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# C2Po1A-03: Design and development of a control valve plug for precise control and measurement of cryogenic flow

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Cryogenic control valves are one of the critical components of a cryogenic fluid distribution system. They are used for both control (process and safety) and isolation of the cryogens within the distribution system. In many cases, control of the cryogenic process flow needs to be directly or indirectly accompanied by accurate flow measurement. Fundamentally, cryogenic flow measurement can be accomplished by expensive instrumentation (e.g. venturi, Orifice, Coriolis meter, which intern require additional instruments like differential pressure measurement etc.). However, the implementation can be challenging due to the additional measurement device introducing heat in-leak, potential thermal hydraulic instability, design complexities and cost. In addition, designing the valve for a maximum Cv can also be use as the flow limiter for safety limits. A well calibrated control valve with precisely known stroke vs. flow coefficient profile has the potential to serve as a cryogenic flow measurement device. As an integral part of the cryogenic distribution system, it is immune to the issues of an added measurement device mentioned above. A valve flow test bench is developed for the calibration and characterization of cryogenic control valve plugs. The test bench incorporates accurate measurement of mass flow using a venturi and Coriolis meter, differential pressure, valve stroke using a digital caliper mounted to the valve stem, as well as pressure and temperature. For applications in helium cryogenic distribution systems, low flow (Cv < 1.0) control valve plugs with equal percent characteristics and high rangeability (≥10) are of particular interest. Several control valve plug profiles for a specific cryogenic control valve (available domestically) are designed using an analytical model. These include equal percent profiles with different rangeability, flow coefficient as well as hybrid profiles with variable rangeability. Flow characteristics of each of these control valve plugs are evaluated using the valve flow test bench, under ambient conditions. The variation of the flow coefficient with valve stroke is calculated from the measurements. The potential variability in the characterization from machining tolerance of the plugs is also studied. An error analysis of the collected data is performed, and the accuracy of the measurements is established. Moreover, a comparative analysis of the measurement accuracy of the proposed set-up against advertised accuracy of trivial flow measurement devices are presented.

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