Sage Model Notes

RadColdFinger.scfn

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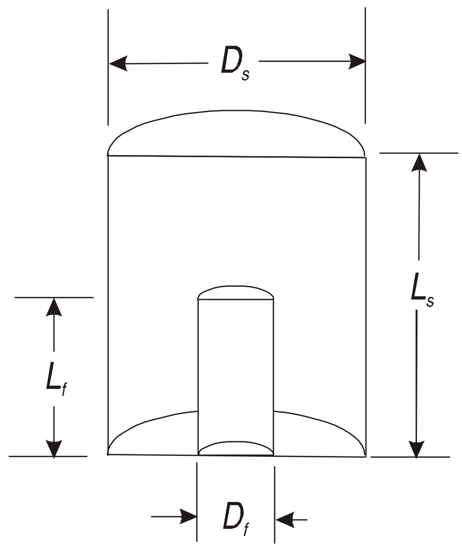
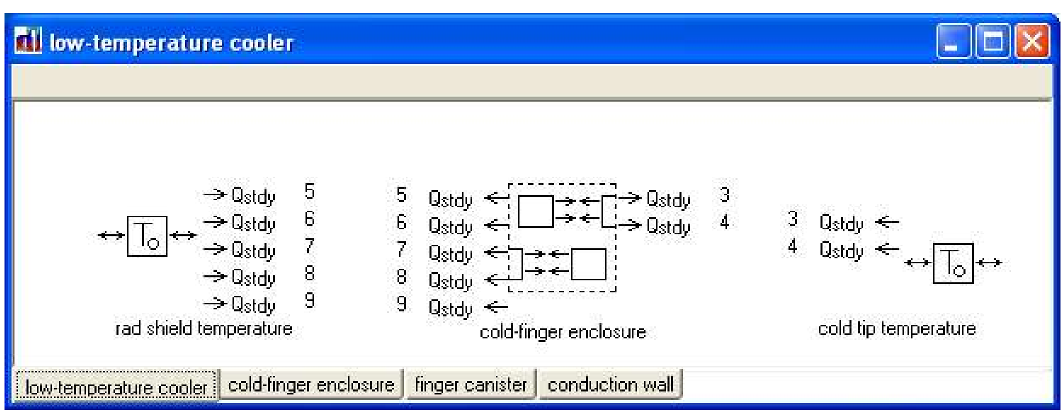
A radiation enclosure consisting of a the outer cylindrical and end surfaces of a *cold finger* exchanging radiation with the inner cylindrical and end surfaces of a radiation shield. In a low-temperature cooler application the cold finger might represent the pressure wall housing the displacer of a stirling-cycle or coaxial pulse-tube cryocooler:

