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)

Authors: M. Stanclik, Z.Rogala, , K. Strzelecka, J. Kielar, M. Chorowski

Authors affiliations: Wrocław University of Science and Technology

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Disclaimer

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EXECUTIVE (or PUBLISHABLE) SUMMARY

This deliverable, prepared by the WrocĹaw 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.