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C3Or2B-03: Optimising cryogenic solutions for STEP: addressing cooling challenges and enhancing energy efficiency

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The STEP program is an ambitious initiative designed to demonstrate, for the first time, a fusion energy prototype power plant capable of delivering net power (>˜100 MWe) to the electrical grid. Planned for construction in West Burton, Nottinghamshire, UK, the tokamak system will utilise high-temperature superconducting (HTS) coils to generate and sustain the magnetic field needed to confine plasma. These superconducting magnets will operate at approximately 20K, cooled by supercritical helium, requiring substantial cryogenic power. Additionally, systems such as fuel cycling, thermal shielding, and current feeders will contribute to significant cooling power demand. STEP and future commercial fusion power plants will require substantial refrigeration capacity at various cryogenic temperatures, approximately 80K, 50K, and 15K, with an estimated total cooling power demand equivalent to ˜100 kW at 4.2K. So far, STEP has developed a concept for the cryogenic plant and is currently exploring innovative ideas for distributing cryogenic coolants and optimising energy efficiency. Achieving commercial viability for STEP requires addressing key challenges, including minimising parasitic electrical loads to maximise net power generation. This work focuses on the challenges of developing a cryo distribution system for the STEP Prototype powerplant. This cryo distribution must comply with a number of critical requirements such as:
1) Distributing cryogens of different temperatures
2) Managing transient impacts (linked to powerplant operations) - this may be achieved with a cryo buffer
3) Managing supply of different cryogens across a multitude of locations within the powerplant
The proposed buffer plays a crucial role in managing cooling circuits. Through a simulation study handling heat loads of up to 10 kW, the work outlines the associated electrical and refrigeration capacity requirements. This work represents a significant step forward in the development of large-scale cryogenic systems essential for STEP and future fusion power plants.

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Author: Dr ALIAGA, David (UKAEA)

Co-authors: Mr ACRES, Jack (UKIFS); Mr RICHARDSON, Paul (UKAEA)

Presenter: Dr ALIAGA, David (UKAEA)

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