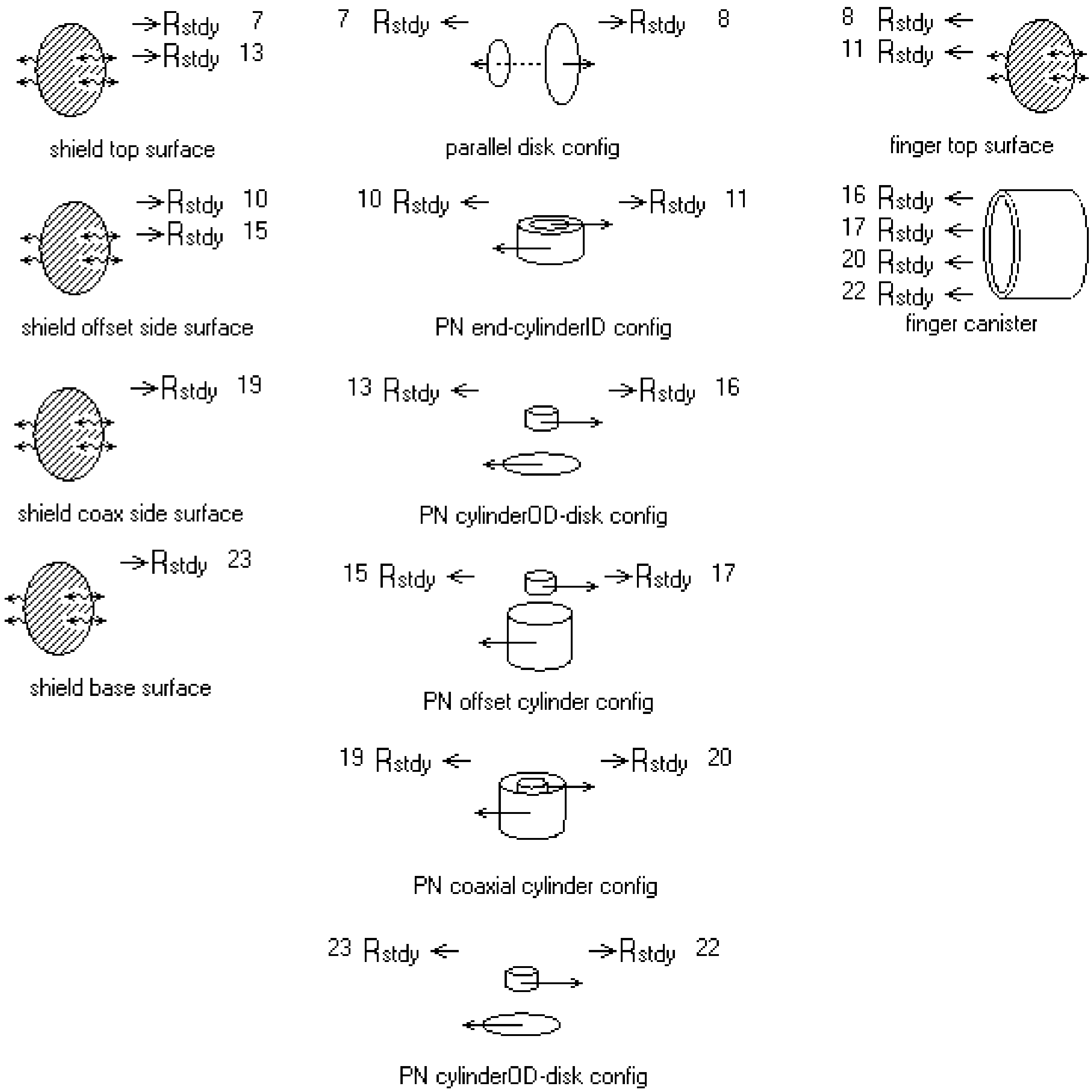


The interesting thing about this model is that the cold finger cylinder has a temperature distribution ranging between the cold-tip temperature and the radiation shield temperature. All the other surfaces have uniform temperatures. Of interest is the net radiation exchange between the radiation shield and cold finger.

This is the top level Sage model:

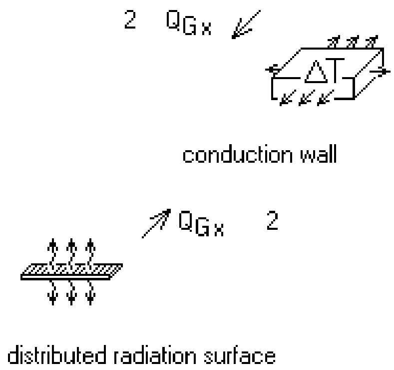


The *rad shield temperature* anchors all the radiation shield surfaces and one end of a cylindrical canister wall (thermal solid) representing the cold finger pressure wall. The *cold tip temperature* anchors the end disk of the cold finger and the other end of the cold finger pressure wall. The cold-finger pressure wall temperature distribution anchors the cylindrical cold-finger radiation surface with a distributed heat transfer connection. The radiation surfaces and canister conduction wall are contained within the cold-finger enclosure submodel which looks like this inside:



The radiation shield surfaces are in the left column and the cold finger surfaces in the right column. Between the two columns are all the view configurations by which the radiation shield surfaces see the cold finger surfaces. The view configurations between individual surfaces of the radiation shield are not included in the model because they are at the same temperature and there is no net radiation exchange between them.

