Sage Model Notes

RadElectrLead.scfn

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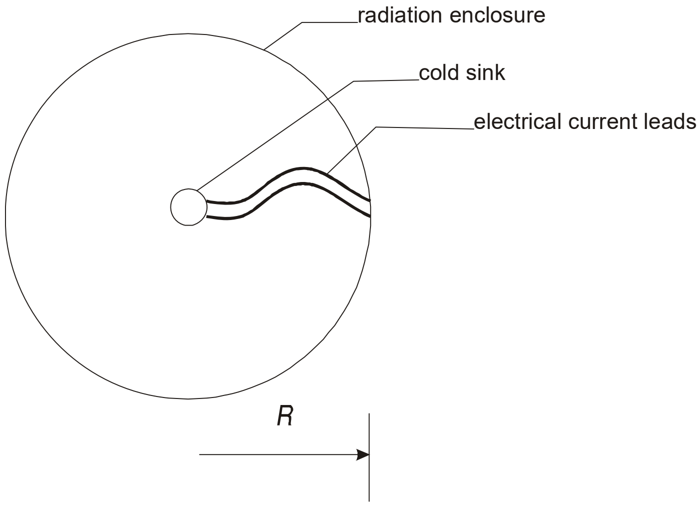
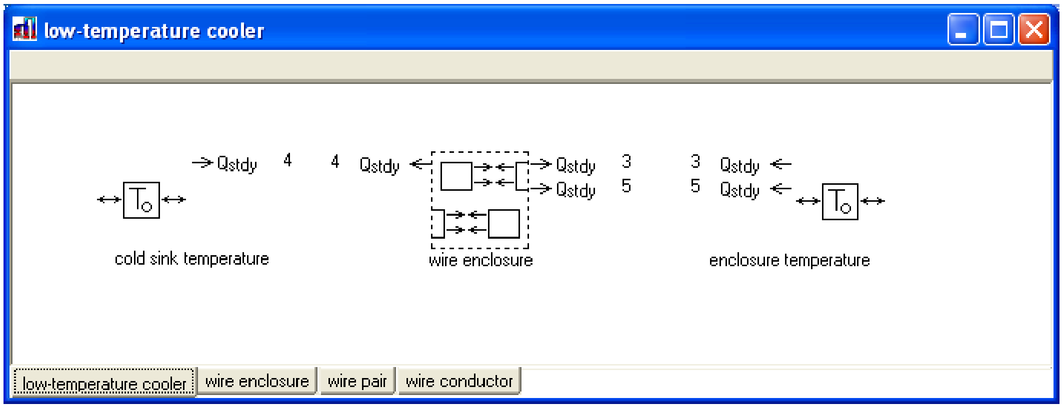
22 March 2010 (revised 1 November 2024)

A pair of electrical leads (wires) within a surrounding radiation enclosure. The leads are thermally conductive and internally heated by an electrical current. They are thermally anchored at one end to the enclosure and at the other end to a cold sink within the enclosure:

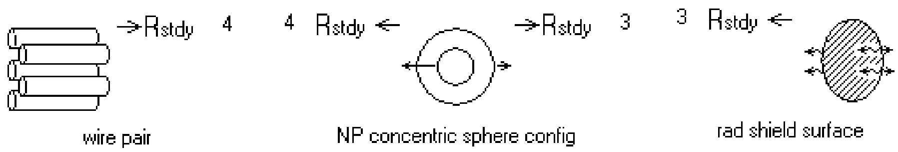


Of interest is the overall energy balance within the wires produced by radiation heat transfer with the enclosure, thermal conduction along the wires and internal electrical heating. The radiation transfer between wires and the cold sink is not part of the model.

This is the top level Sage model:

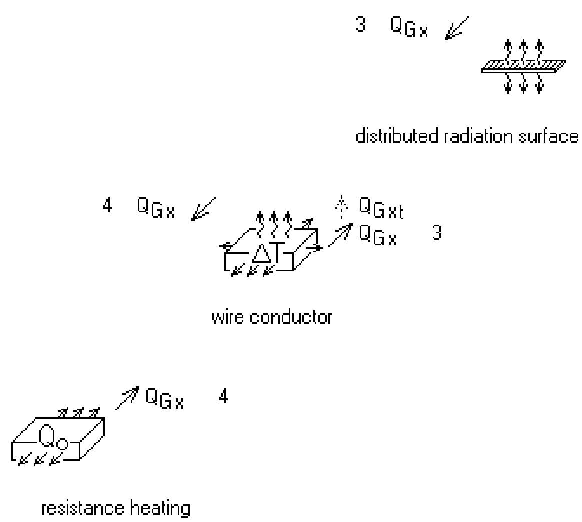


The *cold sink temperature* and *enclosure temperature* anchor the wire ends and enclosure surface within the *wire enclosure* submodel, which looks like this:



The *wire pair* exchanges radiation with the *rad shield surface* through a concentric sphere view configuration. This view configuration applies to any situation where all of the radiation leaving an inner surface reaches an outer surface, so it is a reasonable approximation for a pair of wires that mostly see the surrounding enclosure, The radiation shield is anchored to the enclosure temperature with a Q_{stdy} heat transfer connection at the top level.

