TITLE

TITOLO

PRELIMINARY DESIGN OF THETIS TEST SECTION FOR THE CIRCE FACILITY

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SUMMARY

SOMMARIO

This document reports the preliminary design of the new test section named THETIS (Thermal-hydraulic HElical Tubes Innovative System) to be installed inside the main vessel of the pool-type facility CIRCE. The layout and the features of the main components of the test section are described, providing a geometrical input data for the development of numerical models involved in the validation process for heavy liquid metal applications.

REV.	WRITTEN/ELABORATO	CHECKED / CONVALIDA	APPROVED / APPROVAZIONE
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LIST OF REVISION

Revision	Date	Scope of revision	Page
0	14/01/2021	First Issue	49
1	17/11/2021	Update on the fitting volume geometry	49

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LIST OF ABBREVIATIONS

ADS	Accelerator Driven Systems
ARS	Argon Recirculation System
CIRCE	CIRcolazione Eutettico (Eutectic CIRCulation)
CFD	Computational Fluid Dynamics
ENEA	Agenzia nazionale per le nuove tecnologie, l’energia e lo sviluppo economico sostenibile
FPS	Fuel Pin Simulator
FV	Fitting Volume
GEN-IV	Generation IV
HCSG	Helical Coil Steam Generator
HERO	Heavy liquid mEtal – pRessurized water cOoled tube
LBE	Lead-Bismuth Eutectic
LFR	Lead cooled Fast Reactor
MCP	Main Circulation Pump
MYRRHA	Multi-purpose hYbrid Research Reactor for High-tech Applications
PATRICIA	Partitioning And Transmuter Research Initiative in a Collaborative Innovation Action
RVACS	Reactor Vessel Auxiliary Cooling System
THETIS	Thermal-hydraulic HElical Tubes Innovative System
TS	Test Section

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1 INTRODUCTION

Within the R&D program of GEN-IV Lead Fast Reactors (LFRs) and Accelerator Driven Systems (ADSs), the PATRICIA (Partitioning And Transmuter Research Initiative in a Collaborative Innovation Action) project (EC – H2020) has been launched by the European Commission to support innovative solutions for the development of MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications).

In this framework, the ENEA Brasimone Research Centre supports such R&D activities through experimental campaigns, involving CIRCE (CIRColazione Eutettico), a large scale pool-type facility using Lead-Bismuth Eutectic (LBE) as primary coolant and pressurized water as secondary fluid. A new Test Section (TS) named THETIS (Thermal-hydraulic HElical Tubes Innovative System) for the CIRCE facility is currently under development and it will replace the HERO (Heavy liquid mEtal – pRessurized water cOoled tube) test section, which is presently installed in the CIRCE main vessel. The new test section will be characterized by new features and some new components with respect to the previous one. In particular, a vertical mechanical pump for the primary coolant circulation and a new prototypical Helical Coil Steam Generator (HCSG) will be installed and tested. This type of steam generator turns out to be very interesting for nuclear power plants, since the helical geometry is very compact and it assures a high power removed, taking up the minimum amount of space. The fuel pin simulator, used for the primary coolant heating, will be kept the same as in the previous test section.

The tests foreseen for the experimental campaigns aim at investigating on the thermal-hydraulic behaviour of the system in the steady state operation (forced circulation regime), during operational and accidental transients (postulated scenarios) and in natural circulation regime, as well as to characterize from a thermal-hydraulic point of view the performances of the HCSG. The stability of the system in natural circulation regime will be studied considering as heat sink the HCSG (acting as decay heat removal system) and the RVACS (Reactor Vessel Auxiliary Cooling System), in stand-alone or coupled operation.

The present document reports the preliminary design of the new test section named THETIS to be installed inside the main vessel of the pool-type facility CIRCE. The layout and the features of the main components of the test section are described, providing a geometrical input data for the development of numerical models involved in the validation process for heavy liquid metal applications.

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2 CIRCE GENERAL LAYOUT

The LBE pool CIRCE is an integral effect type facility [1]. The main systems and components are (see Fig. 1):

- S100 main vessel, conceived to host the test sections. It has an inner diameter of 1170 mm, a thickness of 15 mm, and a height of about 8500 mm. It is partially filled with about 70 tons of LBE and argon as cover gas maintained in slight overpressure. The main vessel is insulated by rock wool to minimize the thermal losses in the environment and it is equipped with electrical heating cables, installed on its bottom and lateral surfaces. The heating cables can reach an operating temperature range of 250÷300°C. The cover gas of the main vessel is also equipped by a self-controlled discharge system and a passive pressure safety system (rupture disks), in order to prevent accidental overpressure;
- S200 storage tank, in which the LBE is stored during the periods of maintenance and refurbishment of the facility;
- S300 transfer tank, used during the filling and draining phases of the main vessel;
- the Argon Recirculation System (ARS): the ARS is equipped by a set of 5 compressors connected in parallel and an argon storage tank, acting as gas lung and directly connected to external gas tanks used for argon re-integration;
- RVACS, which allows the cooling of the external surface of the vessel by mean of air injection;
- a once-through secondary loop to supply water to the HCSG at a maximum pressure of ~18 MPa and a temperature of 335°C.

The main geometrical and operating parameters of the CIRCE facility are summarized in Tab. 1.

Parameter	Unit	Designed
Outer Diameter	[mm]	1200
Wall Thickness	[mm]	15
Vessel height	[mm]	8500
Material	----	AISI316L
Max LBE Inventory	[kg]	90000
Temperature Range	[°C]	200 to 500
Power installed	[MW]	1.0
Pump min/max FR	[m^3/h]	10/30
Pump min/max MFR	[kg/s]	28.19/84.57

Tab. 1 – CIRCE main parameters

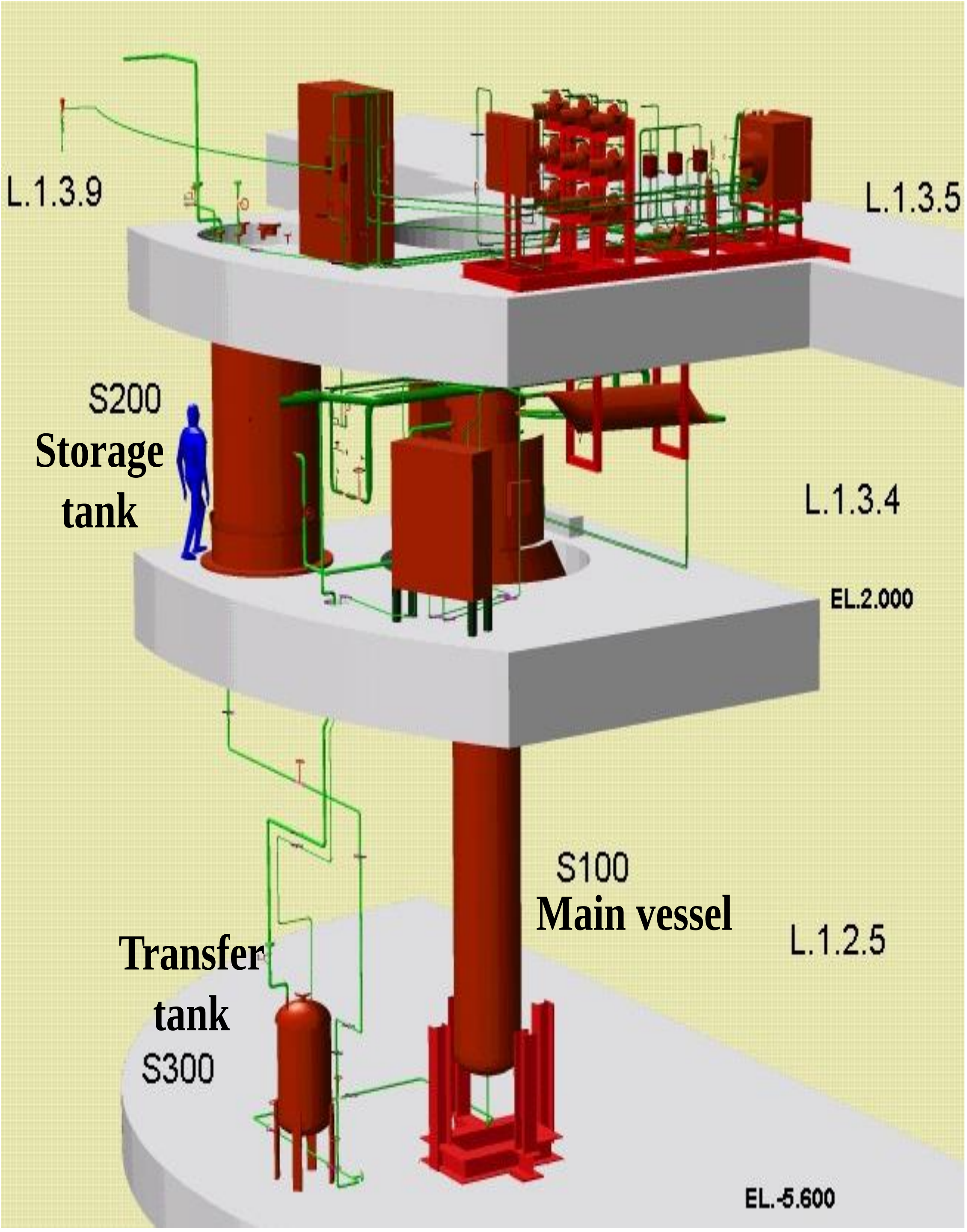

Fig. 1 – 3D sketch of the CIRCE facility

3 PRIMARY SYSTEM COMPONENTS DESCRIPTION

A new test section (Fig. 2, left) is currently under development and it will be composed of the following components:

- Fuel Pin Simulator (FPS), in red in Fig. 2 (left), electrically heated for the coolant heating; it consists of an electrical pin bundle composed by 37 electrically heated pins with a nominal thermal power of ~1 MW; the FPS is already installed in the facility and it is instrumented;
- Fitting Volume (FV), in green in Fig. 2 (left), which collects the hot LBE rising from the FPS;
- riser, in orange in Fig. 2 (left), connecting the FV to the pump suction;
- Main Circulation Pump (MCP), in yellow in Fig. 2 (left), to perform LBE forced circulation [2];
- hot pool (separator, in gold in Fig. 2, left) which will feed the HCSG;
- HCSG, in blue in Fig. 2 (left), for the heat removal from the primary system; this component works in counter-flow, with the LBE flowing shell side downwards and the water flowing tube side;
- dead volume, which encloses and maintains insulated the power supply rods feeding the FPS.

The main flow path of the coolant inside the pool is reported in Fig. 2 (right). The liquid metal enters from the bottom part of the FPS, named feeding conduit (equipped by a Venturi flow meter), and is heated by the electrical pin bundle. Then, the LBE is collected in the fitting volume, from which it flows upward through the riser component and the pump, up to the separator (hot pool) located on the upper part of the TS. From the separator, the hot LBE enters into the shell side of the HCSG, where it is cooled by secondary pressurized water flowing in the tube side of the helical tube bundle. During the cooling, the LBE flows downward through the HCSG shell side and it is discharged into the main vessel, closing in this way the LBE primary loop inside the pool.

The primary coolant can flow along the test section in forced circulation regime by means of the MCP or in natural circulation regime, thanks to the different heights of the thermal barycenters of FPS and HCSG.

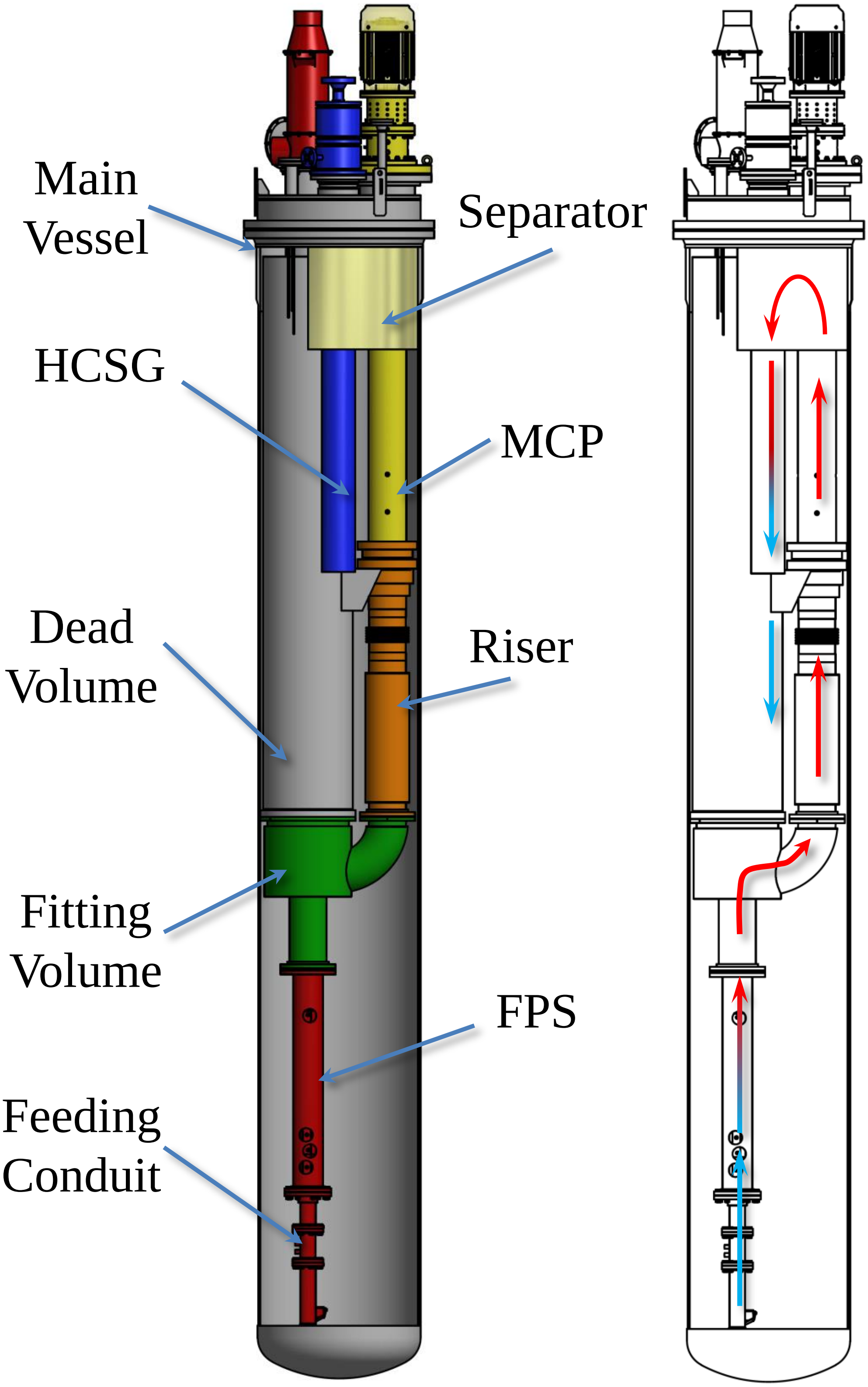

Fig. 2 – Schematic view of the THETIS Test Section (left) and LBE main flow path (right)

3.1 Feeding Conduit

The feeding conduit is composed by three sections connected by 4" flanges (Fig. 3). Two of these (the lower and the upper ones) are 4" sch. 40 pipes with respectively length of 450 and 270 mm. A Venturi flow meter of 250 mm length is installed between these two parts [3]. The differential pressure measured by flow meter includes hydrostatic and dynamic pressure head. The pressure drops across other two sections are negligible compared to the flow meter ones. The mass flow measurement is performed through two pressure measurement lines [3].

