Sage Model Notes

CoAxPTR.scfn

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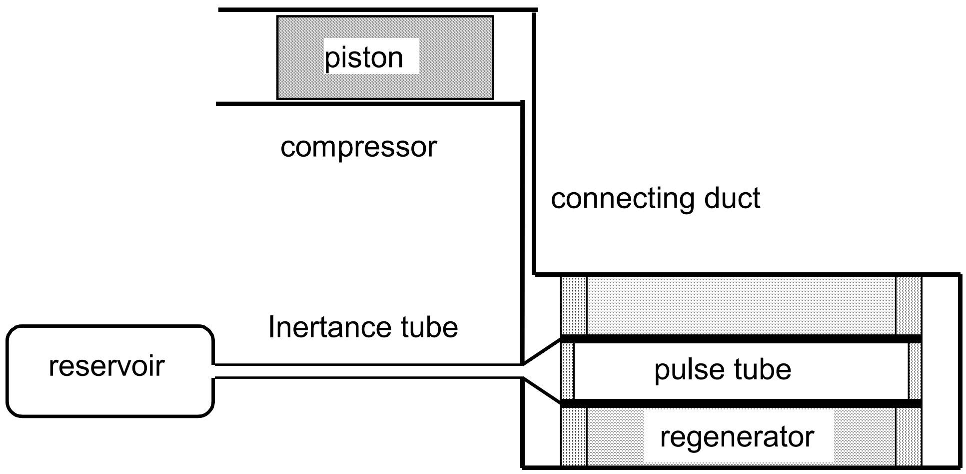
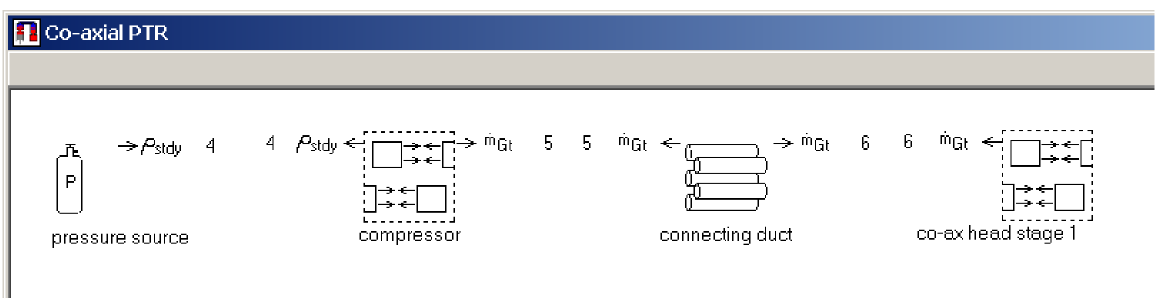
A model for a single-stage pulse-tube cooler with pulse-tube arranged co-axially within an annular regenerator. Here is a rough schematic of the physical layout:

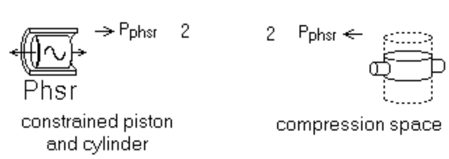


At the top-level the Sage model consists of a compressor submodel and a cold-head submodel with a connecting duct between the two:



Compressor

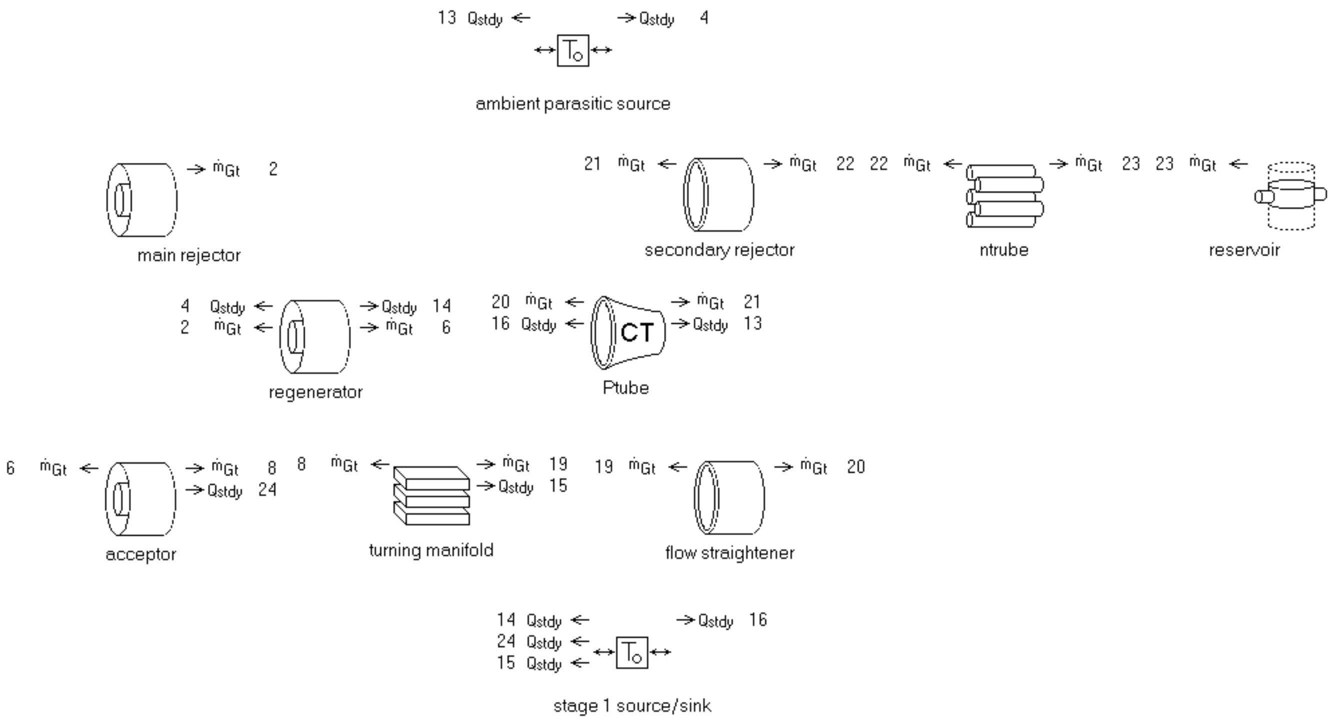
The compressor consists of a single constrained piston driving a compression space:



