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C3Or2B-02: Development and verification of a transient operating methodology for pump-down operation of 2K cold compressor system

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Multi-stage cryogenic centrifugal compressor (cold compressors or CCs) trains used in 2 K sub-atmospheric refrigeration systems require a transient process operation (or 'pump-down') to establish the target low-pressure steady-state conditions. In sub-atmospheric refrigeration systems for superconducting radio frequency (SRF) cavities, the pump-down process establishes a pressure ratio of approximately 40 (i.e. ˜ 30 mbar at the load) across the cold compressor train starting from unity. The compressor train is typically controlled with a lead compressor while the rest of the compressors are coupled through electronic speed ratios. Historically, the transient variation of the electronic speed ratios and the mass flow during the pump-down process has been determined empirically through a tedious trial and error testing process. Often this empirical approach resulted in a pump-down process path that is either unstable or longer than optimally possible. A 1D transient numerical model for the cold compressor pump-down process has been developed to predict and characterize dynamic behavior of the sub-atmospheric system (cold compressors, loads and associated cryogenic distribution). A transient operating algorithm to select the system parameters, i.e. CC speed ratio and overall flow variation, during the pump-down process utilizing the developed model and cold compressor performance maps is proposed. Extensive tests have been performed using the FRIB sub-atmospheric refrigeration system to validate the developed model and to check the applicability of the proposed algorithm. Excellent agreement between the model predictions and the test data provided evidence that improvement in theoretical understanding of the sub-atmospheric system has resulted in simplifications of the pump-down process path. Simplicity of the pump-down process path provides additional benefits of increased reliability and stability of the transient pump-down process.

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