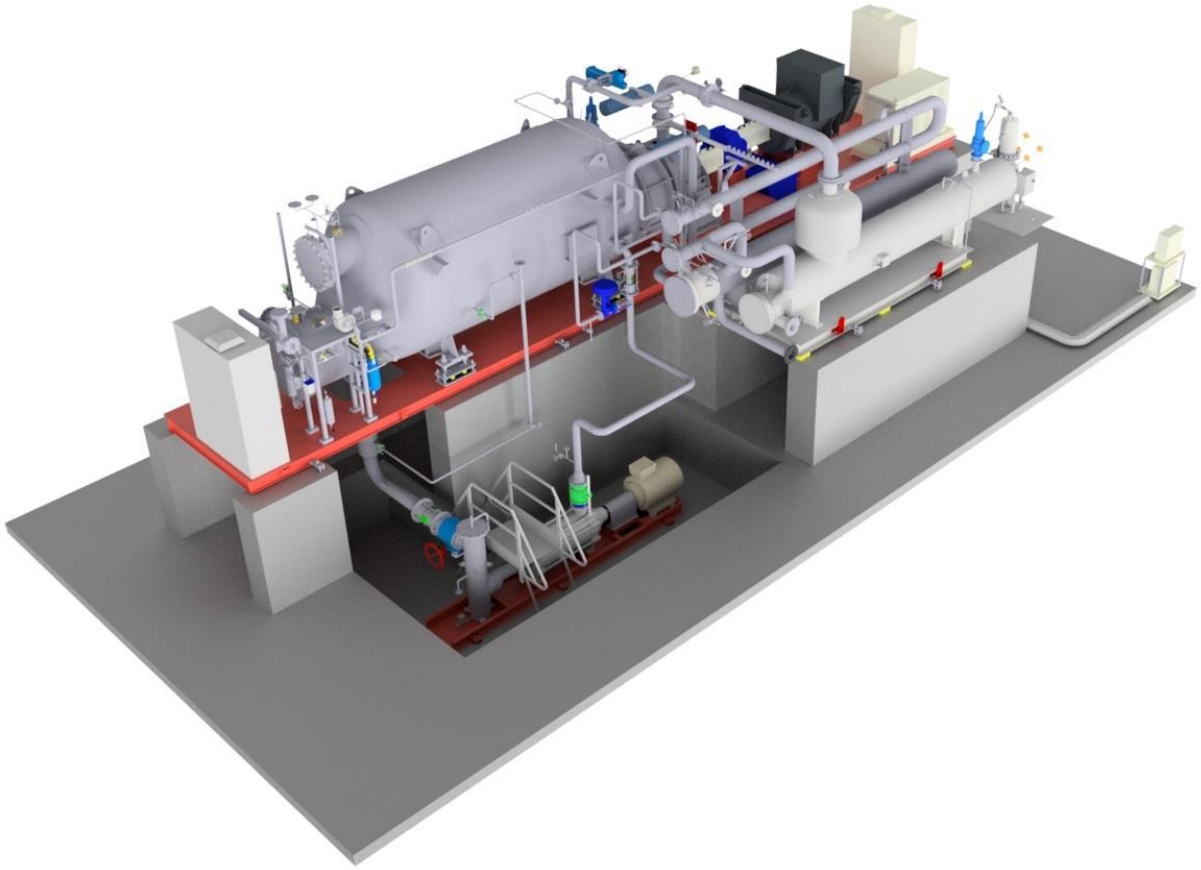
# *OPERATING AND MAINTENANCE MANUAL*



| | |
|---|---|
| MACHINE: | **ORC TURBOGENERATOR** |
| MODEL: | **TURBODEN 10 CHP SPLIT** |
| SERIAL NUMBER | **J02789** |

## Revision registration form

| Revision | Description | Prepared by | Checked by | Approved By | Date |
|---|---|---|---|---|---|
| 0 | First issue | C.S.D.I. | DD0271 | DD0271 | 09/02/2017 |

## REFERENCE STANDARDS

Harmonised standards and other technical specifications that have been applied to the design and construction have been used for the design, construction and implementation of the system:

- EN 13445; EN 13480; EN 4126; EN 10204;
- “Series EN 15607; EN 287-1;
- ISPESL VSR collection, S collection, E collection;
- ASME II Part B; ASME II Part D;
- EN 5817; EN 1779; EN 473
- EN 61439-2; EN 60204-1
- EN 12100; EN 953; EN 61511-1; EN 61511-2 EN 61511-3
- EN 14121-2; EN 61000-6-2; EN 61000-6-4

Applicable EU Directives:

- 2014/68/EU: Pressure Equipment Directive,
- 2006/42/EC: Machinery Directive,
- 2006/95/EC: Low Voltage Directive,
- 2004/108/EC: EMC Directive.

## Summary

## List of illustrations

# 1 GENERAL PREMISES

**Carefully read the information in this manual for correct system operation and to avoid damaging property or harming persons.**

It also contains an outline for system maintenance, which is designed to ensure safety during operation and to maintain efficiency over the course of its service life.

This manual is designed for staff who are involved in the management and maintenance of the system, and may not be reproduced in any form (photocopy, microfilm or digital files), either in whole, or in part, nor may it be loaned to unauthorised individuals without the written consent of TURBODEN S.r.l.

On-site staff shall have read and understood the information and recommendations included in chapter 16 of this manual (safety recommendations).

**TURBODEN S.r.l. will not be held liable in the event of operations carried out by members of staff who do not possess the required qualifications, and have performed any such action without observing the recommendations specified in this manual.**

## 2 CE DECLARATION OF CONFORMITY

| A | The Manufacturer: |
|---|---|

Turboden S.r.l.
Via Cernaia, 10
25124 - Brescia - Italy

| B | The system: |
|---|---|

ORC Turboden 10 CHP SPLIT Turbogenerator
Serial number J02789

| C | Place of installation: |
|---|---|

Uniconfort srl
Newbridge Energy, Lon Gwernydd St., Denbighshire
Ruthin, LL152TN

| D | Equipment classification: |
|---|---|

CAT IV (in accordance with Appendix II, Art. 3)

| E | Conformity assessment procedure: |
|---|---|

Module G (as defined in Appendix III)

| F | Name, address, and number of the Designated Agency responsible for the final assessment |
|---|---|

TÜV SÜD Industrie Service GmbH
Westendstraße 199
80686 MÜNCHEN
Country : Germany
O.N. 0036

| G | Document references from the final conformity assessment (certification, test report): |
|---|---|
| | [certificate] - [test report] |

| H | **Harmonised standards and other technical specifications which have been applied to the design and construction:** |
|---|---|

EN 13445; EN 13480; EN 4126; EN 10204;
Series EN 15607; EN 287-1;
ISPESL VSR collection, S collection, E collection;
ASME II Part B; ASME II Part D;
EN 5817; EN 1779; EN 473
EN 61439-2; EN 60204-1
EN 12100; EN 953; EN 61511-1; EN 61511-2 EN 61511-3
EN 14121-2; EN 61000-6-2; EN 61000-6-4

| I | **Applicable EU Directives:** |
|---|---|

2014/68/EU: Pressure Equipment Directive,
2006/42/EC: Machinery Directive,
2006/95/EC: Low Voltage Directive,
2004/108/EC: EMC Directive.

The manufacturer Turboden S.r.l, referred to in point A, declares that the system described in points B, C, and D, complies with the essential safety requirements as specified in the applicable European Directives listed in section I.

With regards to Directive PED 97/23/EC, Turboden S.r.l. also states that the system has been assessed by the Designated Agency, as indicated in point F, and as referred to in point E, with methods and results included as part of the documents in point G.

## 3 PURPOSE OF THE DOCUMENT

With this manual, Turboden S.r.l. aims to provide guidance on the following points:

- Requesting individuals to pay attention to safety procedures;
- Correct procedure for lifting, operation, installation, dismantling, and recycling or disposal of the **TURBODEN 10 CHP SPLIT TURBOGENERATOR;**
- Information on the **TURBODEN 10 CHP SPLIT TURBOGENERATOR**, including its operational capabilities and limitations;
- Maintenance work, repairs and lubrication;

The equipment shall only be installed in facilities where all requirements relating to hygiene, health and safety are observed within the workplace,

Turboden S.r.l. will not be held liable for any incident which may arise from any damage caused by this type of failure.

The illustrations and drawings shown in the manual serve as a reference for use and maintenance operations; for detailed information, please refer to the attachments provided with this manual

Should the manual be lost or damaged, it is recommended that the user(s) request a new copy from Turboden S.r.l.

**ATTENTION:**

The illustrations and diagrams in the manual represent a source of reference for operation and maintenance. They may not specifically concern the system in question.

## 3.1 Scope of the document

The scope of this manual includes everything that has been expressly identified as part of the supply in the technical specifications for the turbogenerator, along with any contractual agreements, which these documents refer to.

## 3.2 Warnings in the instructions manual

The operation, maintenance, and repair of the system shall only be carried out by professionally trained, qualified, and authorised members of staff. These staff members shall be adequately informed of any dangers which may occur during any such operations.

Any such liability shall be assumed exclusively by the Customer.

In cases where management has been subcontracted to a third party, the Customer shall assume sole responsibility, and shall comply with the legal constraints and suitability of the agreement.

The Customer is required to contact Turboden S.r.l. immediately for cases of malfunction which are not covered in this manual.

### Constructive remarks

Turboden S.r.l. certifies that any component installed on the **TURBODEN 10 CHP SPLIT TURBOGENERATOR** has been designed and manufactured to guarantee the production according to the conditions set out in the technical specification and to minimize maintenance shut-down.

Any system modifications are strictly prohibited without the written consent of Turboden s.r.l.

## 3.3 Symbols used in the user manual

In this manual, all of the information which shall be read and which requires specific attention is highlighted in **bold**.

This symbol is used to highlight information which concerns safety issues. Failure to comply (either in full or in part) with these instructions could pose a serious **danger** to individuals who are operating the system.

This symbol highlights instructions that must be followed in order to avoid **issues with the system** (system failure, damage, etc.) It also provides **suggestions** on how to deal with practical issues which may arise during operation.

This symbol highlights forbidden actions. Failure to observe these instructions (either in full or in part) may lead to damage to the equipment or to the individuals who are working with the system.

## 3.4 Operator/machine interaction

Each procedure in this manual is described taking into account the following conditions:

1. Machine status: work stages and the actual status of the safety systems;
2. Number of operators: the number of operators required to perform the described operations;
3. The level of the operators: the degree of specialisation required by employees for specific operations.

The features of the equipment have been accurately designed. The use of a smaller number of operators, an inadequate level of expertise among the technicians, or an incorrect machine status may lead to dangerous situations for both the machine and exposed operators.

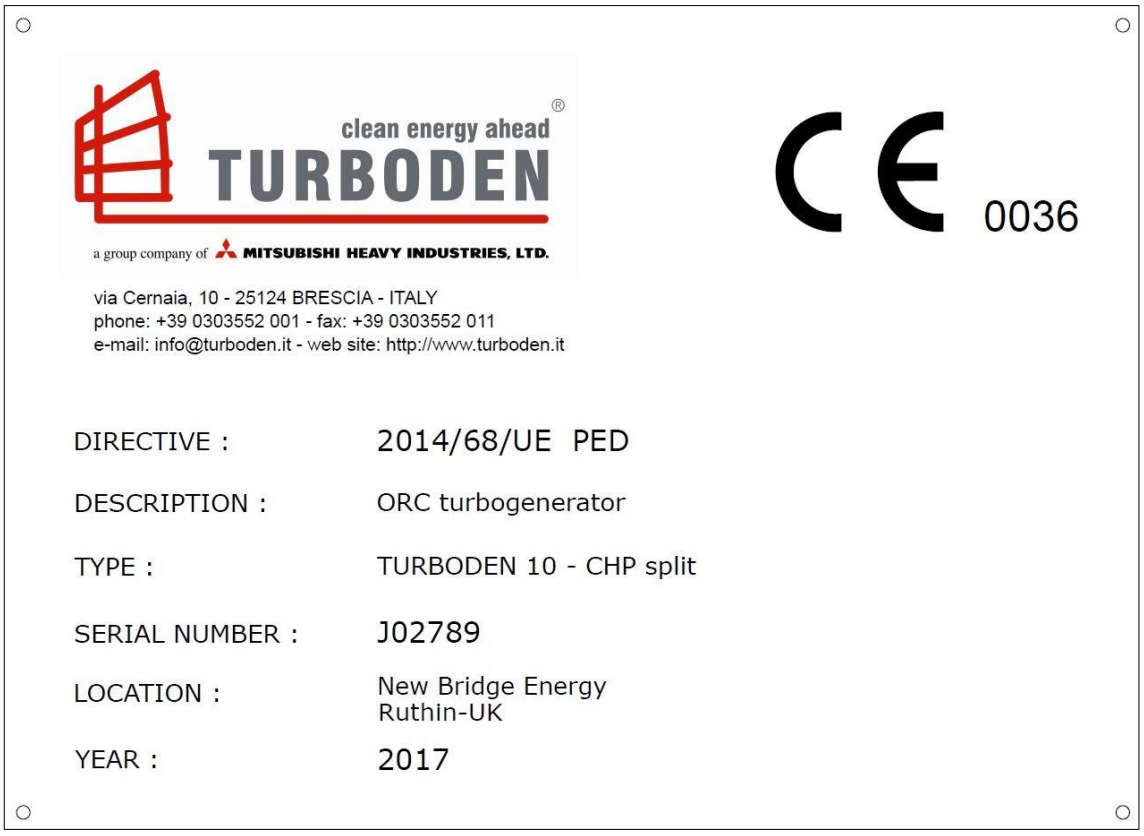
## 3.5 Manufacturer details

| | |
|---|---|
| Name of the manufacturer: | **TURBODEN S.r.l.** |
| Administrative headquarters and production site: | **Viale Cernaia n. 10 - 25124 Brescia (Italy)** |
| Telephone number: | **0039 030 3552001** |
| Fax number: | **0039 030 3552011** |
| E-mail address: | **info@turboden.com** |

### 3.6 Machine details:

| | |
|---|---|
| Name: | **TURBODEN 10 CHP SPLIT TURBOGENERATOR** |
| Serial number: | **J02789** |
| Customer: | **Uniconfort S.r.l.** |
| Year of manufacture: | **2017** |

The machine's information relating to the marking (serial number, year of manufacture, name and address of the manufacturer, EC marking) are specified on the nameplate as required by the Machinery Directive. The plate, as illustrated below must be in a clearly visible position, and placed in an area where it cannot be confused with other information




**If the machine nameplate gets damaged or is illegible, the Customer is responsible for contacting Turboden s.r.l. to obtain a replacement copy.**

## 4 GENERAL TERMS OF WARRANTY

The terms of warranty are defined in the warranty conditions, and are undersigned at the time of stipulating the supply contract.

The machine will be delivered for installation after all of the tests carried out by Turboden s.r.l. are passed. If the installation is executed by third parties, the system shall successfully undergo additional checks required by Turboden S.r.l

Turboden S.r.l. will guarantee the replacement of any defective part during the warranty period if operation and maintenance have been carried out in accordance with the instructions outlined herein.

Parts subject to wear (pump seal, turbine bearings, etc..) and initial filling fluids are excluded from the warranty after 8000 hours of operation.

The WARRANTY shall lapse under the following circumstances:

- Improper usage or usage which is not in accordance with the machine's instructions.
- Incorrect handling or installation which has not been conducted in accordance with these instructions.
- Failures or defects which have been caused by energy supply systems.
- Poor maintenance.
- Any changes and/or operations carried out without relative authorisation.
- The use of any non-original spare parts.
- Failure of the Customer to confirm receipt of the manuals.
- Using the turbogenerator outside of the specific and guaranteed scope of performance.

**Any tampering with the machine, particularly in relation to safety devices, will automatically invalidate the warranty and relieve Turboden S.r.l. of any liability.**

# 5 TECHNICAL SUPPORT AND REPAIRS

Turboden S.r.l. offers its Customers a support and maintenance service (Service). The different Service options and conditions are defined upon the stipulation of the supply agreement, or by signing a specific contract.

The Customer can communicate with the Turboden Service by using a web application called “Turboden Online Service” (TOS), which can be accessed from the URL:

**https://tos.turboden.net/tos/listRequest.php?lang=0**

The TOS application allows the customer to open tickets to receive support or to report information on the operations carried out. Once the ticket is received, the Turboden service team will contact the user to decide upon the type of assistance that will be provided. For more information on the TOS, please refer to the relevant manual provided in the attachments (14-S-9).

# 6 RISKS ASSOCIATED WITH THE TURBODEN 10 CHP SPLIT TURBOGENERATOR

An analysis of the risks associated with the turbogenerator is provided in a specific document attached to this manual.

# 7 STAFF TRAINING

During commissioning, Turboden S.r.l. offers a basic training course aimed at the operators for a smooth and safe use of the system.

It is the sole responsibility of the Customer to ensure that all members of staff involved in machine operation, either directly, or indirectly, attend the training courses.

## 7.1 Training course procedures and programs

The Course will be taught by qualified authorised personnel either from Turboden S.r.l. or of an equivalent standard, and will be held either at the representative's headquarters, or directly at the user's premises.

This consists of:

- A theoretical section, which provides basic knowledge of the machine and its components;
- A practical section, which is conducted directly on the machine and which covers operation and maintenance.

The detailed Course programme is based on the objectives that need to be achieved; the following topics will be covered:

1. ORC components and cycle;
2. Auxiliary systems:
   - Turbine valves;
   - Lubrication control unit;
   - Non-condensable extraction system;
   - Electrical panels.
3. Interface with system:
   - Checks from the electrical control panel;
   - Checks from the PC (SCADA);
4. Start-up sequence
5. Routine shut-down;
6. Emergency stop;
7. Emergency shutdown;
8. Blocks and warnings management;
9. Request from support through TOS:
   - Account creation;
   - Ticket send test;
10. Safety of the ORC;
11. Information on organic fluid;
12. Controls and maintenance operations borne by the customer.

# 8 THE ROLES AND RESPONSIBILITIES OF OPERATORS

To ensure the normal operation of the ORC turbogenerator, only minor daily controls are provided; in case of maintenance or repair works that also involve the systems connected to the turbogenerator, additional staff may be required.

The necessary qualifications are indicated below:

**Head Engineer**: technical staff appointed by the customer or its subcontractor who is qualified in performing complex system operations.

Duties:

- Responsible for the whole working area, including the systems connected to the ORC turbogenerator;
- Management of the reaction plan in case of turbogenerator shut-down (please, refer to chapter 13);
- Agree on routine and unscheduled maintenance;

**Mechanical Maintenance Technician**: a member of the staff employed by the Customer in order to commission and shut-down the system under standard conditions, and to carry out maintenance and repair works under supervision and in agreement with Turboden S.r.l. Service. He/she is not authorised to work on any electrical circuits, or on components that conduct voltage.

**Electrical Maintenance Technician**: a qualified member of staff employed by the Customer in order to commission the equipment under standard conditions, to set electrical parameter settings on the entire permitted field of values, and to carry out maintenance and replace electrical parts in agreement with Turboden S.r.l. Service.

According to the local regulations, he/she is qualified to carry out operations, also in case of powered circuits inside the electrical control panels and the interface terminal blocks for the electric components. Technical skills verification and compliance with safety regulations are requested by local regulations and are under the sole responsibility of the Customer.

**Machine Operator**: An operator who has been designated to run the machine under standard working conditions, who may use the controls installed on-board with all of the safety devices enabled.

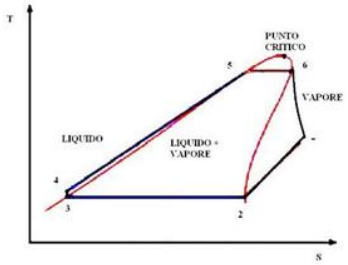
**Turboden S.r.l. Technician**: a technician who may carry out complex and unscheduled operations on the equipment.

# 9 SYSTEM DESCRIPTION

## 9.1 Thermodynamic cycle

The ORC turbogenerator consists of a closed circuit in which an organic fluid (silicone oil) with a high molecular mass evolves, carrying out a working cycle similar to the Rankine cycle. For this reason the machine is identified as ORC (Organic Rankine Cycle). Inside the ORC, the organic fluid (silicone oil) is subject to a working cycle consisting of the following stages:

- Pumping (3 - 4)
- Regeneration (1 - 2)
- Preheating (4 - 5)
- Evaporation (5 - 6)
- Expansion (6 - 1)
- Condensation (2 - 3)



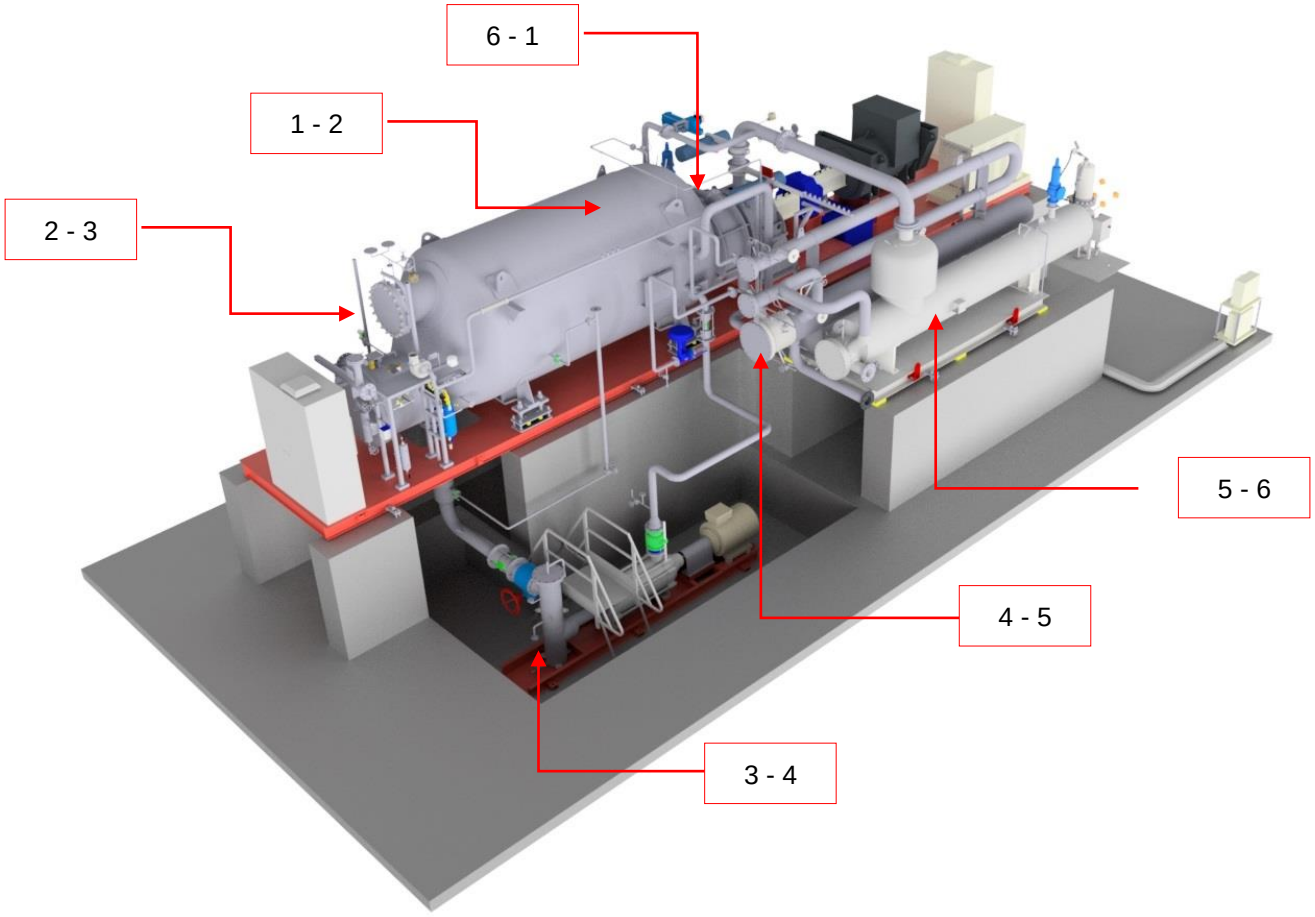




Figure 9.1-1 T – S Diagram of the Thermodynamic Cycle.

