - Permanent means of access to machinery - Part 3: Stairs, stepladders and guard-rails.
- EN ISO 16032 Measurement of sound pressure level from service equipment in buildings - Engineering method.
- ISO 281 Rolling bearings - Dynamic load ratings and rating life.
- ISO 1460 Metallic coatings - Hot dip galvanized coatings on ferrous materials - Gravimetric determination of the mass per unit area.

- ISO 1940/1 Vibration and chock - Balance quality of rigid rotors - Part 1: Determination of permissible residual balance tolerances.
- ISO 8501 Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.
- ISO 10816 Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 1: General guidelines.

Should the requirements stated in the standards be less than the ones stated in this specification, the requirements stated herein will apply.

3.1.2 Dehumidification system requirements

3.1.2.1 General

All plant and equipment will be suitable for the environment in to which it is to be installed.

The plants will be designed for ease of access and maintenance and replacement of plant and equipment considering the location and application.

The plants will be designed to allow the inspection of the surrounding structures.

The design of the dehumidification system will be able to fulfil the following general requirements:

- Reliable operation and safety of personnel.
- Prevention of damage due to the saliferous maritime (salt fog) and climatic conditions, vibrations, lightning and damage due to corrosion and deterioration.
- Ease of inspection and maintenance.
- Ease and clarity of operation.
- Freedom from undue vibration and noise.
- Immunity against electromagnetic disturbances.
- Exclusion of birds, insects etc.

3.1.2.2 Design conditions

The design of the dehumidification systems will be based on the following ambient conditions:

- Maximum air temperature +40 °C
- Minimum air temperature 3 °C
- Average air temperature +18.1 °C
- Maximum air humidity 0.0187 kg water vapour/kg air
- Atmospheric air pressure 101.3 kPa.
- Maximum internal air temperature +60 °C.
- Internal approx. volumes to be dehumidified:

-	Main cables:	4 x	1200	m^3
-	Road and railway box girder section 3, 4, 5 and 6:	4 x	63000	m^3
-	Road and railway box girder section 1 and 8:	2 x	13500	m^3
-	Road and railway box girder section 2 and 7:	4 x	3000	m^3
-	Terminal structure, Sicilia:	1 x	45000	m^3
-	Terminal structure, Calabria:	1 x	32000	m^3
-	Towers:	4 x	63000	m^3
-	Anchor block chambers:	4 x	6500	m^3

The ambient conditions will be assumed to fluctuate within a 12 hour period as follows:

- Temperature: ±15 °C
- Atmospheric air pressure: ±2.5 kPa.

3.1.2.3 Design requirements

The design of the dehumidification system will be able to fulfil the following requirements inside the steel bridge structure:

- Infiltration of ambient air 2% of structure volume/hour.

- Relative air humidity inside structures max 40 % yearly average and operation preset limit value shall not be higher than 40%.
- Relative air humidity inside structures shall not exceed 50% for more than one hour per day.
- Dehumidification max power consumption: 1.45 kW/kg water per hour at 20 °C and 60% RH.
- Dehumidification systems capacity:
  - Design conditions:
    - Ambient 40 °C at 40% RH
    - Inside steel structures 25 °C at 40% RH
    - Inside main cables 20 °C at 40% RH
    - Inside concrete structures 15 °C at 25% RH
  - General, min 0.25 g (water to be removed)/hour per m^3 dehumidified structure volume.
  - Box girders and towers plant including make-up air for main cables, min 0.55 g (water to be removed)/hour per m^3 dehumidified structure volume.
  - Anchor block chamber plant, min 0.45 g (water to be removed)/hour per m^3 dehumidified structure volume.
  - Supplementary plant for main cables, min 2.5 g (water to be removed)/hour per m^3 dehumidified structure volume.
- Air circulation rates for continuous operation of the air circulation fans:
  - Min 2 times per 24 hours for box girders, terminal structures and anchor block chambers.
  - Min 4 times per 24 hours for towers and saddles.
- Air supply rate for continuous operation of the air injection fans:
  - Min 1 time per hour for main cables.
- Distance between injection points max 400m corresponding to airtight cables.
- Air pressure at injection points max 2 kPa.