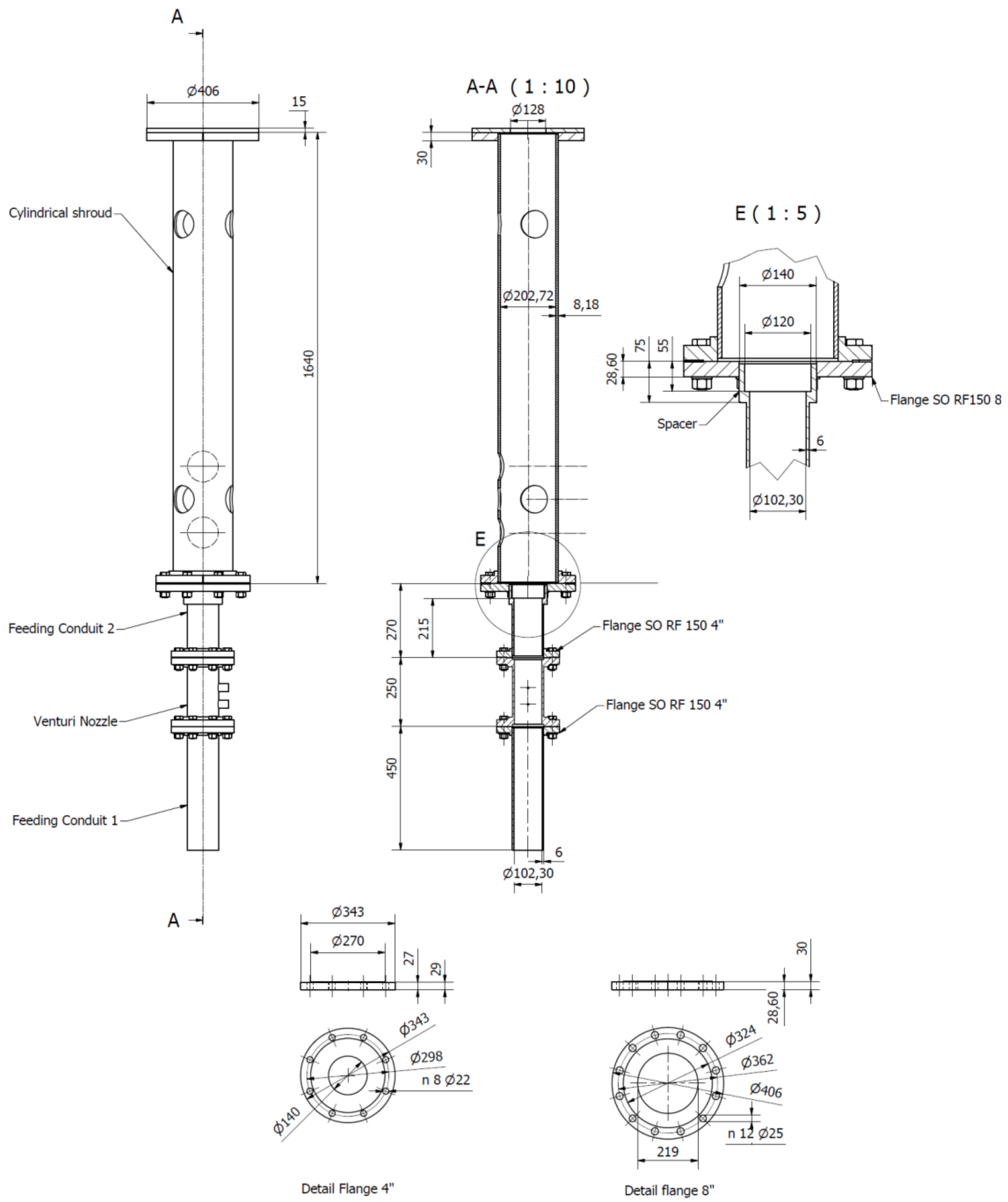

Fig. 3 – CIRCE-THETIS: feeding conduit

3.2 Fuel Pin Simulator

The FPS consists of an electrical pin bundle with a nominal thermal power of 1 MW. The bundle is composed by 37 electrically heated pins (OD of 8.2 mm) arranged in a wrapped hexagonal (inner side of 55.4 mm, *l'* in Fig. 4) lattice with a pitch to diameter ratio equal to 1.8 (on the left of Fig. 4). The design of the component is aimed to provide a coolant temperature gradient of 100 °C/m with LBE average speed of 1 m/s and pin power density of 500 W/cm^3. The design has not been modified with respect to the previous test section CIRCE-HERO.

The electrical pin adopts a double wire solution geometry for the pin manufacturing (on the right of Fig. 4), which implies a thermal flux around the pin not perfectly uniform. From previous calculation the peak factor due to this feature is around 1.15 (15%). The power supply delivers a maximum thermal power of about 25 kW/pin and a heat flux, at the pin wall, of 1 MW/m^2.

Each pin is characterized by an outer diameter of 8.2 mm and total length of 1885 mm. The heat source is limited to the central 1000 mm (Fig. 5). The remaining 885 mm constitute the upstream and downstream mixing zones. These are placed immediately below and over the heating region, respectively characterized by a length of 350 and 535 mm.

The relative position between the pins and the wrapper are fixed by three spacer grids (Fig. 6) placed along the axis of the component. The upper and lower spacer grids are placed between the active and non-active zones of the electrical pins to enclose the mixing zone. The central spacer grid is placed in the mid-plane of the active length.

Moreover, the pins are kept in the correct position with two additional grids: a lower grid (Fig. 7), that guarantees the LBE inlet, and an upper grid (Fig. 8), acting as FPS cap equipped with penetrations for the pins. Downstream of the upper grid, 6 holes allow the exit of the hot LBE.

The FPS hexagonal wrapper is included in a cylindrical shroud, where holes for the instrumentation connections are placed (Fig. 5). These holes are closed with metal foils and the gap, between the hexagonal wrapper and the cylindrical shroud, is filled with stagnant LBE.

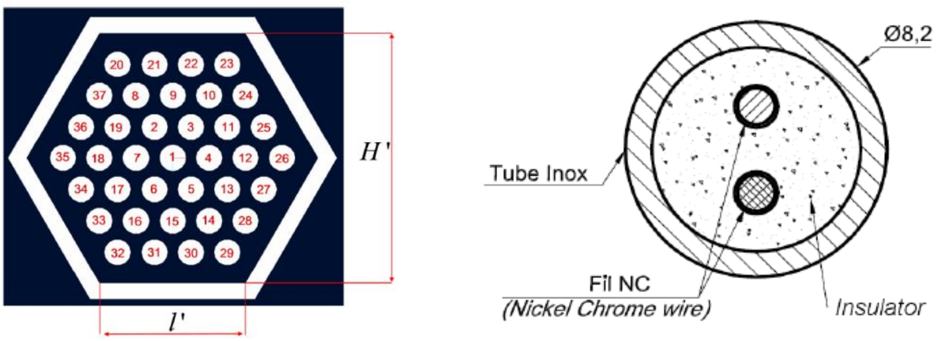

Fig. 4 –FPS cross section (left) and bifilar pin (right)

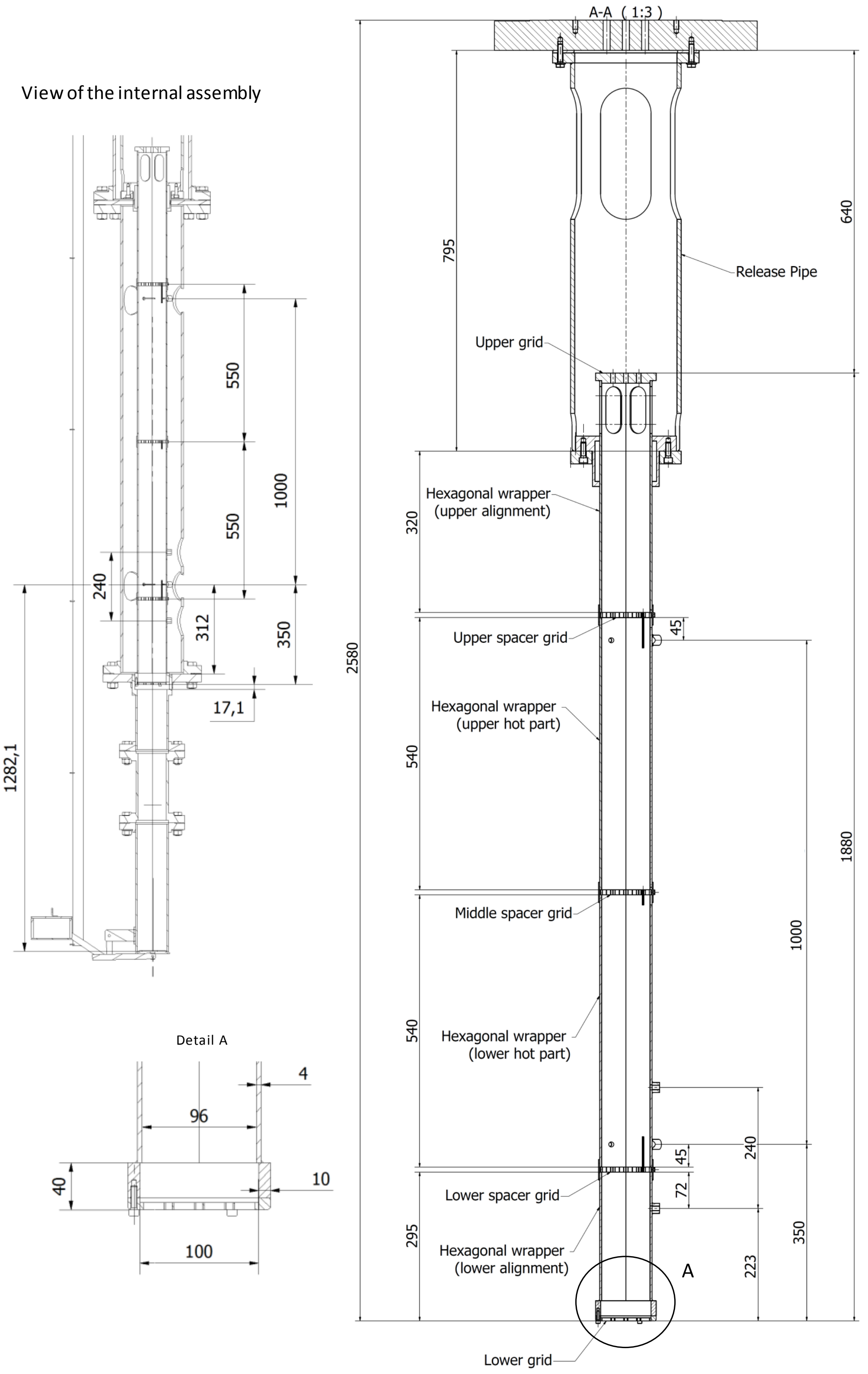

Fig. 5 – FPS arrangement

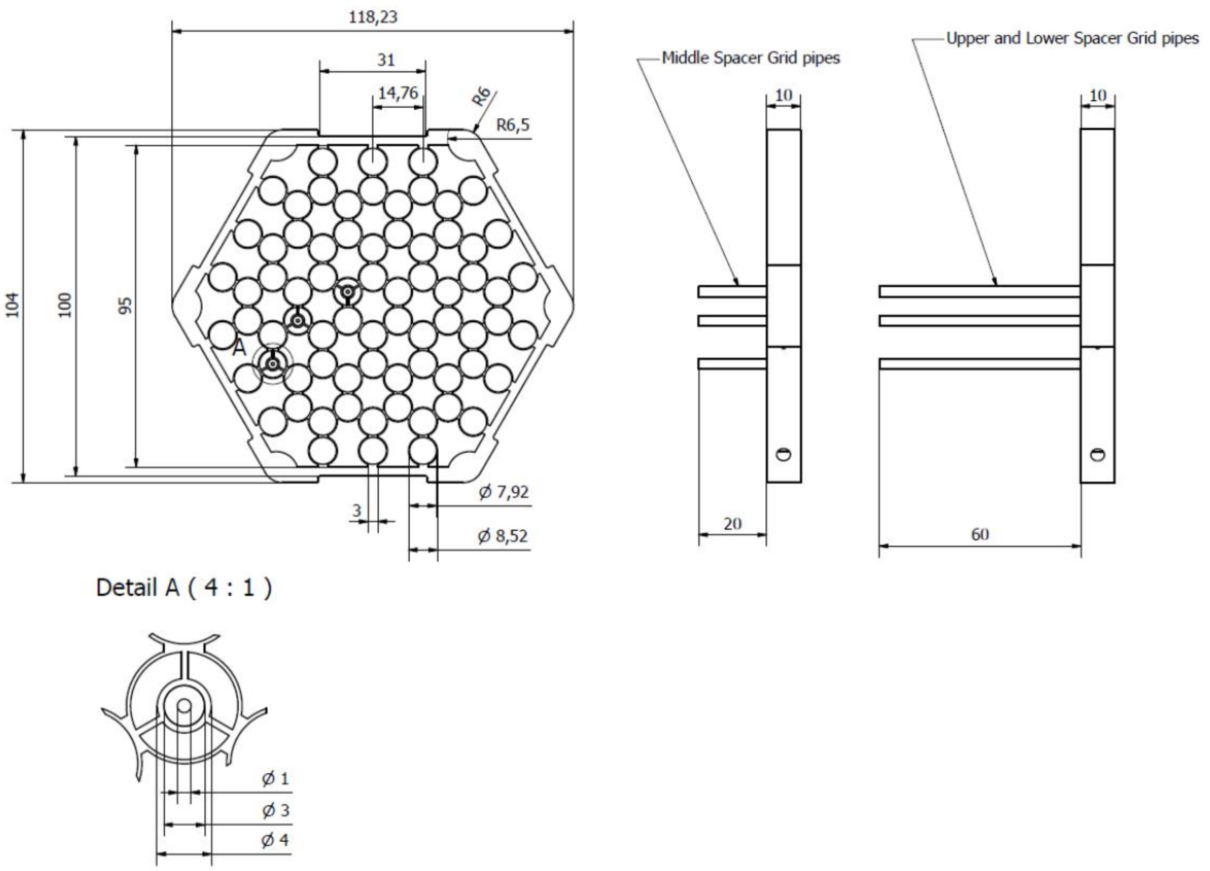

Fig. 6 – Spacer grid

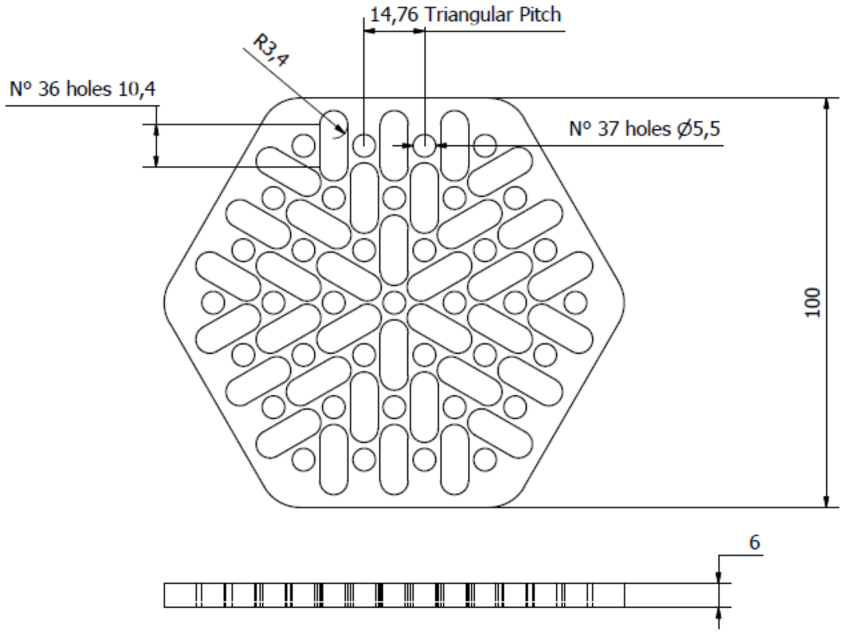

Fig. 7 – Lower grid

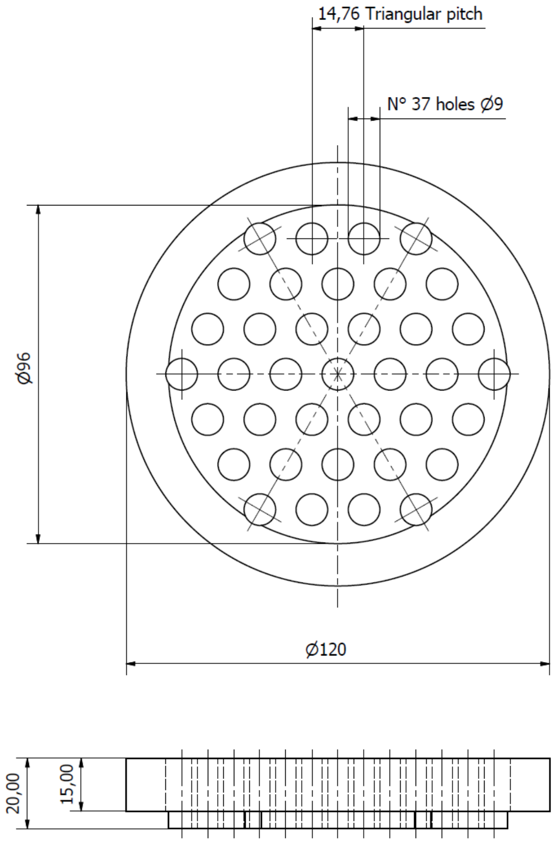

Fig. 8 – Upper grid

3.3 Fitting Volume

The fitting volume allows the hydraulic connection between the heat source and the riser. The hot LBE exits FPS through 6 holes (see Fig. 9) and flows upward inside the release pipe, which is a 8” sch. 40 pipe connected with the fitting volume

Fig. 5 shows the positioning of FPS hexagonal wrapper inside the release pipe. Two series of opening are obtained on the lateral surface (Fig. 10): at the top, 4 holes allow the primary coolant exiting towards the main chamber of the fitting volume and, at the bottom, 2 holes channel LBE inside a 10” sch. 40 pipe (see Fig. 11). At the top of the release pipe, a blind flange drives liquid metal towards the fitting volume and allows the exiting of the pins cold tails.