The silicone oil reaches evaporation (steps 5-6) through the thermal power supplied by the thermal oil, also known as thermal fluid.

With reference to Figure 9.1-1 we have:

- **Pumping phase** (3-4). The organic fluid in liquid phase is pumped and overcomes the cycle pressure and pressure drops.
- **Regeneration phase** (1-2). During this phase, the temperature of the organic fluid in liquid phase increases thanks to an internal exchange with the organic fluid in vapour phase exiting the turbine by means of the regenerator.
- **Preheating phase** (4-5). The organic fluid in liquid phase is heated by the thermal oil until it reaches a temperature close to the evaporation one.
- **Evaporation phase** (5-6). The organic fluid in liquid phase is additionally heated by the thermal oil until complete evaporation and further overheating.
- **Expansion phase** (6-1). During this phase, the turbine expands the pressurised vapour, thus extracting mechanical power, which is then transformed into electric power by the generator connected to it (by means of the reducer).
- **Condensing phase** (2-3). The vapour exiting the turbine is then cooled by the regenerator, which recovers heat (1-2), and enters the condenser unit where it is further cooled and condensed, transferring the heat to water. The condensed fluid returns to the feed pumps.

During routine operation, one section of the circuit (between the pumps and the turbine inlet) is pressurised, while another section (between the turbine exhaust and the pumps inlet) is under vacuum. When the system is shut down, however, the entire circuit is placed under vacuum.

| Circuits | $PS_{max}$ MAWP [ bar_g ] | $PS_{min}$ MAWP [ bar_g ] | $TS_{max}$ design temp [ °C ] | $TS_{min}$ MDMT [ °C ] |
|---|---|---|---|---|
| High pressure silicone oil [1] | 15 | -1 | 293 | -10 |
| Low pressure silicone oil [1] | 6 | -1 | 245 | -10 |
| Thermal oil [2] | 13 | 0 | 340 | -10 |
| Cooling water [2] | 15 | 0 | 150 | -10 |
| Compressed air [2] | 10 | 0 | 40 | -20 |

Table 9.1-1: Design values.

Notes:

**[1]** The Buyer is responsible for the external discharge pipes of the safety systems.

**[2]** The Buyer is responsible for protecting the circuit from overpressure and over-temperature.

## 9.2 System diagram and main components

With reference to Figure 9.2-1, Figure 9.2-2 the main parts of the system are:

1. Condenser
2. Regenerator
3. Pump
4. XSD system
5. Lubrication control unit
6. Panel Q3
7. Panel Q4
8. Turbine
9. Reducer
10. Electric generator
11. Pre-heater
12. Evaporator
13. Split

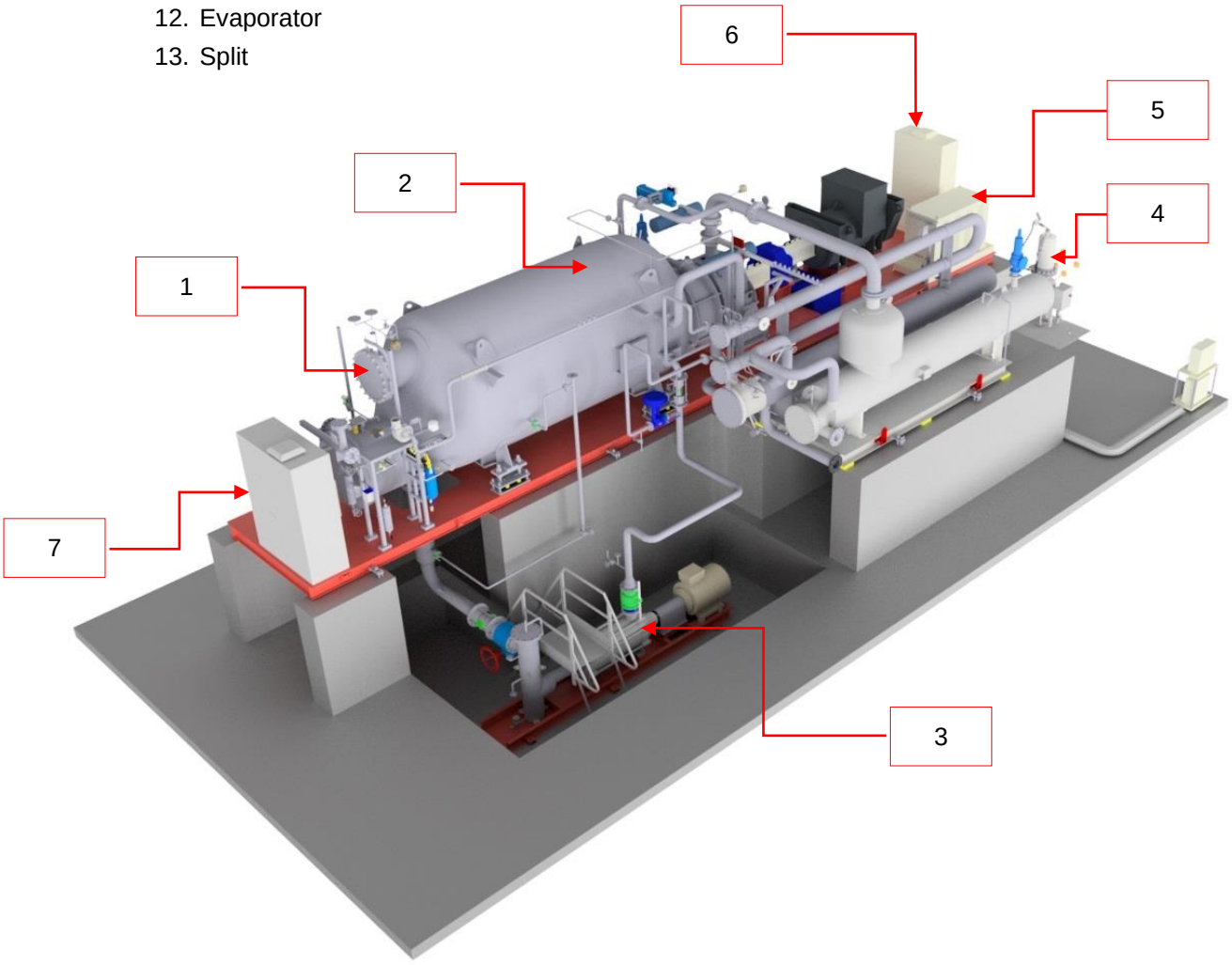



Figure 9.2-1: 3D Drawing of System

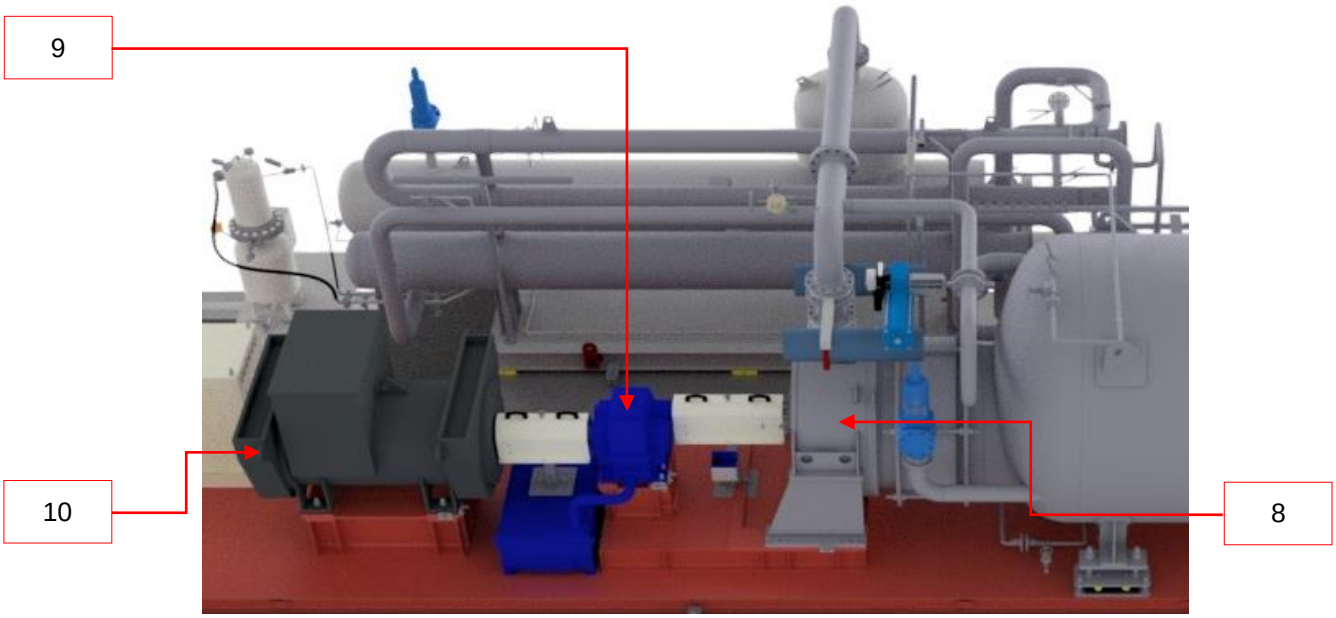



Figure 9.2-2: 3D drawing – turbine side.

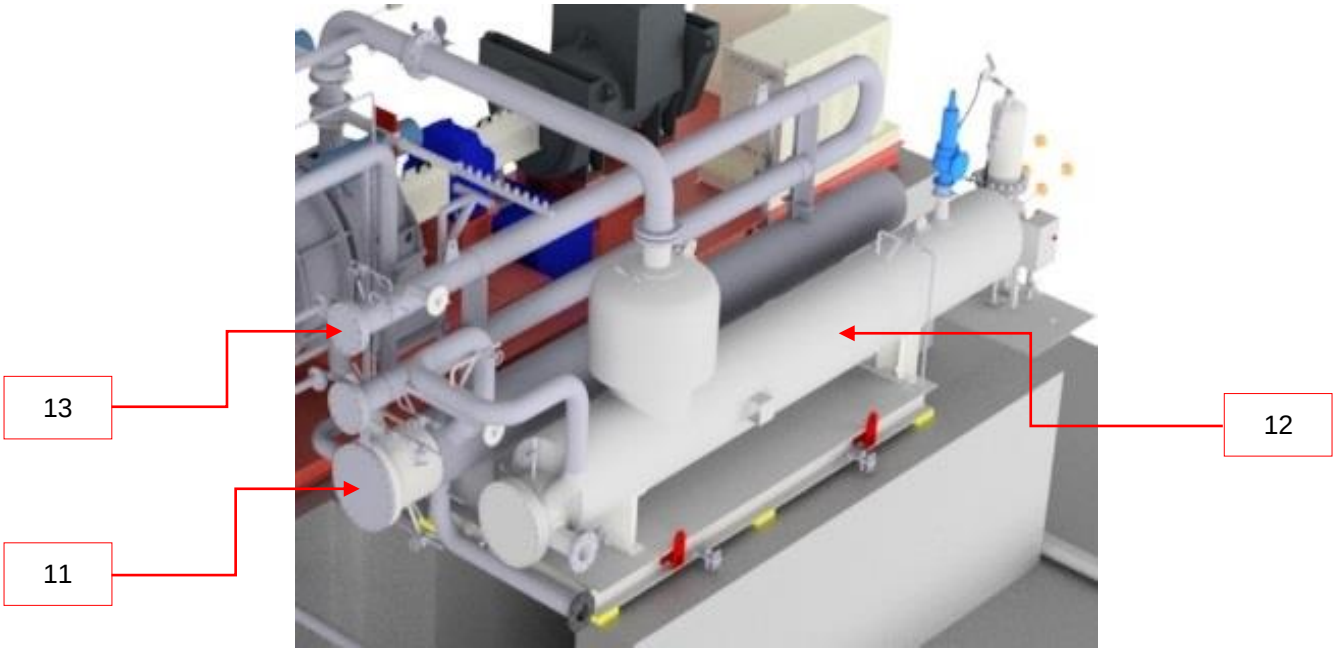



Figure 9.2-3: 3D drawing – hot module.

The functional diagram of the system is illustrated in Figure 9.2-4. The circuits where various fluids flow (silicone oil, thermal oil, water) are highlighted in different colours:

1. The closed circuit containing process fluid is marked in **green**:
   - The darker section identifies the high pressure area of the circuit.
   - The lighter section indicates a low pressure area;

Both sections of the machine (for high and low pressure) are fitted with a rupture disk and a safety valve. The latter is only employed in cases of critical malfunctions and helps stop the pressure from rising above the restricted limits.

2. The hydraulic interface with the high temperature source (thermal oil circuit) is highlighted in **red**;
3. The hydraulic interface with the low temperature source (water circuit) used for condensing the process fluid is highlighted in **blue**;

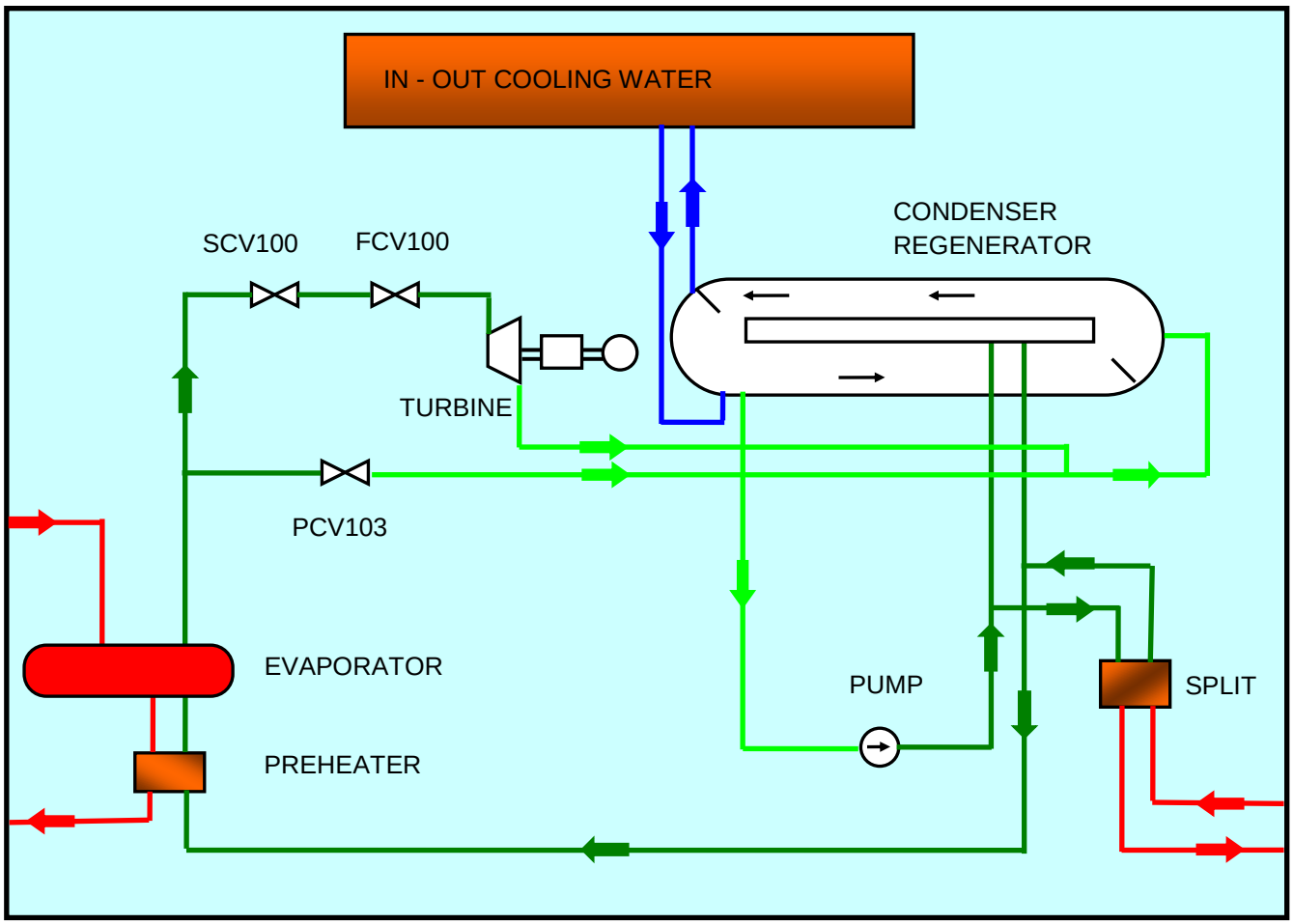



Figure 9.2-4: Cycle diagram outline.

## 9.3 Inlet valves and turbine bypass

Pressurised vapour normally supplies the turbine; if needed (start-up, shut-down), the turbine inlet may be shut-off, thus discharging the vapour directly in the regenerator; the two conditions are detailed below:

- **Turbine vapour expansion** (FCV100 shut-off valves and SCV100 inlet valves are open, PCV103 bypass valve is closed, see Figure 9.3-1); in this configuration, the steam will flow fully into the turbine, which transforms the enthalpy drop entirely into mechanical energy; the electric generator is connected rigidly to the turbine via a connecting joint which then transforms the mechanical energy into electrical energy.
- **Vapour lamination** (PCV103 by-pass valve is open, FCV100 shut-off valve and SCV100 inlet valves are closed, see Figure 9.3-1): in this configuration during start-up, shut down and emergency stop phases, the fluid will reach the regenerator without having to go through the turbine. The vapour lamination line by means of the PCV103 valve can also be activated in case of system overload, in order to limit the evaporator pressure.

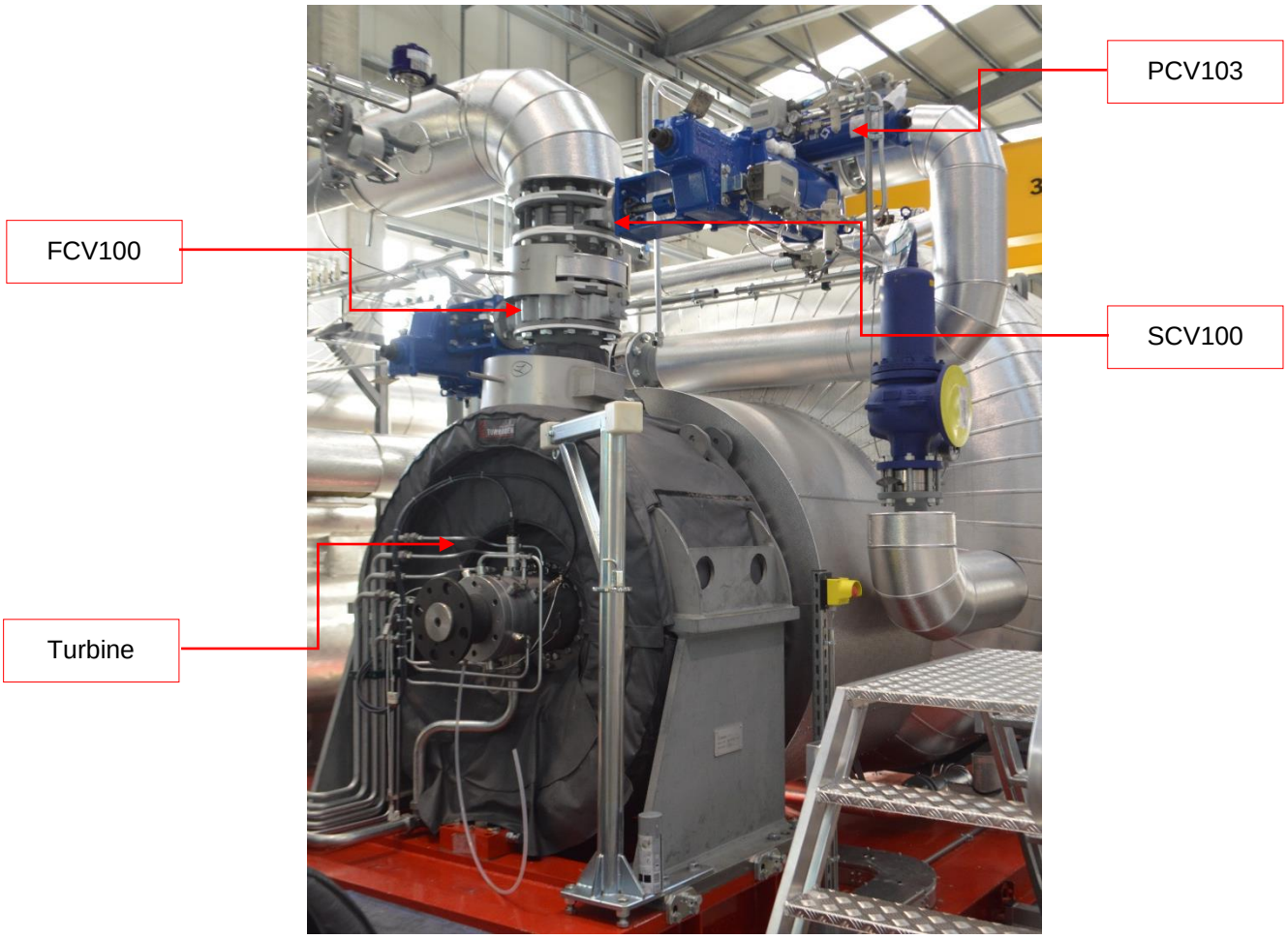



Figure 9.3-1: FCV100, SCV100, PCV103 valves.