- Differential pressure range for pressure control damper system: ±400 Pa (pressure switch hysteresis <20 Pa).
- The machinery of the dehumidification plant will be placed on vibration isolators.
- The friction loss of the ductwork will not exceed: 1 Pa/m.
- The air velocity in the ducts will not exceed: 6 m/s.
- The air velocity in the air intake will not exceed: 2.5 m/s.
- The working load/operation range ratio of the components will not exceed: 75%.
- The functional behaviour of the dehumidification systems will be monitored continuously by means of instrumentation as follows. Signals will be connected to and monitored from the Control and Monitoring System/Supervisory Control and Data Acquisition(CMS/SCADA):
  - Relative air humidity
  - Pressure
  - Temperature
  - Velocity (air flow).
- The sound level must not exceed the following values:
  - Inside structure: 70 dB(A)
  - Outside structure: 60 dB(A).

3.1.3 Functional requirements

3.1.3.1 Control

The dehumidification plants will be designed as an autonomic unit as can operate without any control signals form the CMS/SCADA system.

During normal operation the start and stop of the dehumidification unit will be controlled by electronic humidity sensors connected to dehumidification local control panel, as shown on drawings.

In case the relative air humidity exceeds the preset limit value, the dehumidification unit will start, automatically controlled by the dehumidification control panel. In case of falling value, the dehumidification unit will automatically stop at the lower preset value.

Humidity and temperature recording will be at minimum two relevant locations for each area to be dehumidified.

Hour counters for recording operation time for the dehumidification unit and ammeter for recording of power consumption to be installed for each plant and connected to CMS/SCADA system.

An emergency off switch will be installed at each dehumidification plant.

All ventilation fans for circulation of air in structures and air injection fans for dry air supply to main cables will run continuously.

Remote Control and Monitoring

The dehumidification control panel will be connected via CMS/SCADA system.

The CMS/SCADA system is not part of the work for the dehumidification system.

Signals and operational functions to be exchanged between the dehumidification control panel and the CMS/SCADA system will include, but not be limited to, the following:

Operation signal from the CMS/SCADA system (transfer relays corresponding to the CMS/SCADA signal to be included in the dehumidification plant switchboard):

- Start plant
- Stop plant

Status indications from each dehumidification plant (potential free switch):

- Operational status, such as: automatic operation/manual operation/ stopped
- Safety-switch indications

Alarm indications from each dehumidification plant (potential free switch):

- Tripped over current protector
- Tripped temperature monitor

- System failure

Analogue indications from each dehumidification plant (4-20mA):

- Relative air humidity
- Pressure
- Temperature
- Flow

Override from the CMS/SCADA system:

- Manual override from the CMS/SCADA system will be possible in case of emergency, during inspection of the areas, or to enable repair of the unit.

Signals and operational functions will be accessible at the terminal rack in the dehumidification control board.

All above data will be recorded and displayed.

3.2 Operational requirements

The dehumidification systems will be designed to minimize need for inspections and maintenance.

All equipment will be designed to operate with maintenance intervals of not less than one year.

All equipment requiring periodic maintenance will be installed accessible for inspection and necessary maintenance work. All spear parts must be easy to replace.

3.3 Construction requirements

3.3.1 Marking

3.3.1.1 General

Marking of all components with a designation and numbering system, i.e. electrical, mechanical items, cables, pipes, etc., will be made to ensure a safe and rational operation and maintenance of the plant.

The component number will be indicated on labels in the plant, in documents, e.g. lists of fixtures, drawings, diagrams as well as in display images and prints in the process monitoring system.

3.3.1.2 Labels

A list of labels will be prepared. Labels will be fixed by screws and if required arranged in label holders. Fixing of labels will not decrease the degree of protection. Sealing will be made if necessary.

Signs and markings will be made of a material suitable to the corrosive atmosphere and fastened by screws to the equipment.

3.3.2 Materials

3.3.2.1 General

Materials, components and equipment will be of a recognized and well-known make and be available in Italy as standard components.

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

3.3.2.2 Painting and protective coating

Attention will be paid to the corrosive environment when selecting materials and components.

All mechanical installations related to the dehumidification systems will be of suitable make and protected in such a way that they will sustain without further maintenance for a period of minimum 25 years in the surroundings and environmental conditions that are present in the Messina area.

