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C2Or2C-06: Advancing 1D thermo-hydraulic tools for large cryogenic facilities

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The Cryogenic Division at Fermilab is dedicated to designing and fabricating large cryogenic facilities for particle accelerators, as well as test facilities for superconducting magnets and cavities. The development of these large-scale facilities necessitates innovative numerical tools to aid in the design of various components and to provide more accurate estimates of heat loads. Several years ago, the cryogenic team developed a Python-based code capable of calculating friction factors and pressure drops in various piping components, including manual, control, and relief valves. This initial version of the code has proven instrumental in better estimating pressure variations in large facilities during cooldown and across various operating modes.

This paper introduces new heat transfer functions that have been incorporated into the existing code, along with the enhanced design and diagnostic capabilities they bring. The theoretical foundation and assumptions underlying these heat transfer functions are described in the first section of this paper. The first example demonstrates a one-dimensional thermo-hydraulic calculation applied to various relief pipes of the Proton Improvement Plan-II (PIP-II) particle accelerator at Fermilab. The analysis of pressure and temperature evolution along these pipes informs optimal pipe sizing to minimize pressure drops, limit static heat conduction and prevent damage to relief valves during critical events.

The second example highlights the application of these functions to more accurately estimate heat load evolution and its impact on temperature sensors in a pipe filled with sub-atmospheric helium. This thermal analysis is crucial for accurately diagnosing the temperature evolution of sub-atmospheric gas returning to the cold compressor from cryomodules filled with saturated superfluid helium.

These advancements in the code significantly enhance its utility, offering robust tools for the design and diagnostic processes critical to the development and operation of large cryogenic facilities.

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