## 9.4 Auxiliary systems

The operation of the turbogenerator cycle entails the use of the following auxiliary systems:

**(9.4.1)** Lubrication control unit;
**(9.4.2)** Non-condensable extraction system
**(9.4.3)** Leak monitoring system
**(9.4.4)** Split System low temperature heating system;
**(9.4.5)** Oil separation system (XSD).
**(9.4.6)** Reducer lubrication control unit;

Namely:

### 9.4.1 Lubrication control unit


Figure 9.4-1: Lubrication control unit.

This is designed to:

1. Lubricate and cool the rotating seal on the turbine shaft;
2. Lubricate and cool the ball bearings on the turbine shaft;
3. Cool the sealing flushing tank oil of the circulation pump.

For other important information regarding the lubrication control unit, please see paragraph 15.6.

### 9.4.2 Non-condensable extraction system

A small quantity of air enters from the flanged joints exposed to pressure below atmospheric pressure and accumulates in the condenser. The Turbogenerator is equipped with a system for the extraction of air (and all non-condensable parts in general).

The presence of air inside the condenser unit significantly worsens the performance of the turbogenerator, as it increases the pressure at the turbine exhaust, thus reducing the available enthalpy drop.

The system is comprised of:

1. A P150 vacuum pump;
2. A V103 non-condensable extraction tank;
3. A V104 tank to protect from the suction of the fluid in liquid phase;
4. A V105 water separation tank;
5. A series of shut-off and control valves.

**Warning:**

The parts listed in the following diagrams, marked with their acronyms, can be identified on the system by referring to the P&I diagram "attached to the manual"

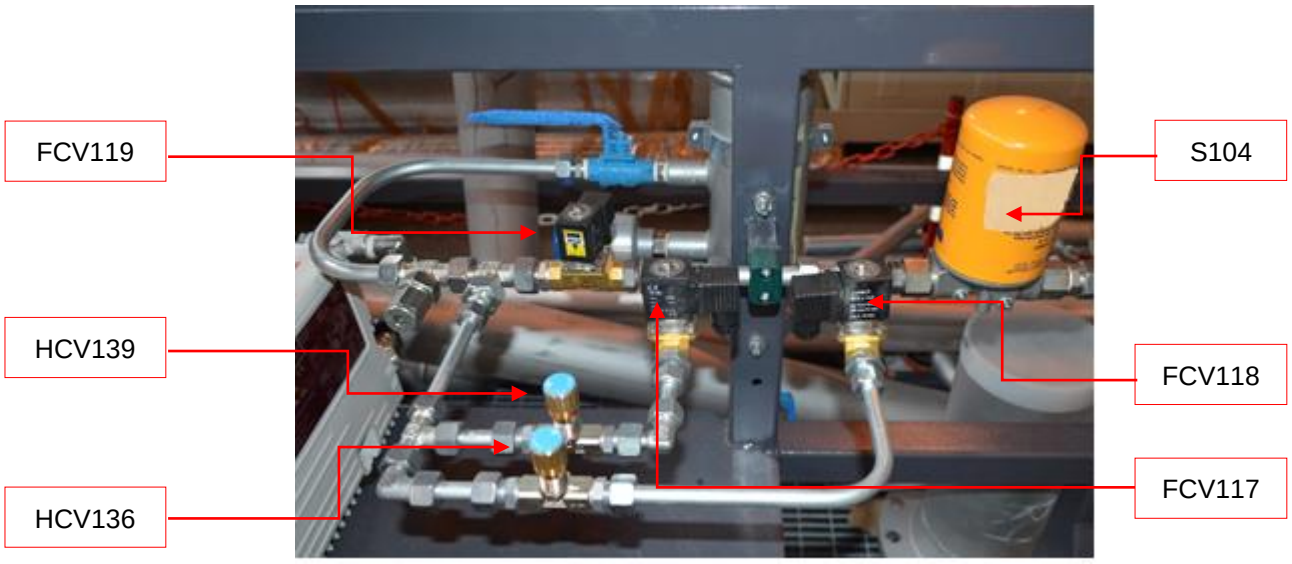



Figure 9.4-2: vacuum system control valves.

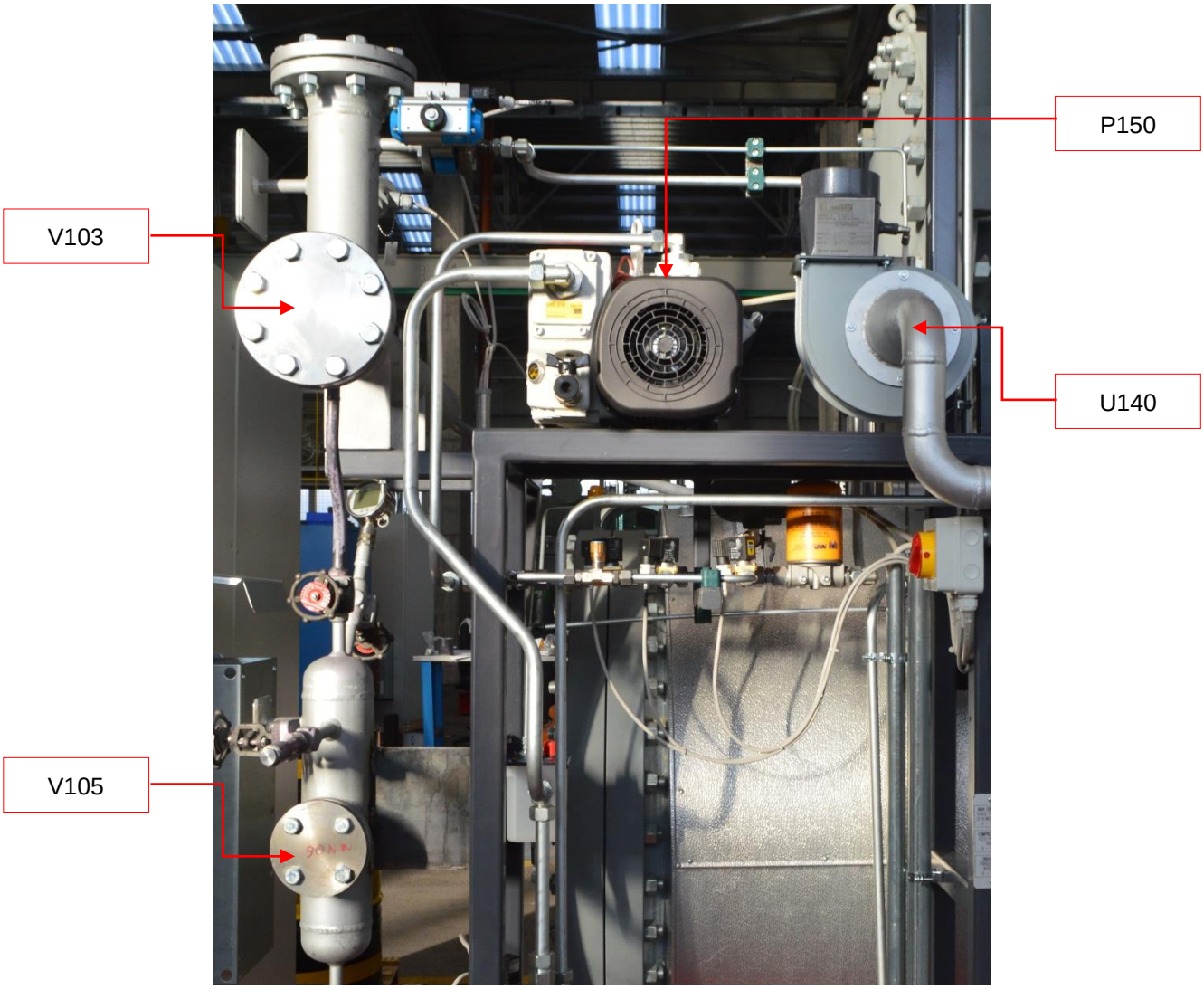



Figure 9.4-3: Non-condensable extraction system.

### 9.4.3 Leak monitoring system

The function of this system is to avoid the formation of explosive atmospheres from building up in safe areas, or to prevent any potential points of emission from leaking (i.e. the connecting flanges).

The pipe flanges that operate above the atmospheric pressure under routine conditions, are enclosed by a steel casing and connected to a manifold which is kept under vacuum by means of a fan (U140).

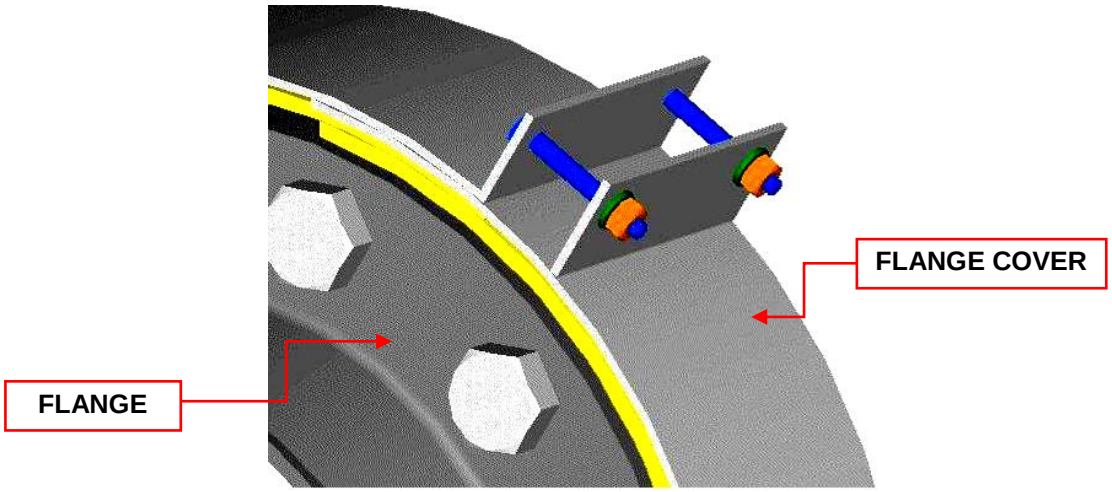



Figure 9.4-4: Containment guards

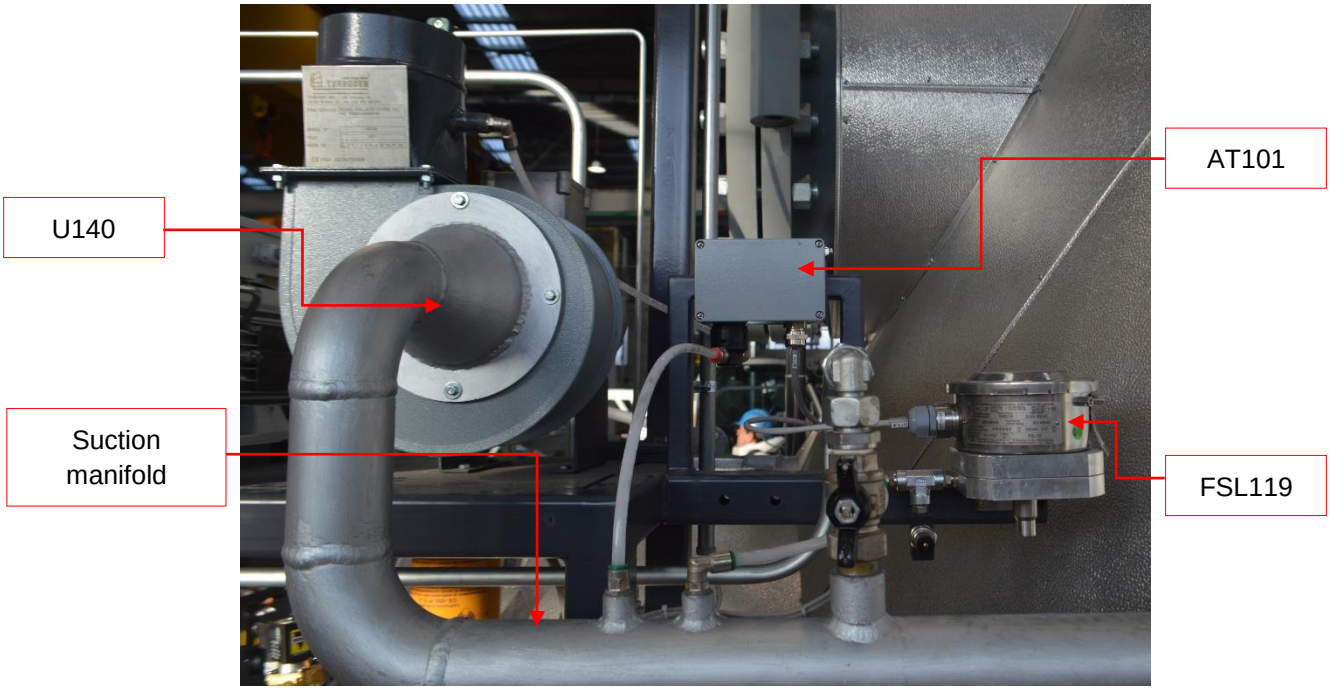



Figure 9.4-5: Suction manifold leak detection system.

The system is comprised of:

- A suction manifold (ø2") and distribution circuit to the flanges.
- A U140 suction fan.
- An FSL119 pressure switch which checks effective fan operation.
- An AT101 concentration sensor that detects the presence of organic fluid.

In the case of a significant leak from one of the flanges, the AT101 sensor will detect it and force the system to shut down. Following this shut-down, the system reaches a sub-atmospheric pressure within a few moments, preventing any explosive atmospheres from forming inside the local ORC system.

**ATTENTION:**

There are some uninsulated parts of the system which reach quite high temperatures and may cause severe burns.

In order to operate equipment safely, members of staff must wear personal protective equipment during maintenance, as described in Chapter16.

For flammable liquids:

Convey the drains of the safety valves and leak monitoring system in an area outside the building; the point of emission may be an area at risk of explosion. Make sure that it is not near sources of ignition.

### 9.4.4 Split System low temperature heating system

In the organic fluid side, the split operates in parallel to the regenerator; its purpose is to preheat any "cold" organic fluid being injected by the feed pump by using thermal oil arriving from the thermal oil boiler. This circuit is shut-off by two manual valves (HV166/HV167) and is adjusted by an automatic valve (TCV134) on the organic fluid side.

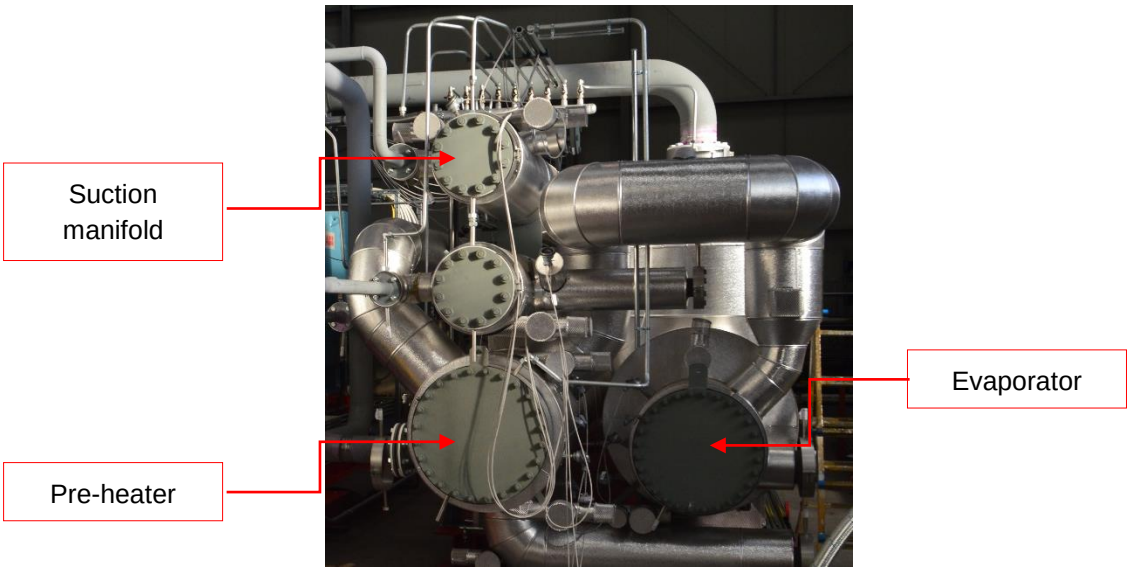



Figure 9.4-6: Split system

### 9.4.5 XSD system

The lubricating oil drawn from the front seal of the turbine, and more generally any other fluid whose boiling temperature is higher than that of the organic fluid, enters the ORC organic fluid circuit. Behaviour and effects of the lubricant that pollutes the organic fluid are various and depend, inter alia, on system layout and project conditions; generally speaking, contamination is possible due to the dragging of fluid and polluting parts.

In order to separate these parts, a negligible amount of vapour (<0.5%) is leaked and then processed through the XSD device, where speed is significantly reduced with controlled expansion in a cyclone with a special coalescing filter. The vapour returns to the regenerator while the separated liquid parts fall into a container that has been duly heated to prevent organic fluid condensation.

Figure 9.4-7: Oil separation system.

### 9.4.6 Reducer lubrication control unit

The control unit lubricates and cools the bearings of the reducer shaft.

The system is composed of:

1. Lubricated oil Tank;
2. Panel for lubricates the gearbox;
3. Pump driven keyed output shaft of the gearbox

At start, is activated the pump unit M2001 + P2001.

When the machine starts spinning there is a period of simultaneity in which they go both the electric pump and the one dragged.

Just before the machine arrives a system, the electric pump is turned off and lubricates is made only using the drag pump.

For other important information regarding the lubrication control unit, please see paragraph 15.6.

## 9.5 Electrical power and control panels

The turbogenerator's electrical system is comprised of two sub-systems:

- The "power" mains: this connects the electric generator to the mains.
- Control network: this includes all instruments installed on the ORC that manages internal and interface signals.

The electrical system consists of electrical panels interconnected to each other and, in turn, connected to the components and field tools by wiring:

a) The control panel of the Q0 generator, in Figure 9.5-2, contains the components necessary to manage the synchronisation, the protection (SEPAM) and the adjustment (AVR) of the electric generator.

b) The Q1 power panel Figure 9.5-1 contains the main electrical power parts for the parallel of the electric generator (isolator, main switch, CT, VT).

c) Control panel Q3, in Figure 9.5-3, includes the PLC, in particular, which has a control push-button panel on it.

d) Control panel Q4, in Figure 9.5-4, contains the components necessary for monitoring the feed pump speed.

**Attention:**

**For details on the electrical system, please refer to the documentation provided in attachment (multi-strand wiring diagrams of the electrical control panels and the operating and maintenance manuals for commonly available parts).**

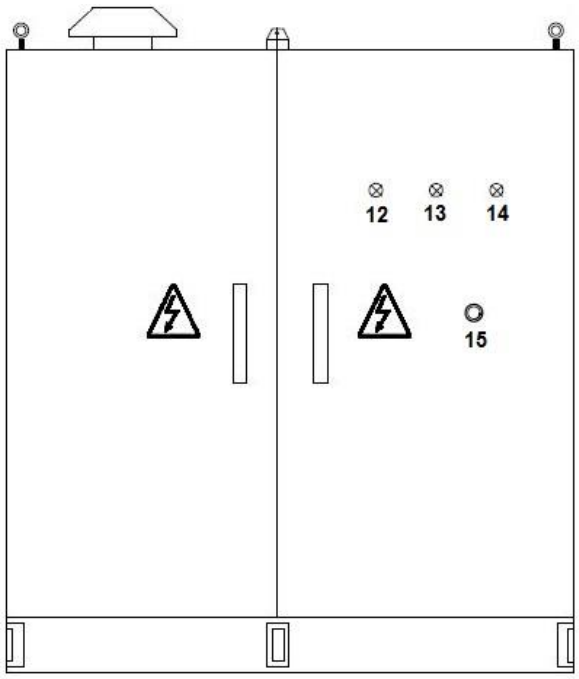



Figure 9.5-1: Q1 Power Panel.


Figure 9.5-2: Q0 generator control panel.


Figure 9.5-3: Q3 Control Panel.


Figure 9.5-4: Q4 Pump Control Panel.

## 9.6 Construction data and technical specifications

### 9.6.1 Approximate dimensions and area requirements

The minimum amount of free space required around the device is specified on the machine's general interface drawing attached to this manual. The implementation of civil works, including any handling systems, in compliance with the interface drawing is solely payable by the Customer.

### 9.6.2 Turbogenerator technical specifications

Turbogenerator technical specifications are summarised in a technical specification sheet which is issued upon stipulation of the contract. You will find the following information in the aforementioned documentation.

| Description | Unit weight (kg) | Num. | Total weight (kg) | Dimensions (mm): L x W x H |
|---|---|---|---|---|
| Hot Module skid (evaporator, split, preheater) | 13000 | 1 | 13000 | 7400x2470x2900 |
| Cold Module skid (condenser/regenerator, turbine, lubrication control unit, panels Q3 and Q4, NCG system) | 34000 | 1 | 34000 | 15550x2750x110000 |
| Electric generator | 4500 | 1 | 4500 | 2013x1650x1391 |
| Reducer | 700 | 1 | 700 | 830x905x700 |
| Pump Unit | 3500 | 1 | 3500 | 4900x1100x1900 |
| XSD | 450 | 1 | 450 | 922x1032x2300 |
| Panel Q0 | 700 | 1 | 700 | 2100x1200x600 |
| Panel Q1 | 500 | 1 | 500 | 2050x1450x837 |

System parts shall be handled considering the weights stated above and the centres of gravity specified in the technical documents attached (see attached lifting diagram). Devices suitably sized to ensure handling in adequate safety conditions shall therefore be used.

## 9.7 Machine operator work station and control panel

The **TURBODEN 10 CHP SPLIT TURBOGENERATOR** may be used by a single operator who has been adequately trained and briefed. The operator's areas of expertise include:

1) A control room with a supervisory system; any preparation of this room is the Customer's responsibility.
2) Perimeter areas around the turbogenerator, as described in the attached interface drawing.

