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HE-FUS 3: Description of the loop and operative conditions

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RAPHAEL IP – DELIVERABLE D-CT1.4

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Abstract

HE-FUS 3 was designed and constructed at ENEA CR Brasimone in mid '90 and successfully operated since that time performing different experimental campaigns mainly focused to the thermomechanical characterisation of HCPB (Helium Cooled Pebble Bed) blanket mock-ups, in the ambit of R&D for the Fusion Technology Programme. Such activities are planned to continue in the next future because of the need to qualify TBMs (Test Blanket Modules) for ITER.
The present loop characteristics allow HE-FUS3 to carry out experiments with He up to a pressure of 8 MPa and 0.35 kg/s of mass flow-rate with a maximum temperature of 500 ℃. Nevertheless, a significant loop upgradin g is planned in 2007 in order to make HE-FUS 3 representative of the real TBM Cooling Circuit. In the upgraded version, HE-FUS3 will be provided with a compressor of 1.4 kg/s of He mass flow-rate, being able to dissipate up to 1 MW of thermal power.
This report describes the present status of HE-FUS 3 loop as well as its main operative conditions also in view of the planned test campaign on the component HEATRIC, which will be carried out in the ambit of the RAPHAEL Project.

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HE-FUS 3: description of the loop and operative conditions

Summary

1. Introduction

HE-FUS 3 was designed and constructed at ENEA CR Brasimone in mid '90 and successfully operated since that time performing different experimental campaigns mainly focused to the thermo-mechanical characterisation of HCPB (Helium Cooled Pebble Bed) blanket mock-ups, in the ambit of R&D for the Fusion Technology Programme. Such activities are planned to continue in the next future because of the need to qualify TBMs (Test Blanket Modules) for ITER.

The present loop characteristics allow HE-FUS3 to carry out experiments with He up to a pressure of 8 MPa and 0.35 kg/s of mass flow-rate with a maximum temperature of 500 °C. Nevertheless, a significant loop upgrading is planned in 2007 in order to make HE-FUS 3 representative of the real TBM Cooling Circuit. In the upgraded version, HE-FUS3 will be provided with a compressor of 1.4 kg/s of He-mass flow-rate, being able to dissipate up to 1 MW of thermal power.

This report describes the present status of HE-FUS 3 loop as well as its main operative conditions also in view of the planned test campaign on the component HEATRIC, which will be carried out in the ambit of the RAPHAEL Project.

2. HE-FUS 3 loop description

As shown in the P&I given in annex 1, HE-FUS 3 is an eight-shape loop with, consequently, two regions working at different temperatures: the hot one hosting the test section; the cold one where the compressor and the flow-rate damping tank are located. An economizer, placed at the crossover point, allows the recovery of the helium enthalpy before the inlet to the compressor. A cooler reduces the compressor inlet temperature to the level of its maximum operating temperature.

The loop was designed[1] to operate in the following modes:

- Long term isothermal cooling flow;
- Slow thermal cycling flow;
- Fast cold thermal shock flow;
- LOCA/LOFA simulation.

The present HE-FUS 3 main operative conditions/performance are reported in Tab. 1:

Table 1 – HE-FUS 3 main characteristics

DESIGN PRESSURE	10.5	MPa
DESIGN TEMPERATURE	530	°C
MAX TEMPERATURE AT THE COMPRESSOR INLET	100	°C
COMPRESSOR HELIUM FLOW RATE	0.05-0.35	kg/s
MAXIMUM COMPRESSOR SPEED	18.000	rpm
MAXIMUM COMPRESSOR HEAD	0.5	MPa
COMPRESSOR ELECTRICAL POWER	136	kVA
HEATERS ELECTRICAL POWER	210	kW
ECONOMIZER THERMAL POWER	564	kW
AIR COOLER THERMAL POWER	280	kW
HELIUM TANK CAPACITY	3	m^3
OVERALL HELIUM LEAKAGE	$2\ 10^{-3}$	mbar l/s

Helium is supplied to the hot part of the loop by a compressor with the following multiple flow-rate control systems:

1. frequency control of the supply of the electrical motor;
2. by-pass valve FV 235;
3. lamination of inlet valve FV 10;
4. lamination of outlet valves HV 2 and FV 213.