3.3.2.3 Lifetime requirements

Service life requirements for mechanical parts of the dehumidification system will be minimum 25 years and the electrical parts minimum 15 years. Maintenance schedule will include necessary periodical replacements of components for a period of 50 years.

3.3.3 Mechanical work

3.3.3.1 General

Replacement of installations and equipment with a short service life will be easy. Components to be regularly inspected and maintained will be easily accessible and removable.

They will be resistant to chemical attack from natural occurring acids and alkalis.

Bearings, casings, e.g. will meet the design lifetime requirement for the equipment where they are used.

The system will not be affected by extreme low or high temperatures to which it can be exposed.

Ducts and components will allow for later inspection and cleaning by necessary access hatches or screwed flange joints.

3.3.3.2 Dehumidification units

There are two different methods to dehumidify the air inside the bridge structures i.e. to reduce the relative air humidity by physically reducing the water content. The one method is adsorption technique and the other one is dehumidification by means of cooling.

Condensation dehumidification: A cooling compressor cools the air to a temperature which is lower than the dew point whereby the moisture condenses.

Dehumidification of the air inside the bridge structures will be based on adsorption. The adsorption system has few moving parts and no refrigerant and compressor like a condenser dehumidification system. This means no risk of spreading legionella bacteria, less operation and maintenance costs and improved environmental friendliness. Further the adsorption system functions in the entire required temperature range for the dehumidification in the bridge where the condensation system has a limited lower temperature range.

The principals for the desiccant rotor are following:
When the dehumidifier is working, two airflows simultaneously pass through the rotor. The process air flows through the rotor and the moist from the air absorbs in rotor surface and the air leaves the dehumidifier as dry air.
The reactivation air (preheated ambient air) flows in the opposite direction through the rotor. This warm air absorbs the moisture which the rotor earlier in the process has absorbed and the rotor

surface is again ready to absorb moisture. The warm and wet air is discharged to outside. This process takes place continuously as long the humidity inside the structure is higher than the preset limit value. The desiccant rotor is built on a fiberglass structure that is coated with a highly hygroscopic material.

All dehumidification units will meet the following minimum requirements:

- The dehumidification units will be provided to meet the required duty, based on adsorption and suitable for the electrical supply voltages.
- No flammable materials.
- Dehumidification units will be manufactured from hot-dipped galvanized steel.
- Inspection doors/hatches will be hinged and will be easy to open and close.
- Air leakage factor will be tested at 400 Pa under pressure. Maximum air leakage 0.44 m^3/(s, m^2) unit surface.
- Insect mesh will be provided at all air intakes and outlets. The meshes will be fine mesh stainless steel AISI 316L. Mesh width will be maximum 10 mm.

3.3.3.3 Filters

Requirements for the filters are dependent on ambient air quality in the area of air taken into the bridge structure and location of air intakes. To protect the structures against the ingress of dust, pollen, etc. from outside there will be installed filters in all dehumidification plants in the bridge. Further the air supply for main cables will have higher graded filters to prevent unwanted particles entering around the strands in the cables.

The filter for make-up air will be of filtering grade F9 (fine filter) and HEPA filter min grade H11 (micro filter) for injection air to main cables.

The filters will be moisture and salt mist proof and have a dust collection capacity corresponding to minimum 6 months operation time.

The filters will be provided with pressure drop meters marked with starting pressure drop for new filters and final pressure drop for dirty filters to be renewed.

F9 filters start 50 Pa and final 200 Pa and H11 filters start 250 Pa and final 400 Pa.

Start/final values will be given at normal air flow for the unit.

Maximum air velocity measured across the surface area will be 1.5 m/s.

3.3.3.4 Fans

Ventilation fans will meet the following minimum requirements:

- The fans will be provided to meet the required duty and will be suitable for electrical supply voltages.
- The fans must have an efficiency of min. 85%
- The fans will be suitable for the environment where they are installed.
- The fans will be able to start and transport air with a minimum temperature of -5°C.
- The fans will meet the sound level criteria according to the Design requirements.
- Bearings will have a minimum nominal lifetime in accordance with ISO 281/1 corresponding to 250000 operation hours.
- Rotating parts will be balanced so that the vibration velocity of the fan and the bearings of the motor are maximum 7mm/s at the nominal number of revolutions.
- The fans will be mounted with vibration isolators designed to reduce the transmission of unbalanced forces to the structure to maximum 2% of the rotor weight.
- The fans must have no external moving parts.
- The fans will be for use with DOL (Direct On-Line) starting and be provided with motors having a min. nominal power of 130% of the power requirement of the fan.