# 10 TRANSPORTATION, INTERNAL HANDLING, STORAGE AND INSTALLATION

## 10.1 The rules for receiving, lifting, unpacking, and handling the turbogenerator and its sub-systems

**This chapter contains information for qualified personnel only.**

**Turboden S.r.l. will not be held liable for any damage to individuals and property as a result of failure to observe these instructions.**

### 10.1.1 Introduction

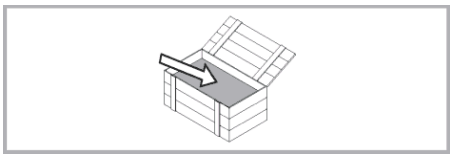
Packaging and degree of protection are designed for each specific material, for the method of transport, for the presumed length of storage time, and for weather conditions.

All materials used for shipping and protecting the equipment shall be recycled or disposed of in accordance with applicable local legislation.

### 10.1.2 Receiving

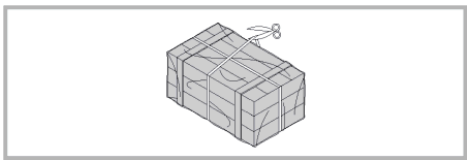
Upon receiving the machine, you shall check that the delivery corresponds to the order, and that the package and its contents have not been damaged during transportation.

Please refer to the packing list for verification of the weight and size of the individual sub-systems.



**Attention:**

The straps used to secure the product to the packaging may be sharp. The operator may be struck and cut by the straps during the unpacking process.



When removing the package you shall follow the instructions provided, which comply with the safety recommendations of this manual (Chapter 16).

Should you discover any damaged, defective, or missing parts, then you shall notify Turboden S.r.l. immediately and also inform the carrier by providing details in the non-compliance section of the Transportation Document.

### 10.1.3 General rules for unloading and safe handling procedures

**Attention**

Handling the material is a truly critical phase of the equipment's lifespan: Turboden S.r.l. recommends having this work carried out by specialised teams who have been trained and equipped with monitoring instruments and protective devices.

These teams must also be well informed about the risks and correct work procedures and be equipped with adequate individual and collective protection; the entire operation must be supervised by an experienced team leader.

Conditions which shall be avoided during transportation and lifting are listed below:

- Load capacity of the vehicle and accessories too low;
- Stability factor of the vehicle too low, even if the load capacity is acceptable;
- Failure to periodically inspect and service the vehicle and accessories, even if the load and stability factors meet requirements;
- Before handling the equipment, the crane and/or unloading operator must check the weight and position of the centre of gravity, by referring to the drawings and information received from Turboden.

When unloading components of the **TURBODEN 10 CHP SPLIT TURBOGENERATOR** from the delivery vehicle, those who are responsible for unloading are required to comply with all applicable regulations regarding safe handling of heavy loads; the supervisor is also required to check unloading areas, and report any potentially dangerous situations to the operators.

This section illustrates the method which shall be applied for the aforementioned operations to be carried out safely. It is therefore necessary to comply with the limitations of the materials and specified methods.

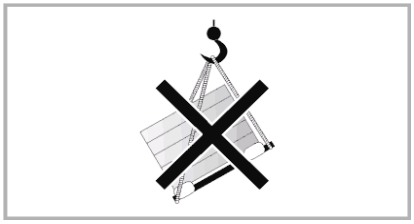
**Attention:**

- Always check the condition of the lifting equipment being used (nylon strips, wire ropes, or chains);
- Always follow the instructions for use provided by the manufacturer of the strips, rope, or chain;
- Do not use strips, ropes, or chains without a label indicating the relevant capacity data;
- Use a handling system with suitable load capacity for the weight of the object to be handled.

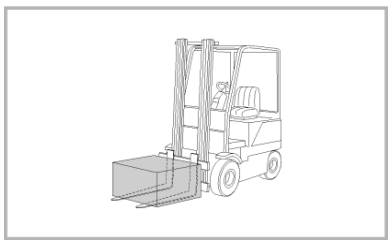
### 10.1.4 Unloading and lifting

Turn off the engine and immobilise the motor vehicle being used for transportation, and set up safety wedges.

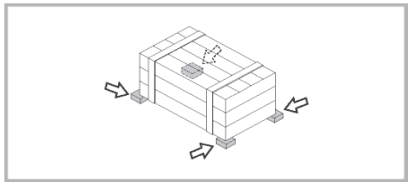
Place warning signs in and around the loading and unloading areas, such as "DANGER! SUSPENDED LOADS!" in order to warn people, and cordon off the area using white and red tape.



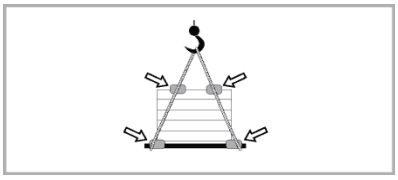
- Do not tilt or turn the packages during lifting and transportation.
- Pay particular attention to the size and capacity of the lifting ropes based on the weight of the machine.
- If the packages have been unloaded by using a forklift, then please make sure that it is operating on a suitable base, and has the ability to lift the required weight and that the weight is balanced on the forks.



- If required, place adequate sized pieces of wood under the package to ensure easy lifting at a later stage.

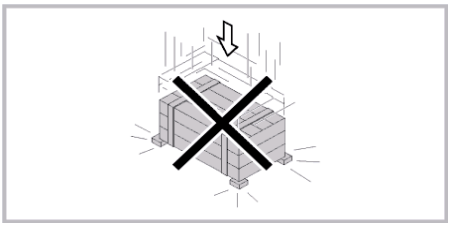


- If the packages are unloaded using a hoist or an overhead crane or a vehicle equipped with a hook, then please make sure that the load is balanced. For slinging, use accessories with technical specifications suitable for the weight being lifted, and which have been approved in accordance with legal regulations.



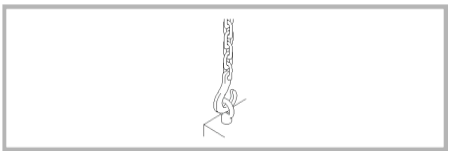
- For packages shipped using pallets, make sure that the lifting accessories do not damage any protruding parts when powering up.

- Do take care to avoid any violent impact when lifting and lowering the package.



### 10.1.5 Handling the machine

- Before removing the machine or any of its components from the packaging, make sure it is firmly attached using the lifting accessories to prevent slipping or tipping.



## 10.2 Warehouse storage

The **TURBODEN 10 CHP SPLIT TURBOGENERATOR** and its components must be kept in a covered and dry place, protected against dust and moisture.

During the storage period, please refer to storage specification **08-C-221** attached.

## 10.3 Installing the turbogenerator

### 10.3.1 General observations during the installation phases

**Attention**

Installation must be carried out by a team of professionals who have been adequately trained and equipped with all the required individual and collective protective equipment, and are able to carry out operations in accordance with the general safety requirements in force. The entire process must be supervised by an experienced team leader.

**Attention**

The foundations must be prepared carefully: they must be suitable and clean, and must be based on the latest version of the foundation drawings.

- Positioning: The **TURBODEN 10 CHP SPLIT TURBOGENERATOR** must be placed in its correct position as specified in the system diagram NB1-ENG.IID-1.
- The workplace shall be kept free from any unnecessary tools in addition to any waste material in order to avoid any damage to components requiring installation.
- It is strictly forbidden to connect the earthing clamp of the welding equipment to the pipes.
- The welding power supply shall not pass through the bearings, gears, wheels, etc.
- The earthing connection of the welding equipment shall be located close to the welding point.
- All the threads shall be lubricated prior to being installed.
- All parts, including any accessories and tools which are required to complete the installation of individual components shall be available in the installation area, and shall be checked for reliability.

### 10.3.2 Tools required for installation

The choice of suitable equipment for lifting and handling the turbogenerator and its components is the responsibility of the Customer, and should be based on the weight specified in the packing list, in the interface drawing, and in the lifting diagram attached to this manual.

The minimum required equipment is

- Mobile crane
- Metal cables or belts suitable for harnessing and lifting the parts.
- Lifting chains equipped with rings which have a minimum internal diameter of 150 mm
- Small lifting beams with separate hooking points
- Vehicles used for supporting lifting points
- Tirfor
- Hydraulic jacks.
- Set of standard workshop tools.

### 10.3.3 Anchoring of the foundation guides

The anchored foundation plates shall be positioned as shown in the interface drawing attached to this manual. Once the entire reinforcement and relative supports for the frame are set up, you can begin to pour in the concrete.

Once the concrete mixing phase is complete, you should then allow a minimum of 28 days before loading the foundations with the base structure.

The Customer is in charge of building the foundation guides and all civil works.

The foundations shall be sized by the user, based on the characteristics of the machine and on the type of terrain. The thickness, however, shall be suitable for use of the required anchor bolts.

The foundations shall be built prior to machine installation to allow for a period of consolidation.

**Attention**

The correct operation of the system depends on the exact positioning and on the mechanical and geometrical characteristics of the ground fixings.

### 10.3.4 Measures to limit vibrations

In order to restrict the amount of vibration produced by the turbogenerator, anti-vibration mats made from polymeric material have been positioned under the frames of the main sub-systems.

For the size and position of these elements, please refer to the interface drawing included within this manual.

### 10.3.5 Bolt torque

Before attempting to start the turbogenerator, the torque of all the bolts within the system must be verified, and if required, they must be tightened according to the parameters specified in the flange assembly drawings attached to this manual.

### 10.3.6 Installation of the TURBODEN 10 CHP SPLIT TURBOGENERATOR

Installation of the **TURBODEN 10 CHP SPLIT TURBOGENERATOR** is carried out by highly specialised, trained teams of Turboden S.r.l. employees.

Should the Customer wish for his/her own team to carry out all installation phases, then he/she will be required to follow all of the safety regulations as specified in the preceding sections, in addition to following safety regulations in force within the country where the **TURBODEN 10 CHP SPLIT TURBOGENERATOR** is installed.

## 11 CONNECTIONS AND FINE TUNINGS

### 11.1 Connections

The positions of the electric cables have been designed to minimise the risk of wear and cutting whilst the machine is in operation. The main power lines have been inserted into crush-proof plastic sheaths or metal conduits in order to reduce the risk of cutting and fraying.

### 11.1.1 Connection to the power network

**Attention**

The screens which have been installed in order to protect electrical contacts shall not be removed under any circumstances, as this helps to avoid injuries and accidents due to accidental contact.

**Attention**

The connection to the power line, the preparation of required protective equipment and machine's earthing system shall all be set up by the Customer in accordance with local regulations.

The cable should have sufficient features to avoid an overall drop in voltage exceeding 5%.

The procedures which shall be followed to install electrical equipment shall be carried out by qualified personnel, in possession of the legal requisites. The phases of this activity can be summarised as follows:

1. Place the electrical panel in the position specified in system diagram DOR-ENG.IID-1.
2. Set up all of the connections which are specified in the electrical diagrams.
3. The **TURBODEN 10 CHP SPLIT TURBOGENERATOR** connection to the power supply line must be set up directly on the terminals inside the electrical power panel.
4. The cables from the power line shall be positioned in an appropriate conduit for the entire distance to the electrical panel.
5. When labelling the cables and terminal blocks, use the numbering which is shown in the electrical diagrams.
6. To connect the **TURBODEN 10 CHP SPLIT TURBOGENERATOR** to external components, you must remember to run the cables in separate conduits from those used for power and signals.
7. Use crimping terminals for all connections, and make sure that they are firmly positioned under the respective screws.
8. Power up the device, providing protection from the live parts in order to prevent accidental contact.
9. Check the utilities to make sure they are connected to the electrical control panel correctly.

### 11.1.2 Connection to the compressed air unit

Given that the machine is equipped with pneumatically operated equipment, you must connect the machine's FRL unit (filter, reducer, lubricator) to the compressed air distribution network. The pneumatic system must maintain a pressure level between 6 and 10 bar.

Refer to the pneumatic diagram attached to this manual to connect the pneumatic supply, see chapter 19.

The supply of compressed air shall comply with the requirements set forth in the technical specification supplied by Turboden together with the commission documents.

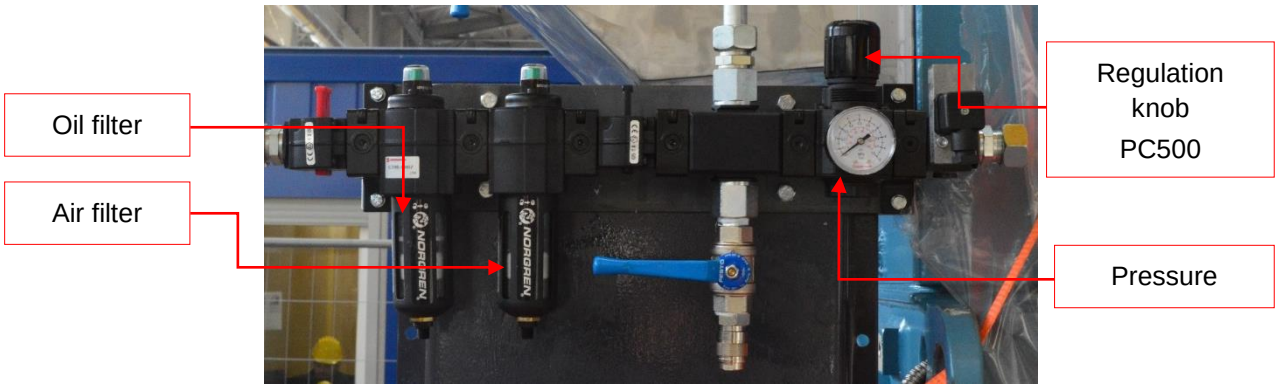



Figure 11.1-1: FRL unit – Compressed air.

How to adjust the air pressure value:

1. lift the dial upwards, releasing it;
2. turn the knob until the pressure gauge is showing 6 bar;
3. close the knob, and then release it.

Even minor compressed air leaks from the circuit and from the joints can result in projection of debris into the eyes. **Wear goggles with side protection.** See chapter 14 16.

### 11.1.3 Pneumatic system operating test

1. Check that the value of the air pressure which has been supplied by the network is between 6 and 10 bar by taking a reading from the pressure gauge which is positioned upstream of the feed point (this is not supplied by Turboden S.r.l.).
2. Check the pneumatic circuit for any air leakage.
3. Check the correct operation of the vacuum pump and the relevant shut-off valve.

### 11.1.4 Functional testing of the stop and shut down buttons (to be carried out when the machine is not running)

1. Pressing the emergency push buttons without protection on the machine shall trigger the emergency stop warning light, and the fail safe closure of the turbine inlet and bypass valves, but not interruption in the supply of the lubrication unit
2. Pressing the emergency push buttons on the machine, protected from accidental activation (under cover or glass) shall trigger a signal which indicates an emergency shut down warning light, and the fail safe closure of the turbine inlet and bypass valves, and interruption in the supply of the lubrication unit

## 11.2 Fine tuning

Below is a list of operations which will be carried out by specialised Turboden S.r.l. technicians.

- ✓ **Painting.**
  Any damage to paintwork during either shipping or installation must be rectified by using special materials.

- ✓ **Pneumatic connection.**
  Pneumatic supply is connected as described in paragraph 11.1.2.

- ✓ **Turbine / Reducer / Generator alignment.**
  Refer to chapters 15.7.3 and 15.8.3.

- ✓ **Pump - motor alignment.**
  Refer to chapters 15.10.2.

✓ **Testing pneumatic connections.**

Check the pneumatic connections by testing the correct manual operation of the movements.

✓ **Lubrication**

Before starting the hot test, it is necessary to start up the lubrication control unit and to adjust the operating pressure of the different lubricated utilities (turbine, feed pump, reducer, generator) according to Turboden specifications.

✓ **Functional checks.**

Here is a list of all of the functional checks which must be carried out prior to commissioning the **TURBODEN 10 CHP SPLIT TURBOGENERATOR**:

- The correct installation of the PLC hardware and the correct execution of the control program are checked (CPU in Run with the program updated).
- All of the sensors and switches are checked and adjusted if necessary.

✓ **Hot test with partial load.**

The partial load cycle is activated with the turbine in bypass mode in order to check the correct functioning of the components and the related automatic checks.

✓ **Commissioning.**

The turbine is started up at limited revs while a few-hours running in is carried out, by gradually increasing the revs of the turbine to check the ORC operation.

✓ **Reaching the synchronous speed**

The turbine reaches the synchronous speed and a first parallel to the network is carried out by optimising the parameters of the generator voltage check device (AVR) and the turbine inlet valve is checked.

✓ **Monitoring safety devices.**

The following safety checks are carried out:

- Tripping of the safety devices;
- Test of the UPS uninterruptible power supply;
- Stop test in case of blackout;

# 12 TURBOGENERATOR CHECKS AND STARTUP

The system is equipped with a PLC-based control system, which is programmed to manage ORC entirely automatically (the PLC is in the control panel).

The control system is interfaced with the operator via:

A) Controls, indicator lights, and instruments installed on-board the electrical panels

B) The supervisory program installed on the PC (included), located in the control room.

All of the following control operations can be conducted from either interface mode : A or B

- Startup,
- ORC shutdown,
- Checking and resetting the alarms.

**Attention:**

**Should the supervisory PC experience any malfunctions, it is possible to have complete control in mode A only.**

## 12.1 Operator interface on the electrical panels

### 12.1.1 Controls and warning lights on control panel Q3

With regard to the numbering marked in Figure 12.1-1, the devices and controls that interface with the control system on board the electrical panels will be described.

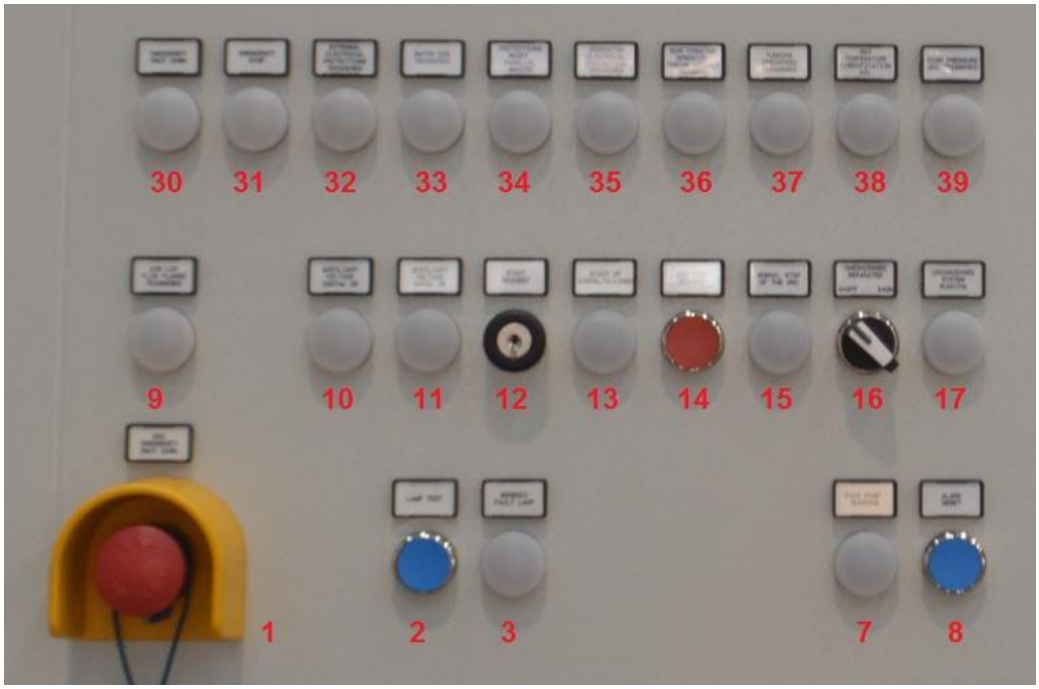



Figure 12.1-1: Control Panel Push Button Panel Q3

1 Emergency stop request:

Push button with locking position. Pressing the standard mushroom push-button (1) shuts down the turbogenerator in quick mode (i.e. emergency), and entails:

a) The turbine inlet valves closing rapidly (SCV100, FCV100) and the bypass valve opening (PCV103);

b) Shutting down all of the auxiliary systems, including the cooling and turbine lubrication control unit and the feed pump. For normal system shutdown, in order to let the rotating parts cool down, these remain running for a few hours after the main cycle has stopped. A shutdown of the turbogenerator will be analysed in detail in chapter 14 “TURBOGENERATOR SHUT DOWN”, where the array of components and issues which may arise, and their re-arming features, are highlighted.

**Attention:**

**Use of the emergency push button shall be restricted to situations of absolute necessity; frequent use may shorten the life span of some of the turbogenerator components. Its use and the reasons leading to its use shall be recorded and reported promptly to Turboden.**

**Attention:**

Restarting the turbogenerator after an emergency stop shall be carried out according to the following procedure:

- Check if the emergency conditions remain.
- Rectify the situation which caused the emergency, and rotate button (1) in order to unblock the turbogenerator.
- Reset by pressing button (8)
- Automatic restoration of the power supply to the auxiliary controls.
- The auxiliary controls that should start running again will restart automatically.

2 Signal light test control:

This performs a test on the signal lights which are situated on the electrical control panel. All of the lights should switch on by pressing this button.

8 Alarm reset:

This button enables you to delete any triggered blocks saved in the memory, either those related to safety protection devices, or those processed by the PLC, in addition to the routine system stop request log.

12 Start-up request:

Insert the key and turn the dial clockwise to start the automatic start-up sequence for the turbogenerator. The turbogenerator can start up if there are no faults (such as blocks).

**Attention:**

The automatic start-up sequence for the turbogenerator is only possible if there are no faults.

Check the conditions specified in paragraph 12.3.

14 Routine stop request:

Press this button to start the system's automatic shut-down sequence (routine stop).

16 Non-condensable separation:

When set at 1, the selector enables the automatic removal sequence of the non-condensables from the system condenser. This sequence is managed by the control PLC, which activates it depending on the appropriate process conditions. Position “1” is that of normal operation. On occasion, it may be necessary to use this control as specified in paragraph 15.12.

**Attention:**

If the blocks saved in the memory do not switch off when you try to clear the lights, this means that the cause of the block still applies and shall be corrected before you will be able to restart the system.

The lights on the control panel are as follows:

3 Generic fault with the ORC unit:

This indicates a block caused by a fault in the turbogenerator. Check the supervisory system to see where the block has occurred.

7 P100 pump in operation

9 Low air flow rate to flanges.

10 Current auxiliary voltage of 230Vac

11 Current auxiliary voltage of 24Vdc

13 Start-up requested and enabled:

This means that a system start-up has been requested using control (12), and that the PLC has saved the request. This only occurs when the operator uses the start-up key (12), and there are faults or blocks preventing the machine from starting up. This light switches off if, when the machine is in operation, a block intervenes or there is a stop request.