The helium tank V205, located on the compressor outlet, with a capacity three times the overall volume of the piping, provides the necessary pressure fluctuation damping due to the compressor. Furthermore, it serves to control the pressure variation due to the temperature excursion during the experimental test activity. Two different lines are linked to the expansion tank, the former for filling the helium from the bottles and the latter for evacuating it from the tank to the environment, equipped with appropriate electronic pressure controlled valves. This system can maintain the tank pressure within ± 1% or 0.1 MPa of the imposed set point.

The instruments on the piping and its components, mainly consisting of pressure, temperature and flow-rate transducers, can be divided into three categories:

1. measurement chains;
2. regulation chains;
3. safety and protection chains.

The material for tubes, flanges, fittings and vessel sheets is AISI 316, in compliance with the ASTM standards. The flange metal gaskets are in silver plated stainless steel AISI 316 or INCONEL X-750.

2.1. Piping

The piping material is stainless steel AISI 316. The design pressure is the same throughout the whole facility, 10.5 MPa, while the design temperature corresponds to the maximum temperature envisaged for each section of the loop. The diameter of the main He pipes, 4” for the cold zone and 5” for the hot zone, were calculated with the limitation of the helium velocity below 20 m/s. For the whole piping the tube scheduling was fixed at 80 SCH (extra strong).

The stress-strain analysis for the whole loop arrangement was performed by ANSYS computer code, taking into account the geometry and the boundary conditions (the operating pressure and temperature for each section).

The loop piping includes two by-pass lines, one at the hot branch for flow-rat control and one for the cold thermal shock operating mode.

The overall length of the piping is about 80 m, with an integral volume of 4 m^3 (including 3 m^3 of the expansion tank capacity) and a weight of about 15 ton.

The piping is thermally insulated with special asbestos-free material, 60 or 160 mm in thickness, in order to reduce contact temperatures below 50°C, and covered with an aluminium sheet for mechanical protection of the insulator. The nominal heat loss are reduced to 20 kW.

The loop measured parameters are pressure (differential, relative or absolute), flows-rates and temperatures so as to monitor the facility during the different operating modes. Further measurements include valve positioning for both on/off and regulating valves.

2.2. Compressor

The compressor, developed by RTM on the base of a specific R&D activity, has a specially designed regenerative impeller developed by the University of Genova. The electrical motor is completely immersed in the helium flow. The electrical motor is provided with an inverter driving system capable of controlling the frequency in the range 5-300 Hz, guiding the rotor speed at 300-18000 rpm.

The maximum compressor inlet temperature is fixed at 100 °C to control and maintain the nominal bearing clearances at acceptable values.

The main compressor design data are:

- ✓ Maximum design temperature 160 °C
- ✓ Maximum design pressure 10.5 MPa
- ✓ Design flow-rate 0.05-0.35 kg/s
- ✓ Vessel inside diameter 350 mm
- ✓ Vessel sheet thickness 45 mm
- ✓ Vessel total height 700 mm
- ✓ Inlet design pressure 6.0 MPa
- ✓ Outlet design pressure 6.5 MPa
- ✓ Maximum design flow-rates 0.35 kg/s
- ✓ Maximum design inlet temperature 100 °C
- ✓ Mechanical power 90 kW
- ✓ Electrical motor power 110 kVA
- ✓ Inverter maximum current 210 A
- ✓ Inverter maximum frequency 400 Hz
- ✓ Maximum impeller speed 18000 rpm
- ✓ Impeller diameter 230 mm
- ✓ Motor shaft diameter 65 mm
- ✓ Rotor diameter 130 mm

The measure compressor parameters include: helium inlet pressure, helium and water temperatures, bearing temperatures, differential pressure, axial and radial clearance on the three bearings, vessel vibration noise and impeller shaft rotating speed.