3.3.3.5 Dampers

Dampers in dehumidification system and ducts will meet the following requirements:

- Dampers will be designed and installed so that the tightness requirements of the connected ductwork are fulfilled.

- Air leakage through a closed pressure control damper will be less than 0.1 m^3/s per m^2 damper surface at 400 Pa pressure difference. For other dampers, less than 0.5 m^3/s per m^2 at Δp = 400 Pa.
- Damper blades will be stable and able to close towards a difference in pressure which can be expected on a bridge without permanent deformation of the blades.
- Louver dampers will have opposite closing blades.
- Material will be stainless steel, AISI 316L.

3.3.3.6 Indoor ductwork including supports

Ductwork will be hot-dipped galvanized steel.

Ductwork will be mounted according to documentation from the manufacturer and to a method that has been tested and proven to fulfill the requirements.

All ductwork and supports will be vibration resistant.

3.3.3.7 Outdoor ductwork including supports

The ductwork will be polished stainless steel SAF 2205 (EN 1.4462) and flexible ductwork on main cables and hangers will be wind, weather and UV resistant.

3.3.3.8 Duct supports

All duct supports will be designed for the weight of the duct plus a concentrated live load of 1.5 kN.

3.3.3.9 Tightness requirements for mounted ductwork

The ductwork system will be constructed and mounted so that:

- Tightness class with leak factor 0.44 litres/(s, m^2) at 400 Pa test pressure is achieved for all rectangular ducts and for circular ducts in ductwork systems with a total surface of $\leq$ 50 m^2.
- Tightness class with leak factor 0.15 litres/(s, m^2) at 400 Pa test pressure is achieved for circular ducts in ductwork systems with a total surface of > 50 m^2.

3.3.3.10 Sound absorbers

Sound absorbers will be designed and installed so that the tightness requirements of the connected ductwork are fulfilled.

It will be possible to demount sound attenuators for cleaning and inspection.

3.3.3.11 Airtight doors

Access doors will be self closing airtight doors.

3.3.4 Electrical work

3.3.4.1 General

The electrical work will be as follows:

- Electrical work (power and control) between components and the local control panel is part of the dehumidification plant
- Local control panel
- Instrumentation

Following list is an overview of electrical components:

- Switchboard and control panels as well as all components for installation inside switchboard and control panels
- Cables, instruments, cableways and electrical accessories and cable work
- Motors
- Programmable Electronic System (PES) units/field bus interface
- Grounding and equipment bonding

3.3.4.2 Grounding and bonding

There will be provided design, supply, installation and commissioning for the complete grounding and bonding installation as required by the latest edition of relevant standards. The grounding and bonding design will include all grounding aspects including main, supplementary and equi-potential

bonding.

All plant and ductwork etc. subject to its construction material will be bonded to the bridge structure.

Grounding connection will allow connection for minimum 25 mm^2.

3.3.4.3 Instrumentation

All instruments will produce output signal 4 - 20 mA.

The equipment will be suitable for conditions inside or outside.

The quality of instruments, sensors and installations will 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 in the enclosure. The instruments will be made of stainless steel AISI 316L and have IP code 65.

All external input (PES/Power) circuits will 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.

3.3.4.4 Humidity indicators and transmitters

Humidity measurements will comply with the following requirements:

- Range: 5 - 90% RH
- Accuracy: ± 1% RH over the entire range

3.3.4.5 Differential pressure measurement

Differential pressure measurements between the inside and the outside of the bridge structure will comply with the following requirements:

- Range: - 1000 to + 1000 Pa (-10 to +10 mbar)
- Accuracy: ± 0.5% over the entire range

3.3.4.6 Pressure switches and indicators

- Range: 0 to 500 Pa
- Accuracy: ± 0.5% over the entire range

3.3.4.7 Pressure transmitters

- Range: 0 to 3000 Pa
- Accuracy: ± 0.5% over the entire range

3.3.4.8 Temperature transmitter

- Range: -5°C to + 70°C
- Accuracy: ± 0.5% over the entire range

3.3.4.9 Flow transmitters

- Range: 2 to 15 m/s
- Accuracy: ± 3% over the entire range

3.3.4.10 Installation of instrumentation

Installation of instrumentation will be in accordance with the manufacturers' recommendation including cable selection. The following requirements must also be fulfilled:

- Signal transmission cables for connection of sensors will be armoured.
- Multi-pair for routing multi-channel signals
- Individually screened
- Galvanic isolated

Test of the instrumentation will include but not be limited to the following:

- Functional test of each system.