Fig. 12 shows the main geometrical quotes of the fitting volume. It can be divided into three volumes: the 10” sch. 40 pipe, which includes the release pipe, the main chamber, that achieves the hydraulic connection with the riser, and the upper cylindrical volume, which allows the mechanical coupling with the dead volume through a flange (see Fig. 11). . The fitting volume is double wall with a gap filled by air in order to minimize the heat losses toward the main pool.

A 1/8" tube is connected below the flange of the FV connecting the component with the dead volume. Such tube is supported by the dead volume up to the separator and it allows the discharge of the argon during the filling procedure of the S100, avoiding the establishment of a gas concentration in the upper part of the FV, in the volume between the riser inlet section and the flange connected to the dead volume.

More details of the FV can be found in APPENDIX 1.

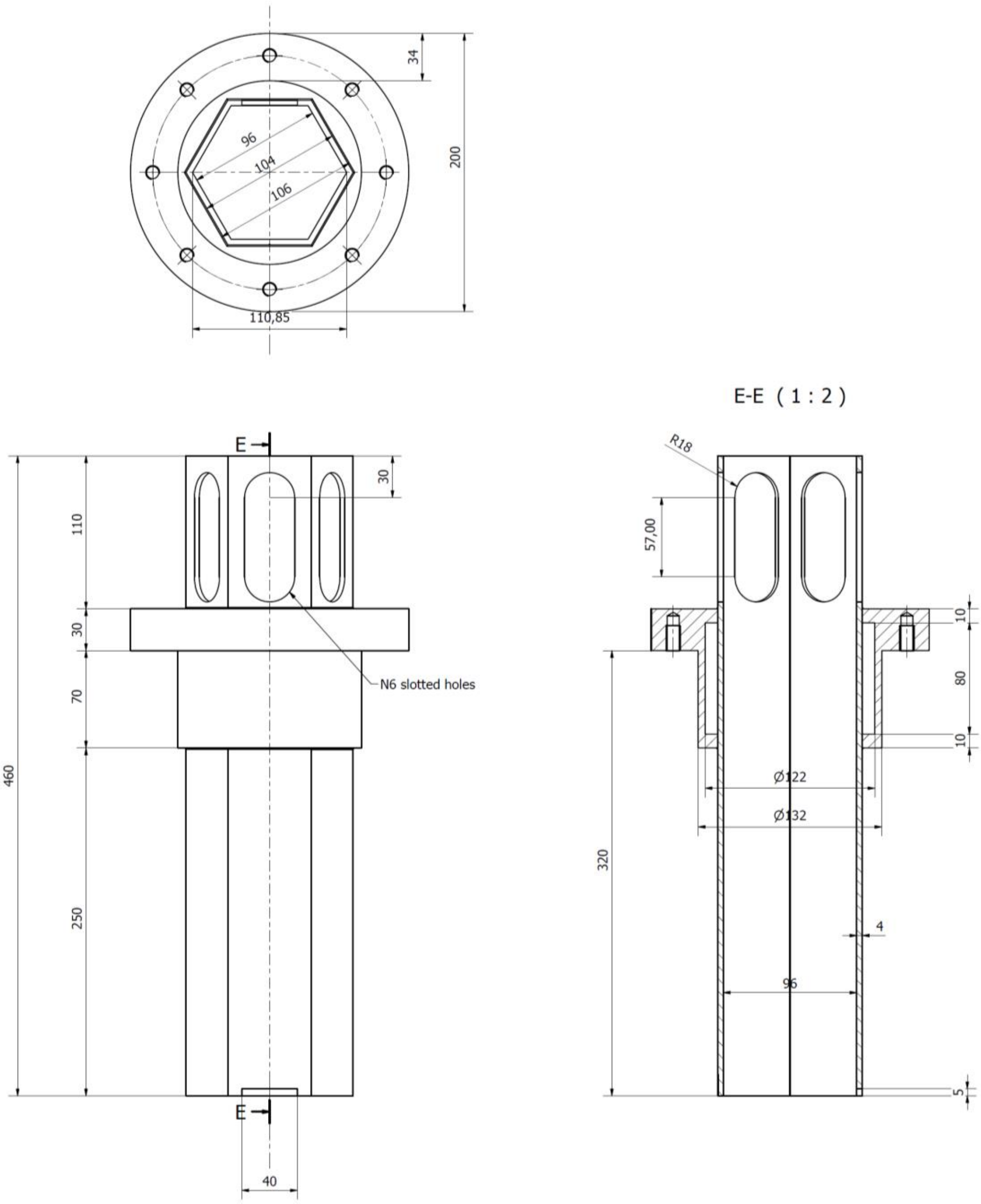

Fig. 9 – FPS hexagonal wrapper (upper alignment)

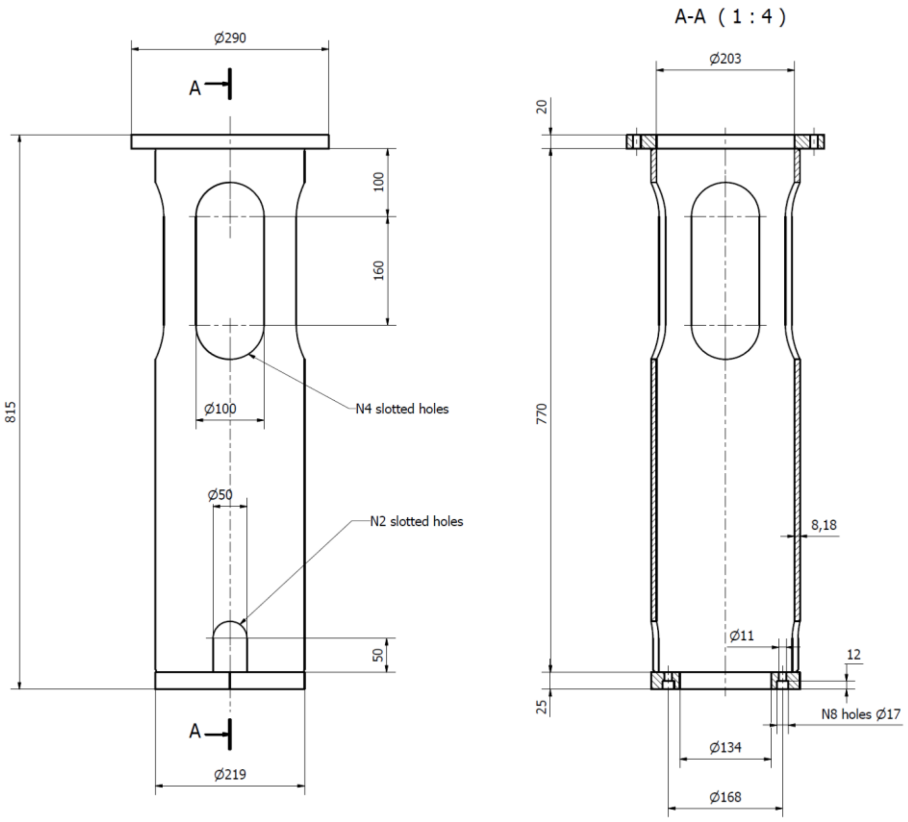

Fig. 10 – Release Pipe

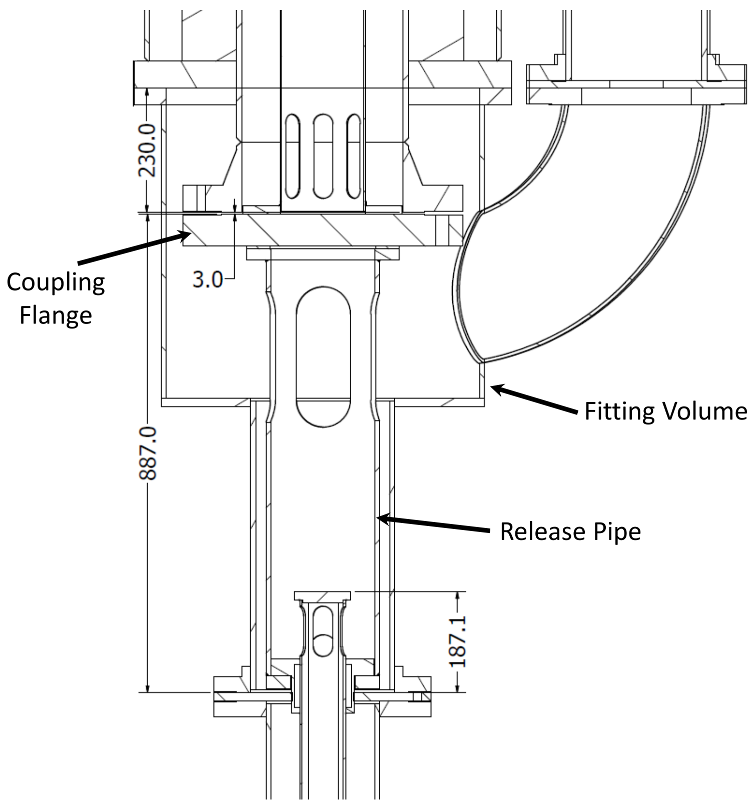

Fig. 11 – Release Pipe location

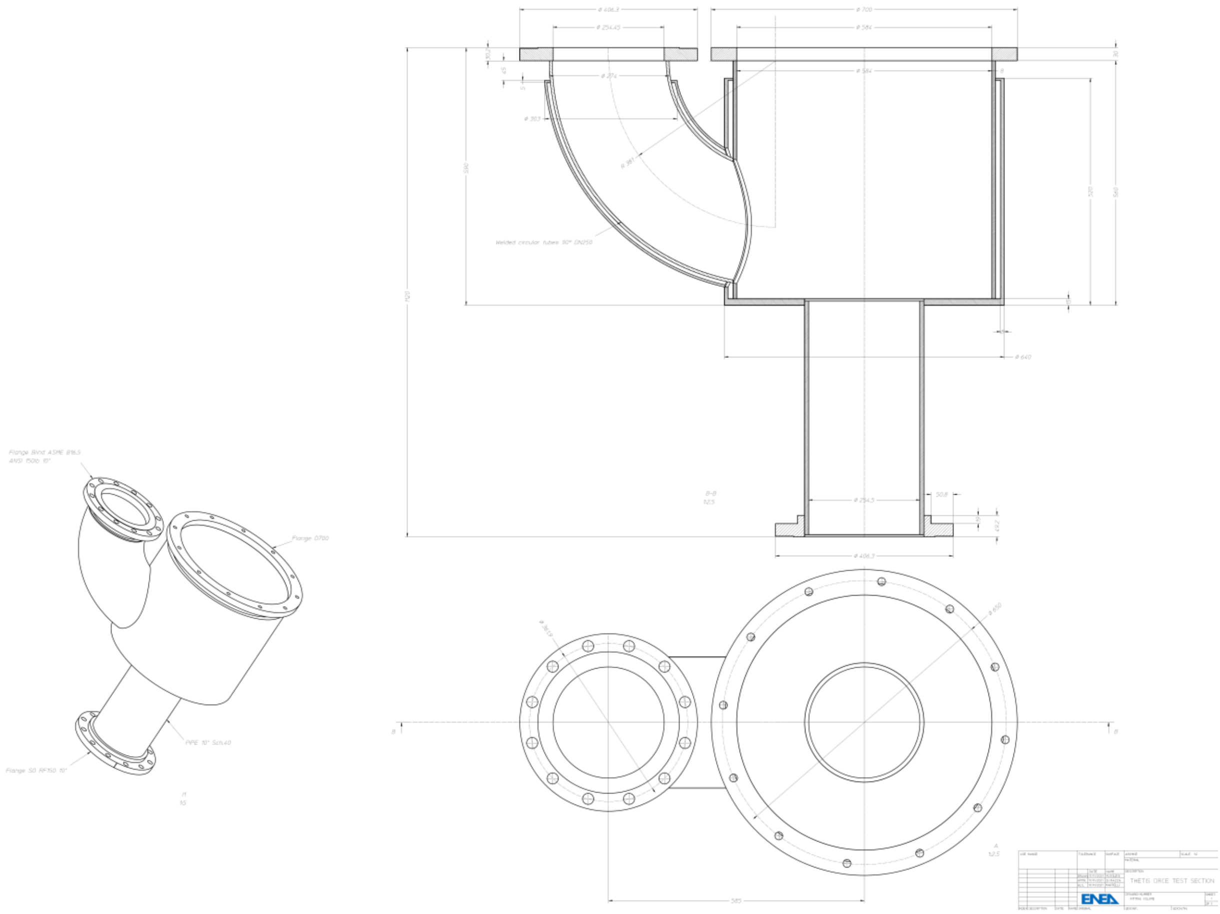

Fig. 12 – Fitting Volume

3.4 Riser

The riser connects hydraulically the FV outlet with the pump suction. It is a 10” Sch.40 pipe characterized by an overall length of 2019.7 mm and equipped with an axial bellow with a length of 380 mm (see Fig. 13). A double wall air-filled pipe prevents the heat losses from the riser to the pool. The external tube has an inner diameter of 304.9 mm, an outer diameter of 323.9 mm and a length of 960.0 mm (Fig. 13).

The outlet section of the riser is provided by a fitting with a change of diameter in order to accommodate the pump suction (see Fig. 14).

Details of the riser geometrical features are reported in APPENDIX 1.