2.3. Expansion Vessel

At the compressor outlet, on the cold branch, an expansion vessel is provided in order to damp the pressure and flow fluctuations during loop operation. The vessel is cylindrical with a volumetric capacity of about 3 m^3

The connections welded to the loop are: two for the inlet/outlet main flow, one to the outlet purification circuit, one from the filling and pressurizing line and the last one for the controlled flow discharge to the environment. A further connection is necessary for mounting the passive safety rupture disk.

The parameters measured on the tank are the helium temperature and its absolute pressure.

The design pressure is 10.5MPa, the same as that of the whole facility, and the design temperature is 160°C corresponding to the helium compressor maximum outlet temperature.

Summarising, the main tank design data are:

✓ Design temperature	160 °C
✓ Design pressure	10.5 MPa
✓ Hydraulic test pressure	13 MPa
✓ Maximum design flow-rate	0.35 kg/s
✓ Vessel capacity	3 m^3
✓ Vessel outside diameter	890 mm
✓ Vessel inside diameter	800 mm
✓ Vessel sheet thickness	45 mm
✓ Cylinder height	6659 mm

2.4. Economizer

This component is a tube-shell helium/helium heat exchanger located between the cold and the hot branches. A bundle of tubes is welded between two tube plates, with straight connection, and they are immersed in a cylindrical pressure vessel. The primary helium flows towards in the shell side through a series of diaphragm sheets for the overall thermal conductance improvement. The secondary helium flows inside the tubes in a single passage. The tube bundle is floating respect to the shell by a tube-bellow compensation system.

The pressure vessel is cylindrical and is provided with four welded pipes for the loop connections. The higher the efficiency ($\varepsilon \geq 0.79$) the lower the electrical power to be installed on the loop heater.

The main parameters are:

✓ Design temperature	530 °C
✓ Design pressure	10.5 MPa
✓ Hydraulic test pressure	23.0 MPa
✓ Max. allowable differential pressure	0.5 MPa
✓ Maximum design helium flow-rate	0.35 kg/s
✓ Nominal thermal power	564 kW

- ✓ Overall heat transfer surface 27.7 m^2
- ✓ Overall thermal conductance 256 W/m^2K
- ✓ Design efficiency 0.79
- ✓ Design 1° pressure drops 1660 Pa
- ✓ Design 2° pressure drops 212 Pa
- ✓ Tube outside diameter (1/2”) 21.3 mm
- ✓ Tube thickness 1.6 mm
- ✓ N° of ½” tubes 73
- ✓ Tube outside diameter (3/8”) 16 mm
- ✓ Tube thickness 1.0 mm
- ✓ N° of 3/8” tubes 12
- ✓ Vessel internal diameter 270 mm
- ✓ Vessel active length 5000 mm
- ✓ N° of tube diaphragms 18

The parameters to be measured on this component are the helium temperatures on the four inlet/outlet pipe connections and the two differential pressures on the primary and secondary branches.

2.5. Electrical heaters

The electrical heaters consist of tree different modules. They are located between the economizer and the Test Section in order to supply a maximum helium flow rate of 0.35 kg/s at a maximum temperature of 525 °C. The nominal global electrical supply is 210 kW (70kW per module).

The inlet temperature per each module is related to the helium flow-rate, the maximum operating compressor inlet temperature and the thermal efficiency of the economizer. The relative design value is the highest inlet temperature 420°C. The temperature increment per each module is about 35°C, as calculated at nominal conditions.

The module arrangement consists of vertical cylindrical vessels and bundles of flanged immersion heaters.

The electrical supply, control and monitoring is independent for each module.

The hydraulic configuration of these three modules can be changed by opening or closing three manual valves HV 250, HV 251, HV 252, in order to:

1. supply a Test Section with the whole power (three modules) and with a module serial configuration;
2. supply a Test Section with 1/3 of the power (one module) an 2/3 of the power (the other two modules) by means of are cycling line on the same Test Section.

Each rod bundle is made of U-bent pins with stainless steel sheaths; the resistors are made of Ni-Cr spiral wires insulated by MgO powders. The pin cold legs are welded to an upper plate, flanged to the vessel, by interposing tubes for the welding accommodation.

The heaters organization is vertical with an immersion flanged pin bundle provided with diaphragm plates for heat transfer improvement.