The *wire pair* is a tube bundle component originally developed for modeling tubular heat exchangers. Gas normally flows through the tube insides but in this model the tube inner diameter is very small and there is no gas flow. Instead the tube wall thickness is set so that the tube walls simulate circular wires. The *wire pair* component contains some child components inside:



The *wire conductor* in the middle represents the thermal solid of the wires. The reason for using a conductive surface rather than a distributed conductor for this purpose is because it inherits its solid cross-section area from parent component inputs, leaving only transverse conduction length D to be specified as an input. The Q_{Gxt} connector is normally reserved for connection to the gas flowing through the tubes but is not used in this model. Two Q_{stdy} connections at the top level anchor the end temperatures to the cold-sink and enclosure temperatures.

The *distributed radiation surface* represents the outer surfaces of the wires that exchange heat with the *rad shield surface* one level up. A transverse Q_{Gx} thermal connection anchors the radiation surface temperature distribution to the wire solid temperature distribution.

The *wire conductor* intrinsically models thermal conduction and automatically calculates thermal conductivity as a function of temperature. But there is no intrinsic modeling for electrical heating. That comes from the Q_{Gx} connection to the separate r*esistance heating* component, a line heater with heat production distribution recast in terms of user defined variables for electrical current and resistance.

Recast Variables

User-defined inputs and outputs at the *wire enclosure* submodel level define the wire electrical properties, key dimensions and radiation properties of the model:

Inputs

Rshield	shield radius (m)	1.000E-01
EmShield	emissivity shield (NonDim)	5.000E-01
EmWire	emissivity wires (NonDim)	9.000E-01
Dwire	wire diameter (m)	2.500E-04
Lwire	wire length (m)	2.000E-01
OhmMwire	wire resistivity (ohm m)	1.720E-08
Iwire	wire current (A)	2.000E+00

Outputs

OhmWire wire pair series resistance 1.402E-01
2 * OhmMwire * Lwire / (0.25*Pi*Sqr(Dwire))

These inputs are referenced by recast inputs of components within the *wire enclosure*. The recast inputs are:

rad shield surface
A = 4*Pi * Sqr(Rshield)
Emiss = EmShield

wire pair
Twall = 0.5 * Dwire
Length = Lwire

Making the wall thickness half the wire diameter along with a small value input for the tube internal diameter has the result that the cross sectional area of the *wire conductor* child component is equivalent to circular wires with diameter Dwire.

distributed radiation surface
A = 2 * Lwire * Pi * Dwire
Emiss = EmWire

wire conductor
D = 0.25*Dwire

This is the effective conduction length through which heat flows transversely to the *distributed radiation surface* and *resistance heating* components.

resistance heating
Qhtr = unit spline...
(0.000E+00, Sqr(Iwire) * OhmWire)
(1.000E+00, Sqr(Iwire) * OhmWire)

For this model the electrical heating is uniformly distributed. It would be possible to refine the model so that electrical heating is a function of position along the wire length, according to the temperature expected at that position. There is no way to directly specify heating distribution as a function of the solved wire temperature.

Net Radiation transfer

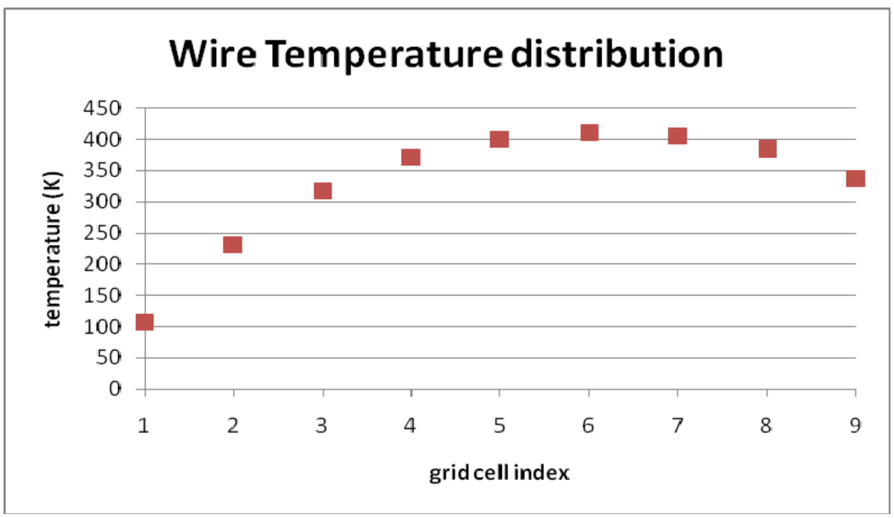
The net radiation transfer between the wires and radiation shield is given by output Rad in the *distributed radiation surface*:

Rad net incoming radiation flow (W) -1.339E-01

There is a net radiation flow from the wires to the shield. Without electrical heating it would be the other way around because the wire temperature would always be lower than the shield temperature. But because of electrical resistance heating the wires get hot enough in the middle to offset the radiation transfer at the cold end.

Wire Energy Balance

The combination of radiation heat transfer, thermal conduction down the wires and electrical resistance heating combine to produce the wire temperature distribution plotted here:



The above plot is in file Wire.xlsx which was derived from a solution grid dump at the *wire pair* component level (File | Save Solution Grid).

The electrical resistance heating produced by the uniform Qhtr distribution within the *resistance heating* component is a uniform 2.80 W/m, for a total of 0.56 W over the wire length. Of that 0.56 W, some leaves the wire by radiation and some by conduction at the ends, as shown in this table:

Wire electrical heating input (W)	0.56
Radiation heat rejection	-0.133
Conduction rejection cold source end	-0.298
Conduction rejection rad shield end	-0.129