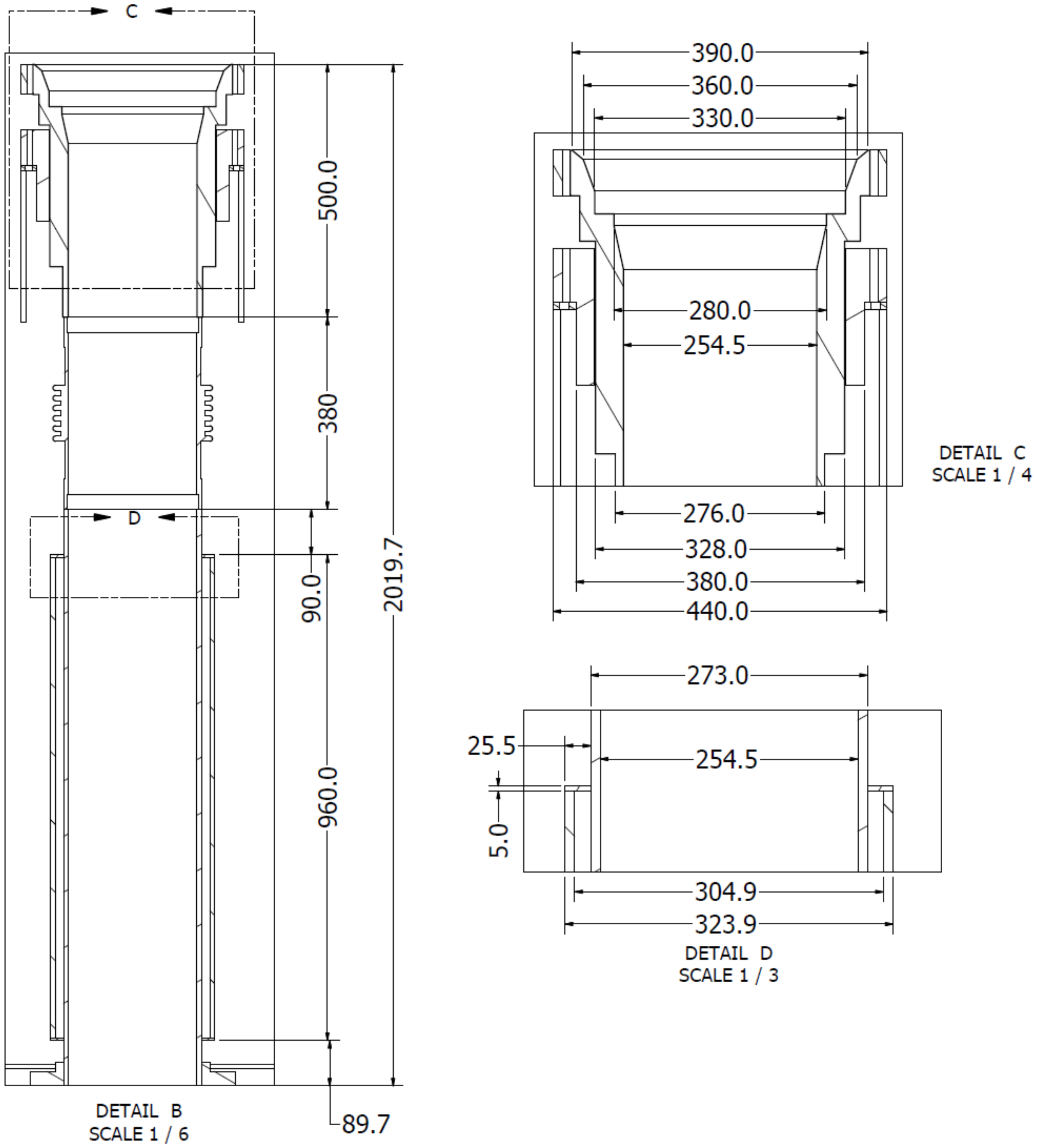

Fig. 13 – View of the riser and details of riser dimensions

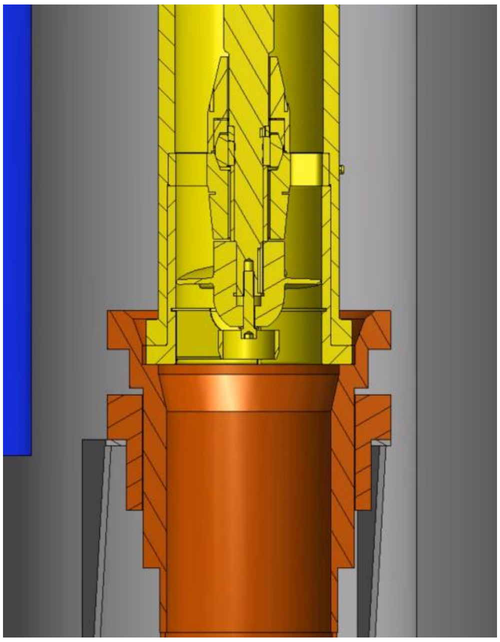

Fig. 14 – Detail of the connection between the riser outlet (orange) and pump suction (yellow)

3.5 Main Circulation Pump

The circulation of the LBE in forced circulation regime is performed by means of a centrifugal vertical pump (Fig. 15) [5]. The pump case and all the parts facing the LBE are built in austenitic steel. The impeller is realized in AISI 316 (Fig. 16). The pump is sustained on the vessel top flange by means of a dedicated coupling flange and it is equipped with an electric motor supplied at 380 V, 50 Hz, for a total power of 30 kW.

The position of the pump is reported in Fig. 17, which also shows the detailed dimensions of the hydraulic connection between the riser outlet and the pump suction. Further details are provided in the technical drawing of the pumps reported in APPENDIX 1.

Fig. 15 – CIRCE-THETIS Main Circulation Pump

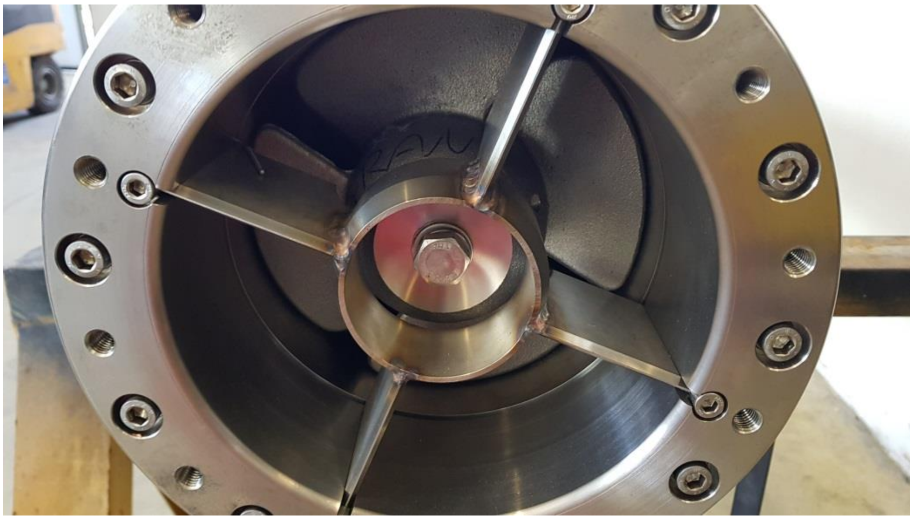

Fig. 16 – Main Circulation Pump, detail of the suction and impeller

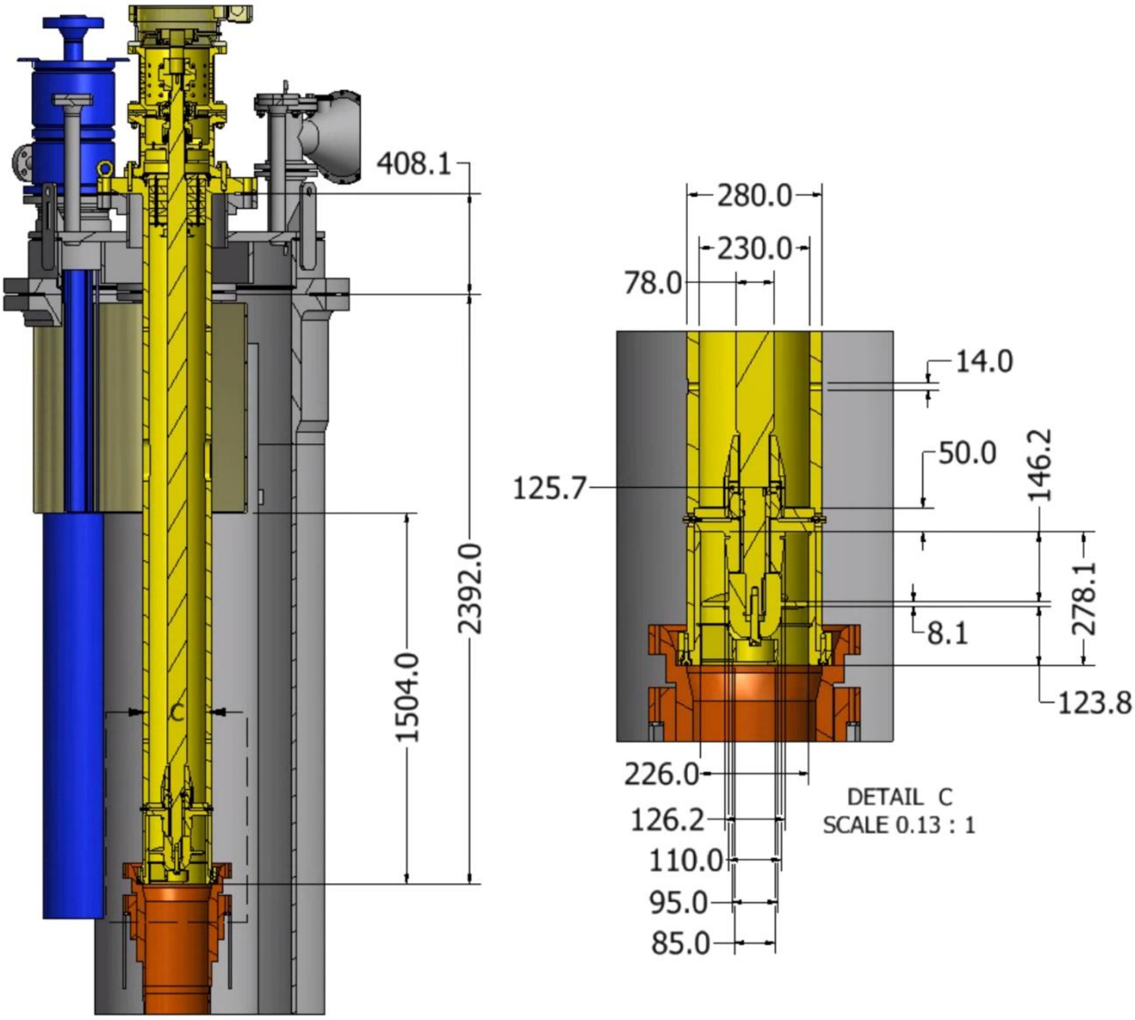

Fig. 17 – Pump position and details of the pump suction

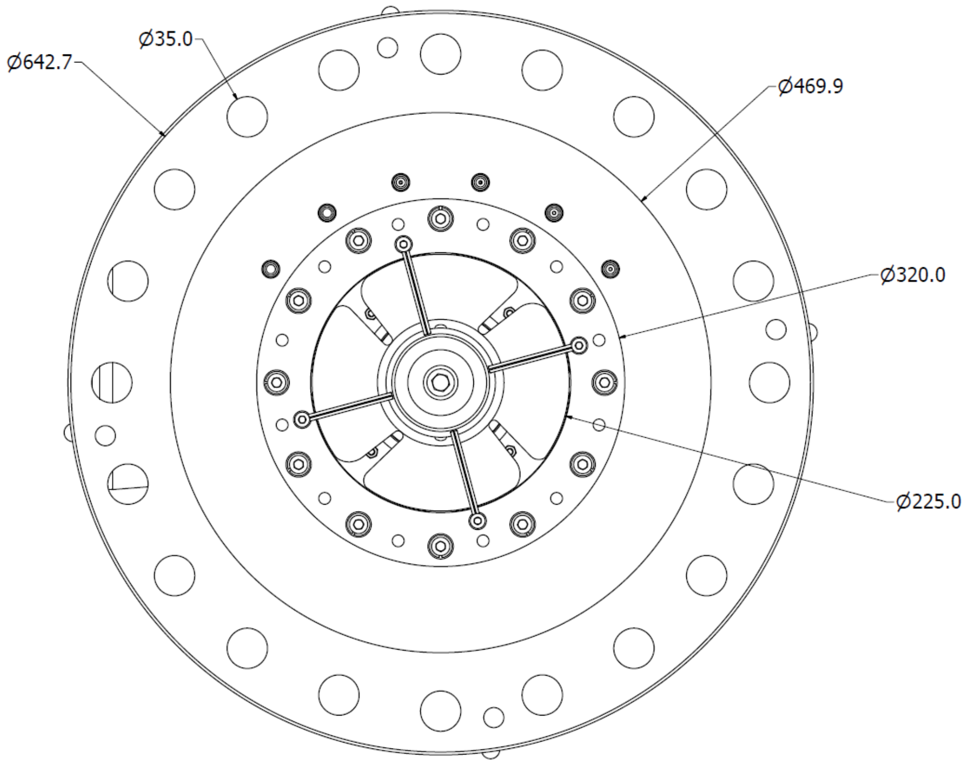

Fig. 18 – Bottom view of the pump

3.6 Separator

The separator (hot pool) collects the hot LBE arising from the FPS (see Fig. 19 and Fig. 20). The level of the LBE inside the separator changes as a function of the LBE flow rate elaborated by the pump. In order to avoid that LBE would overcome the separator, the walls have a height of 0.850 mm (see Fig. 20) and this has been computed preliminarily basing on the maximum LBE flow rate foreseen during the tests and the corresponding pressure losses in the HCSG. Furthermore, in this component, the LBE enters in contact with the main vessel cover, which is filled with inert gas (Argon).

From the separator, the hot LBE is driven downward, towards the HCSG inlet, providing in such a way the hydraulic connection between the riser-pump leg and the descending leg (HCSG).

Moreover, the separator has the function of an expansion tank, allowing the LBE to change its volume during transients.

Further details of the separator are provided in APPENDIX 1.

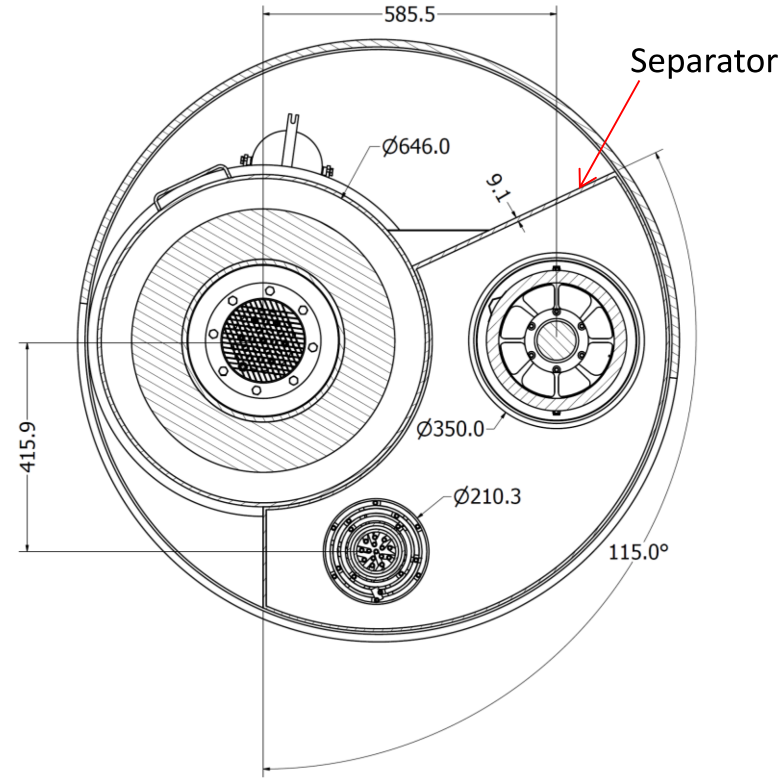

Fig. 19 – Top view of the separator

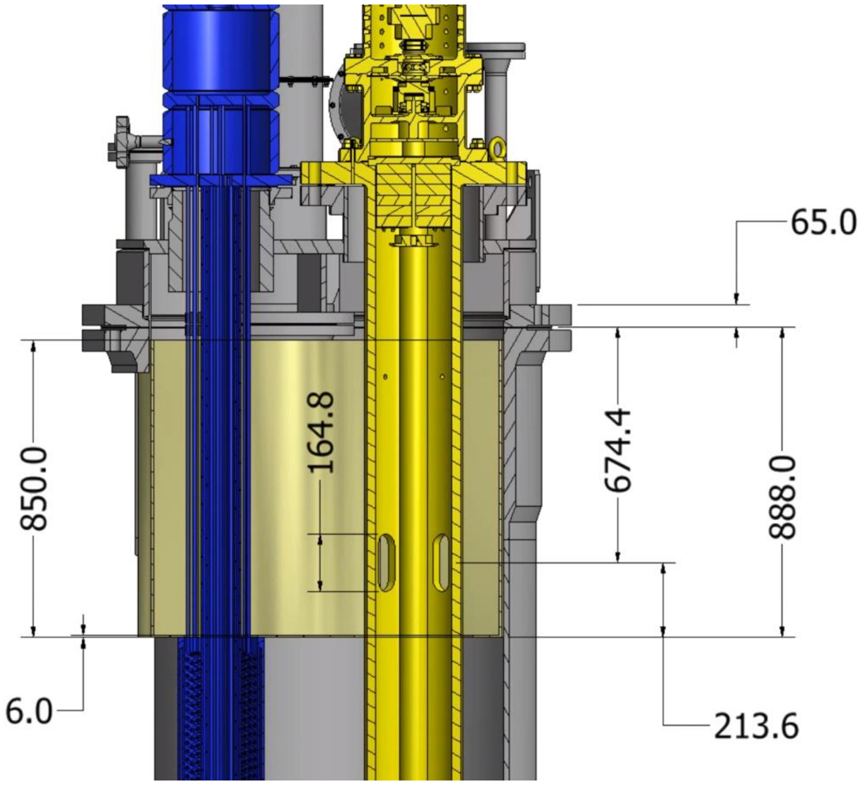

Fig. 20 – Section of the separator

3.7 Helical Coil Steam Generator

The steam generator for the THETIS TS consists of a prototypical solution with a helical tube bundle, which assures a high power removed, taking up the minimum amount of space. The HCSG is conceived to work in counter flow, with LBE as the primary coolant, flowing along the shell side, and pressurized water as secondary coolant, flowing in the tube side. The 2D and 3D views of the component are depicted in Fig. 21 and Fig. 22. Details on the geometrical data of the HCSG are reported in Tab. 2 and Tab. 3, while the technical drawing is reported in APPENDIX 1. The preliminary layout of the HCSG is composed of:

- a top flange (ex-vessel) with a perforated plate to accommodate the downcomer tubes (15 holes) and the riser tubes. The flange connects the HCSG to the CIRCE main vessel and it sustains the feedwater manifold, the steam chamber, the tube bundle and the inner shell;
- a feedwater manifold (ex-vessel) for the feedwater distribution among the tubes. The manifold is welded above the top flange and it has appropriate holes to accommodate the riser tubes which are fixed to the holes by welding to avoid leakages;
- a straight tube downcomer bundle, having 15 tubes 3/8” BWB 16 and a height of 1.5 m, which feeds the helical tube rising bundle;
- a helical tube rising bundle (in-vessel), with 15 tubes 3/8” BWB 16, having a height of 1.5 m, in which the vaporization occurs;
- a steam chamber in which the steam produced is collected (ex-vessel), connected to the discharge line;
- an inner double wall shell, having a height of 1.5 m from the separator bottom, in which the straight tube downcomer bundle is enclosed (in-vessel). The shell is composed by two coaxial shells forming a gap filled by air acting as insulator between the LBE inside the inner shell and the LBE flowing in the annular region between the inner and outer shells;
- an outer double wall shell , having a height of 1.62 m from the separator bottom, surrounding the helical tube riser bundle (in-vessel). The shell is composed by two coaxial shells forming a gap filled by air acting as insulator between the LBE flowing in the annular region between the inner and outer shells and the LBE inside the S100;
- dedicated spacers will be foreseen in order to keep the tubes in position.