The electrical supply is 380 V three-phase at 50 Hz, while the single helium outlet temperature is controlled for each module by an SCR controller.

The parameters to be measured are the temperature at the inlet/outlet of each module an d on the surfaces of the cladding sheaths of the heater pins.

The main heater design parameters are:

- ✓ Design helium temperature 530 °C
- ✓ Design cladding temperature 560°C
- ✓ Design helium flow-rate 0.35kg/s
- ✓ Design helium pressure 10.5 MPa
- ✓ Hydraulic test pressure 23 MPa
- ✓ Total electrical power 70x kW
- ✓ Overall heat transfer surface 4.52 m^2
- ✓ Overall thermal conductance 809 W/m^2K
- ✓ Design helium pressure drops 1011 Pa
- ✓ Rod diameter 15 mm
- ✓ N° U-bent rods 30
- ✓ Vessel internal diameter 270 mm
- ✓ Rod heated length 1800 mm
- ✓ Rod cold leg length 300 mm
- ✓ N° of diaphragm plates 12
- ✓ Diaphragm pitch 145 mm

The design pressure is the same as that of the whole facility and the design temperature corresponds to the maximum design temperature of the loop.

2.6. Mixers

The mixers are used for the temperature mixing between different main and by-pass flow rates. They are constituted by two annular tubes, with the internal one drilled and provided with sliding pads, assembled in order to avoid the relative temperature stress accumulation an the welding zones. These mixers are welded to the pipelines.

These two components are located:

1. in the cold zone between the by-pass line and the outlet from the economizer providing the thermal mixing of the hotter branch, from the economizer outlet, with the colder one, from the hot by-pass line;
2. the hot zone between the by-pass line and the outlet from the heaters providing the thermal mixing of the hotter branch, from the heaters outlet, with the colder one, from the hot by-pass line.

The cold flow-rate is range between 30-100 % of the maximum compressor flow rate (0.35 kg/s).

The parameters to be measured are the three temperature of the three connection pipes.

The main design parameters for the cold zone first mixer are:

- ✓ nominal cold helium inlet temperature 350 °C
- ✓ nominal hot helium outlet temperature 130 °C
- ✓ design helium pressure 10.5 MPa
- ✓ design helium flow rate 0.35 kg/s

The main design parameters for the hot zone second mixer are:

- ✓ nominal cold helium inlet temperature 530 °C
- ✓ nominal hot helium outlet temperature 130 °C
- ✓ design helium pressure 10.5 MPa
- ✓ design helium flow rate 0.35 kg/s

2.7. Air cooler

This component is located at the compressor inlet in order to reduce the corresponding temperature to the level of the compressor inlet maximum temperature (100°C).

The helium flows inside the tube bundle whilst the air flows outside the finned surface of the tubes. The arrangement is as compact as possible with finned tubes welded to two distributors and arranged in triangular array. The fins are made with a helicoidal stainless steel sheet with 0.4 mm in thickness and with a pitch of 3.4 mm.

The secondary cooling fluid is air pumped from a fan towards an air duct provided for this purpose. The fan motor is driven by an inverter system in order to regulate the fan speed in the range 50-3000 rpm. The connections of the four temperatures at the inlet/outlet of the primary and secondary lines.

The design pressure is the same as that of the whole facility and the design temperature will correspond to the maximum temperature at the outlet of the thermal mixer.

The main cooler design data are:

- ✓ Design helium temperature 240 °C
- ✓ Design helium pressure 10.5 MPa
- ✓ Design helium flow-rate 0.35 kg/s
- ✓ Pressure drop at design conditions 4000 Pa
- ✓ Design air pressure 1 MPa
- ✓ Design air flow-rate 6.1 kg/s
- ✓ Design air pressure drop 1200 Pa
- ✓ Thermal power 280 kW
- ✓ Overall heat transfer surface 165 m^2
- ✓ Overall thermal conductance 21 W/m^2K
- ✓ Finned tube outside diameter 21.3 mm
- ✓ N° of ½”tubes 22
- ✓ Fan electrical power 15 kW
- ✓ Fan speed 50-3000 rpm

2.8. Valves

The loop is provided with the necessary valves for regulation, flow configuration and safety control. The main control valves, FV 213, FV 234, FV 235 and FV 10, are globe valves with a metallic bellow tightness, pneumatically actuated and with a stem opening indicator system. The on/off valves, FV 230, FV 231, HV 250, HV 251 , HV 2, FV 247 and FV 249, are similar to the previous ones, with a manual or pneumatic actuation and open/close indicator system. Helium leakage is $\leq 1\ 10^{-5}$ mbar l/s per each valve.

