



DELIVERABLE D8.3

Assessment of minimal mechanical requirements for the cryogenic system based on experimental tests results.

Lead Beneficiary: Wrocław University of Science and Technology (WUST)

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Contents

1	Introduction	7
2	Experimental tests results	8
3	Laser drill string relevant standards analysis	12
4	Materials	14
4.1	Material properties	15
4.2	Pipes allowable stress	18
4.3	Casing pipe allowable stress	19
5	Assessment of minimal mechanical requirements for the laser drilling string	20
6	Laser drill string design	27
6.1	Thermal expansion compensation	28
6.2	Laser drill string segments coupling	29
6.2.1	Design of the mechanical connection between segments	29
6.2.2	Design of the connection between process pipes	31
6.2.3	Design of the connection between electrical cables	32
6.3	Laser drill string vacuum insulation	34
7	Drill string design experimental validation	36
8	Conclusions	37

List of Figures

1	Concept of DeepU drilling technology	7
2	Placement of the bronze filters (in red squares) in the drill string design.	9
3	Manufacturing of the experimental kit.	10
4	Experimental kit structure.	10
5	Experimental kit during liquid nitrogen tests.	11
6	Categorisation criteria of pipes with liquids of group II in acc. to PED	13
7	Minimum applicable temperature of the austenitic stainless steels [11]	15
8	Mechanical properties of the 1.4306 austenitic steels [13]	15
9	Mechanical properties of N08028 / 1.4563 austenitic stainless steel [4]	16
10	Average thermal expansion of 1.4563/1.4306 stainless steel as a func- tion of temperature ($T_{ref} = 300K$) [14]	17
11	Thermal conductivity of 1.4563/1.4306 stainless steel as a function of temperature [14]	17
12	Young modulus of 1.4563/1.4306 stainless steel used in the model [14]	18
13	Schematic view of the vacuum insulated laser drilling string with pres- sure distribution in key components	21
14	Input parameters in PYTHON code	22
15	Output parameters in PYTHON code	23
16	Stress components in process pipe as the function of borehole depth	24
17	Stress components in Casing pipe as the function of borehole depth	24
18	Minimum material Yield Strength in MPa as the function of borehole depth in meters	26
19	General view of the drilling string segment, dimensions in mm,	27
20	Thermal expansion compensation method	28
21	Design of the bellow with inner sleeve	29
22	The design of mechanical connection	30
23	Design of the shape connection ensuring coaxiality and a specific an- gular position	31
24	View of the mechanical connection after assembly	31
25	Design of the process pipes coupling	32
26	Design of the seal seat	32
27	The electrical cables connection	33
28	The design of electrical feedthrough	33
29	The electrical cables connection after assembly	34
30	Vacuum pumping system port	34
31	Vacuum key	35
32	Vacuum pumping process - step I	35
33	Vacuum pumping process - step II	36
34	Vacuum pumping process - step III	36

List of Tables

1	The laser drilling string design parameters	8
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EXECUTIVE (or PUBLISHABLE) SUMMARY

This deliverable, prepared by the Wrocław University of Science and Technology (WUST) within the DeepU project, assesses the mechanical and material requirements for a cryogenic system integrated into a laser-based deep geothermal drilling technology. The study defines and validates the mechanical design of a vacuum-insulated, multi-pipe laser drill string capable of operating at 4000 m depth under cryogenic conditions.

The DeepU concept replaces conventional drilling with high-power laser rock ablation, supported by cryogenic nitrogen flow to remove molten and spalled material. Experimental tests on the initial bronze filter design revealed inadequate phase-separation performance, prompting a redesign toward a vacuum-insulated cryogenic transfer line compliant with API and EU Pressure Equipment Directive (PED 2014/68/EU) standards.

A computational tool was developed to calculate minimum mechanical strength, stress limits, and wall thicknesses under realistic load and temperature conditions. Austenitic stainless steels were selected as optimal materials for both the process (1.4306 / AISI 304L) and casing (N08028 / 1.4563) pipes, offering cryogenic resilience, corrosion resistance, and weldability.

The final design comprises 12-meter modular segments integrating cryogenic pipes, a laser conduit, and electrical cabling. Key features include thermal expansion compensation, quick-connect double-thread mechanical joints, cryogenic copper-gasket seals, and vacuum-powder insulation with a dedicated pumping port.

Prototype segments will undergo mechanical (up to 1 MN load), pressure (34 MPa at 77 K), and leak-tightness testing to confirm performance. Overall, the design merges drilling-industry robustness with cryogenic precision, forming a validated foundation for scalable, efficient, and low-carbon deep geothermal energy extraction.