Each tube starts from the feedwater manifold on the top part of the HCSG and it goes down straight up to the bottom part, where it curves and rises with a helical shape up to the steam chamber. The coil inclination angle and the vertical pitch are managed in order to maintain constant the length of each helix. The horizontal pitch of the helical ranks is designed to avoid bypass zones for the LBE flow.

The helical tubes are arranged in three horizontal ranks: the inner rank is composed of 4 tubes, the intermediate one is composed of 5 tubes and the outer rank has 6 tubes. The minimum horizontal rank number of 3 is required, in order to assure the representativeness of the component respect to the systems of interest and to reproduce in a reliable way the main phenomena involved.

The three horizontal ranks are wrapped in alternate directions: the inner and outer rank have a clockwise direction, while the intermediate rank has a counter clockwise direction. This configuration aims at reducing the LBE secondary circulation due to the helical shape. This aspect has been investigated in a dedicated CFD analysis reported in the next paragraphs. Actually a strong secondary circulation takes place in the LBE shell side.

The helical tube bundle is enclosed between a double wall outer shell and a double wall inner shell, as shown in Fig. 4. During the operation, the total LBE mass flow rate passes through the annular region formed between the two shells, allowing the heat exchange with the helical tube bundle only. The downcomer bundle is enclosed in a double wall inner shell (see Fig. 4), where the LBE is stagnant. This implies that the heat exchange between the descending feedwater and the stagnant LBE is strongly reduced, since during the operation the two coolants reaches almost the same temperature. In this way, the vaporization occurs in the ascending helical tubes only, avoiding eventual flow instabilities in the tubes during the HCSG operation. The gap within the double wall of the two shells is filled by air acting as thermal insulator. This allows to avoid the heat exchange from the hot LBE flowing in the annular region to the stagnant LBE inside the inner shell and the LBE in the main pool, enhancing in such a way the thermal-hydraulic performances of the component.

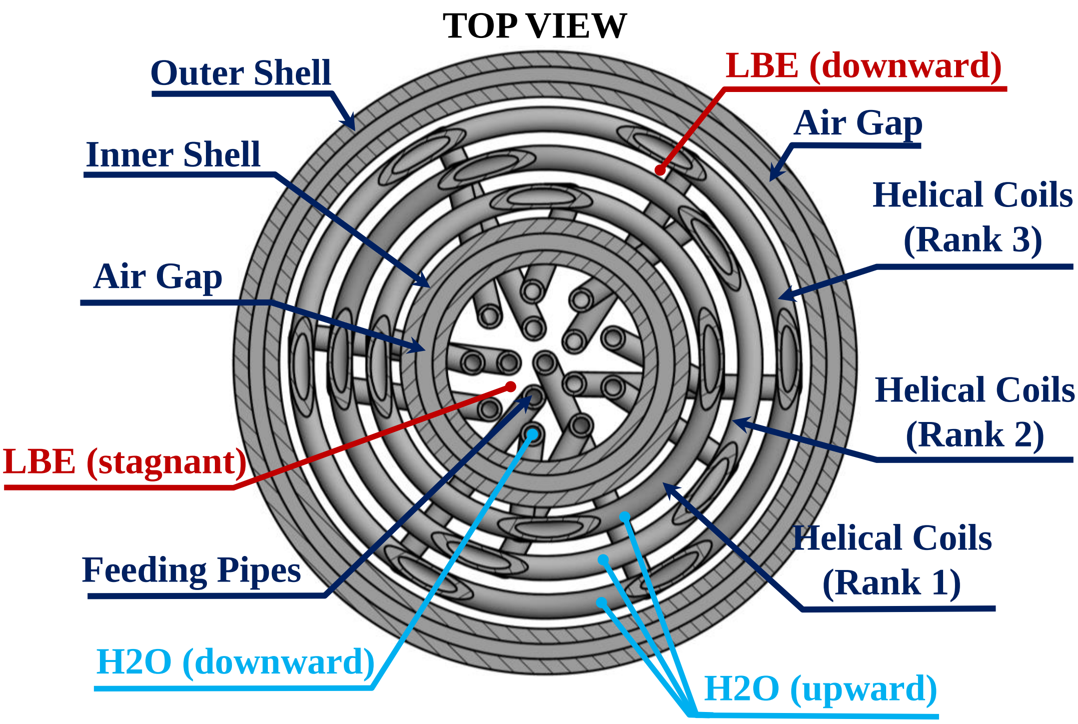

Fig. 21 – Top view of the HCSG

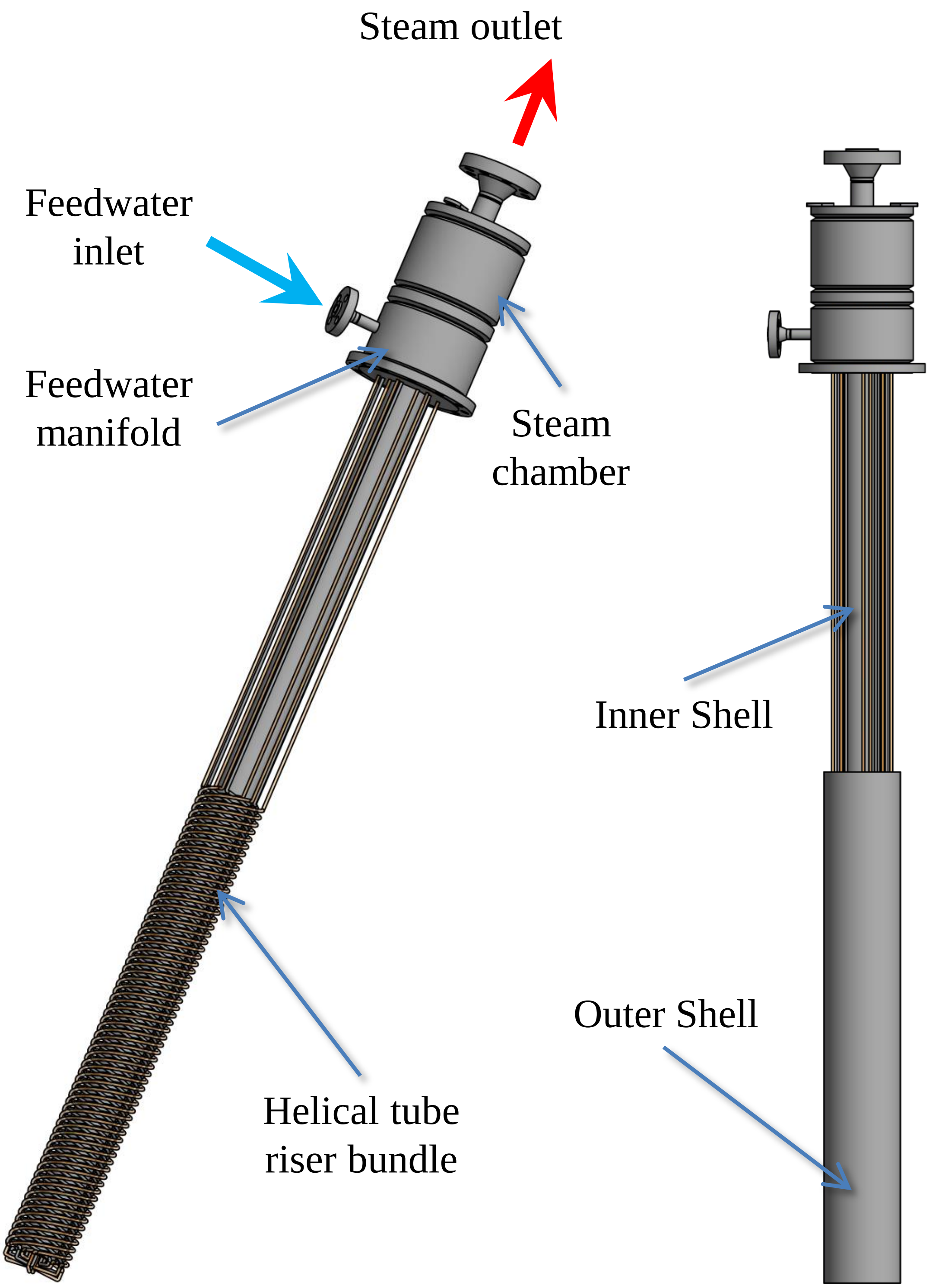

Fig. 22 – 3D view of the HCSG

Geometrical Data	**Unit**	**Horizontal Rank N°1 (inner)**	**Horizontal Rank N°2 (middle)**	**Horizontal Rank N°3 (outer)**
Height	[m]	1.5	1.5	1.5
Tubes I.D.	[m]	0.00622	0.00622	0.00622
Tubes O.D.	[m]	0.00952	0.00952	0.00952
N° of tubes (vertical ranks)	----	4	5	6
Horizontal P/D	----	1.6	1.6	1.6
Horizontal Pitch	[m]	0.0152	0.0152	0.0152
D helix*	[m]	0.132	0.162	0.193
Coil Vertical P/D	----	10.08	12.61	15.13
Coil Vertical Pitch	[m]	0.096	0.120	0.144
Inclination angle	----	13.05°	13.24°	13.38°
L coil (active length)	[m]	6.642	6.547	6.484
Total length 1 tube*	[m]	8.142	8.047	7.984
Vertical Pitch	[m]	0.024	0.024	0.024
Vertical P/D	----	2.521	2.521	2.521
L tot (active length)***	[m]	26.569	32.735	38.901

**Considering the tube axis*
***(L coil + 1.5 m) – lower and upper connections not included*
****lower connections not included*

Tab. 2 – Main geometrical parameters of the HCSG tube bundle

Geometrical Data	**Unit**	**I..D.**	**Thickness**	**O.D.**
Inner Shell (H=1.5 m)				
Inner Tube	[m]	0.07792	0.00549	0.0889
Air Gap	[m]	0.0889	0.00668	0.10226
Outer Tube	[m]	0.10226	0.00602	0.1143
Outer Shell (H=1.62 m)				
Inner Tube	[m]	0.21027	0.006	0.22227
Air Gap	[m]	0.22227	0.006	0.23427
Outer Tube	[m]	0.23427	0.006	0.24627

Tab. 3– Main geometrical data of the HCSG shells

3.8 Dead Volume

The dead volume is composed of two concentric pipes. The inner one at the bottom supports the FPS by the coupling flange (see Fig. 11 and Fig. 23) and at the top is bolted to the cover head flange, bearing the entire weight of the test section.

The volume inside the inner pipe is called insulation volume and it encloses the wirings of and electrical connections to the rods of FPS, which are cooled by air blown near the coupling flange. The annulus between the inner and the outer pipes is partially filled by air and a layer of a thermal insulator in order to reduce the heat losses towards the insulation volume (see Fig. 24).

Details of the dead volume geometrical features are reported in APPENDIX 1.

