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First operation of the cryo supply for Wendelstein 7-X cryo vacuum pumps

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The stellarator fusion device Wendelstein 7-X (W7-X) consists of a vacuum vessel and 70 superconducting coils located within a vacuum-isolated cryostat. The coils generate the magnetic field that confined the high-temperature plasma and keeps it away from the first wall of the vacuum vessel. A thermal shield inside the cryostat protects the cold components from thermal radiation. A helium refrigerator with an equivalent cooling power of 7 kW at 4.5 K produces cold helium for the cooling of the superconducting coils and the cold structures to 3.9 K. The refrigerator also supplies helium at 60 K for the current leads of the coil feeders and supplies helium in a range of 50-80 K for the cryostat thermal shields.
Between 2018 and 2021, W7-X was upgraded with 10 Cryo Vacuum Pumps (CVP) in order to enhance the neutral gas exhaust during plasma operation in the sub-divertor region of the vacuum vessel. The supply of the CVP requires a cryo supply system that consists of a four-channel transfer line with a length of 55 m running from the refrigerator to a distribution valve box below the W7-X cryostat. From there 10 transfer lines run to the 10 supply ports at the W7-X cryostat. The process pipes of the transfer lines are connected to each CVP.
The four-channel transfer lines contain two helium process lines (feed and return) and two nitrogen process lines (feed and return). The helium flow cools the cryo panels of the CVP at a feed temperature of 3.9 K in a parallel cooling schema. A two-phase nitrogen flow cools the thermal radiation screen to 80 K. First operation of the cryo distribution with connected CVP was conducted in 2022 and 2023.
The paper presents the design parameters of the cryo supply system with respect to heat loads, allowed pressure drop and required mass flow rates, and compares the values with measurements. The helium cooling of the cryo panels was done with a total mass flow rate of 250 g/s and a cooling temperature of 3.9 K. The achieved liquid nitrogen supply ensured an outlet temperature of the flow in saturation condition. A controlled cool down of the CVP from 300 K to 4 K could be achieved for the helium cooling circuit. Cool down of the thermal shield with liquid nitrogen was done with a small liquid nitrogen flow.
In addition, the paper discusses the impact of the cryo pump operation on the operation of the helium refrigerator. The helium cooling of the magnet system and the cooling of the cryogenic pumps are closely coupled in the design of the helium refrigerator. It turned out that the transient operation modes of the CVP had significant impact on the other cooling circuits. While the superconducting coils operate stationary at 4 K over a week, the cryo pumps are cooled down from 60 K to 4 K for CVP operation and heated up to 60 K for regeneration of adsorbed hydrogen. Warm up to 300 K over the weekend and cool down back from 300 K to 60 K for a full regeneration cycle was also required in addition. Heat load changes in sub cooler baths and heat exchangers, changes in mass flow rates or redirection of flow paths produced complex operation scenarios that required manual operations. The detailed planning of CVP operation in support of the experimental program needed to take into account the time consuming mode changes in the cryogenic system.

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