Modelling the Thermodynamic Response of a Cryocooler after Switching It Off

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In order to reduce thermal noise, devices may be cooled down to cryogenic temperatures. In many such cases, interference caused by the cooler (such as vibrations or electromagnetic noise) is not acceptable. Therefore, standard off-the-shelf coolers need to be operated remotely with some kind of thermal link, or need to be switched off during the sensitive operation of the device. In the latter case, the noise-free operating time is an important parameter. In order to estimate this operating time in the design phase of the total system, the thermodynamic response of the cooler to its interrupted operation needs to be known. For that purpose, a thermodynamic model of a warming-up cooler is developed. Basically, each stage of the cooler is modelled as a lumped heat capacity linked to the warmer stage by a thermal conductor (or as the reciprocal analogue, by a thermal resistor). Heat capacity and thermal conductance are considered temperature dependant, but the exact materials are unknown. We present a method for determining these model parameters based on a set of experiments. The method is illustrated with experiments performed on a two-stage pulse tube cooler (Cryomech PT405). Heat capacity and conductance results of these experiments are discussed and the warm-up behaviour predicted by the resulting model is compared to experimental data and discussed.