- Origin and calibration certificate test.

3.3.4.11 Control system

The dehumidification plants will be designed as autonomic units and will operate without any control signals from a CMS/SCADA system, called "auto operation".

3.3.4.12 Local control panel/CMS interface

Each plant will in the local control panel be equipped with input/output signals to the control and monitoring system CMS, accessible at a terminal rack or field bus interface labelled PES-signals in the local dehumidification panel as follows:

Potential free contacts (input signals, including interface relays) for:

- Circulation fan on/off command
- Injection fan on/off command
- Dehumidifier unit standby/off command
- Service stop command

Potential free contacts (output signals) for:

- Power on
- Auto operation (REMOTE)
- Air injection fan operating
- Air circulation fan operating
- Dehumidifier unit operation
- Pressure control damper open
- Common failure/alarm

Analogue signals (output signals):

- Relative humidity (mean of 2 points).

- Temperature
- Differential pressure
- Pressure
- Airflow

3.3.4.13 Power supply

Local control panels will be provided with a front operated incoming switch with terminals for connection of external power supply cables.

The electrical supply will be sized to serve each dehumidification plant. Full details of the electrical load for the plants will be confirmed with the dehumidification equipment specialist.

3.4 Workmanship

All installations will be carried out by skilled personnel and with due consideration to the environment.

All equipment will be installed in such a way that future maintenance and repair works can be done in a safe and ergonomically correct way. The safety aspects will apply to relevant national standards.

3.5 Inspection, testing and commissioning

3.5.1 General

Dehumidification systems will be tested and adjusted in order to ensure that operational data and functions indicated in specifications, drawings and bids and other contract documents are met. It should particularly 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 pressure measurements and flow adjustments will be carried out.

All tests including measurements, adjustments etc. will be documented in test reports.

3.5.2 Testing of Workmanship Procedures

3.5.2.1 Testing of Welding Procedures

Welding, brazing, soldering and braze welding of metals and testing of the same will be done by skilled and approved personnel.

3.5.3 Commissioning and Testing

Dehumidification systems will be tested and adjusted in order to ensure that operational data and functions indicated in specifications, drawings and bids and other Contract documents are met. It should particularly be ensured that all functions and functional contexts, e.g. in connection with control and monitoring, are tested and that a record is prepared.

There will be prepared a complete test program with appurtenant test record indicating tests and adjustments to be made.

All test and commissioning results will be collected and checked within 3 weeks after finishing the tests.

3.5.4 Testing and Inspection - Prior to Delivery to Site

Works inspections and testing of major plant items will be carried out in accordance with the relevant Codes and Standards and the following clauses.

Where specialist test equipment is required, there will be required to supply such equipment for the purpose of the test. All test equipment will have a current test/calibration certificate.

The tests will not only demonstrate the compliance of plant with the requirements of the specification regarding operation, they will also demonstrate the output to the plant monitoring and environmental control system.

Factory acceptance test schedules will be compiled.

3.5.5 Testing and Commissioning on Site

3.5.5.1 Noise and Vibration Tests

Noise and vibration tests will be made according to relevant ISO standards.

3.5.5.2 Tightness Test of Installed Ductwork and Dehumidification plants

Leak air flow will be measured at a test pressure of 400 Pa unless otherwise stated.

The sum of the measured leak air flow and measurement error will not exceed the value for the required tightness class by more than 15%.

Duct systems to be tested will be split up in part systems having a perimeter area of approximately 25 m^2 and not less than 10 m^2. A tightness tested system including the dehumidification unit, the equivalent perimeter area of the unit, Ae, m^2, will be added to the test area which will then be larger than (10 + Ae) m^2.

100% of ductwork systems and systems including dehumidification units will be tested.