Within the *constrained piston and cylinder* component there is a constrained piston with an area attachment connected to the compression space. That area *A* is an independent input by default but in this case recast to 0.25*Pi*Sqr(Dshell) so it automatically adjusts to the piston diameter Dshell input of the *constrained piston and cylinder*.

Cold Head

Within the cold head (*co-ax head stage 1*) are a number of components that simulate a co-axial pulse-tube arrangement. The reason for the naming '*stage 1'* is to anticipate the possibility of copying the entire submodel and pasting it back into the model to implement a higher stage.



The components are ordered in rows of decreasing temperature downward rather than according to their physical layout in an actual machine so some mental stretching is required to understand the model. Physically, the three annular canister components (*main rejector, regenerator, acceptor*) are stacked on top of each other with the pulse and related components tube (*flow straightener*, *ptube, secondary rejector*) turned around and passing back through the common hole in the center. The annular canister ID's are equal to the pulse-tube OD. No radial thermal interaction is possible between the pulse-tube *ptube* and *regenerator* because of opposite orientations of the axial temperature profile. The outer wall of the regenerator canister represents the pressure wall (important for modeling thermal conduction loss) and the inner wall is just a very thin wall (wall thickness *Win* set very thin) reflecting the fact that it is not physically present in the hardware.

After the secondary rejector comes the the inertance-tube phase shifter *nrtube*, which is roughly 1/4 wavelength long, bounded at far end by the reservoir.

The *ambient parasitic source* anchors only parasitic wall thermal conductions. The *stage 1 source/sink* anchors wall conductions as well as cooling-power via conduction to the *acceptor* and *turning manifold* heat exchangers.

There are a number of user-defined inputs and outputs at the submodel level:

Inputs

IDregen	regenerator matrix ID (m)	1.500E-02

ODregen	regenerator matrix OD (m)	2.500E-02
WptubeNeg	pulse tube wall thk neg end (m)	1.000E-03
WptubePos	pulse tube wall thk pos end (m)	1.000E-03

Outputs

Lptube pulse-tube length 7.700E-02
Lregen + Laccept
QrejColdhead1 net rejection to ambient 6.089E+01
Qloss0 - (Qrej1 + QsecRej1 + Qnrtube1 + Qreserv1)
Export level: Co-axial PTR
Qlift1 first stage net lift 3.743E+00
Qstage1

Except for the last two these are used by lower-level components to recast their inputs according to geometrical constraints.

main rejector
Canister ID and OD are recast in terms of user-defined inputs of the cold-head submodel and local wall thickness inputs. The *conductive surface* within that models radial heat flow through the wires has input *D* recast to represent the annular thickness of the screens.

regenerator
Canister ID and OD are recast in terms of user-defined inputs of the cold-head submodel and local wall thickness inputs.

acceptor
Canister ID and OD as well as conductive surface *D* are recast as for the *main rejector*. There is also a solid conduction path to the *stage 1 source* temperature. This conduction path (*wall distributed conductor*) simulates an annular copper block thermally bonded to the screens. Its input *D* is recast to the outer wall thickness *Wout* inherited from the *acceptor* canister.

turning manifold
A rectangular duct represents a radial-flow manifold by recasting Length to manifold radius and Wchan to mean circumference.

flow straightener
Canister ID is recast so it always equals the inner diameter of the pulse tube at its cold entrance.

Ptube
Inputs *Length*, *Dtube* and *Twall* are recast according to user-defined inputs and variables at cold-head level.

secondary rejector
Canister ID is recast so it always equals the inner diameter of the pulse tube at its warm exit. A conductive surface represents a copper screen conduction path to the outer canister wall with conduction-length input *D* are recast as 1/2 the screen radius.

Cold Temperature

The file is currently set up for a cold-end temperature of 70K. To change cold-end temperature change the *T* input for the *stage 1 source/sink*, which establishes the acceptor screen temperature by solid conduction. Also, you might want to change Tinit at the positive end of the regenerator and negative end of the pulse-tube. These changes are not strictly necessary because the regenerator and pulse-tube temperatures are solved, with Tinit only providing initial values.

Bottom-Line Outputs

Net cooling power is available in the *co-ax head stage 1* submodel user-defined variable *Qlift1*. Included in *Qlift1* are the heat flows absorbed by the helium in the *acceptor* and *turning manifold*, less the conduction losses down the regenerator and pulse-tube canisters.

Compressor PV power input is available in user variable *Wpv* in the *compressor* submodel. There is no model of the motor driving the compressor piston so electrical power input is not available.

Optimization

The model contains a rudimentary optimization specification. The objective is to maximize net cooling power *Qlift1*, subject to compressor PV power equal to 100 W (*Wpv* = 100). Optimized variables are compressor piston amplitude *Xamp*, regenerator matix *Porosity* and intertance tube *Length*.

Also optimized is the stiffness *K* of the spring attached to the compressor piston in order that the required force provided by the drive motor (*FF*) be in phase with the piston motion (*FF.Real = 0*).

This optimization is intended as a starting point for more serious design optimizations.