15 Routine system shut down:

This means that shut down is requested from button (14).

17 Non-condensable separation in operation

30 Emergency stop

It stops the ORC by disconnecting supply to all the users.

**Attention:**

The sudden stop of the unit entails a high possibility of damages to mechanical rotating parts.

31 Emergency stop

32 Intervention due to external network protection devices

33 Intervention due to PLC Watch-Dog:

This indicates that PLC operation has been disrupted (control system).

34 Protective devices tripping for parallel switch.

35 Intervention due to generator protective devices

36 Intervention due to maximum levels of vibration in the turbine unit - generator

37 Intervention due to turbine overspeed

38 Intervention due to max lubricating oil temperature

39 Intervention due to high ORC pressure

Restoring blocks signalled by the blinking lights.

**Attention:**

During routine turbogenerator operation:

- all of the lights from 30 to 39 must be switched off
- The lights (3) and (9) must be switched off.
- The lights (10), (11), (13) must be switched on.

**Attention:**

Blinking lights identify the causes which led to the emergency stop of the system, at the same time indicating that these causes are no longer present.

In this case, it is necessary to reset the alarms (using the relevant key (8) in Figure 12.1-1) and only after will it be possible to restart the machine.

### 12.1.2 Instruments on panels

The synchro control panel Q0 contains:

1. Woodward Synchroniser
2. Opening status of client's line switch between Q1 and external network (green).
3. Closing status of client's line switch between Q1 and external network (red).
4. Opening status of the generator parallel switch (green).
5. Closing status of the generator parallel switch (red).
6. Power meter of Sicam P50 generator
7. Sepam G62 generator protection relay.
8. Generator parallel enabling selector.
9. Emergency push button.


Figure 12.1-2: Synchro control panel Q0.

On the front of the Q4 inverter, you will find:

54 Feed pump isolator;
55 P100 pump inverter ready;
56 Network analyser (Simeas P50);
57 Emergency stop;

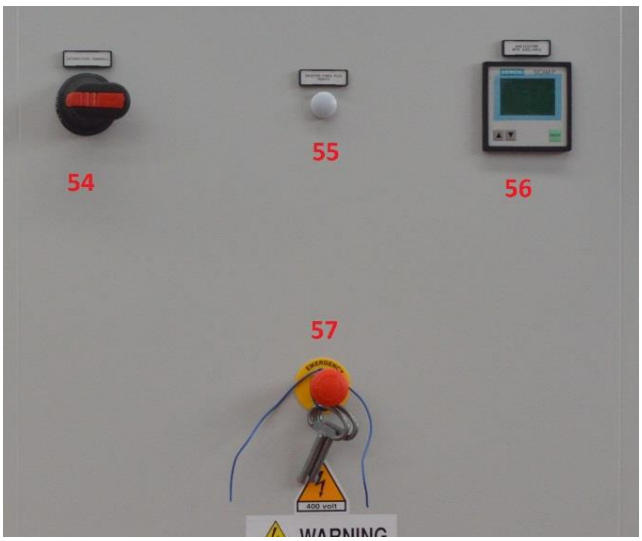



Figure 12.1-3: Q4 Feed Pump Inverter.

On the Q3 control panel you will also find:

50 Control circuits isolator
51 Turbine speed meter
52 Operator panel

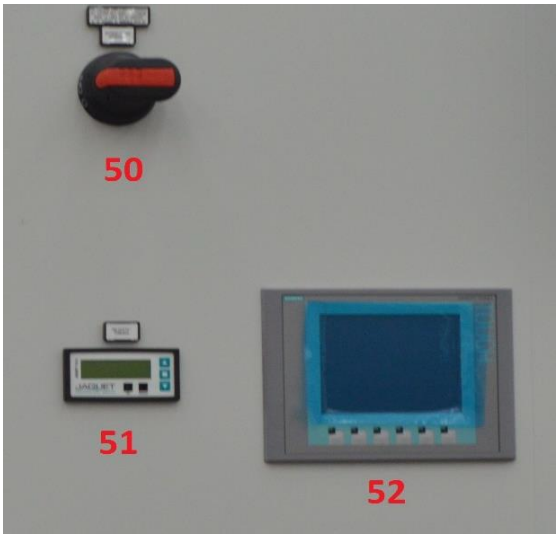



Figure 12.1-4: Control Panel Q3 Instruments.

Power panel Q1 also features:

**12.** Opening status of the generator parallel switch.

**13.** Engaged/not engaged status of the generator parallel switch.

**14.** Closing status of the generator parallel switch.

**15.** Emergency push button.

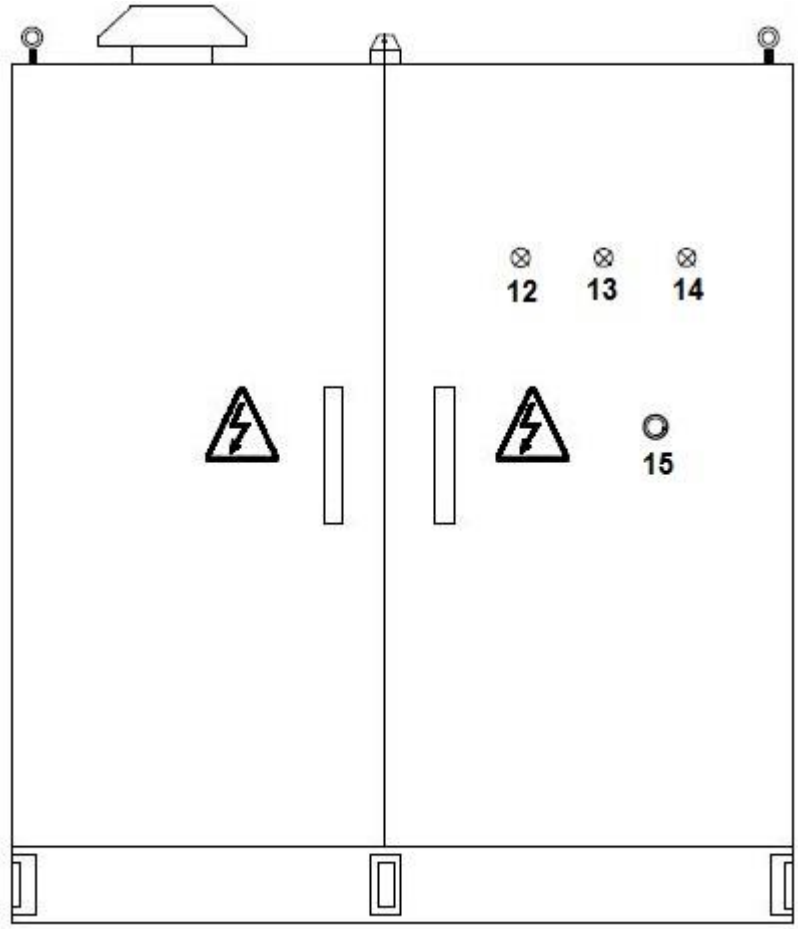



Figure 12.1-5: Power panel Q1.

### 12.1.3 Operator panel

The turbogenerator can also be controlled through the operator panel installed on control panel Q3. In addition to starting and stopping the ORC, it is also used for monitoring the process quantities similarly to the supervisory system. The details relating to using and interfacing with the operator panel are defined in the attachment “Graphic interface manual”, chapter 19.

## 12.2 Interface on the supervisory system

The turbogenerator's PLC is connected to the PC by a data exchange network. Exchanged data (temperature, pressure, levels, engines status, etc.) are managed by a control programme performing the following main functions:

A) Controlling the turbogenerator (start-up, shut down, monitoring).

B) Storing operational historical data on the PC's hard disk.

C) Remote supervisory system linked to Turboden in order to provide assistance.

**Do not under any circumstances open, edit, remove or add hardware components to the monitoring Personal Computer.**

**You may neither install nor remove any programs, nor may you in any way change the configuration of the Personal Computer.**

**Contact Turboden S.r.l. immediately if the PC or supervisory software are not operating correctly.**

**Note: the power supply to the auxiliary systems cannot be restored from the supervisory program, but only from the "auxiliary insertion" button on the control panel.**

You can also manage the ORC from the interface (buttons, warning lights) on the control panels (see paragraph 12). For this reason, problems with the PC will not affect turbogenerator operation or machine maintenance and safety.

Operation of the PC and the supervisory program are essential to correct performance of the data storage and remote monitoring functions.

**Make sure your supervisory PC is switched on, and that both the supervisory software and the connection from the remote station are in full working order. The customer is solely responsible for providing a correctly operating ADSL network for the remote PC connection.**

The SCADA control program is divided into pages, which are associated to various parts of the system. The details relating to using and interfacing with SCADA are defined in the attachment “SCADA operating instructions”, chapter 19.

## 12.3 Preliminary operations and checks for startup

With reference to the P&ID (attached to this manual), before startup, the following checks shall be carried out on the system and turbogenerator.

**Complete system**: make sure that the pneumatic air supply to the system is operating as specified.

1. **Oil and water circuits**:
   - Make sure that the manual valves are in their operating positions, so that when the control system (PLC) calls for the pumps to start and open the 3 way valve for the oil supply, the oil and the water will circulate through the turbogenerator;
   - Make sure that thermal oil in the circuit is available at a temperature over 190°C.
   - Make sure that the external cooling circuit is operating and that the water entering the turbogenerator is near nominal values, preventing rapid gradients.

2. **Turbogenerator:** Set the status of the manual valves (open/closed) as per the system P&ID.

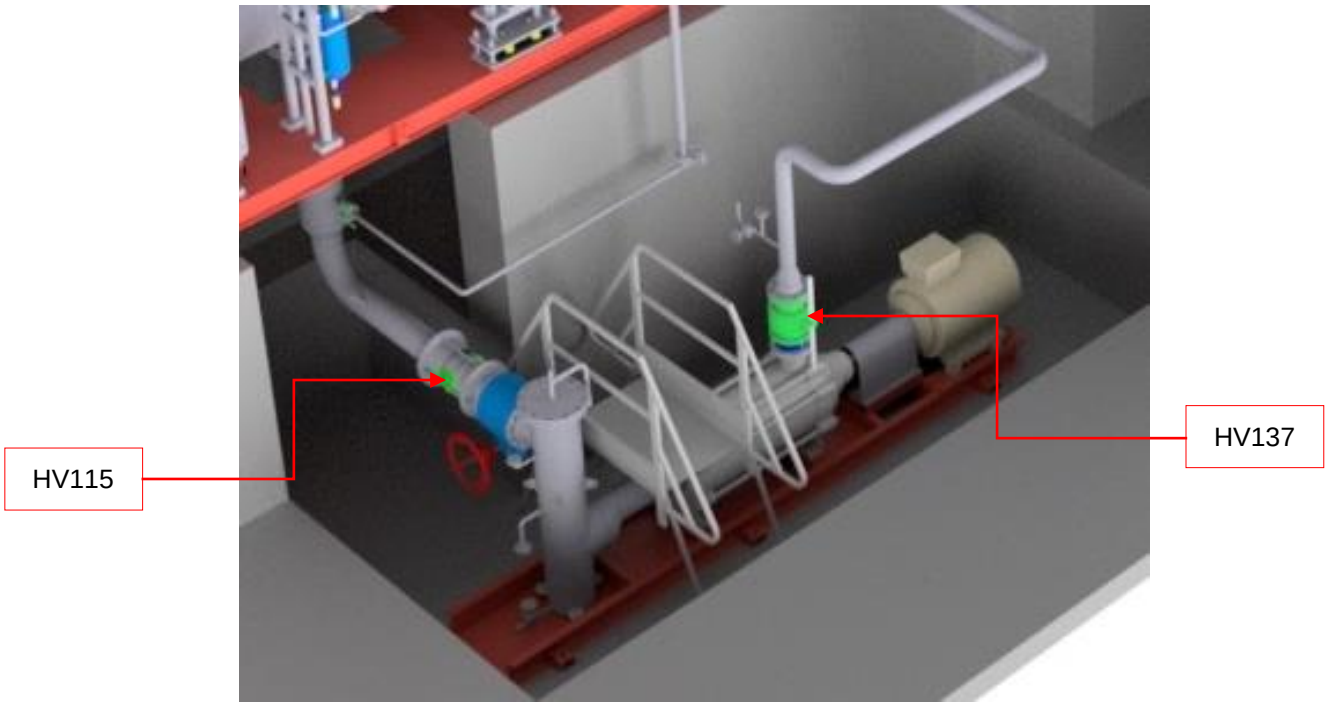



Figure 12.3-1: Pump suction and flow valves

3. **On the control panel**:
   - Make sure there is a voltage supply to the auxiliaries;
   - Make sure there are no blocks, i.e.
     1. The green lights are ON;
     2. The red lights summarising the blocks are OFF;
   - Test out the operation of the lamps by pressing the appropriate (2) "lamp test" button;
   - The switch (12) which initiates the start-up sequence shall be set in position 1;
   - The selector switch (16) "non-condensable system" must be set in position 1;
   - Make sure that the protected emergency stop button (1) is not pressed;

For all of the tests that shall be carried out on the control panel, use figure Figure 9.5-3

4. **On the supervisory PC**:

   The supervisory and the archiving PC for historical data shall be on and running, i.e. when logging into the synoptics page make sure that the readings from the field variables are being updated in real time.

   Otherwise:
   - Check that the serial cables are connected to the PC
   - Reboot the PC.

## 12.4 Starting up the turbogenerator

The running stages may be checked at any time from the supervisory programme, or from panel OP7 on the control panel.

There are two ways of startup (START-UP):

1. **Cold system**: where the temperatures of the thermal oil IN (TT100) / OUT (TT101) of the heat exchangers are below 190°C. This situation will arise following prolonged turbogenerator downtime, when the thermal oil circuit has been shut off and there has been no flow;

**Attention:**

Under these conditions, it is important to gradually heat the heat exchangers so that the **difference in inlet and outlet thermal oil temperatures (TT100 and TT101) is either less than or equal to 1°C per minute, and that the temperatures marked by TT100 and TT101 are both greater than 190°C**.

2. **Hot system**: following a **routine stop**, for example for "routine maintenance", where both of the IN (TT100) / OUT (TT101) thermal oil temperatures to the heat exchangers are greater than 190°C

**Important Warning!**

Heat exchangers in which thermal oil flows must not be put under thermal stress by high temperature gradients.

The presence of non-insulated plant parts poses a burn hazard for workers. Keep at a safe distance from hot parts.

Under these conditions, start-up is determined by the following sequence of manual controls:

I. **Reset alarms and blocks**, press the button (8), on the control panel, Figure 9.5-3 or click on the "alarm reset" key on the supervisory programme page;
II. **Request start-up**, in relation to Figure 9.5-3, by simply turning the dial (12)to position 1 using the key, or by clicking on "request start-up" which can be found on the alarm page of the supervisory program.

If following this operation (II) the control system switches to phase 1, then this is evidence that the start-up procedure has been successful. If not, it means there are blocks preventing the automatic startup sequence from starting. In this case, the blocks shall be analysed to eliminate the causes and retry the procedure from step (I). The startup procedure is successful only when the control system starts the boot process.

**Warning:**

During the startup procedure, the thermal oil valve (TOV) is managed by the Turboden control system. The Customer will assume control after phase 22.

If during the operation (II), the green lamp to the right of the key does not switch on (i.e. if the startup request has not been saved), this means that:

- There is a block (see the PC supervisory system);
- No voltage has been restored to the auxiliary circuits (press key (8));

You can always try pressing the blue button to reset the alarms (8) and request start-up again.

## 12.5 Key stages managed by the Turbogenerator PLC

The turbogenerator is down: the control system on the PC may display **Phase 0** in progress.

- **Phase 0: this indicates that the system is at a standstill.**
  The evaporator and condenser units are at the same pressure, the bypass valve is completely open, the turbine valves are closed, the thermal oil valve is open at a minimum value (typically 10%).

**Warning:**
The removal of protection casings of the pump and turbine coupling is prohibited during turbogenerator start-up.

If the feed pump is serviced without Turbodon assistance, it is important to cut off the power to pump Q4 and implement the required LOTO procedures before carrying out any service work (Lock-Out Tag-Out).

**Attention:**
Even when the system is shut down, part of the system may remain at a pressure level which is higher than atmospheric pressure.

- **Phase 1:** Start-up of the turbine lubrication and cooling auxiliary circuits and feed pump. The control system forwards the ORC cooling system start-up request and waits for the circuit to be operational in nominal conditions before switching to the next stage.

- **Phase 2:** The thermal oil valve opening (TOV) varies according to the temperature of the thermal oil entering the hot module. The control system checks that the oil reaches the temperature required to preheat the hot module adequately.

- **From phase 3 to phase 5:** During these stages the hot module is preheated and the optimal start-up conditions are met (thermal oil minimum temperature).

- **From phase 6 to phase 7:** The feed pump starts, its rotation speed varies and automatically adapts, thanks to a control loop, the flow rate of the process fluid according to the operating conditions.

- **Phase 8 to phase 13:** Non-condensables extraction system auxiliary circuit start-up (9.4.2). Complete opening of the turbine inlet valve FV100 and partial opening of the start-up valve (SCV100) according to the turbine rotation speed. By changing the opening of SCV100, the turbine is first of all preheated, at constant speed, and then accelerated until reaching a rotation speed of 3000 rpm. At this point synchronisation procedure begins, ending with closing of the generator switch, once voltage and frequency to the generator terminals match the voltage and frequency of the upstream power supply. From this stage onwards the generator will begin to supply the network with electricity.

- **From step 14 to step 15:** Gradual closure of the bypass valve (PCV103), with full opening of the turbine start-up valve (SCV100), and gradual opening of the thermal oil valve (TOV and TOVS) up to 50%.

- **From phase 16 to phase 21:** in systems equipped with splits, the TOVS is opened gradually according to the temperature of the thermal oil and process fluid existing the split. During these phases TOV control is up to the customer.

- **Phase 22:** routine operation of the turbogenerator.

## 12.6 Routine operation of the turbogenerator

During routine operation (phase 22) the turbogenerator is managed automatically by the relative control system.

The system is able to adapt to normal changes in temperature or in flow rate for both thermal oil and cooling water, for which the presence of an operator will only be required to monitor the system status.

**Attention:**

The required system status checks are listed in paragraph 15.2.

The PLC constantly analyses the operating conditions and in the case of malfunctions it will shut the system down safely. Furthermore, the independent safety devices will also intervene, in quick mode (closing the inlet valves inside the turbine and opening both the bypass valve and the mains switch) when any one or more faults occur, as described in paragraph “13”.

The mechanical seals of the pump and of the turbine allow a certain amount of barrier oil to seep into the organic fluid circuit.

This leakage could be physiological or caused by a failure in the sealing.

This could downgrade performance of the ORC turbogenerator by some percentage points during life of the system, although decreased performance has only been signalled on a small part of ORCs in operation.

The properties of the fluid can be restored by correctly treating the organic fluid in order to remove sealing oil entered in the system.

Over the years, the properties of the fluid can be restored by correctly treating the organic fluid in order to remove sealing oil entered in the system.

Turboden has developed systems and procedures to be selected and optimised according to individual cases.

## 12.7 Measures to prevent the heat exchangers from rupturing

To preserve the service life of the thermal exchange unit, the operator on the "thermal oil" and "condensation water" circuit must:

- Pay attention to the thermodynamic (temperature) conditions of the thermal oil.
- Pay attention to the quality of the first filling, top-up and process water.

**Warning:**

For the Turbogenerator to work properly, the operator must strictly observe and carefully read the references provided in the following paragraphs of this manual.

### 12.7.1 On the "thermal oil" circuit:

The startup procedure of the turbogenerator can last from a few minutes (system hot) to a few hours (system cold).

In this case, it is crucial not to force dynamic turbogenerator start-up, e.g. by increasing the temperature or thermal oil flow, otherwise the heat exchangers (evaporator - pre-heater) may become damaged.

If the system does not start after several attempts, then you must repeat the startup request process, as described in the previous paragraph.

**Warning:**

Please contact Turboden if the system does not start up after 3 or 4 hours.

**Important Warning!**

Heat exchangers in which thermal oil flows must not be put under thermal stress by high temperature gradients.

Failure to observe this warning may result in thermal stresses which can reduce the service life of the heat exchanger and can cause its premature failure:

1. Keep the thermal oil valves facing the ORC open so that it circulates in the ORC turbogenerator during the initial heating stages of the boiler, in order to prevent the ORC exchangers from heating up too quickly;
2. Even when the ORC turbogenerator is out of service, the oil valves remain partially open and the exchangers remain hot.
3. If the valves are closed and the ORC cools down completely, make sure the oil temperature is below 150 °C before opening the valves back up.
4. While the ORC is running, strictly avoid suddenly opening/closing the thermal oil valve (max. speed: fully open or closed in 300 seconds) or nevertheless avoid rapid changes in flow rate/temperature.

### 12.7.2 On the "condensation water" circuit:

**Attention:**
The ORC condenser requires cooling water complying with Turboden specifications.

**Attention:**
Poor quality of the process water and improper management of the dissipation system can cause:

- Direct reduction of condenser efficiency (fouling of exchange surfaces)
- Indirect reduction of the efficiency of the entire system (equipment damaged due to corrosion and/or clogging)

The possible configurations of the heat dissipation system which the ORC is supplied with can be:

a. District heating circuits and closed cycle heat exchangers (dry cooler),
b. Evaporation towers

The following operations should be carried out precisely and regularly:

a. Checking water quality
b. Maintenance of entire heat dissipation system.

**The circuit must be managed with the utmost attention and preferably entrusted to a specialised company.**

### 12.7.3 District heating systems and closed cycle heat exchangers (dry cooler),

This includes:

- Cooling systems with closed circuit circulation, with a closed expansion tank;
- Cooling systems with closed circuit circulation, equipped with an open expansion tank;
- Heat usage systems with closed circuit circulation, equipped with a closed expansion tank;
- Heat usage systems with closed circuit circulation, equipped with an open expansion tank;

The following recommendations must be respected to correctly operate the system:

- **UNI 8065:** "Requirements of water used in heating systems and frequency of analysis."
- **EN 12953-10:** "Shell boilers - Part 10: Requirements for feedwater and boiler water quality" valid throughout the EU.
- Guide lines supplied by Turboden
- Recommendations issued by suppliers of the water treatment system, of the district heat or heat dissipation systems connected to the turbogenerator, complying with the most restrictive conditions among those mentioned.