2.9. Passive safety system

Although the control process system monitors the loop continuously, both during normal and off-normal conditions, and there is an additional redundant independent protection system, a passive safety system is also provided according to the Italian Authority (ISPESL) and its Standard Rule.The passive safety system is based on a series of safety rupture disks located on the expansion tank and on two of the heater vessels. The explosion value of each disk is certified at 10.6 MPa.

Furthermore, two ¼” bellow safety valves are located on the filling line, downstream of the manual pressure reducer, and on the expansion tank line upstream of the pressure controlled discharging valve.

3. Filling and pressure control system

The helium filling of the loop is carried out by a special line between the gas bottle packages, at 20MPa and room temperature, and the expansion vessel.

The line is provided with:

- ✓ a manual pressure regulator from 20 MPa up stream to 1-10 MPa downstream;
- ✓ a pressure controlled valve for keeping the expansion tank downstream filling pressure constant in the range of 1-10 MPa, within ± 1 %.

The parameters measured are the temperature and the pressure in the bottles and the pressure values at the controlled pressure valves.

The design pressure for the filling line is the maximum helium storage pressure, 20 MPa, and the design temperature is room temperature. The relative values for the discharging line are 10 MPa and 160°C respectively.

The facility is not provided with a purification system. The usual grade of the Helium fed in HE-FUS 3 is called 5.5 that correspond to the He purity of 99.9995% with the impurities contents as listed in Table 2.

Table 2: Impurities at HE-FUS 3 loop filling system

Element	Content (ppm V)
H_2	< 0.1
$CO + CO_2$	< 0.2
H_2O	< 3
O_2	< 1
N_2	< 3
C_nH_m	< 0.2

4. Vacuum system

The vacuum system operates in order to protect the facility from undesirable air contamination when it is stand-by mode and is already evacuated of the helium inside the loop. There are two vacuum connections to the loop, opened by two valves, in order to preserve the vacuum in a single part of the loop during particular maintenance operations. These vacuum connections are located on the expansion tank, by valve FV 9, and close to the Test Section, by valve FV 261.

The unit consists of a two-stage rotary vane vacuum pump, He leakage tested, with a volume flow-rate of 120 m^3/h and a maximum vacuum absolute pressure of $1x10^{-3}$ mbar, at a temperature of 90 °C. the unit is completed by a filtering and a oil separator device. The instruments included in this system are a Pirani vacuum gauge head and its control and display unit.

5. Gas analysis system

Gas analysis system operates as an independent unit connected to a number of measurement points by means of their own lines and valves. These connections are located in the expansion tank, by valve FV 8 and, downstream the Test Section, by valve FV 262.

The gas analysis system operates in sampling mode, by means of its own sampling line with a system to reduce the pressure by a multiple expansion from 10 to 0.1 MPa (or atmospheric pressure) ion order to match the inlet pressure limit of the mass spectrometer. A PC computer system records the gas mass spectrum within the range of 1-100 amu. The menu driven software provides data processing, graphic presentation and mass spectrum comparisons with the other data previously stored.

Gas analysis is based on a quadrupole mass spectrometer with:

1. mass range;
2. low partial pressure;
3. automatic peak adjustment.

The gas analysis pump unit consists of a rotary vane vacuum pump, He leakage tested, with a volumetric flow-rate of 47 m^3/h and a maximum vacuum absolute pressure of 2x10-3 mbar, at a temperature of 90 °C and a turbo-molecular pump of 50 l/min at a pressure of 1x10-5 mbar. The instruments included in this system are a Penning and a Pirani vacuum gauges and their control and display units.