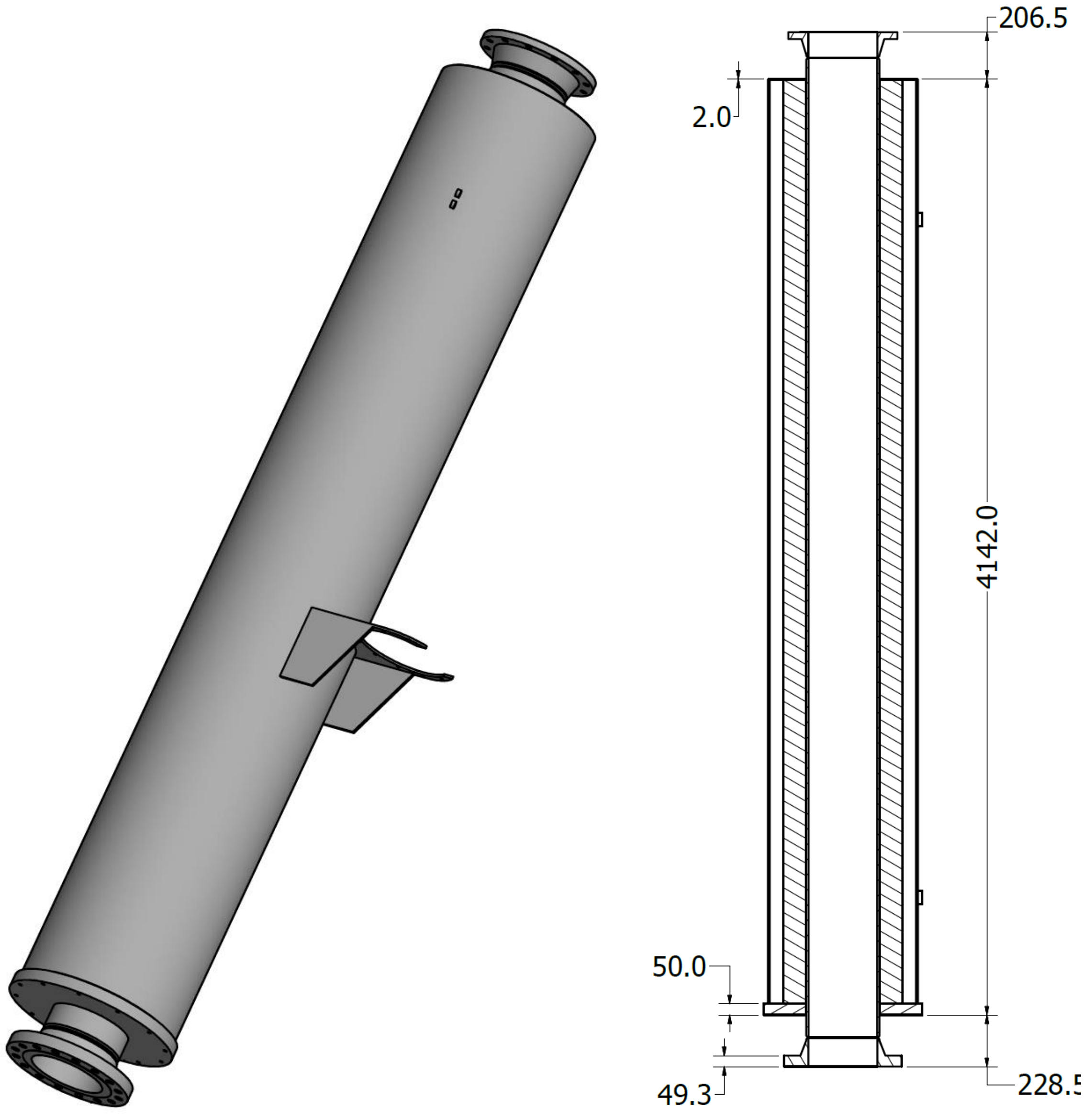

Fig. 23 – Dead Volume

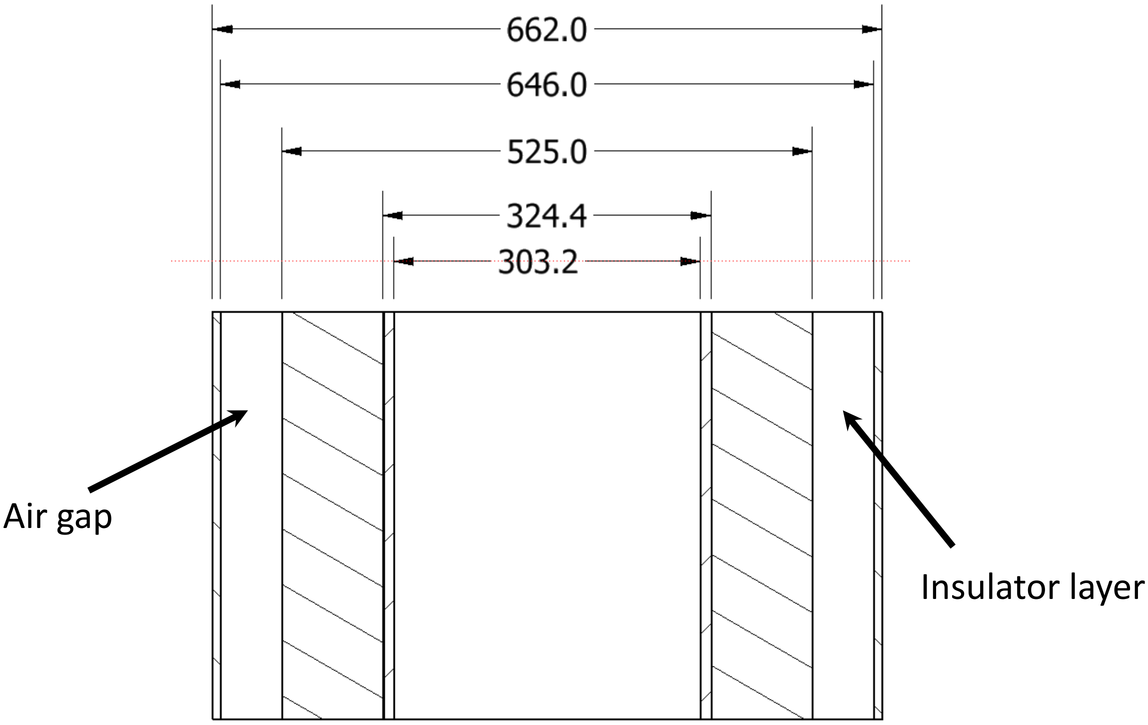

Fig. 24 – Dead Volume, details of the insulation

3.9 Main Pool

The CIRCE main pool consists of the volume between the test section and the main vessel, which allows the hydrodynamic connection between the outlet section of HCSG and the inlet section of the feeding conduit (Fig. 2 and Fig. 25). The positions of the components inside the vessel are reported in Fig. 25 from the level "0.0 mm" in correspondence of the upper flange of the test section, as reported in Fig. 26.

Details of the main vessel top flange are reported in APPENDIX 1.

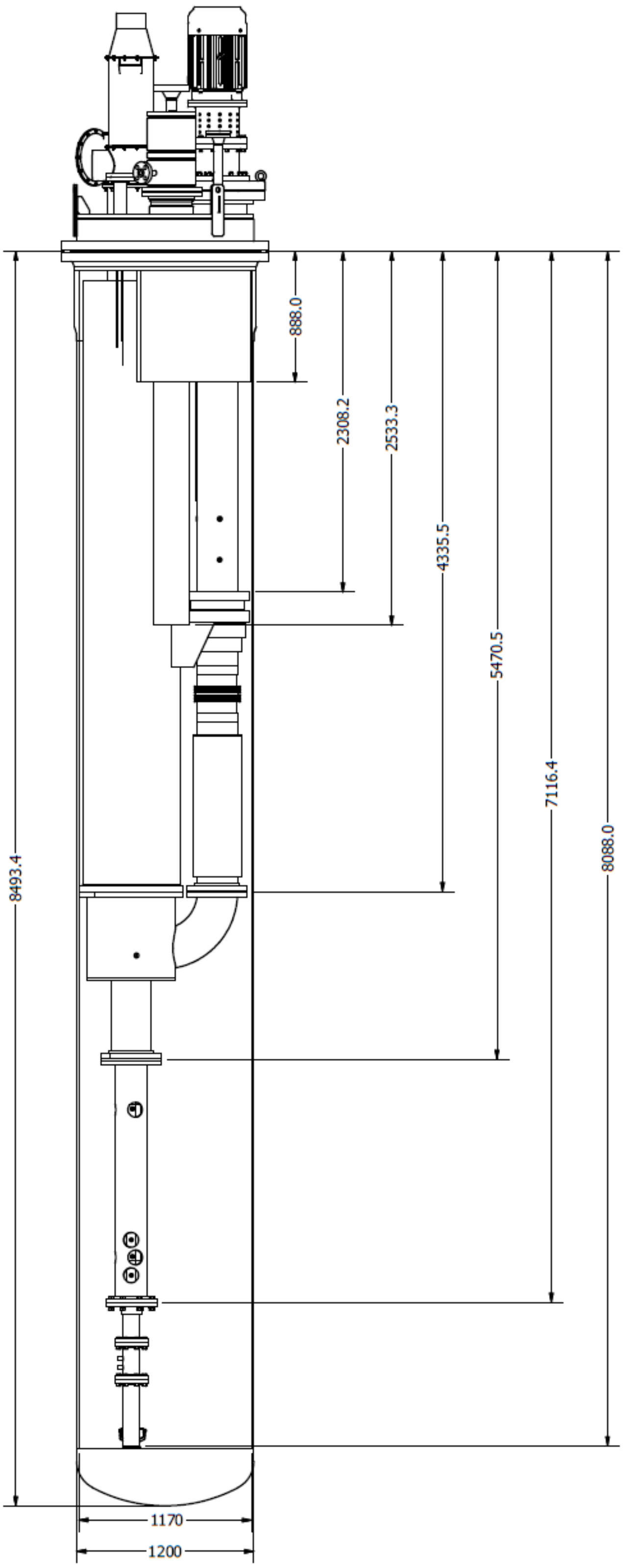

Fig. 25 – Main pool dimensions and positions of the components inside the vessel

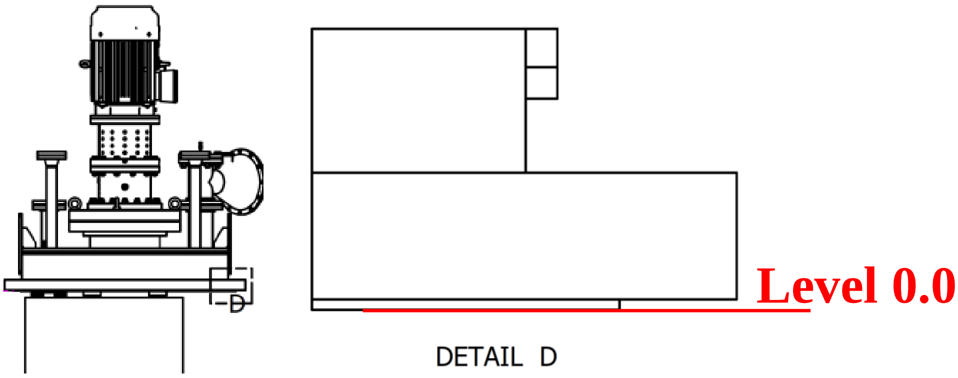

Fig. 26 – Reference position for the level 0.0 mm

3.10 Reactor Vessel Auxiliary Cooling System

The RVACS is a vessel external air circulation system conceived to remove decay power through the main vessel in long-term conditions or in the case the main DHRs immersed in the pool are lost during the postulated transients. In the case of the CIRCE facility, the main vessel S100 must be cooled with an air flow rate flowing externally between the reactor vessel and the insulation. The RVACS for CIRCE was designed and realized by ANSALDO NUCLEARE SPA (ANN) in 2000 as a part of the installation of the whole CIRCE facility [6].

The cooling system consists of a circular gap in the upper part of the S100 shell. The air is circulated by a blower with a flow rate of 2 m^3/s and it enters in the gap in the top part of the shell from two nozzles at 180°. Then the air circulates along the gap for a length of 2200 mm and it comes out from the gap from two nozzles at 180° and at 90° from the inlet ones.

For the main vessel S100, the external diameter of the vessel is D_e=1200 mm, while for the thickness δ of the gap where the air flows between the vessel and the insulator, the value is δ=80 mm. The external diameter of the gap, i.e. the internal diameter of the insulation is $D_r=D_e+2\delta=1360$ mm, with the annular channel closed between D_e and D_r. Details on the RVACS dimensions are reported in Fig. 27.

The RVACS has been verified from an heat transfer point of view by correlation calculations and CFD calculations [7], and it can evacuate about 45 kW with 2 m^3/s of inlet air flow rate in nominal TEHIS condition for the pool. The evacuated power can be modulated by regulating the air mass flow rate.

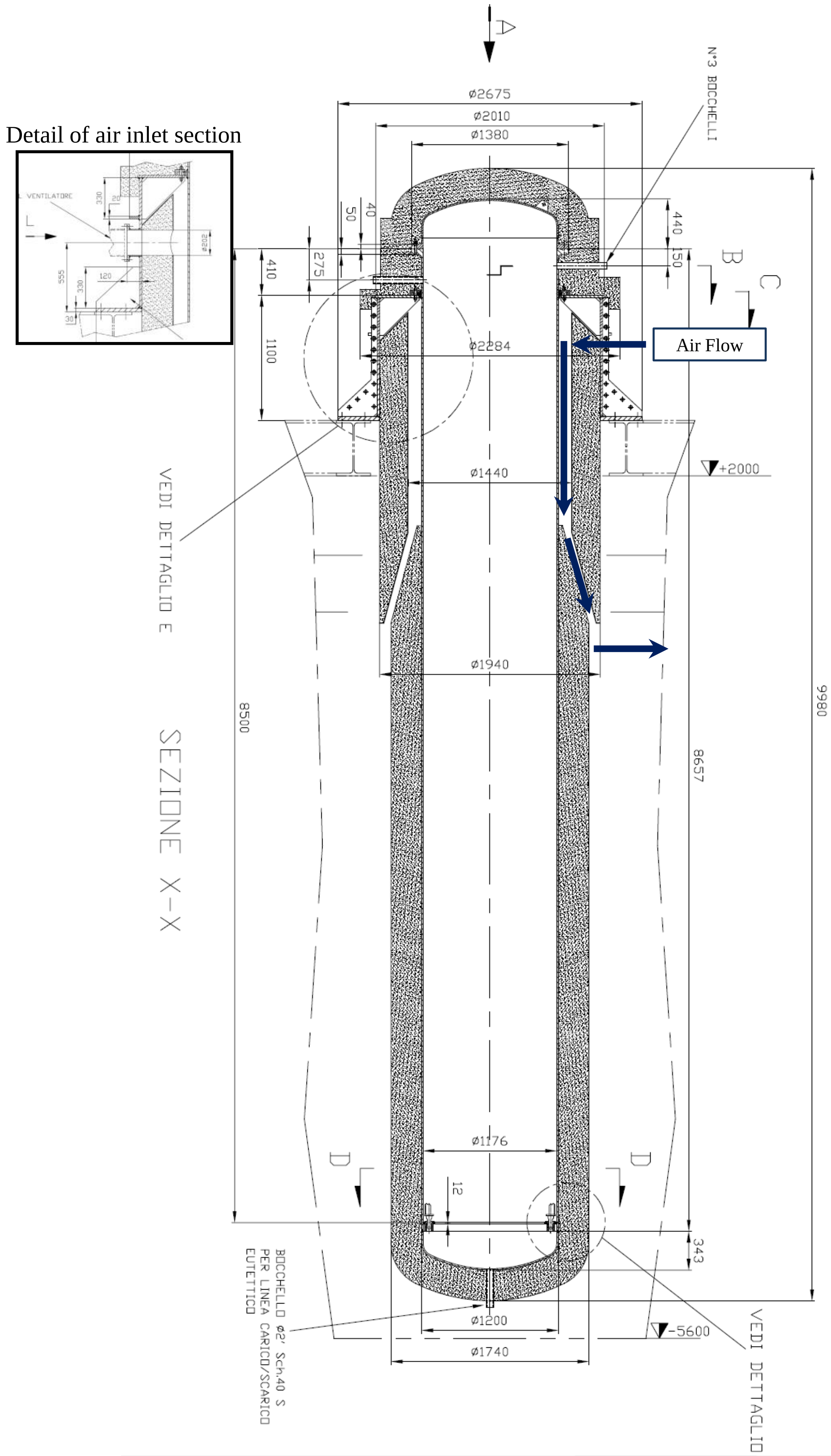

Fig. 27 – RVACS main dimensions

4 CONCLUSIONS

In the framework of PATRICIA project (EC – H2020) Work Package 42, the validation of numerical tools for simulating large 3D scale effects in geometries relevant for pool type LFRs, is pursued comparing different numerical approaches (system thermal-hydraulic codes, CFD models) on the basis of experimental data provided by the pool-type facility CIRCE (WP 42, Task 11). For this purpose, a new test section named THETIS has been designed at ENEA Brasimone R.C. to be implemented in the CIRCE main vessel.

The scenarios intended to be reproduced aim at investigating the thermal-hydraulic behavior of the system in the steady state operation, as well as during operational and accidental transients (postulated scenarios). The THETIS TS is designed to be relevant for LFRs and it is instrumented to provide high quality data suitable for the validation process of numerical tools, with particular reference to relevant 3D phenomena affecting pool natural convection.

This report provides information about the CIRCE facility configuration and geometry of the THETIS test section, highlighting for each component the significant dimensions to ensure reliable input data for the modelling activity.

REFERENCES

[1] A. Pesetti, N. Forgione, V. Narcisi, P. Lorusso, F. Giannetti, M. Tarantino, A. Del Nevo ENEA CIRCE-HERO Test Facility: Geometry And Instrumentation Description CI-I-R-343, ENEA report, June, 22, 2018.

[2] M. Tarantino, PRIMARY PUMP per impianto sperimentale a metallo liquido pesante CIRCE, CI-D-S-355, ENEA report, October, 11, 2018.

[3] P. Lorusso, I. Di Piazza, D. Martelli, A. Musolesi, A. Del Nevo, M. Tarantino, Primary loop instrumentation of the THETIS test section for the CIRCE facility, CI-I-R-517, ENEA report, October, 21, 2020.

[4] P. Lorusso, D. Martelli, I. Di Piazza, A. Del Nevo, M. Tarantino, Preliminary requirements of HCSG test section for CIRCE facility, CI-I-R-449, ENEA report, March, 24, 2020.

[5] M. Tarantino, PRIMARY PUMP per impianto sperimentale a metallo liquido pesante CIRCE, CI-D-S-355, ENEA report, October, 11, 2018.

[6] F. Paoletti, Dimensionamento Sistema di Raffreddamento, CIRCE5TMLX0070, restricted report, 2000.

[7] I. Di Piazza, P. Lorusso, D. Martelli, Conceptual design of the RVACS for the CIRCE facility, CI-I-R-457, ENEA report, April, 2, 2020.