### 12.7.4 Open tower cooling systems

The following recommendations shall be respected to correctly operate the system:

- **EN ISO 16784-1** which describes requirements of water consumption in towers and their management.
- Guide lines supplied by Turboden
- Requirements issued by suppliers of the water treatment system, or of dissipation systems connected to the turbogenerator, complying with the most restrictive conditions among those mentioned.

### 12.7.5 Freezing of the systems

To avoid damage during winter while the system is shut down, antifreeze systems should be provided especially for closed-circuit systems.

**Attention:**

**Failure to control freezing of the cooling water can irreparably damage the heat exchanger.**

**Attention:**

It is important to consider that, in case of low temperatures, the use of antifreeze systems prevents the formation of local tensions due to increase in water volume by solidification.

These systems can be:

- **Active**: Systems that are only activated if the turbogenerator's integrity is in hazardous conditions. These systems, mainly consisting of heaters and/or auxiliary circulators, shall also guarantee operation in the event of a power failure.
- **Passive:** These are always available and mainly involve dissolving antifreeze products in the circuit's water. The use of antifreeze increases pump consumption as a result of the circulation of the cooling liquid, which is due to the increase in pressure drops and reduced thermodynamic efficiency of the condenser, which in turn is due to a reduced heat exchange coefficient. Inform Turboden if you intend to use this type of protection.

**Attention:**

A more thorough and frequent check of the chemical-physical status of the circuit is required when antifreeze is used and the control, storage and disposal of the chemical substance shall be carried out in compliance with local laws regarding environmental pollution.

Pay attention to the hazardous properties of the antifreeze by referring to the safety data sheet submitted by the supplier of the product

### 12.7.6 Draining of circuits containing water in long stops

To avoid damage caused by deposits and corrosion due to air inlet (in particular of its oxygen content) during long stops, it is prescribed that the circuits be completely emptied and preserved with nitrogen at a pressure of 0.2 ÷ 0.3 barg.

The prescription applies:

1. To the water circuit for condensers both in closed cycle and in open tower.
2. To the hot exchanger circuit in which water steam or pressurised water flows

# 13 AUTOMATIC BLOCKS AND ALARMS

## 13.1 General description of blocks

The plant is equipped with a cyclic control logic that checks the conditions for a smooth operation, however any loss whatsoever of safety requirements and/or deviation from the controlled set points and values will result in system shut down in safe conditions (either through normal shut down or safety chain, see paragraph 14.1).

The supervisory system will alert the operator and will record the machine status while displaying the chronological sequence of events, divided into Blocks or Alerts (see "Alarms" page).

**Attention:**

Blocks cause the system to shut down, while alerts will only highlight a potential fault without causing the system to shut down.

No adjustments are required as the entire system is controlled by an autonomous logic which does not allow for any operator intervention during operation, other than routine maintenance or the management of alerts.

**ATTENTION: for the set point and re-arming values and relevant activation times, see the attached document "Alarm list with troubleshooting", chapter 19, which contains updated system data.**

**Note**: Electrical protection, overspeed thresholds, pressure switches, the turbine vibration sensor, and the control PLC watchdog, in addition to signalling the respective blocks to the control, they also directly control the quick closing of the turbine valves and the opening of the parallel switch

**It is possible that a block caused by these independent protections is also detected as a block by the control system, and that such condition is displayed together with the block that actually led to the shut down of the turbogenerator.**

**For example, the tripping of grid protections always causes turbine overspeed, which however is a consequence, and not a cause, of shut down.**

**Attention:**

There are some uninsulated parts of the system which reach quite high temperatures and may cause severe burns.

In order to operate equipment safely, members of staff must wear personal protective equipment during maintenance, as described in Chapter 16.

# 14 TURBOGENERATOR SHUT-DOWN

The automatic sequences of system shut-down are:

a) Routine shut-down
b) Stop due to shut down of Safety Chain
c) Red Emergency stop push button

## 14.1 Routine Shut-down

During this type of shut-down, the PLC controls the automatic system shut-down sequence.

This involves the "**routine**" method of opening and closing the parts, i.e. slowly and gradually, so that the system shuts down avoiding excessive pressure and thermal gradients.

The PLC does the following:

- Opening bypass valve (PCV103) so that the pressure inside the evaporator drops, and the turbine rpm slow down.
- Shuts off the feed pump by reducing the number of RPM required to close the inlet (FCV100) and to turbine startup (SCV100) valves.
- Opens the parallel switch (after 60 sec).
- The PLC recovers control of the TOV (three-way valve) system. Valve TCV134 closes after 3 minutes.

In the case of routine shut-downs, the lubrication circuit remain powered in order to ensure lubrication to the turbine as it shuts down.

Shut-down in **normal mode** may be requested:

- **By the user**, in this case, the system can be shut down at any time simply by pressing the standard request stop button (14) on the control panel.
- **Triggering of a block** which shuts the system down in normal mode (see Chapter on Blocks and Alerts).

**Important:**

Shut-down can also be controlled via the "stop request" button on the main screen on the supervisory system.

The key feature which distinguishes this type of shut-down is the automatic sequence controlled via the PLC which prevents the turbine from over-speeding.

## 14.2 Stop due to shut down of Safety Chain

For this type of shut-down, the automatic sequence is not to be carried out by the timer and PLC-controlled ramps, but by the following hardware devices installed in the system:

- **PSH106**
- **PSH107**
- **VT100**
- **FSL119**
- **Generator protections**
- **Turbine overspeed**
- **Emergency push buttons**
- **Auxiliary systems voltage failure**
- **Customer grid protection**
- **PLC sequence control watchdog**
- **TSH213 - TSH214 - TSH2000 lubrication thermostats**

**ATTENTION:**
The emergency stop button also disconnects the supply of power to the turbine lubrication and to the safety chain (Refer to Sec 14.3)

This involves the "**emergency**" method of opening and closing the parts, i.e. quickly, so that the system shuts down in the shortest amount of time made possible by the action of the individual devices.

**The emergency sequence** simultaneously performs:

- **Closing** (approx. 0.3 seconds) of the inlet valves (FCV100), starting of the turbine (SCV100) valves and opening of the bypass valve (PCV103)
- Immediate **shut down** of the feed pump
- Instant **opening** of the parallel switch:
  - As a consequence the turbine is subject to **overspeed**
- The PLC recovers **control of the TOV** (three-way valve) system. **Valve** TCV134 closes after 3 minutes.

With shut down by the Safety Chain or by unprotected emergency stop push button, the lubrication circuit only stays powered for the amount of time required to cool down the rotating parts, that slow down by inertia.

## 14.3 Unprotected Red emergency stop push button

For this type of shut-down, the automatic shut down is requested by the user by pressing any one of the emergency push buttons on the system, see Figure 14.3-1


Figure 14.3-1: Emergency stop push button

**Attention:**

**Use of the emergency push-button must be restricted to situations of absolute necessity. Use of the emergency stop button along with the reasons that led to its use must be noted down in the machine's log book (see Appendix attached to this manual) and must be promptly reported to Turboden.**

If it is necessary to press this button during machine operation, then you shall proceed as follows:

- Check to see if it really is necessary to stay in emergency conditions. As soon as possible, turn the button (1), reset it by pressing it (8).
- The auxiliary controls that should start running again will restart automatically.

## 14.4 Emergency stop by pressing the protected "red mushroom" push button

For this type of shut-down, the automatic shut down is requested by the user by pressing any one of the emergency push buttons on the system, see Figure 14.3-1

Figure 14.4-1: Emergency stop push button

The peculiarity is that voltage to all of the auxiliaries and turbine lubrication immediately shut down.

This method of shut-down may reduce the service life of the turbine, as a consequence of overspeed and overheating of the rotating supporting elements.

**Attention:**

**Use of the emergency shutdown button must be restricted to situations of absolute necessity; frequent use may shorten the life span of some of the turbogenerator components. Use of the emergency push-button along with the reasons that led to its use must be noted down in the machine's log book (see Appendix attached to this manual) and must be promptly reported to Turboden.**

If it is necessary to press this button during machine operation, then you shall proceed as follows:

- Check to see if it really is necessary to stay in emergency conditions. As soon as possible, turn the button (1), reset it by pressing it (8).
- The auxiliary controls that should start running again will restart automatically.

## 14.5 Methods and procedures for re-arming the turbogenerator.

Re-arming the system following any type of shut down described in the previous paragraphs is carried out differently depending on the type of shut down, as well as the type of request which was made.

### 14.5.1 Re-arming following a routine shut-down

Paragraph 14.1 explained that an ORC shut down in Normal mode can be requested by the user, or may be due to a block.

The re-arming mode (manual or from the supervisory program) is the same for both types of requests, however the procedures are different.

This requires a different type of classification.

1. A request made by the user without a block; proceed as follows to conduct a manual re-arming:
   - **Manual** on the control panel, see Figure 12.1-1:
     - Turn the dial (12) clockwise and set it to position 1;
   - **From the supervisory programme** on the alarm page :
     - Sending a run request with a simple click;

2. Request due to a block that triggered a routine shut-down (see Chapter 14).
   In this case, before re-arming, you will have to find a solution as to why the Turbogenerator shut down, and perform all of the checks mentioned in paragraph 12.3;
   The re-arming procedure is as follows:

   - **Manual** on the control panel (Figure 12.1-1):
     - Pressing the alarm reset (8) button;
     - Turning the switch (12) clockwise;
   - **From the supervisory program** on the alarm page, by:
     - Resetting the alarms from the alerts box;
     - Sending a run request with a simple startup request click.

**Attention:**

For both **manual** and **supervisory programme** re-arming, you must follow the instructions specified in **paragraph** 12.3 of this manual, otherwise the procedure may fail.

### 14.5.2 Re-arming after stop due to the Safety Chain

In this case, before re-arming (either manually or via the supervisory programme) you will need to identify and resolve the issue that forced the safety chain to shut down the turbogenerator, referring to paragraph 13 which describes automatic blocks on the ORC.

Once the causes for the blocks are removed, carry out all of the checks as specified in paragraph 12.

The re-arming procedure is as follows:

- **Manual** on the control panel:
  - Pressing the alarm reset (8) button;
  - Turning the switch (12) clockwise;
- **From the supervisory program** by:
  - Resetting the alarms from the alerts box;
  - Sending a run request with a simple startup request click;

### 14.5.3 Re-arming following a red emergency stop push button (1).

This type of shut-down differs from the others by how it is re-armed.

The only way to re-arm a system after the red push button has been pressed is manually.

After you have found the reason that caused the emergency then the **procedure for a manual re-arming** is as follows:

- turn the mushroom push button (1) on the control panel to release it;
- Reset by pressing button (8);
- Carry out all of the checks specified in paragraph 3.2;
- Start-up the turbogenerator by turning the key (12)

**Attention:**

The buttons mentioned in the list are all located on the control panel.

**Attention:**

**Use of the emergency push-button must be restricted to situations of absolute necessity; frequent use may cause some of the turbogenerator components to break prematurely.**

**Use of the emergency push-button along with the reasons that led to its use must be noted down in the machine's log book (attached to this manual) and must be promptly reported to Turboden.**

# 15 TURBOGENERATOR MAINTENANCE

## 15.1 General information

- Responsibility for maintenance operations is governed by the undersigned maintenance contract.
- Proper maintenance is a mandatory requirement for the validity of the warranty.
- Below is a description of turbogenerator maintenance activities carried out weekly (Paragraph 15.2), annually (Paragraph 15.3) and over several years (Paragraph 15.4).

**Before carrying out any checks or maintenance, please read the safety recommendations outlined in Chapter** 16

**The description of any maintenance operations and any anomalous features that are discovered shall be reported to Turboden s.r.l.**

## 15.2 Routine supervision and inspection activities

**Before every start-up** of the turbogenerator and in any case, on a **weekly basis**, the operator shall supervise/inspect the system, as indicated below.

Contact Turboden S.r.l. if damage or obvious faults are detected during the inspection.

**Any obvious changes in colour or viscosity of the lubricating oil of the lubrication control unit is considered an anomaly.**

- **System sealing:**
  Check there is no oil, water or process fluid leakage from fittings, valve joints.

- **Compressed air availability:**
  - The circuit pressure must be kept at 6 bar via regulator PC500. See Figure 11.1-1. Refer to the pneumatic diagram annexed to this manual.

- **Lubrication of mechanical components:**

  - **Turbine**: detection of irregular noise compared to the usual noise coming from the spindle.

  - **Reducer:** Check that the grease level is correct, for further details refer to the operation and maintenance manual of the gearbox attached to this manual. See chapter 19.

  - **Electric generator:** Check that the oil level is correct, for further details refer to the operation and maintenance manual of the electric generator attached to this manual. See chapter 19.

  - **Feed pump**: if the feed pump is equipped with automatic greasers, check their oil cartridge and replace if required (spare cartridges can be supplied by the Turboden After-Sales Service).

  - **Vacuum pump**: the type of oil used and the recommended level shall comply with the pump operating and maintenance manual. Check that the oil level is about halfway up the inspection glass and that the lubricant has no foam or evident colour changes. Otherwise inform Turboden.

  - **Lubricating oil filters**: the lubrication system filters shall be kept clean: any clogging problems are reported by the supervisory system of the machine, and you can check it via the optical indicator provided on each filter. If the system reports the presence of one or more clogged filters, contact Turboden to agree on the actions to be taken.

  - ORC **lubrication control unit**: Here we will just reiterate the importance of monitoring the oil content in the control unit, which can be measured directly by the operator via the on-board visual indicator: the level shall be within the MIN and MAX thresholds indicated therein.

  - **Heat exchangers for cooling** lubricating oil: Check the operation and cleanliness of the heat exchanger in order to guarantee the suitable cooling of the oil returning from the turbine.

- **State of the valves**:

  Check the position (OPEN vs CLOSED) of the manual drive valves, in particular:

  Instruments:

  - All of the instrument shut-off valves shall be **open**.
  - Check the tightness of the closing caps.

  Heat exchangers, tanks and piping:

  - All draining and vent valves shall be **closed**.
  - Check the tightness of the closing caps.

  Feed pump:

  - Suction valve (HV115) **open**;
  - Supply valve (HV137) **open**.
  - Supply valve (HV167) **open**.
  - Moreover, check the tightness of the closing caps.

  Vacuum system:

  - - suction valve (HCV165) **open;**
  - - condensate return valve (HCV164) **open;**

- **Supervisory Personal Computer shall be operating regularly.**
  - Check that various measurements in the graphs on the main page, or on the historical data page are clearly visible.
  - Also check that the "CONTROL MAESTRO" application is on (icon in the bottom Windows bar). Otherwise close the application and restart it.

- **No alarms (red lights) on the control panel.**
  - Controls on the control panel are in their normal operation position, in particular.
  - The selector (16), which is used to monitor the separation of non-condensables, must be in position 1.
  - Signalling lamps test on panel Q3 must be positive.

- **The organic fluid leak monitoring system is operating correctly**, (par. 15.5).

## 15.3 Annual maintenance activities

The turbogenerator, at least annually, shall undergo the tests and maintenance activities listed below. The activities can be carried out:

- With the system running
- With the system shut down.

For some of the activities carried out with the system shut down, the system must still be hot and the oil must still be at operating temperature.

Only schedule maintenance when you can start the system at a time that is not in conjunction with other maintenance activities that could prevent the system from start-up.

Send Turboden s.r.l. the data of the operations carried out by means of the dedicated function present in the TOS.

### A - Maintenance tasks with system down

| Task | | Paragraph |
|---|---|---|
| General | Check the leak monitoring system | 15.5 |
| | Topping up the level of organic fluid | 15.16 |
| Lubrication control unit | Changing clogged cartridges and filters | 15.6.2 |
| | Clean packs on the oil/air exchanger | 15.6.3 |
| Electric generator | Check reducer-generator alignment | 15.7.3 |
| Reducer | Replacing or topping up lubricant oil | 15.8.1 |
| | Check turbine-reducer alignment | 15.8.3 |
| Turbine | Check bearing units and turbine seal | 15.9.2 |
| Feed pump | Feed pump alignment | 15.10.2 |
| | Replace/clean filter | 15.10.4 |

### B - Maintenance tasks with system running

| Task | | Paragraph |
|---|---|---|
| Lubrication control unit | Check temperature and pressure in the lubrication circuit | 15.6.4 |
| | Topping up or changing the lubricating oil | 15.6.1 |
| | Optical inspection of lubricating oil | |
| Electric generator | Acquiring vibration spectra | 15.7.2 |
| | Contollo/ingrassaggio dei cuscinetti | 15.7.1 |
| | Optical inspection of lubricating oil | |
| Reducer | Acquiring vibration spectra | 15.8.2 |
| Turbine | Check bearing assembly and turbine seal (from supervisory system) | 15.9.2 |
| | Acquiring vibration spectra | 15.9.3 |
| Feed pump | Acquiring vibration spectra | 15.10.3 |
| | Topping up and checking feed pump lubricants | 15.10.1 |
| Vacuum pump | Replacing vacuum pump lubricant | 15.11 |
| | Cleaning vacuum system valves | 15.11.1 |
| General | Draining any water which is present | 15.12 |
| | Check effective amount of organic fluid | |
| | Check ORC stop and safety chain | 15.18 |
| | Back-up of the display programme and PLC software | 15.13 |
| Electrical panels | Cleaning the heat sink and replacing the fans (if necessary) of the Inverter | See attachment |

## 15.4 Long-term maintenance

| Task | References | Frequency |
|---|---|---|
| Generator windings insulation test | | 4 years |
| Analysis of turbine lubricating oil characteristics and a full oil change | | 4 years |
| Analysis of organic fluid properties: kinematic viscosity, distillation test, gas chromatography | ASTM D 445<br>ASTM D 86 | 4 years |
| Comparison in performance against system acceptance data | | 4 years |
| Turbine overhaul | | 5-6 years |

In conjunction with periodic system inspection, pursuant to local regulations, it is advisable to schedule the general maintenance operation to check the flange torque. If removal of the insulation is particularly difficult, it is advisable to focus on the flanges positioned in proximity of the feed pump and the turbine body, which are subject to considerable stress.

The operation for checking the flange torque must be performed referring to the flange assembly drawing annexed to this manual and by observing the sequence of operations described in the specification (13-ENG.VPR-4).

**Warnings:**

- ✓ *Only use calibrated torque wrenches.*
- ✓ *All of the ORC flanges shall at least be checked after a thermal cycle.*
- ✓ *Make sure that the system is cold (T < 60 °C) and not pressurised*
- ✓ *Hot-tightening and hot-torquing operations **are expressly prohibited**.*
- ✓ *All tightening or torque control operations must be recorded on a specific form.*

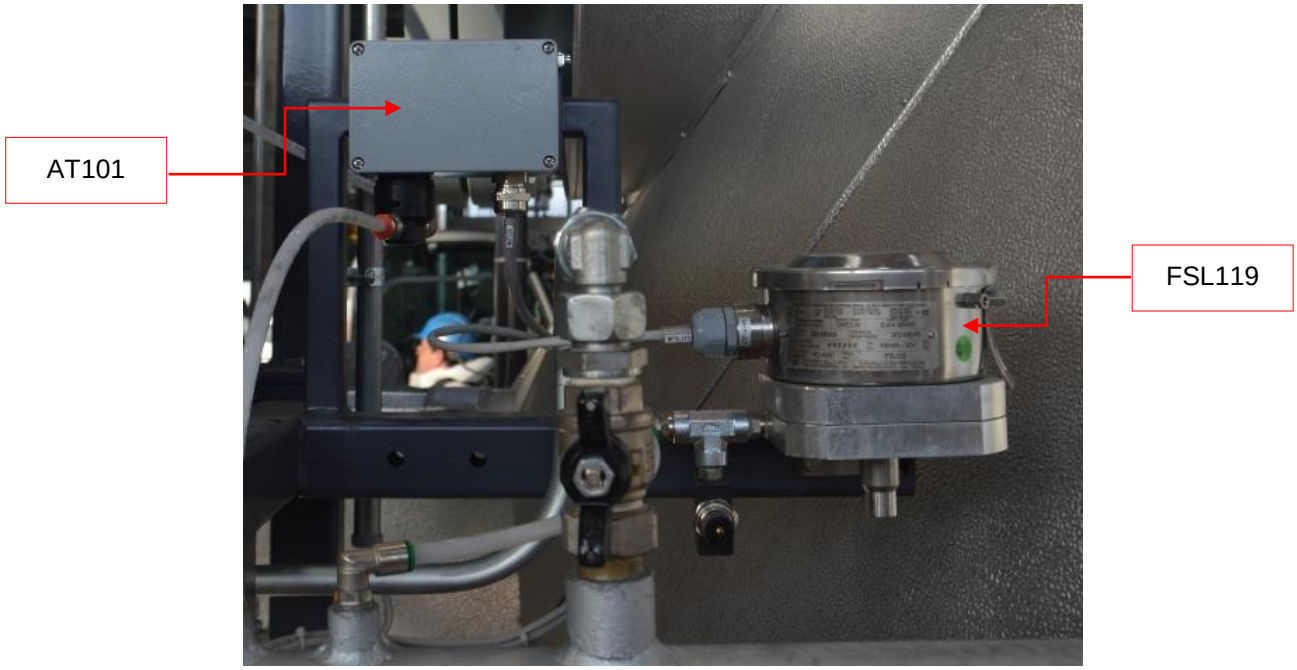
## 15.5 Control of the leak monitoring system

Under conditions of normal use, a part of the system is subject to a pressure greater than that of the atmosphere; therefore, silicone vapour leaks may occur if the flanged torque seals are not perfect.

For this reason, the junctions subject to internal pressure (high pressure piping) are equipped with a flange cover with suction system, which collects the air and any silicone vapour leaks by creating local negative pressure around the junction.

This system is equipped with an organic fluid vapour detector (AT101).

The system operation must be checked every year (or as agreed with the competent Authorities) in compliance with the instructions provided in attachment 11-H-11.




At the end of the activity, send Turboden s.r.l. and keep the information available to the Authority.

## 15.6 Maintenance of lubrication control unit and of the reducer lubrication system

For maintenance of this control unit, the hydraulic diagram attached to this manual can be a useful source of reference for the operator. This diagram shows the typical circuits of the hydraulic system, along with the part list and enables you to easily find instruments and components of the lubrication control unit.

The reducer is self-lubricated via closed circuit. For further information, see diagram 16-M-4 attached to this manual.

Any obvious changes in colour or viscosity of the oil in the lubrication control unit is considered an anomaly.

**Attention:**

Before any operations disconnect the power supply by opening the isolators. There may be auxiliaries activated by the automatic control system even with the ORC system idle

**Attention:**

Before coming into contact with lubricating oils, read the requirements provided by the fluid manufacturer in the safety data sheet and follow the instructions contained therein.

