Sage Model Notes

RadShieldNested.ltc

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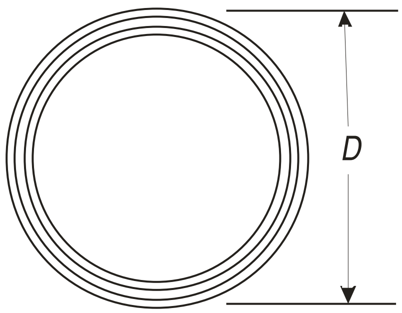
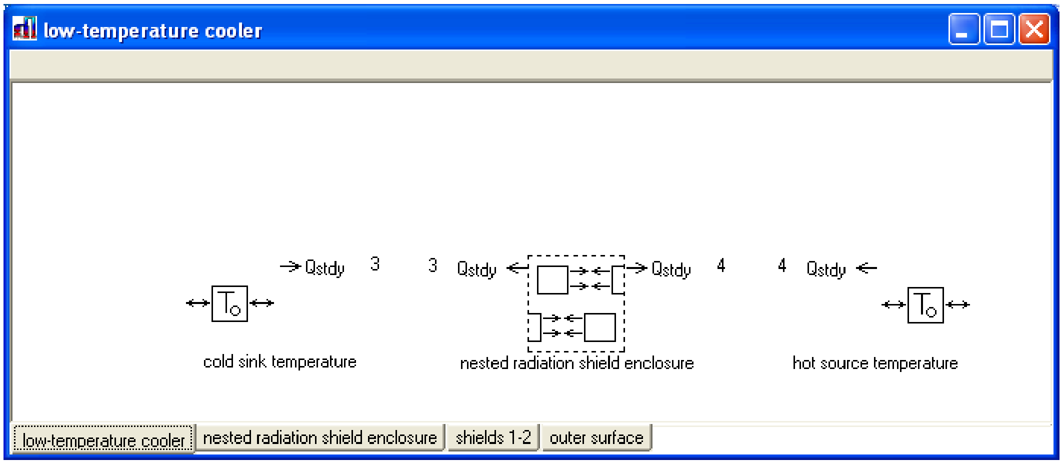
Four closely-spaced concentric spherical surfaces serve as radiation shields to insulate the inner volume from the outside environment. All spheres have essentially the same diameter *D*:



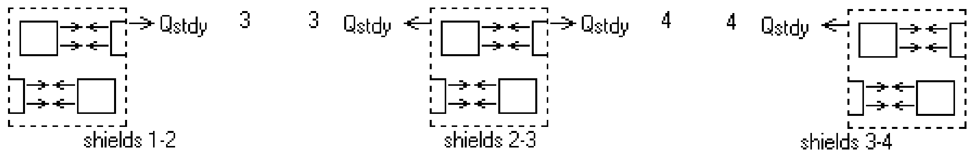
The inner and outer surfaces are anchored to external fixed temperatures. Of interest is the net radiation exchange between them. The inner two shields float in temperature. With fixed temperatures the inner shield might actually represent the surface of some payload that is to be insulated and the outer surface a container wall in good thermal contact with the ambient temperature. In which case there are only two actual radiation shields.

At any rate the top level Sage model looks like this:

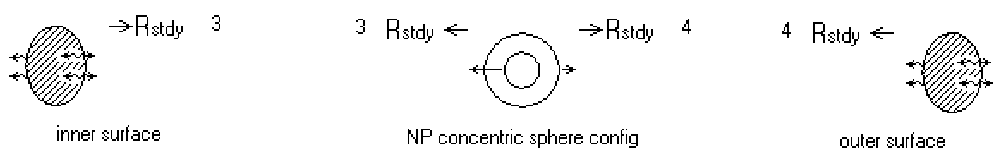


The *cold sink temperature* and *hot source temperature* anchor the two ends of the radiation shields located within the *nested radiation shield enclosure* submodel.

Inside the *nested radiation shield enclosure* submodel are a number of additional submodels each representing the radiation enclosure formed by two adjacent shields:



It is possible to increase the number of shields by disconnecting one of them and copy/pasting any number of times. The actual radiation exchange components within any one of the *shields* submodels are shown here:



The *inner surface* and *outer surface* have ordinary (conductive) heat flow connections moved up to the submodel level for connection to a radiation surface of another *shield* submodel or to one of the root-level temperature sources. Connecting a shield surface to a temperature source fixes its temperature. Connecting two shield surfaces together forces their temperatures to be equal but allows both to float as part of the solution.

The view-factor components *NP concentric sphere config* calculates the view factor for concentric spherical surfaces.

Recast Variables

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

Dshield	spherical shield diameter (m)	1.000E-01
EmShield	emissivity all surfaces (NonDim)	1.000E-02

These inputs are referenced by recast inputs of the inner and outer surface components:

Inner surface* and *outer surface
A = Pi * Sqr(Dshield)
Emiss = EmShield

The surface areas A of all the shields is the same which is technically impossible but does not bother the Sage model. It is a reasonable approximation for multilayer foil insulation.

Net Radiation transfer

The net radiation transfer is given by output Rad in any surface component. In the *inner surface* the result is:

Rad	net incoming radiation flow (W)	2.417E-02

Theoretical Validation

It is easy to verify the Sage solution by comparison with the theoretical prediction of radiation heat transfer. Holman[1], p. 300-302, derives a formula for the radiation heat transfer through N infinite-plane radiation shields of equal emissivity ε:

$$\frac{q}{A} = \frac{\sigma(T_h^4 - T_c^4)}{(N+1)\left(\frac{2}{\varepsilon} - 1\right)}$$

Infinite planes are equivalent to closely spaced spheres in so far as view factors for both are 1.0. In Holman terminology the above Sage model corresponds to two radiation shields between two fixed-temperature planes, so $N = 2$. Substituting Sage model values A = 3.142E-02, T_h = 300, T_c= 4, σ = 5.6696E-8 and $\varepsilon = 1.0\text{E}{-2}$, gives q = 2.417E-2, same as the value calculated by Sage.

[1] J.P. Holman, *Heat Transfer*, fourth edition, McGraw-Hill (1976)