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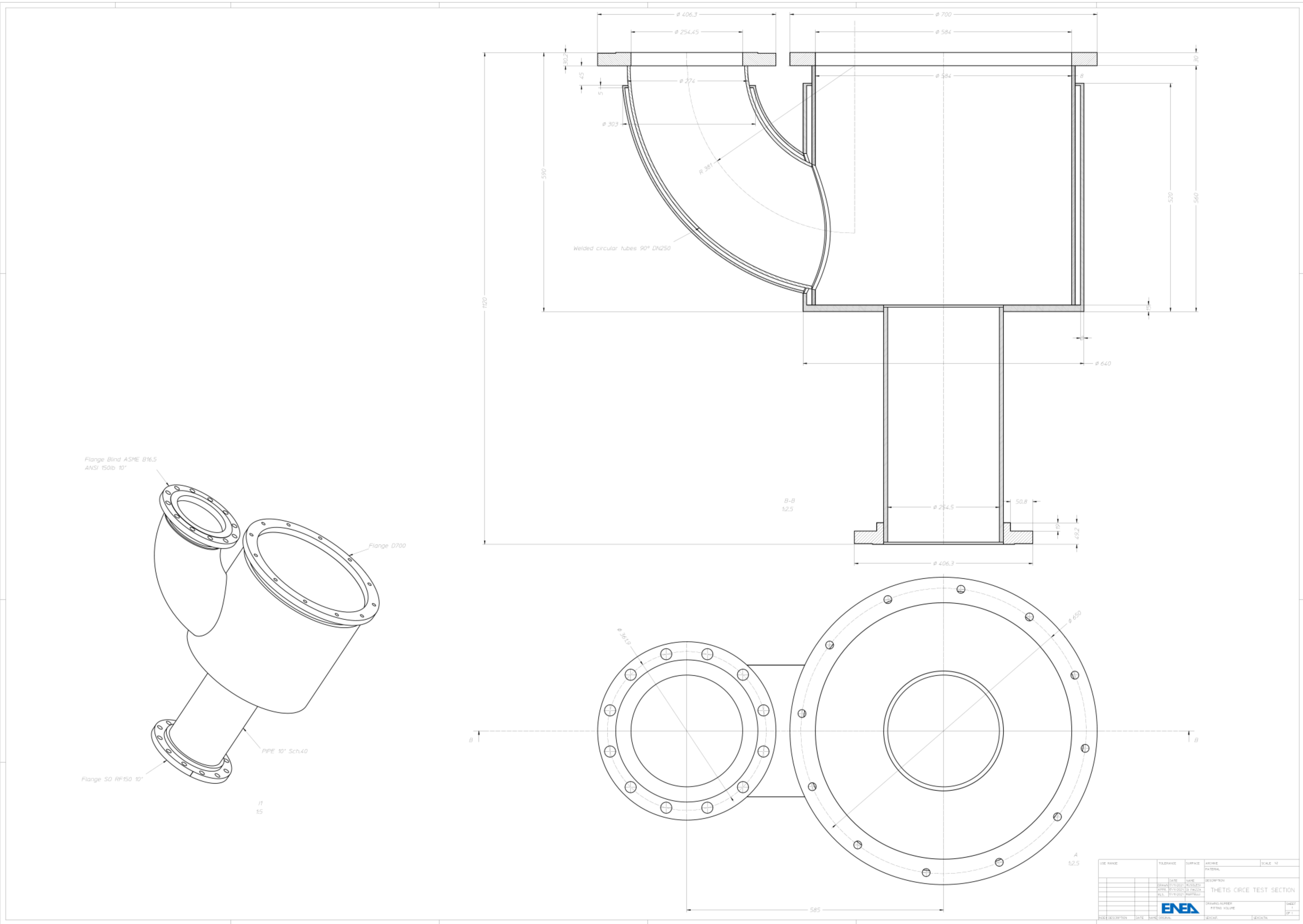
APPENDIX 1

Technical drawings of the THETIS TS components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ø 254.45
ø 274
ø 303
R 381
ø 700
ø 584
ø 640
ø 254.5
ø 650
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1120
590
520
560
30
45
50.8
B-B
1:2.5
A
1:2.5
B
THETIS CIRCE TEST SECTION
DRAWN 17/11/2021 MUSOLESI
APPR. 17/11/2021 DI PIAZZA
RLS. 17/11/2021 MARTELLI
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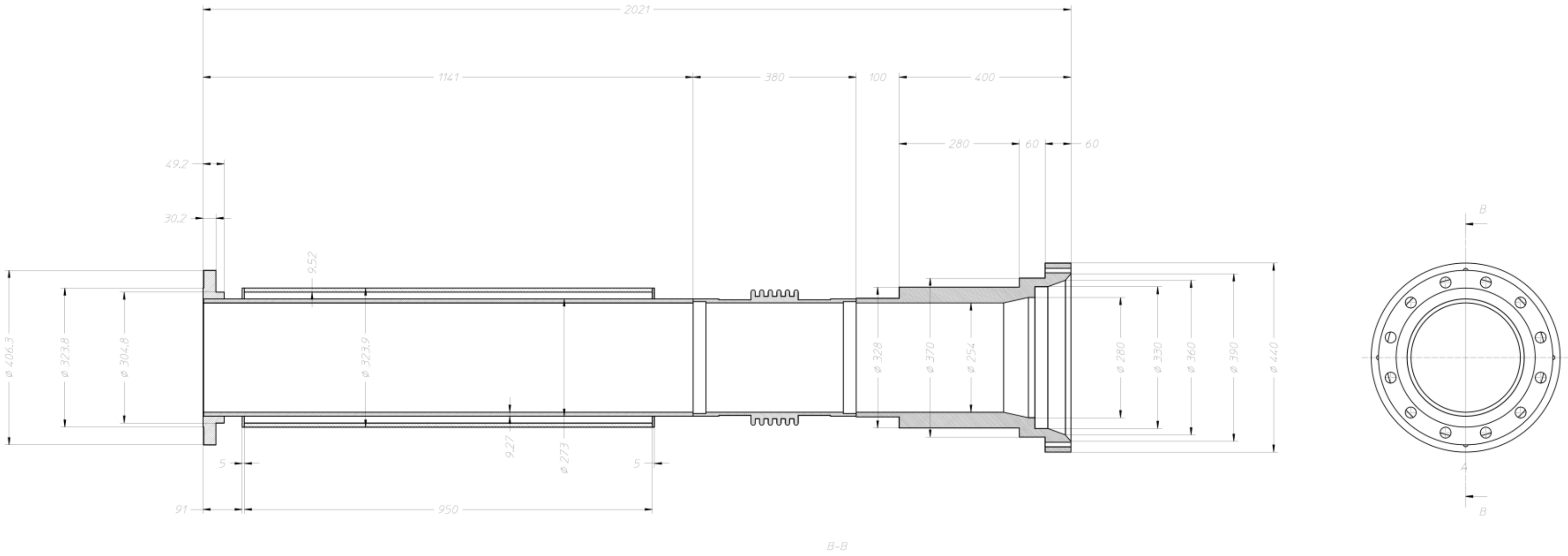
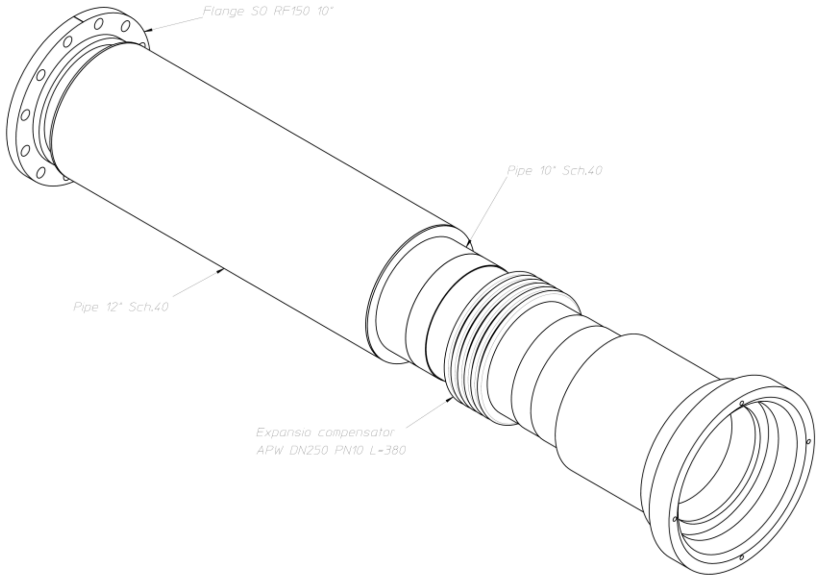
OF 1





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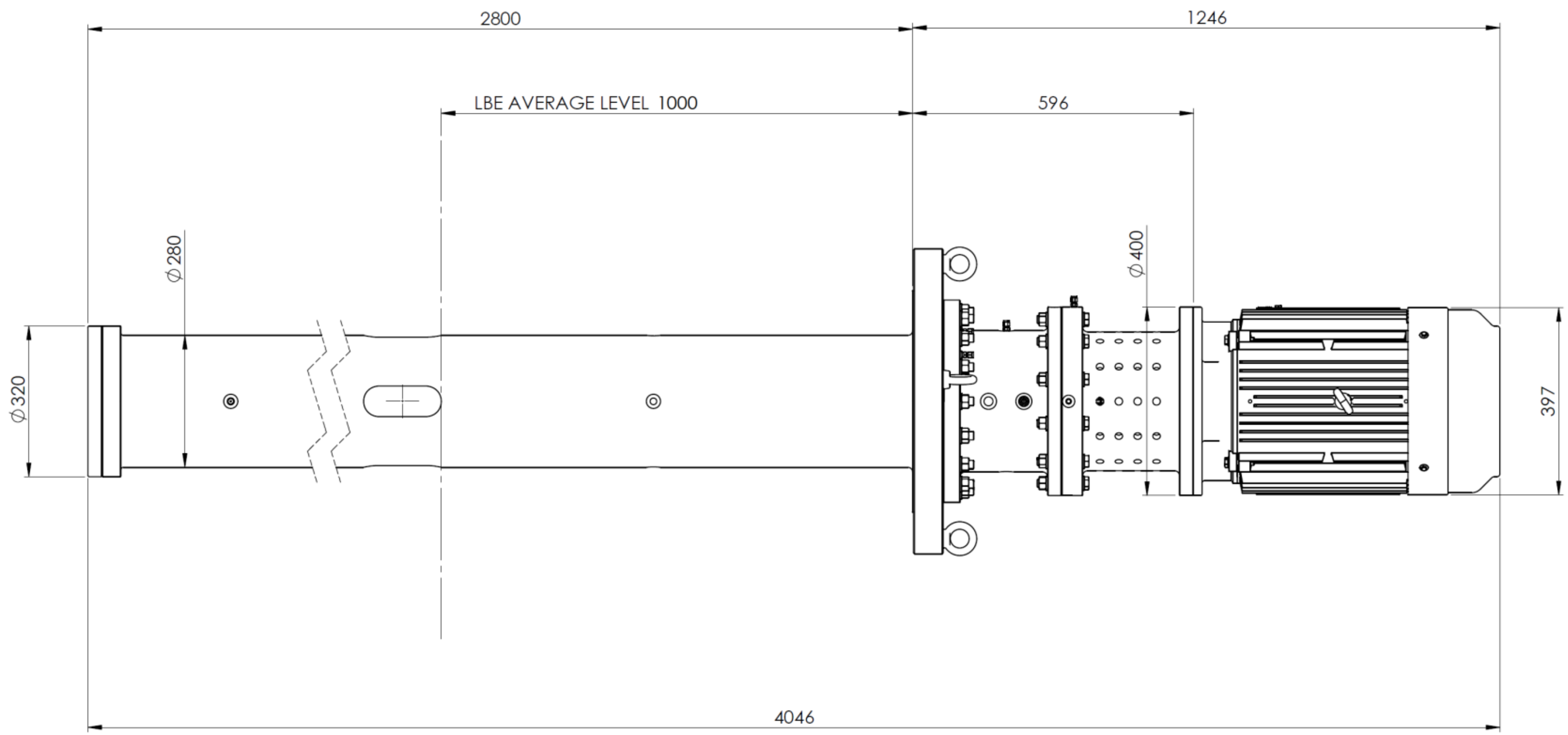

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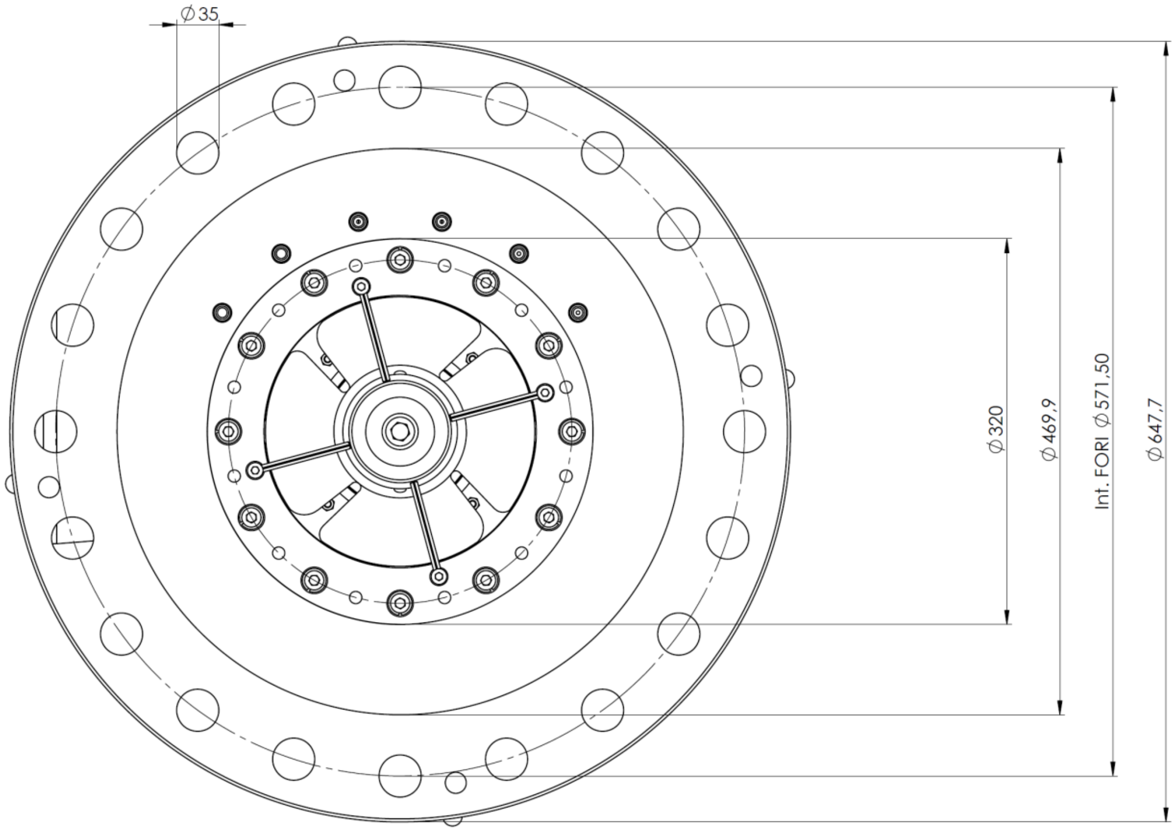

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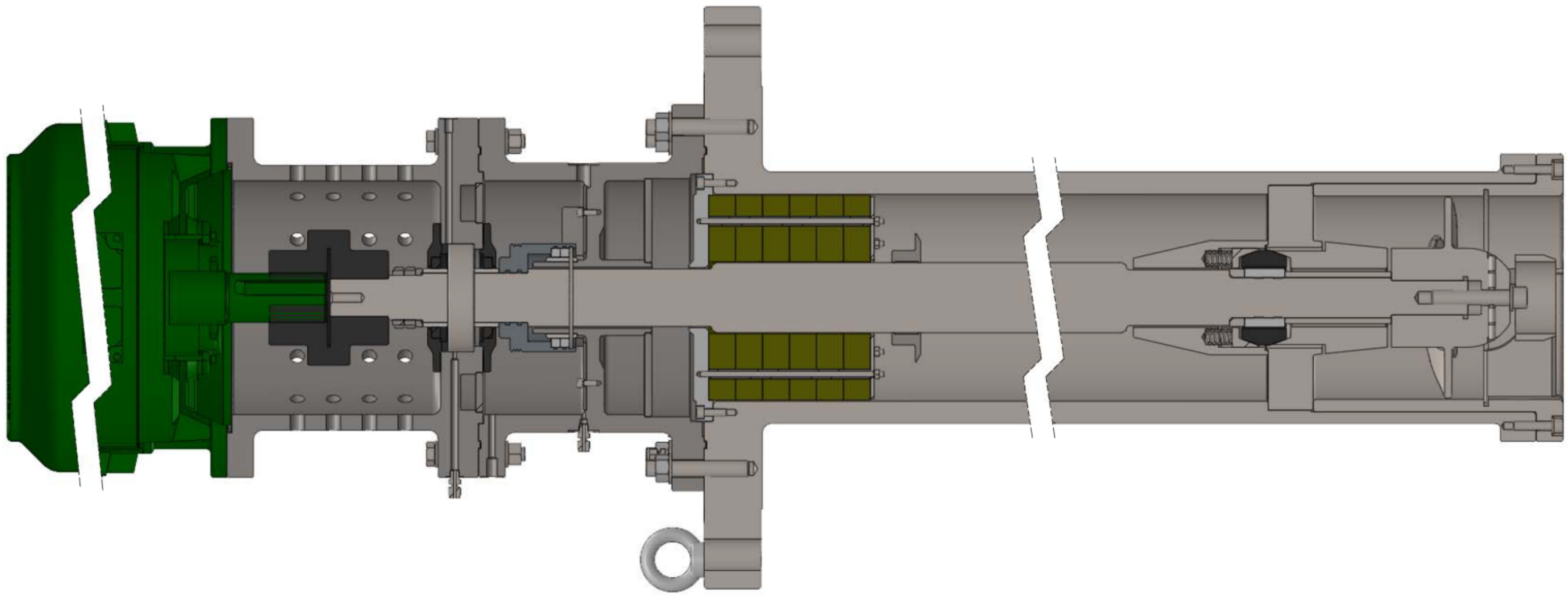