### 15.6.1 Restoring levels and changing oil

The lubrication control unit supplies five circuits:

- Turbine cooling circuit.
- Turbine rear and front bearing lubrication circuit.
- Turbine front seal lubrication circuit.
- Turbine rear seal lubrication circuit.
- Pump seal lubrication circuit

The levels indicated by PT212 (turbine) and PT213 (pump): the correct amount of oil must fall within 3/4 and 4/4 on the visual indicator next to the lubrication control unit (LI200/LI201). Only use the same type of oil if it needs to be topped up or replaced 15.19.

Also check the proper oil level which shall be between 3/4 and 4/4 on the visual indicator installed on the side of the reducer lubrication tank (LI2000).

**ATTENTION:**

The reducer tank has its own filler cap.

**ATTENTION:**

In order to prevent the risk of contamination of the reducer tank, do not top up the level of lubricant oil with oil taken from the control unit.

**ATTENTION:**

The lubricant oil storage tank of the hydraulic power pack is divided into two separate sections (feed pump seal/turbine seal and turbine lubrication). Each section has its own filler cap. Both sections shall be filled and/or topped up.

**ATTENTION:**

In order to avoid the risk of contamination in the sections of this storage tank, do not for any reason top up the level of lubricant oil with oil taken from the sealed collection tank.

### 15.6.2 Replacing the oil filter cartridges

All circuits of the control unit are provided with their filter (S203, S204, S206, S207 and S205) with a filtration degree of 6 microns. The filters S203, S204, S206 and S207 are equipped with differential pressure switches while the filter on the cooling circuit of the spindle (S205) is provided with a simple pressure switch.

In the event of clogging a signal is sent to the supervisory system and the filter symbol starts flashing. **We recommend replacing the filters at least once a year.**

The lubrication circuit of the reducer is equipped with a S2003 filter with filtering degree 6 µm. The filter is fitted with a differential pressure switch, and therefore in the event of clogging a signal is sent to the supervisory system and the filter symbol starts flashing. **We recommend replacing the filters at least once a year.**

**Do not perform early stops of the lubrication control unit to replace the filters. Otherwise, when operation of the ORC system has stopped, wait for the control system to switch off according to the set logic (this may take several hours).**

**It should be noted that when the differential pressure switch trips, signalling that the filter is clogged, it does not block the system, but only generates a warning. The operator must contact Turboden to set up a prompt replacement of the clogged valves.**

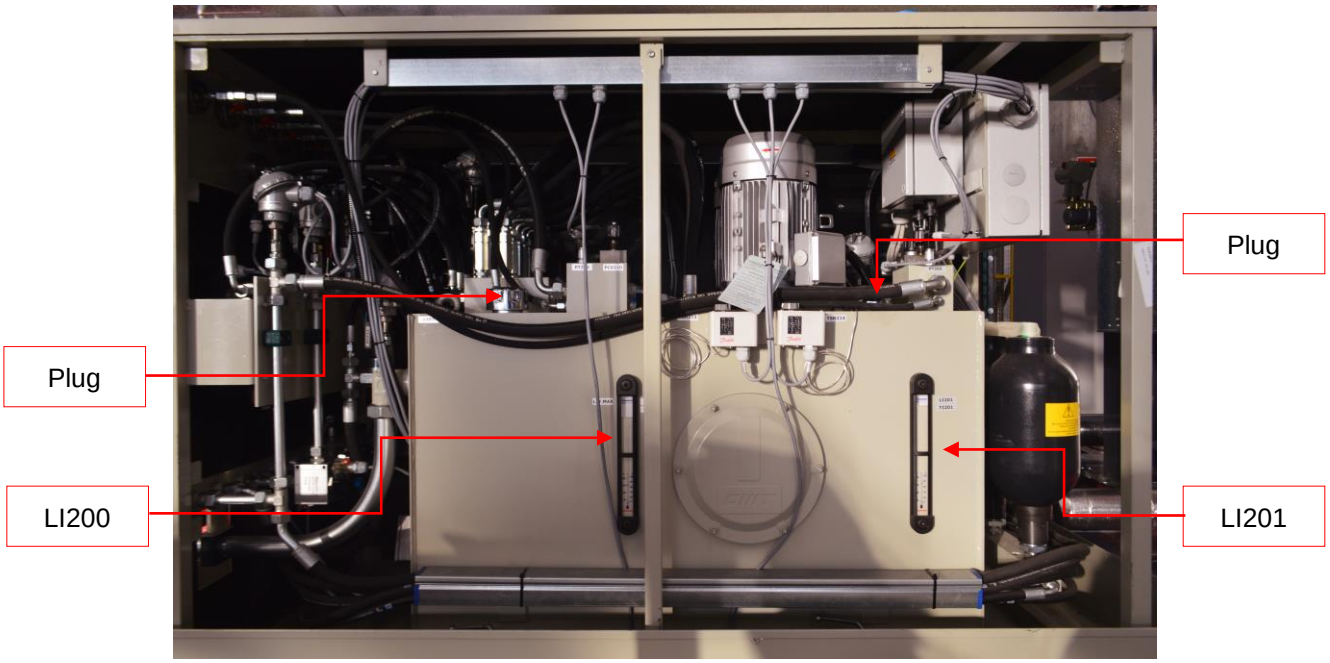



Figure 15.6-1: Lubrication unit – internal part.

Figura 15.6-2: Pannel for lubrcated gearbox.

### 15.6.3 Cleaning the cooling finned packs

The air heat exchanger guarantees lubricating oil cooling.

Periodically clean the surface of the thermal exchange (finned pack) to guarantee cooling efficiency overtime. This operation, for which a jet of compressed air is sufficient, must be carried out with caution to prevent damaging the finning.

After cleaning, check that no biomass or dirt leaks from the heat exchanger.

**Attention:**

The use of compressed air for cleaning the finned surfaces can result in the projection of debris in the air, **always wear glasses for eye protection**.

**Also protect the airways by wearing facial filters to prevent breathing dust or airborne debris.**

Figure 15.6-3: Oil - air exchanger lubrication system.

### 15.6.4 Check the temperature and pressure of the lubricant in use

With the machine running under stable conditions for at least 1 hour, check the values of the following parameters (indicated in par. "Lubricating the display system"):

*Oil temperature*

Turbine front seal oil return line: TT212

Turbine oil collection tank: TT210

Check that: TT212 – TT210 < 15°C / 20 °C

Also check the inlet oil temperature to the reducer:

30°C < TI2002 < 45°C

*Oil pressure*

Check the pressure of the various circuits detected by the pressure gauges on board the control unit and check their compatibility with the values indicated in the table:

| Description | TAG | Pressure [Bar] |
|---|---|---|
| Front turbine seal return | PI200 | 1.5 +/- 0.5 |
| Rear turbine seal return | PI216 | 0.5 +/- 0.2 |
| Feed pump seal return | PI204 | 1.5 +/- 0.5 |
| Cooling radiator delivery | PI210 | < 3.5 |
| Turbine bearings delivery | PI202 | 5.0 +/- 1.0 |
| Feed pump seal delivery | PI203 | 4.5 +/- 1.0 |
| Spindle cooling delivery | PI217 | 3.5 +/- 0.5 |
| Front turbine seal flow | PI201 | 5.0 +/- 1.0 |

Also check on the reducer circuit that: 1.5 bar < PI2002 < 2.5 barg.

For further information, contact Turboden S.r.l.

Send Turboden s.r.l. the data of the operations carried out by means of the dedicated function present in the TOS.

## 15.7 Electric generator

### 15.7.1 Replacing bearing lubricant

See chapter 15.2, paragraph "LUBRICATION OF MECHANICAL COMPONENTS".

Send Turboden s.r.l. the data of the operations carried out by means of the dedicated function present in the TOS.

**Attention:**

Before coming into contact with lubricating oils, read the requirements provided by the fluid manufacturer in the safety data sheet and follow the instructions contained therein.

### 15.7.2 Acquisition of the vibration spectra

Acquire a vibration spectra between 10-500 Hz and 10-10000 Hz measured right next to the bearings. Mark the position where the reading was made so that the exact same point can be used for subsequent measurements. Transmit Turboden s.r.l. the detected spectra. The customer is entitled to contact specialised companies to perform these operations. In this case, after performing the inspection, a report should be submitted to Turboden S.r.l.

### 15.7.3 Reducer - Generator alignment

It is recommended to check the alignment between generator and reducer when there are abnormal operating situations, such as excessive vibrations detected by the sensor VT187 or VT102 (indicatively higher than 2 mm/s), base of structure deformed, repeated breakage of bearings.

The customer is entitled to contact specialised companies to perform these operations. In that case, once alignment of the unit has been checked, it is requested to send a report to Turboden S.r.l. Any changes of the position of the movable part (electric generator) must be agreed beforehand with Turboden S.r.l.

**Warning**

All work on the reducer shaft line - the generator or the electric motor - and on the feed pump should be carried out with:

- Machine stopped and after waiting for the rotary parts to cool down (to be assessed by the staff involved in the operation).
- After disconnecting panels Q0, Q1, Q3 and Q4.
- After using appropriate LOTO systems to prevent the operation of rotary machines during the alignment procedures.

These precautions help to avoid the risk of movement in the machines

## 15.8 Reducer

### 15.8.1 Lubricant change

See chapter 15.2, paragraph "LUBRICATION OF MECHANICAL COMPONENTS".

Send Turboden s.r.l. the data of the operations carried out by means of the dedicated function present in the TOS.

**Attention:**

Before coming into contact with lubricating oils, read the requirements provided by the fluid manufacturer in the safety data sheet and follow the instructions contained therein.

### 15.8.2 Acquisition of the vibration spectra

Acquire a vibration spectra between 10-500 Hz and 10-10000 Hz measured right next to the bearings. Mark the position where the reading was made so that the exact same point can be used for subsequent measurements. Transmit Turboden s.r.l. the detected spectra. The customer is entitled to contact specialised companies to perform these operations. In this case, after performing the inspection, a report should be submitted to Turboden S.r.l.

### 15.8.3 Reducer - Turbine alignment

It is recommended to check the alignment between the reducer and turbine when there are abnormal operating situations, such as excessive vibrations detected by the sensor VT100 or VT186 (indicatively higher than 2 mm/s), base of structure deformed, repeated breakage of turbine bearings.

However the customer is entitled to contact specialised companies to perform these operations. In that case, once alignment of the unit has been checked, it is requested to send a report to Turboden S.r.l. Any changes of the position of the movable part (reducer) must be agreed beforehand with Turboden S.r.l.

**Warning**

All work on the turbine shaft line - the reducer or the electric motor - and on the feed pump should be carried out with:

- Machine stopped and after waiting for the rotary parts to cool down (to be assessed by the staff involved in the operation).
- After disconnecting panels Q0, Q1, Q3 and Q4.
- After using appropriate LOTO systems to prevent the operation of rotary machines during the alignment procedures.

These precautions help to avoid the risk of movement in the machines

## 15.9 Turbine

### 15.9.1 Replacing bearing lubricant

See chapter 15.2, paragraph "LUBRICATION OF MECHANICAL COMPONENTS".

Send Turboden s.r.l. the data of the operations carried out by means of the dedicated function present in the TOS.

**Attention:**

Before coming into contact with lubricating oils, read the requirements provided by the fluid manufacturer in the safety data sheet and follow the instructions contained therein.

### 15.9.2 Bearing Unit and Turbine Seal

Replacement of the roller bearings and turbine seal depend on the operating parameters (vibrations, temperatures, levels and historical trend). The unit shall be replaced by qualified personnel from Turboden S.r.l. In normal conditions, consumables and their scheduled replacement are defined in the service contract.

Take the following measurements on an annual basis in order to be able to predict performance levels:

- Make sure that the VT100 velocimeter has the correct settings by using a velocity transducer which has been calibrated independently, placed on the spindle of the turbine near velocimeter VT100 and compare the values read by the data acquisition system and testing instrument. The difference shall be less than 0.5 mm/sec.
- The maximum admissible vibration on the turbine spindle is 4 mm/sec.
- Acquire the vibration spectra between 10 and 500 Hz and between 10 and 10,000 Hz.
- Transmit Turboden s.r.l. the measured data.
- Send Turboden the detected spectrum for a comparison with previous data, and come up with an evaluation of the maintenance needs of the turbine bearings unit based on predictive evaluation criteria of the peaks and their evolution over time.

### 15.9.3 Acquisition of the vibration spectra

Acquire a vibration spectra between 10-500 Hz and 10-10000 Hz measured right next to the bearings. Mark the position where the reading was made so that the exact same point can be used for subsequent measurements. Transmit Turboden s.r.l. the detected spectra. The customer is entitled to contact specialised companies to perform these operations. In this case, after performing the inspection, a report should be submitted to Turboden S.r.l.

## 15.10 Feed pump

### 15.10.1 Feed pump lubricants

For periodic maintenance, please refer to the operating and maintenance manual for the pump, attached to this manual. The required lubricants are specified in table 15.16 in this manual. Transmit Turboden LTD the changes made.

**Attention:**

Before coming into contact with lubricating oils, read the requirements provided by the fluid manufacturer in the safety data sheet and follow the instructions contained therein.

### 15.10.2 Feed pump alignment

It is recommended to check the alignment between motor and pump when there are abnormal operating situations, such as excessive vibrations detected by the sensor VT101 (indicatively higher than 2 mm/s), base of structure deformed, repeated breakage of turbine bearings.

The customer is entitled to contact specialised companies to perform these operations. In that case, once alignment of the unit has been checked, it is requested to send a report to Turboden S.r.l. Any changes of the position of the movable part (the motor) must be agreed beforehand with Turboden S.r.l.

**Warning**

All work on the turbine shaft line - the generator or the electric motor - and on the feed pump should be carried out with:

- Machine stopped and after waiting for the rotary parts to cool down (to be assessed by the staff involved in the operation).
- After disconnecting panels Q0, Q1, Q3 and Q4.
- After using appropriate LOTO systems to prevent the operation of rotary machines during the alignment procedures.

### 15.10.3 Feed pump vibration spectrum

Acquire the vibration spectra between 10 and 500 Hz and between 10 and 10,000 Hz. Send Turboden the detected spectrum for a comparison with previous data, and to come up with an evaluation of the maintenance needs. The customer is entitled to contact specialised companies to perform these operations. In this case, after performing the inspection, a report should be submitted to Turboden S.r.l.

### 15.10.4 Replacement of feed pump filter

The volume of liquid contained in the filter and in the feed pump is intercepted and taken to ambient pressure, then the filter cover is opened and the filter is removed.

**Warning**

All interventions shall be carried out with:

- Machine and system shut down and cold;
- Parallel switch disconnected from the network;
- Electrical panels Q3 and Q4 power supply disconnected;

Affix LOTO signs on the panels:

- Q3: On the start key and on the supervisory PC;
- Q4: Front of panel.

***Filter shut-off valve:***

- Close valves HV137 (on pump flow), HV115 (under condenser) and HV167 (on split flow);
- Close the non-condensable system valve HV116;
- Remove the cap and open valve HV163 in order to let air in (see Figure 15.12-1);

**Use the system P&ID to identify the valves.**

**Attention**

Further operations entailing the presence of naked flames are forbidden during draining operations.

Opening the filter can result in the formation of flammable atmospheres (and/or asphyxiating in the event of F-gases, cyclopentane, isobutane, etc.). Before proceeding with operations make sure that there is adequate ventilation/extraction.

Working in a pit, can result in the creation of a confined space. Before proceeding make sure that the operators are informed and trained to operate in such environments and that there is always a system to measure air quality available, to check the concentration of oxygen and flammable substances.

***Filter extraction:***

- Loosen all of the cover's tie rods and remove the nuts (M20 or M24);
- Use the arm integrated in the filter to lift the cover and rotate it to access the filter;
- Before handling the cover, make sure the arm is well-regulated for the movement and that the cover cannot accidentally fall;

Be especially careful with the O-ring and its seat, which are to be thoroughly cleaned. Replace the O-ring if it is worn or broken.

**During operations, do not let metal parts rub against each other in order to prevent the formation of static electricity or friction sparks**

- The filter is below the fluid level. Use slip joint pliers to grip the filter and to remove it from its seat. **Do not** grip the filter with your hands. Wear latex protective gloves.

Before removing the filter, check the characteristics of the fluid contained in the safety data sheet provided by the manufacturer and follow the instructions in relation to PPE.

**Attention:**

When the system has just been stopped the fluid temperature is above 80-120°C; you should therefore use a thermometer to make sure it is below 45°C before starting any replacement operations.

In order to operate equipment safely, members of staff shall wear personal protective equipment during maintenance, as described in Chapter 16.

Contact with hot fluids exposes to burn and scalding hazards and to the possibility of inhaling fluids in vapour state. Use systems to protect the airways in accordance with what is indicated in the safety data sheet of the process fluid.

***Replacement or cleaning:***

In the event of **replacement**, extract the worn filter and insert the new one.

In the event of **cleaning**, turn the filter upside down and blow with compressed air:

- Wear protective goggles, a mask with FFP3 protection and protective latex gloves before using compressed air;
- Make sure there are no active ignition sources within a range of at least 5 metres from the compressed air point of use.
- Blow from the outside to eliminate every particle from the mesh. Even a few particles stuck to the mesh next to the mouth can cause cavitation. Make sure the filter mesh is intact, with no cuts or damaged zones. Never direct the compressed air flow towards your body or towards anybody else's body.
- Put the filter back in;

The filter blowing operations must take place outside the pump pit.

***Restoration:***

- Make sure the O-ring and its seat are completely clean and the O-ring is properly positioned;
- Reposition the cover, making sure you vertically lower it onto the O-ring;
- Insert the tie rods and tighten the nuts. Min. tightening torque 420 – Max. 500 N*m. Make sure you check that the flanges are properly tightened by following the specification attached to the manual (13-ENG.VPR-4).
- Close valve HV163 and put the cap back in place;
- Open HV116 and then HV115, HV137 and HV167;
- Remove the LOTO signs and agree on system start-up with the customer.

The results of the maintenance shall be transmitted to Turboden s.r.l.

Once maintenance is finished, close all drains and vents.

The operator shall perform any maintenance operation with close reference to the user manual of the pump attached to this manual.

Obtain all of the PPE carefully following all safety indications in chap. 16.

Dispose of any organic fluid in accordance with local environmental regulations.


Figure 15.10-1: Feed pump filter and cartridge.

## 15.11 Vacuum pump

Set the selector to "non-condensable gases separation" located on Q3 control panel in position "0". Set it back to "1" at the end of maintenance.

Refer to the instructions contained in the pump manual attached to this manual to replace the vacuum pump lubricant.

**Attention:**

Before coming into contact with lubricating oils, read the requirements provided by the fluid manufacturer in the safety data sheet and follow the instructions contained therein.

Fill up the tank using only the same type of oil that it already contains. Fill up to 50% of the inspection window on the pump casing.

The required lubricant is specified in paragraph 15.19.

Transmit Turboden s.r.l. the measured data.

During filling operations pay the utmost attention to prevent impurities from entering.

### 15.11.1 Cleaning vacuum system valves

With reference to the Figure 9.4-2, close the HCV139 and HCV136 valves counting the number of turns that were originally used to open them. Open and close, fully, at least 2 times (7 rotations) and place back in the original opening. 3 turns are normally used to open HCV139 valves for and 2 turns for HCV136.

Transmit Turboden s.r.l. the measured data.

Figure 15.11-1: Vacuum pump.

## 15.12 Purging non-condensable gases from the condenser

The presence of humidity and air or other non-condensable gases inside the condenser increases the organic fluid condensation pressure and, thus, reduces the power generated by the ORC.

With the turbogenerator running under stable conditions, the indicators of the possible presence of non-condensables are as follows:

- The TT126 temperature of V103 barrel, when it drops below 30-35°C
- The Dtcond = T105Ant – TT104 parameter when significantly higher (by at least 4°C) than the value detected during the system acceptance tests, normally ranging between 0 and 5°C, depending on the flow rate of the condenser cooling mixture and its chemical-physical characteristics.

These parameters can be monitored from the supervisory system

The purging system starts automatically to remove non-condensables from the condenser. If the condenser pressure still fails to fall within the correct values within a few minutes, the purging system stops and sends a signal, which is visible from the "Alarms" page of the display system, to the control PLC (Note: At this point, the purging system will no longer activate automatically).

The condensate produced in the V103 barrel consists of a mixture of water and silicone oil, which is collected in the V105 separator.

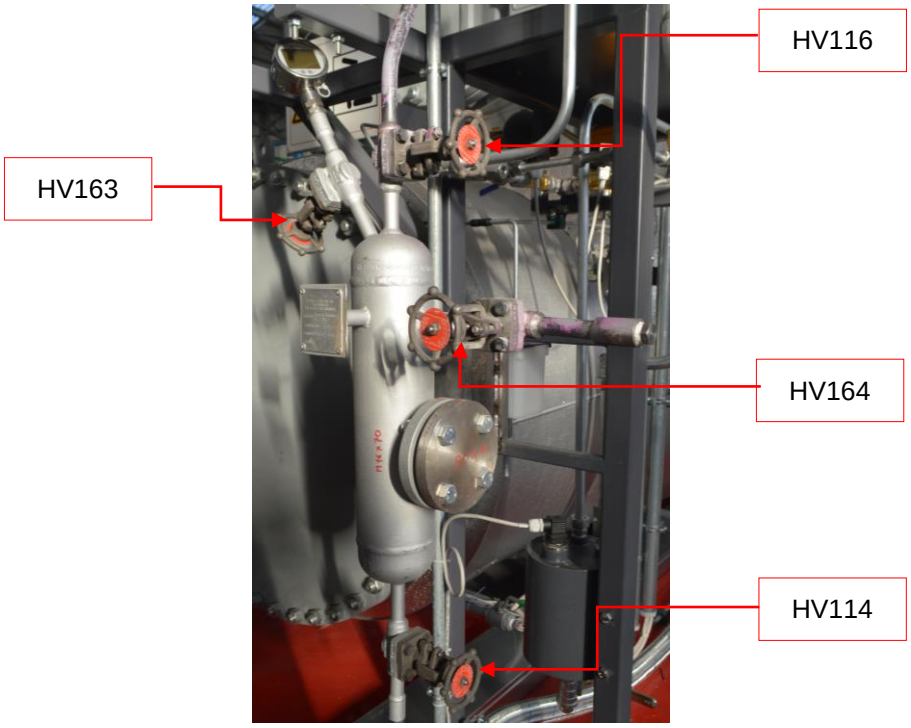



Figure 15.12-1: V105 separator.

