*Sage Model Notes*

# 6KJTLoop.ltc

D. Gedeon
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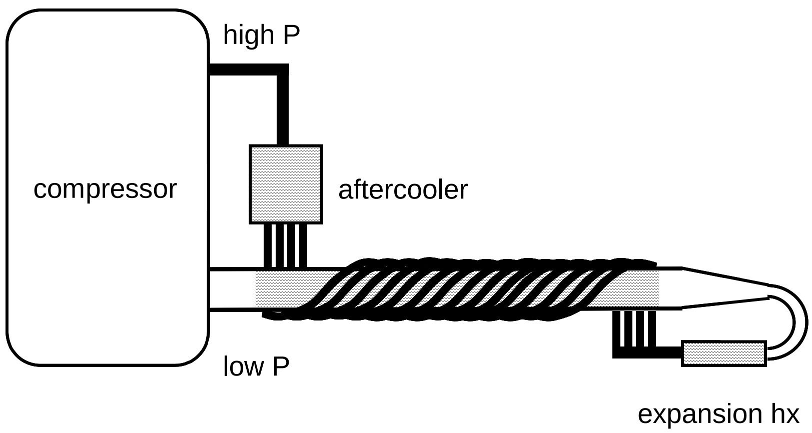
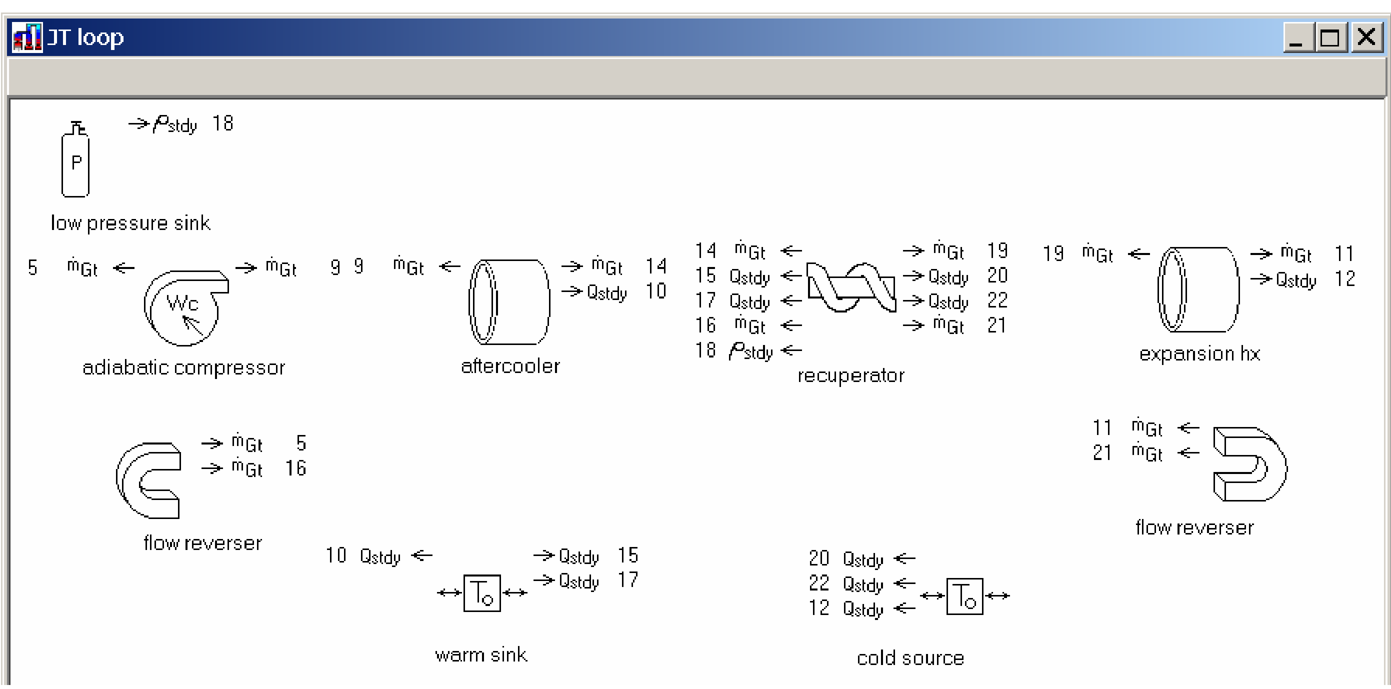
A model for a closed-cycle Joule-Thomson cryocooler operating between temperatures of 15 K and 6K, employing helium as the working gas. The recuperator consists of a number of high pressure tubes spiral-wrapped around a single low pressure return tube filled with copper screens bonded to the tube wall to improve heat transfer to the high pressure tubes. This type of recuperator is intended for illustration purposes and may not be the best practical design. The aftercooler and expansion heat exchanger also employ copper screens bonded to the tube wall. The cryocooler is represented schematically like this:

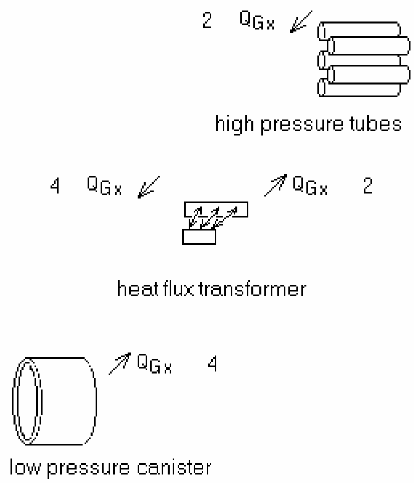



This is the Sage model:

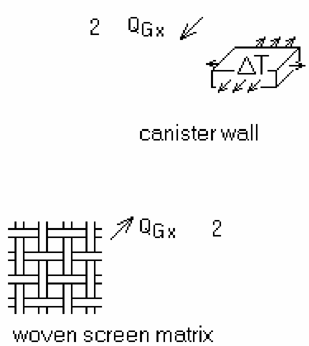


The *adiabatic compressor* provides a positive (directed toward right) high-pressure flow through the *aftercooler* then into the *high pressure tubes* of the *recuperator*. Flow then passes through the *expansion hx* where the pressure drops from high to low and the Joule-Thomson cooling effect takes place. The flow then reverses direction in a *flow reverser* and passes up the *low pressure tube* of the *recuperator*, precooling the gas in the *high pressure tubes*, then returns to the compressor via another flow reverser.

The recuperator simulates a counterflow heat exchanger and looks like this inside.




In the *high pressure tubes* there is a *tube wall* solid conduction path (conductive surface) through which heat flows laterally (*y*-directed) to the wall of the *low pressure canister*. The *heat flux transformer* takes care of matching the different flow lengths of the *high pressure tubes* and *low pressure canister*. In the high pressure *tube wall* the fin conduction length input *D* is recast to half the tube diameter (0.5 * *Dtube*) as a rough approximation of the transverse distance heat flows up to the thermal bond to the low pressure *tube wall*. In the low pressure *canister* the transverse conduction length input *D* of the *canister wall* is recast to the wall thickness (D = Wout), consistent with the heat-flow geometry. Within the *low pressure canister* there is also a *woven screen matrix* that models heat transfer to the helium and also radial conduction in the screens to the canister wall via the heat connection illustrated here:



A *conductive surface* within the *woven screen matrix* models the radial heat flow in the screen wires and its “fin conduction length” input *D* recast to one-quarter the canister diameter (*D* = 0.25 * *Din*) .  (*See* sample problems in the Stirling Manual for more discussion about why.)

The *aftercooler* and *expansion hx* are also canisters filled with copper-screens similar to the *low pressure canister* of the recuperator. Modeling is similar except the canister walls are copper and relatively thick allowing the heat from the screens to flow axially along the wall to/from the right end of the *canister wall* to the *warm sink* or from the *cold source* via the heat flow connector at the root level.

The *warm sink* and *cold source* components anchor the temperatures of the *aftercooler* and *expansion hx* as well as the endpoint *tube wall*  and *canister wall* temperatures of the *recuperator*.

# Bottom Line Outputs

Net cooling power is available in the top-level user-defined variable *Q*. Included in *Q* are the heat absorbed by the helium in the *expansion hx*, less any conduction losses down the walls in the *recuperator*.  Adiabatic compressor power is available in top-level user-defined variable *Wcomp*.

# Optimization

The optimizer is set up to maximize cooling power Q subject to an adiabatic compressor power input of 5 W (*Wcomp* = -5.0).  Variables selected for optimization are the compressor low-side pressure (*Pcharge* of *low pressure sink*) , the *Length* of the *expansion hx* and the mass flow rate of the *adiabatic compressor* (*FRhoUA.Mean*). Together, the second two optimized variables control the high-side pressure and compressor power.