6. Facility control and measurement system

6.1. Process control system

The loop can be managed, for each functioning mode, by an automatic Process Control system (PCS) or manually acting on the regulating chains both located in control room.

The PCS consists of one PLC unit and two PC computers, one used for the loop control and the other for changing the loop parameters. The entire operation of the lop, both the logic sequential functions and the regulating functions, are controlled by PLC.

The PC computers, in parallel and contemporary, communicate between the regulation loop system and the PLC, via an RS 232 interface. The computer screens also provide synoptic views of the loop, visualization of the regulation loops, alarm processing and loop control.

The Synoptic pages are divided into:

1. general synoptic view of the loop;
2. synoptic view of the hot zone;
3. synoptic view of the cold zone;
4. synoptic view of the filling system.

Moreover, the system enables operator to manage the data and information contained in the PC databases concerning the status of the plant, its instrumentations and components. The PCS synoptic schemes are facilitated by the used of bar-graphs, coloured palettes, blinking flags and so on, or by specific help pages on screen, called up from the keyboard. An alarm management system is provided to constantly monitor the loop and its parameters in order to modify the operating parameters independently of the system's operation.

Further system capability includes specific PC software applications for the data retrieval and graphic presentation. Data post processing, using specific spreadsheet software (i.e. EXCEL) is also provided.

In order to ensure a safe lop management, the diagnostics of the PLC is fully available to the operator by an auto-check of the system. It is possible to verify the correct status of the sensors, decode the function blocks, and visualize the internal parameters, in ladder logic, of the function blocks.

The three loop functioning modes, isothermal and slow/fast thermal cycling, are controlled and managed in automatic mode by the PCS, even without the continuative presence of personnel.

In case of loop failure, the PCS controls and sets the loop in the safety operating mode.

6.2. Compressor control system

An independent system provides for the control and monitoring of the loop compressor. This is based on a PC computer unit for the system control (PCSC), located in the field near the compressor. This PCSC, via an optical fibre RS 232 serial link, communicates with anther PC system Supervisor (PCSS) located in the control room. The operator, using a LABWINDOWS software interface can prepare and monitor the compressor during the loop exercise. The PCSS transmits to the PCSC the data necessary to manage the inverter driving unit and the helium ancillary circuits, as the pressure of the flow injected to the bearings and the water heat transfer loop parameters, for the compressor start up. The operator can decide to manage the compressor in local mode, acting on its PCSS unit or, in remote mode, submitting the compressor and the opening of the inlet valve FV 10. In the second remote mode, the operators enters the request of flow rates to the flow-meter FT 212 and regulation chain on PCS unit. The PCS converts this flow request into a compressor speed request transmitting it to the PCSC.

Some principal data, as inlet/outlet helium temperatures, the inlet pressure, the compressor head and its rotating speed, are transmitted from the PCSC to the PCS which displays these on the synoptic views and stored them in the databases.

6.3. Measurement and control chains

The operator can manage, in local manual or automatic remote modes, the following six measurement and control chains:

- ✓ TT 232 – Test Section helium temperature with feedback control on the hot by-pass valve FV 235;
- ✓ TT 223 – heater E 219/1 outlet helium temperature with feedback control on the relative SCR heater supply control;
- ✓ TT 222 – heater E 219/2 outlet helium temperature with feedback control on the relative SCR heater supply control;
- ✓ FT 212- compressor helium flow-rate with feedback control on the relative inverter driving motor control;
- ✓ FT 228 – Test Section outlet helium flow-rate with feedback control on the main valve FV 213;
- ✓ TT 242 – air cooler E 240 outlet helium temperature with feedback control on the fan inverter driving motor control.

6.4. Flow measurements

The primary element of the two He mass flow-rate meters, FT 212 and FT 228, is a Vortex flow-meter. In order to compute the massive flow-rate, the volumetric flow signal is integrated with measurement of the temperature and pressure upstream of the flow meter location. The two mass flow-rate meters have an accuracy of 1% FS (0,5 kg/s).