In the first days after commissioning and thereafter empty the separator at least once a year in compliance with the instructions below:

- Locate the water separation tank as illustrated in the figure.
- Prepare a 2-litre transparent container with a small amount of water in it (about 0.2 litres) marking the level accurately.
- Close manual valves "HV116" and "HV164" all the way
- Open valve "HV163" by removing its cap
- Open valve "HV144" collecting the fluid in the transparent container previously filled with water
- The silicon will float on the water in the container, leaving a clear interface. Check any increase in the previously-marked water level. Inform Turboden of the volume of water drained during the annual inspection.
- Close valves "HV144" and "HV163" with their relative caps firmly and open valves "HV164" and "HV116" back up

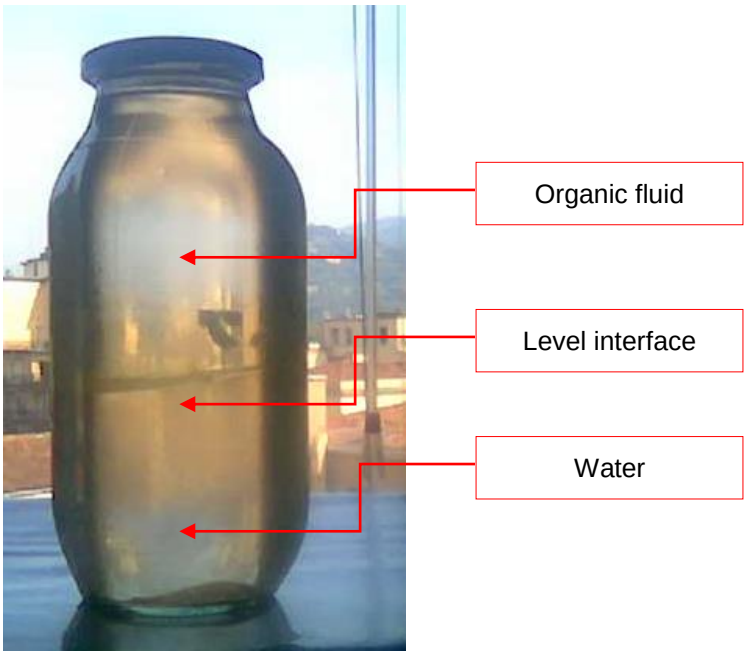



Figure 15.12-2: Silicon/Water Interface.

## 15.13 Purging leakage sensor protective barrel

When the protective barrel has filled up it is necessary to empty it. Prepare material to absorb any leakage and a dust fire extinguisher in the vicinity. The system operator is responsible for supplying all the material.

Accidental spills of fluid on the ground can generate flammable atmospheres. If necessary absorb the spilled fluid as soon as possible and remove any source of ignition

The fluid can be drained into a plastic or metal container with a narrow spout (bottle or can); if the recipient is made of metal, place it on the ground using cables with crocodile clips.

The operations follow this sequence:

1. Before starting, set the non-condensable selector (16) at “0” (Figure 12.1-1);
2. Close valves HV174 and HV175.
3. Unscrew the closing plug of draining valve HV176.
4. Fit an appropriate diameter flexible hose on the free side of the HV176 valve.
5. Open the HV176 valve until the container is completely empty.
6. Close valve HV176.
7. Disconnect the container and the hose; the container must be re-closed immediately.
8. Screw on the plug of valve HV176.
9. Reopen the HV174 and HV175 valves.
10. Set the non-condensable selector (16) at “1” and reset the warning from the supervisory program.

The system operator is responsible for disposing of the container with the drained fluid.

**Attention**

Further operations entailing the presence of naked flames are forbidden during drainage operations.

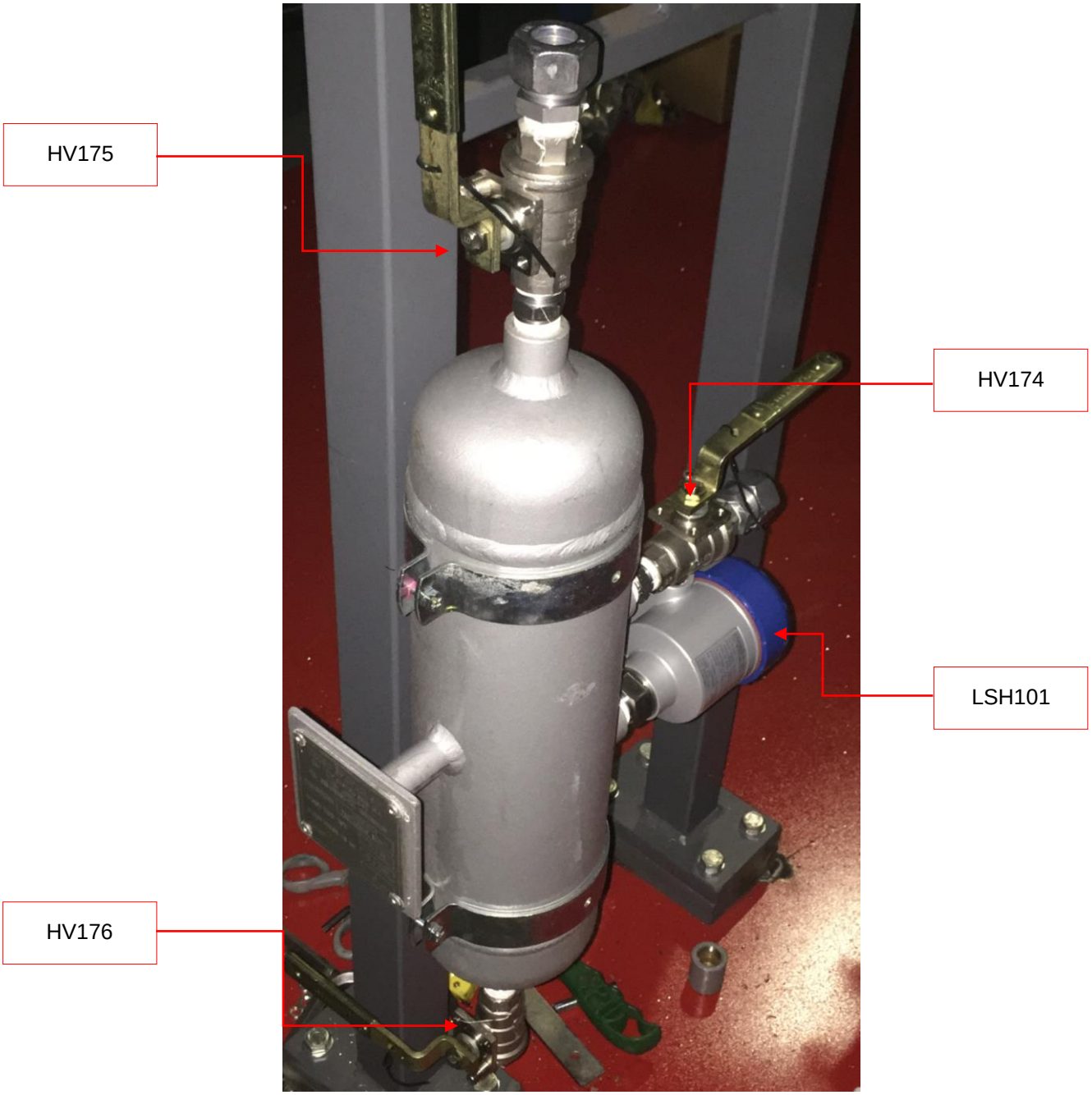



Figure 15.13-1: V104 leakage protective drum.

## 15.14 Water exchangers draining (winter period)

If the ORC is not used for a long time during the winter, the water-containing components shall be protected from damage caused by freezing.

There are 2 ways to protect the water-containing systems without glycol:

- Guaranteed continuous circulation;
- Complete drainage and filling with inert gas (nitrogen) or new filling with glycol water (33% to protect up to -20 ° C).

**Attention:**

Before using and handling glycol water, read the safety instructions provided by the manufacturer in the product safety data sheet.

**Attention:**

Further operations entailing the presence of naked flames are forbidden during draining operations.

**Attention:**

The only complete drainage without added nitrogen or glycol water exposes the surfaces to oxidation with risk exchanger clogging

## 15.15 Oil separator container draining

To drain container V700 please refer to the specification attached to this manual.

See chapter 14 19.

**Attention:**

Further operations entailing the presence of naked flames are forbidden during draining operations.

**Accidental spills of fluid on the ground can generate flammable atmospheres. If necessary absorb the spilled fluid as soon as possible and remove any source of ignition**

## 15.16 Topping up the level of organic fluid

The organic fluid can be topped up for various reasons:

- Fluid spills due to leaks or maintenance interventions.
- Physiological leaks due to vacuum system;

A significant reduction in the fluid content inside the machine increases the evaporator parameter DTSH: if, during STABLE and RATED working conditions, this parameter value exceeds by 5°C the value recorded during start-up a topping up of the fluid is required.

In this case contact Turboden service to request:

× Authorisation to top up the level of organic fluid;
× Determination of the amount required.

As the silicone fluid is flammable and shall be considered a dangerous fluid, we recommend paying the utmost attention when handling it. In the event that it shall be topped up, the operator shall comply with the following documents (attached to the manual):

- The operating procedure (10-C-89).
- The organic fluid safety data sheet.

**Do not fill or drain the organic fluid without first having agreed with Turboden S.r.l.**

**Before using and handling fluids, read the safety instructions provided by the manufacturer in the product safety data sheet.**

## 15.17 Control software back-up

Perform an image of the hard disc once a year.

The PLC software and display system can be copied and stored on other media only and exclusively by Turboden staff either on site or remotely. Please contact Turboden for any queries to this regard.

## 15.18 Check of the safety chain

Conduct a test on the correct operation of the safety chain each year.

In order to do so:

- Check that the turbogenerator is running;
- Press the unprotected emergency stop button;
- Check that the following events occur:
  1. The parallel switch opens;
  2. The turbine inlet valves FCV100 and SCV100 close;
  3. The feed pump shuts down;
  4. The bypass valve PCV103 opens.
- At the end of the test, re-arm the button;
- Reset any blocks that tripped and reboot the system;
- Transmit Turboden s.r.l. the measured data.

**The required test must only be carried out on unprotected emergency buttons (therefore not on Q3).**

**Entrust Turboden technicians to run the protected emergency button test.**

## 15.19 List of standard lubricants

| Position | Type of lubricant |
|---|---|
| Turbine bearings and seals | Standard: AGIP OTE 32<br>Equivalent grades by other brands (see note *) |
| Pump Bearings | AGIP OSO 68<br>Equivalent grades by other brands (see note *) |
| Pump Seal | Standard: AGIP OTE 32<br>Equivalent grades by other brands (see note *) |
| Generator Bearings | See generator manual.<br>Equivalent grades by other brands (see note *) |
| Vacuum pump | Leybold: LVO 130<br>Equivalent gradients by other brands (see note *): |
| Electric motor grease | UNIREX N3 ESSO EXXON.<br>Equivalent grades by other brands (see note *) |
| Reducer bearings | Standard: AGIP OTE 32<br>Equivalent grades by other brands (see note *) |

**Replacing or refilling lubricant:**

* When refilling it is necessary to use exactly the same gradient and brand of lubricant. When changing the lubricant, it is possible to use a different brand with the same features upon written consent by TURBODEN.

To replace or refill the lubricant, refer to the individual specific manuals attached.

**Dispose of any exhausted lubricant in accordance with local environmental regulations**

# 16 SAFETY RECOMMENDATIONS

## 16.1 General recommendations

To avoid potentially dangerous situations, here is a list the main rules of conduct that shall be followed during routine system operation.

- The system can be a source of danger if used inappropriately, or for unintended use, or by untrained members of staff.

**Attention:**

**The manufacturer will not be held liable for any damage or accident due to improper use of the system; In this case the user assumes full responsibility for the risk.**

**Warning:**

**Employees assigned to system operation and maintenance shall have read and understood the entire manual provided upon first start-up, in particular the information regarding safety.**

- The operation, maintenance, and repair of the system shall only be carried out by **trained and authorised** members of staff.

**Attention:**

These members of staff shall be adequately

- Informed of any dangers which may occur during any such operations.
- Professionally trained

- The user agrees to operate the machine only if it is in perfect condition.

**Attention:**

The system is equipped with control and protection devices required to guarantee its safety.

**Warning:**

**Do not remove or tamper with these safety devices.**

**Attention:**

In particular, during routine system operation it is forbidden to remove the casings on the joints of the turbine and the feed pump, and the protective grilles on the cooling fans of the lubrication control unit.

- In case of failure or any other type of problem, the system shall remain shut down until all the safety devices are functioning again. Refer to Annex "Security Analysis" for the risk evaluation and implemented preventive measures.

Refer to Annex "Security Analysis" for the risk evaluation and implemented preventive measures.

- Maintenance operations can be particularly dangerous. This is why they must only be carried out by skilled and properly trained personnel, using the applicable LOTO procedures.

**Important warning!**

**During routine shut-down, the feed pump may start up automatically for a few seconds at 100 rpm**

- Maintenance on rotating machines can create very dangerous situations and injuries for the operator / maintenance technician.

**Warning**

**All work on the turbine shaft line - the generator or the electric motor - and on the feed pump should be carried out with:**

- **The machine and the system shut down and cold**
- **The parallel switch disconnected from the network**
- **Q4 pump electric panel power supplies disconnected**
- **Q3 control panel power supply disconnected**
- **Use relative LOTO signalling systems**

**These precautions help to avoid the risk of movement in the machines**

- Maintenance, including electrical faults, shall only be repaired by authorised technical personnel. TURBODEN provides the first system start-up and the staff training and instruction course.

**Warning:**

It is against the law for **unauthorised and/or not professionally trained personnel** to commission and operate the system. In this case, any warranty claim will lapse.

**Warning:**

The turbogenerator contains flammable fluids (organic fluid, lubricating oil). **Accordingly, it is forbidden to smoke and use open flames causing sparks near the system.**

**Important:**

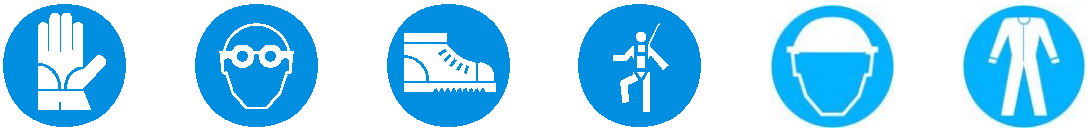
Never, for any reason whatsoever, remove plates and danger signs of any kind that are applied to the system and in the room where it is installed.

- The machine has been designed so that no form of electrical, hydraulic or pneumatic energy remains stored after shut-down, with the exception of the sealing circuit which is pressurised by oil at a pressure of approx. 2 bar and the compressed air tanks that are powered by compressed air at 6 bar.

**Attention:**

The emergency stop push button under cover also immediately stops lubrication to the turbine, which continues to rotate without lubrication until it comes to a stop (approx. 6 minutes), and is therefore exposed to damage to the bearings and seal. Only use the emergency shutdown push button in situations of real, serious danger!

## 16.2 Personal protective equipment



During system maintenance it is essential to use individual and collective safety devices, suitable for the work to be performed. The list of minimum PPE:

- Protective gloves in compliance with MSDS recommendations.
- Protective goggles.
- Fall-prevention harness for operations carried out at a height.
- Hearing protection or earmuffs in the case of plant running;
- Safety shoes.
- Head protection helmet.
- Protective suit.

**WARNING: providing the full list of PPE, selecting them, assessing of compliance with the regulations in force as well as the risk analysis and the requirements for carrying out work operations safely, are the sole responsibility of the Customer.**

## 16.3 Lifting device

The machine is equipped with a lifting device to remove the feed pump in the event of maintenance or failure.

It is strictly forbidden to use the lifting device without permission from Turboden.

## 16.4 Pipes and pressure vessels

While the system is operated, certain components are pressurised and hot and others are under vacuum. Opening a communication passage from inside the system to the external environment can generally cause the organic fluid to leak and/or the ambient air to be drawn.

**Warning:**

**Be careful when opening valves or other devices in the system towards the outside (accordingly equipped with safety caps, which shall not to be removed except for maintenance operations).**

**Warning:**

**Manual operation (partial or total) of the shut-off valves installed on the pipes inside the system may, on the other hand, cause damage to the mechanical parts of the valves or devices (pump, heat exchangers, etc..) affected by the shut-off, or create dangerous over-pressurised closed circuit sections.**

**Important:**

**Never, for any reason whatsoever, open or close manual valves on the outside or on the inside of the circuit, during system operation. If it is necessary, shut-off certain parts of the system, with the system shut down, and with authorisation issued by the Turboden service team.**

**Warning:**

To avoid the danger of burns, when it is necessary to remove insulation from various sections of the system, this shall only be carried out for unscheduled maintenance and when the system is cold.

**It is forbidden to remove the thermal insulation except for maintenance operations carried out when the system is down and cold.**

**Warning:**

There are some uninsulated parts of the system which reach quite high temperatures and may cause severe burns.

In order to operate equipment safely, members of staff must wear personal protective equipment during maintenance.

## 16.5 Organic fluid

The organic fluid is non-toxic and not harmful to humans. It is flammable, however, albeit with an elevated flash point. It is necessary to store the organic fluid in accordance with the recommendations outlined in the attached safety data sheet.

**Warning:**

Accordingly, **it is forbidden to smoke or use tools that can create sparks or open flames in and around the entire area of the system**.

**Important:**

**Store the organic fluid inside special barrels sealed and kept in a closed and ventilated area in accordance with the recommendations provided in the safety data sheet attached to this manual.**

**Important:**

**The fluid is not harmful to humans. However, as a precaution, avoid ingesting or inhaling fluid vapours when the circuit is open for maintenance.**

In case of ingestion or inhalation of the fluid, consult the safety data sheet attached to this manual.

The fluid remains inside the circuit during normal operation of the turbogenerator; spills or leaks of fluid into the atmosphere are exceptional events due to ruptures or manoeuvring errors affecting the manual valves.

# 17 RESIDUAL RISKS

## 17.1 Residual risks due to falling or thrown objects

When the Customer's staff installs or dismantles the turbogenerator, some parts may come off as a result of improper assembly or disassembly.

Compulsory use of a helmet

## 17.2 Residual risks due to extreme temperatures

While there is specific insulation set up to avoid burns from contact, maintenance operations that require removing layers and protective mesh and carried out without compliance with the safety instructions provided in this manual, may result in burns from contact.

Compulsory use of protective gloves for high temperatures

Compulsory use of protective coveralls for high temperatures

## 17.3 Residual risks due to noise

The turbogenerator is designed and built so as to minimise sound emissions and the associated risks. Measuring campaigns carried out on the various types of machines have provided a mapping proving that values are kept under 90 dB (A) @ 1 m in open spaces. However, the required assessment of risks due to noise and the choice and size of the appropriate PPE is the sole responsibility of the Customer.

For more information and specific data, please submit a request to Turboden S.r.l.

Compulsory use of hearing protection

### 17.4 Residual risks due to vibration

The turbogenerator is designed and built so as to minimise the emission of vibrations and associated risks. In addition the units rest on strips of anti-vibration material, whereas the condenser-regenerator features elastic supports.

Measuring campaigns carried out on the various types of machines have classified the turbogenerator in zone B ex UNI 10816-3 and, therefore, without the need for vibration protection for the surrounding environment (TE-BK-0 / RB-KK-0).

For more information and specific data, please submit a request to Turboden S.r.l.

### 17.5 Residual risks due to start-up without the joint cover fitted.

The Customer's personnel might accidentally start up the system without the joint cover fitted. Stop the system immediately, reassemble the joint cover and then restart the system.

In case of moving parts it is forbidden to use gloves.

### 17.1 Residual risks due to the presence of confined spaces

Heat exchangers, if opened during special maintenance or periodic checks conducted by certification bodies, constitute a confined space with risks of suffocation, explosive and/or flammable atmospheres and risk of entrapment for staff entering.


Any entrance should take place only after careful planning of the intervention and solely by staff appropriately informed and trained.

Turboden S.r.l. is available to assist the Customer either directly or indirectly with any such requests.

## 18 DISMANTLING AND DEMOLITION

ORC turbogenerator dismantling activities, due to their complexity and structure, shall be considered unscheduled operations and accordingly, they shall be managed by a specific work plan.

Turboden S.r.l. is available to assist the Customer either directly or indirectly with any such requests.

## 19 ATTACHED DOCUMENTS

For full technical documentation, on commercial parts, or specific documents drawn up by Turboden S.r.l., refer to the document "List of Attachments".

| PROJECT DOCUMENTATION | |
|---|---|
| **NUMBER** | **DESCRIPTION** |
| NB1-ENG.ASM-2 | Lifting board |
| NB1-ENG.AAD-1 | Flange assembly drawing |
| NB1-ENG.E3LD-1 | Single line diagram |
| NB1-ENG.E3LD-2 | Generator protection & control panel (Q0) wiring diagram |
| NB1-ENG.IID-1 | Complete system interface drawing |
| NB1-ENG.VMA-3 | List of ORC blocks and intervention threshold values |
| NB1-ENG.PPID-1 | P&I diagram - Main process |
| NB1-ENG.PPID-2 | P&I diagram - Turbine instrumentation |
| NB1-ENG.PPID-3 | P&I diagram - Non Condensable Gas Removal System |
| FR-M-T-0 | P&I diagram - Compressed air |
| 15-M-27 | P&I diagram - Hydraulic lube system |
| 16-M-4 | P&I diagram - Reduction gear lube system |
| 14-ENG.PPID-6 | Oil separator XSD P&I Diagram |
| NB1-ENG.VSD-2 | Risk Analysis |

| TURBODEN PROCEDURES AND SPECIFICATIONS | |
|---|---|
| **NUMBER** | **DESCRIPTION** |
| 08-C-221 | ORC turbogenerator storage system and long-term conservation procedures |
| 10-C-89 | Specification for working fluid refilling operation |
| 10-C-196 | Specification for lubrication control unit filter replacement |
| 11-H-11 | O&M manual of flange seal control system |
| 13-C-175 | Turbogenerator periodic check. |
| 13-ENG.VPR-4 | Flanges tightening operating procedure |
| 14-ENG.ASM-1 | Turbine alignment specification |
| 14-ENG.ASM-2 | Pump alignment specification |
| 14-ENG.ASM-4 | Flange suction system test procedure |
| 14-S-9 | TOS Manual |
| 15-C-26 | Instructions for XSD drainage separator |
| 16-ENG.ASM-4 | Table of tightening torques |
| NB1-C-4 | Operating instruction manual for SCADA |
| 17-C-22 | HMI user manual (operator panel on Q3) |

**NOTES:**

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