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# Thermodynamic and technological optimization of complex cryogenic insulation systems

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Abstract of the doctoral thesis

Future accelerators like the Future Circular Collider (FCC) under study at CERN, will be considerably larger than the Large Hadron Collider (LHC) presently in operation, with consequently increasing demands for cryogenically efficient cryostat solutions. With a cold mass surface exposed estimated to be five times higher than the one of LHC, the insulation solution of the cryostat will be critical for its operating costs. Multilayer Insulations Systems (MLI) remain the technology of choice for large accelerators. MLI are used in cryogenic or space application in presence of good vacuum and their main function is cutting radiation heat transfer. They are composed of several reflective layers made of a thin insulation material core and a reflective coating like aluminium. Layers are kept separated by low conductivity material spacers ensuring the minimum contact. MLI blankets offer a very good compromise between thermal performance and cost-effectiveness. Thermal design solutions for cryostats can employ different combinations of intermediate thermal shields operating at intermediate temperatures between the cold mass temperature and the ambient temperature, with optimally chosen MLI solutions. The temperature at which the thermal shield operates is the key parameter to determine the total power of refrigeration needed in the cryostat for the static heat loads. The total refrigeration power during operation is the sum of the cooling power of the thermal shield and the cooling power of the cold mass. This latter de- pends on the performances of MLI at different thermal screen temperatures. Data in literature is scarce though for MLI performance at 4.2K when operating with a thermal shield kept between 60K and 20 K. Therefore, a dedicated test program for the qualification of MLI samples was done at CERN, exploring different MLI configurations with a shielding radiative heat from 20 - 60K to 4.2K and with residual gas pressures between $10^{-7}$ and $10^{-4}$ mbar. The experimental campaign on MLI performances was performed with a boil-o_ cryostat provided by Wroclaw University of Science and Technology. The system was previously used for experiments involving the temperature range 300 -77K therefore it has been modified for a use with liquid helium. The blankets were prepared with an original methodology for the control of their layer density. This thesis work shows all the steps done for further optimizing the experimental set-up that brought to the measurement of different systems and all in different degraded vacuum conditions too. The mathematical approaches to predict the MLI performances and the optimization of the temperature of an active cooled screen for FCC are presented as well. The results of the experimental campaign show that MLI insulation performance does not improve significantly when the hot boundary is kept below 45 - 50 K. The collected data is used in an exergy approach aiming at finding the minimum refrigeration power vs thermal screen temperature. The resulting optimal temperature for operating the thermal screen is found to be 53K and the refrigeration power for the FCC cryostat corresponding to this point is 6W/m.