6.5. Temperature measurements

The temperature sensors are thermocouples ANSI K (NiCr/NiAl), with ungrounded junctions for temperature values higher then 200 °C and Platinum Thermoresistances ANSI PT 100 for lower temperature values. The accuracy is better then ±5% on the measuring point.

The thermocouple wire insulator is MgO, and the cladding sheaths is AISI 316. the diameter of the outer thermocouple sheath is 3 mm.

All the measurement points are provided with AISI 316 thermo-wells welded to the pipes and with interchangeable fitting connections.

Only the thermocouples TT 222, TT 223, TT 232, TT 233 and TT 242, used for the regulation chains, are directly exposed to the fluid in order to monitor as rapidly as possible the local helium temperature. The temperature signals are locally compensated and linearized by transmitters. The signals are transmitted to the control room via 4-20mA.

6.6. Pressure measurements

The pressure measurements are based on diaphragm cell transmitters; the pressure signals are transmitted to the control room via 4-20 mA. Only one manometer, mounted on the expansion tank, is a Bourdon type without signal transmission.

All the pressure transmitters are provided with interception manifolds (5-way for differential transmitter). The accuracy of the gauges is better than ± 0.5 % on the measuring point.

6.7. Electrical supply

The HE-FUS 3 building, its technological hall and its auxiliary are connected to a local power supply station with four electrical transformers:

- ✓ N° 2 transformers, 5000 V – 380 V, of 800 kVA;
- ✓ N° 1 transformer, 5000 V – 380 V, of 400 kVA;
- ✓ N° 1 transformer, 5000 V – 380 V, of 250 kVA.

The main electrical charges, the compressor, the E 219 1/2/3 heaters, the E 240 air cooler, the vacuum pump, the control room, the UPS system, the pneumatic valves FV 230, Fv 231, FV 213, FV 234, FV 235 and Fv 240, are connected to an 800 kVA transformer only.

7. Auxiliary circuits

These utilities consist of air, water, electrical power, as supplied to the facility.

7.1. Air supply

The compressor air supply consists of:

- ✓ Volumetric air compressor 1 MPa -35 Nm^3/h – 30°C;
- ✓ Air tank 1 m^3;
- ✓ Filtering unit 1 ppm;
- ✓ Pressure control valves 1-0.01 MPa.

7.2. Electrical Power Supply

The HE-FUS 3 facility is supplied by a transformer 800 kVA and a 3-phase 380 V – 600 A bus way line. The electrical supply is carried-out from the switchboard room to the electrical cubicles or MCC located close to the facility.

7.3. Ultimate Power Supply

The facility is provided with a low-noise absolute continuity Ultimate Power Supply (UPS) unit, with dry cell battery, for continuous operation during outages. The UPS is designed to supply both the Process Control System in control room and the compressor inverter driving unit.

The supply voltage is 220 V, 50 Hz (± 2%) with a power of 15 kW in order to provide sufficient control and monitoring of the facility during the emergency. The emergency power supply unit can operate continuously at full power at least 30 minutes.