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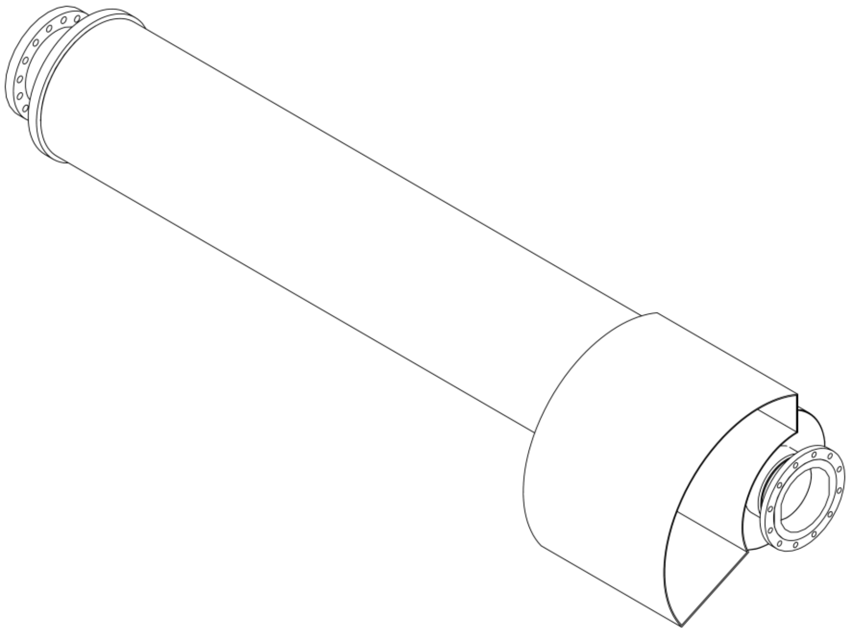

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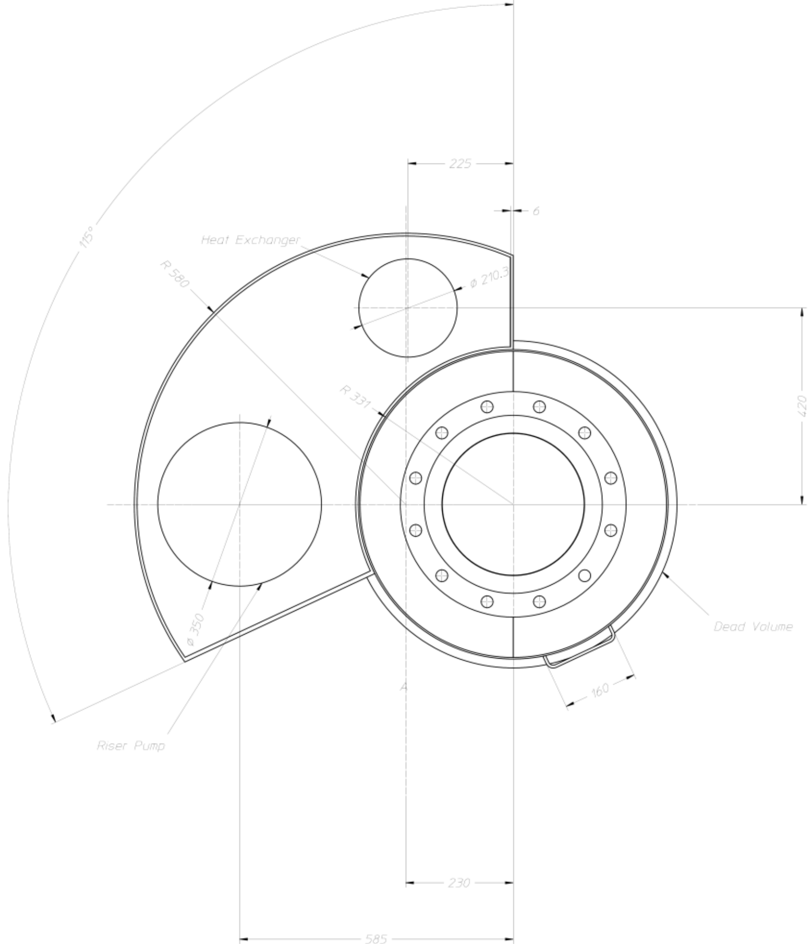

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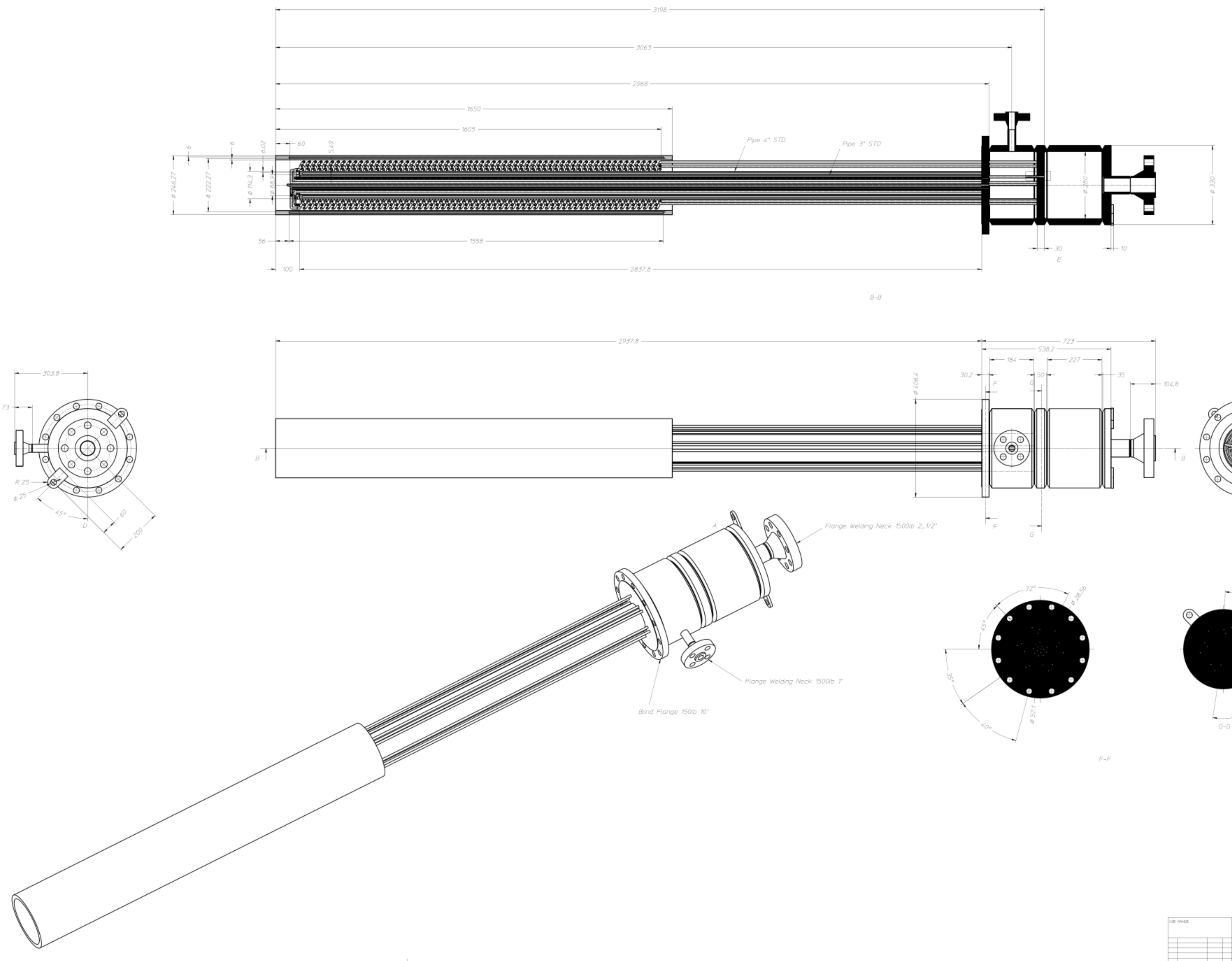

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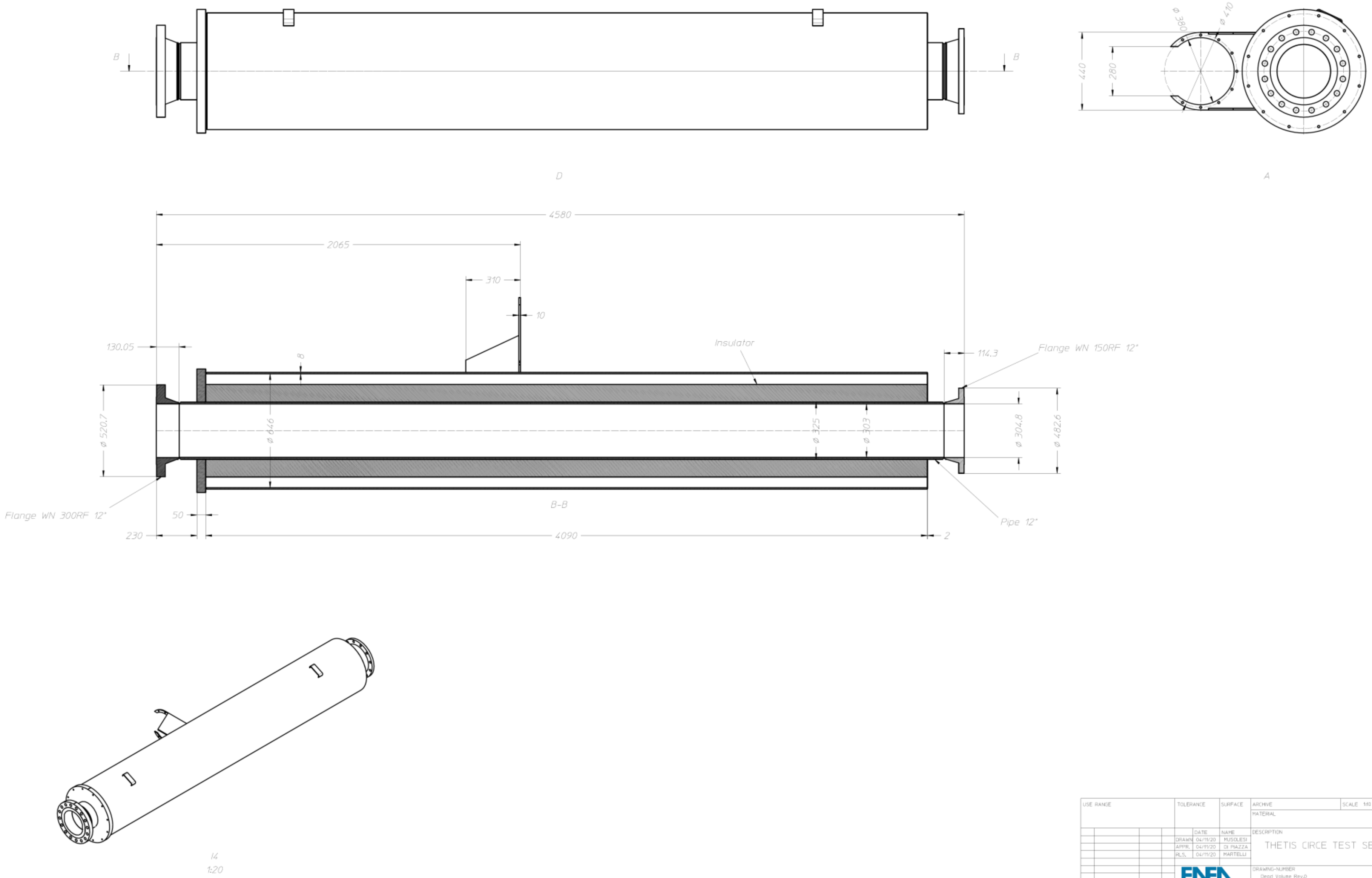

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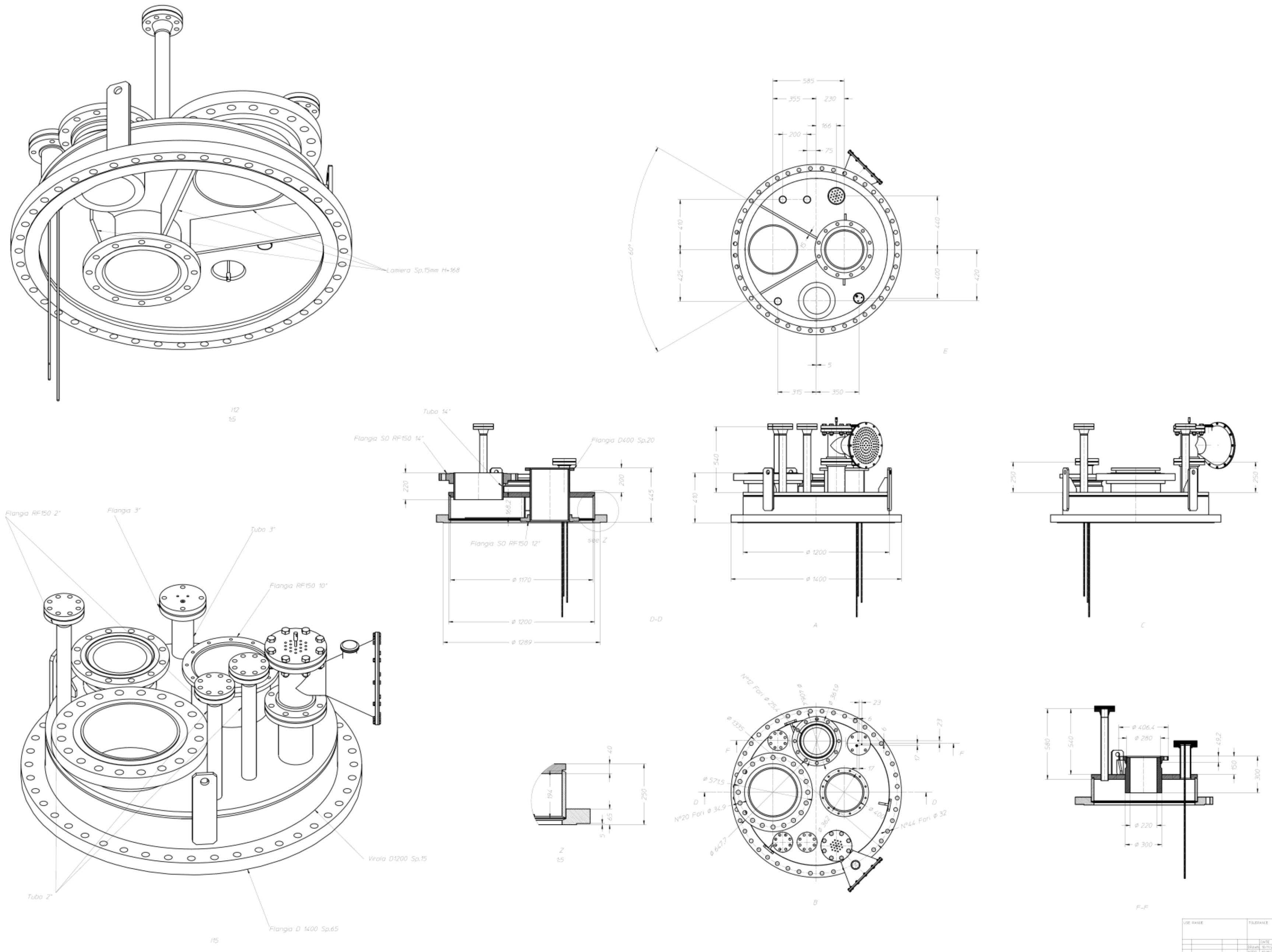

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