The radiation surface is located within the *finger canister* component from which it inherits its Length and other properties that support distributed heat flow connections:



The heat flow connection Q_{Gx} anchors the *distributed radiation surface* temperature to the *conduction wall* temperature distribution. The *conduction wall* temperature is solved according to the energy balance between axial thermal conduction down the wall and distributed radiation heat transfer.

Recast Variables

User-defined inputs at the can enclosure submodel level define the overall geometry and radiation properties of the enclosure:

Dshield	shield can diameter (m)	1.00000E-01
Lshield	shield can length (m)	1.00000E-01
EmShield	shield emissivity (NonDim)	1.00000E-01
Dfinger	cold finger diameter (m)	2.00000E-02
Lfinger	cold finger length (m)	5.00000E-02
EmFinger	cold finger emissivity (NonDim)	5.00000E-01

These inputs are referenced by recast inputs of the individual radiation-surface and view-factor components within the submodel, making it easy and somewhat foolproof to change the radiation shield or cold finger specifications without bothering to manually adjust individual component inputs. The recast inputs are:

shield top surface
A = 0.25 * Pi * Sqr(Dshield)
Emiss = EmShield

shield offset side surface
A = Pi * Dshield * (Lshield - Lfinger)
Emiss = EmShield

s**hield coax side surface**
A = Pi * Dshield * Lfinger
Emiss = EmShield

shield base surface
A = 0.25 * Pi * Sqr(Dshield)
Emiss = EmShield

finger top surface
A = 0.25 * Pi * Sqr(Dfinger)
Emiss = EmFinger

finger canister
Length = Lfinger
Din = Dfinger

conduction wall
D = Wcan

distributed radiation surface
A = Pi * Dfinger * Lfinger
Emiss = EmFinger

parallel disk config
Sepr = Lshield - Lfinger

PN end-cylinderID config
Dcyl = Dshield

PN cylinderOD-disk config
Dcyl = Dfinger
Sepr = Lshield - Lfinger

PN offset cylinder config
DcylInner = Dfinger
DcylOuter = Dshield

PN coaxial cylinder config
Hcyl = Lfinger

PN cylinderOD-disk config
Dcyl = Dfinger

Net Radiation transfer

The net radiation transfer to the end and cylindrical surfaces of the cold finger are given by the Rad outputs:

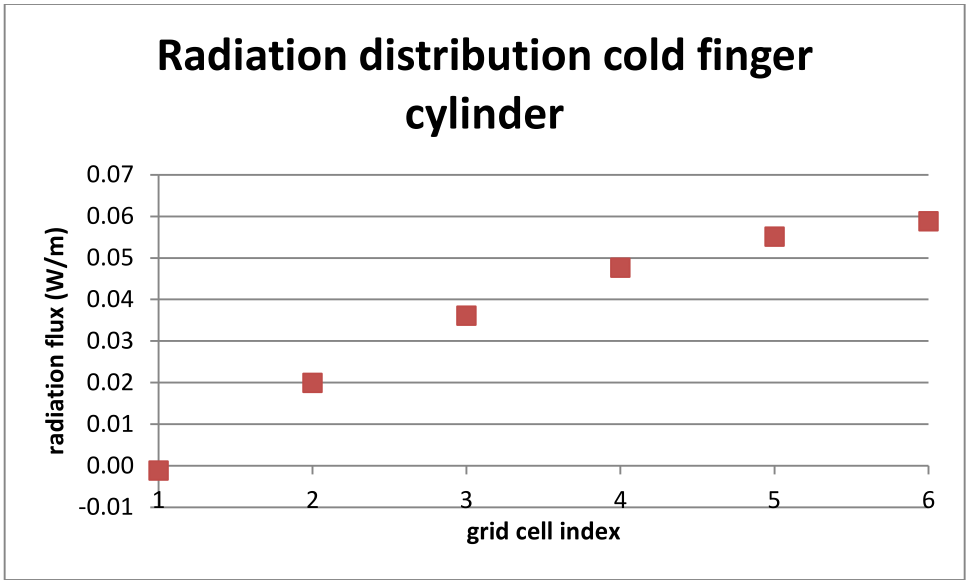
finger top surface

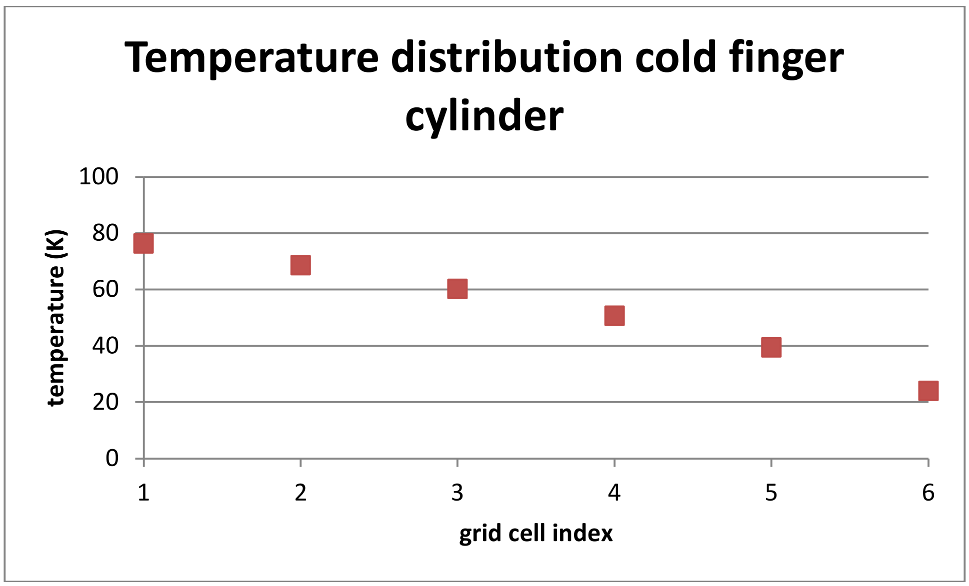
Rad	net incoming radiation flow (W)	3.18022E-04

finger canister | distributed radiation surface

Rad	net incoming radiation flow (W)	1.76882E-03

Of interest are the distribution of radiation to the cold finger cylindrical surface and its temperature which can be examined by saving the solution grid for the *distributed radiation surface* and plotting in MS Excel:





As the temperature decreases toward the cold tip the radiation load increases, as expected. Somewhat unexpected is that the radiation load is slightly negative (-0.002) for the first cell at a temperature of 76 K, which is lower than the radiation shield. In other words there is radiation *leaving* the cold finger surface near the warm end even though it is colder than the radiation shield. This happens because the emissivity of the shield is less than one (0.1 in fact) which means that the warm parts of the cold finger exchange radiation with the cold parts via reflection off the radiation shield surfaces.

View Factor Consistency Check

In this example the cold finger surfaces are convex so their self view factors Fself should be zero as they are in the model. This verifies that all the radiation exchange with the surfaces of the cold finger is accounted for.

For the radiation shield surfaces the base and top surfaces are convex but the two side surfaces are not. That means the Fself outputs for the side surfaces should be greater than zero, which they are, consistent those surfaces seeing themselves. The Fself outputs for the base and top surfaces should be zero but they are not. They are both on the order of 0.9 which means that most of the radiation leaving those surfaces is not accounted for in the model. But that is OK because the views to the other surfaces of the radiation shield were intentionally omitted to simplify the model.