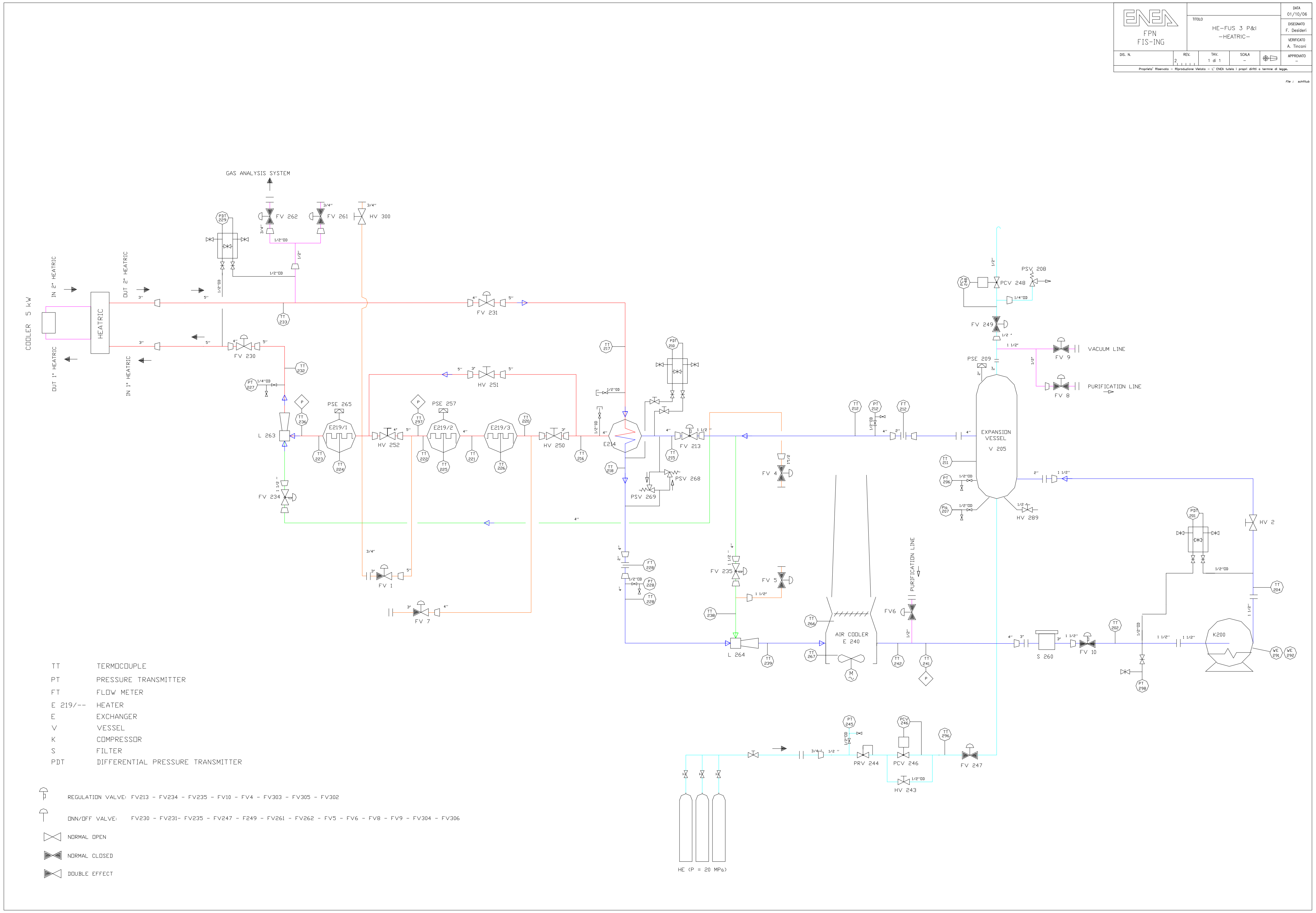
7.4. Water supply

The facility is equipped with a 3-1/2” - 0.3 MPa industrial water supply line.

The supply includes the connection to the exiting line providing the final user units with valves, pressure and flow rate measuring and control system, filtering units and connection to the discharge line.

Reference

[1] *G. Dell'Orco*, "HE-FUS 3, European Cooled Blanket Test Facility for DEMO", ENEA Report DM3ING.DOC, 9/7/1996



HE-FUS 3 P&I
-HEATRIC-
FPN
FIS-ING
GAS ANALYSIS SYSTEM
COOLER 5 kW
HEATRIC
EXPANSION VESSEL V 205
AIR COOLER E 240
VACUUM LINE
PURIFICATION LINE
K200
HE (P = 20 MPa)
TT TERMOCOUPLE
PT PRESSURE TRANSMITTER
FT FLOW METER
E 219/-- HEATER
E EXCHANGER
V VESSEL
K COMPRESSOR
S FILTER
PDT DIFFERENTIAL PRESSURE TRANSMITTER
REGULATION VALVE: FV213 - FV234 - FV235 - FV10 - FV4 - FV303 - FV305 - FV302
ONN/OFF VALVE: FV230 - FV231- FV235 - FV247 - F249 - FV261 - FV262 - FV5 - FV6 - FV8 - FV9 - FV304 - FV306
NORMAL OPEN
NORMAL CLOSED
DOUBLE EFFECT