3.5.5.3 Adjustment of Air Flows

Air flows to each bridge sections will be adjusted to calculated values. The adjustment procedure will either be "The proportional method" or "The pre-set method".

3.5.5.4 Measurement Protocol

A protocol specifying calculated and measured values for each bridge section will be prepared not later than 3 weeks after the final adjustment has been made. The protocol will specify measurement and adjustment methods used, instrument types, when and how they have been calibrated, and the probable measuring error.

The probable measurement error will be calculated as follows:

$m = (m_1^2 + m_2^2 + m_3^2)^{1/2}$

m_1 = measurement instrument error

m_2 = measurement method error

m_3 = measurement reading error

All values will be in %.

3.5.5.5 Commissioning of the Interface between SCADA and Dehumidification plants

The Contractor of dehumidification systems will prepare test program and participate in testing and will cooperate with the Contractor of the SCADA-system concerning commissioning of the interface between SCADA and the dehumidification systems.

The commissioning test will comprise testing of all signals and interlocking and operation facilities.

3.5.5.6 Test Operation

Test operation of dehumidification installations will be made in the following order:

1. Preparation and presentation of a test program and test records covering the dehumidification systems
2. The test operation program will comprise normal operation, manual operation and testing of the operational reliability in case of failure of different voltage systems.
3. The test program will be carried out.
4. Collection and check of the results of the test operation not later than 3 weeks after the test is completed.

3.6 Training of Owner's Personnel

Owner's operation and maintenance personnel will be inform and trained as regards function, operation and maintenance of all equipment included in the works.

Complete program for training of the Owner's personnel will be prepared. Information to the personnel will be based on the operating instructions and technical documentation and will include:

- Prior to plant start-up the operating and maintenance personnel will be given a theoretical training on the structure and function of the plant.
- The personnel will be trained to maintain the plant during normal operation.
- The personnel will be trained to use and program the control and monitoring system.
- The personnel will be instruct and trained in the start-up, operation and maintenance of the installations.

3.7 Operation and maintenance

3.7.1.1 Commissioning spare parts

All spare parts and consumables necessary for testing and commissioning the dehumidification systems will be included.

3.7.1.2 Critical spare parts

A list of spare parts supplied for the operation of the dehumidification systems will be included. As a minimum, all spare parts recommended by the manufactures/suppliers for the supplied equipment for the same applications for time period of 5 years will be supplied.

4 Documentation

The following documentation will be submitted:

- As-built drawings of all installations, inclusive schematic diagrams and installation drawings.
- A general part comprising contents, and description of the installation
- Functional description
- List of components indicating manufacturer, type, component numbers, ordering numbers, other data and position
- Maintenance instructions stating maintenance routines and intervals
- Calibration reports for analogue signal circuits
- Data leaflets: performance curves, diagrams, test certificates etc.
- List of spare parts
- Operation and Maintenance (O&M) Manuals
- Site Acceptance Test (SAT)
- Commissioning report

Immediately after the Test on Completion, the suitable corrected manuals will be compiled into its final form and be submitted to the Engineer for approval.

Any additions, alterations or deletions, which may be required following the experience gained during the Defects Notification Period, will be incorporated into the final versions in the form of additional pages or complete replacement of sections as specified by the Engineer. All costs of these amendments will be deemed to be included in the Contract.

5 Appendices

5.1 Drawings

The basic requirements and principle for the dehumidification systems are shown on the following drawings:

- CG.1000-P-1L-D-P-SS-R4-00-00-00-00-01-B Secondary Systems - Dehumidification, System key plan
- CG.1000-P-1A-D-P-SS-R4-00-00-00-00-01-B Secondary Systems - Dehumidification, Anchor block chambers
- CG.1000-P-1A-D-P-SS-R4-00-00-00-00-02-B Secondary Systems - Dehumidification, Main cables
- CG.1000-P-1A-D-P-SS-R4-00-00-00-00-03-B Secondary Systems - Dehumidification, Suspended deck, Road and railway girders
- CG.1000-P-1A-D-P-SS-R4-00-00-00-00-04-B Secondary Systems - Dehumidification, Towers
- CG.1000-P-1A-D-P-SS-R4-00-00-00-00-05-B Secondary Systems - Dehumidification, Terminal structures