This technote deals with the choice of material in order to provide for thermal insulation while maintaining a (relative) high stiffness. This document compares Titanium Ta6V with Stainless Steel-321. This in order to be able to decide whether ss-321 or Ta6V is the material with the better overall properties.

Temperature laws

The temperature law for this type of stainless steel is (MSSL data, in line with general literature):

Kss = 0.1T-0.1 [W/m K] and 4 K < T < 15 K

Lionel Duband provided us with this temperature law for Ta6V (derived from his measurements, in line with general literature)

Kti = -4.045 10^{-4} T^2 + 7.61 10^{-2} T -4.48$10^{-2}$ [W/m K] and 2 K < T < 50 K

Selection criterion

In order to be able to compare both materials we need to normalise them with regard to stiffness and then look at the ratio. That is:

Kti *Ess/Eti : Kss

This means that the cross sectional area of the titanium design needs to be Ess/Eti times bigger than a stainless steel cross sectional area to provide for the same stiffness. We are assuming here that for the critical sections of the supports the cross-sectional area is driving the overall stiffness. This is the case both for the A-frames as well for the cone. The criterion is therefore

Kti *Ess/Eti > Kss → stainless is effectively a better insulator

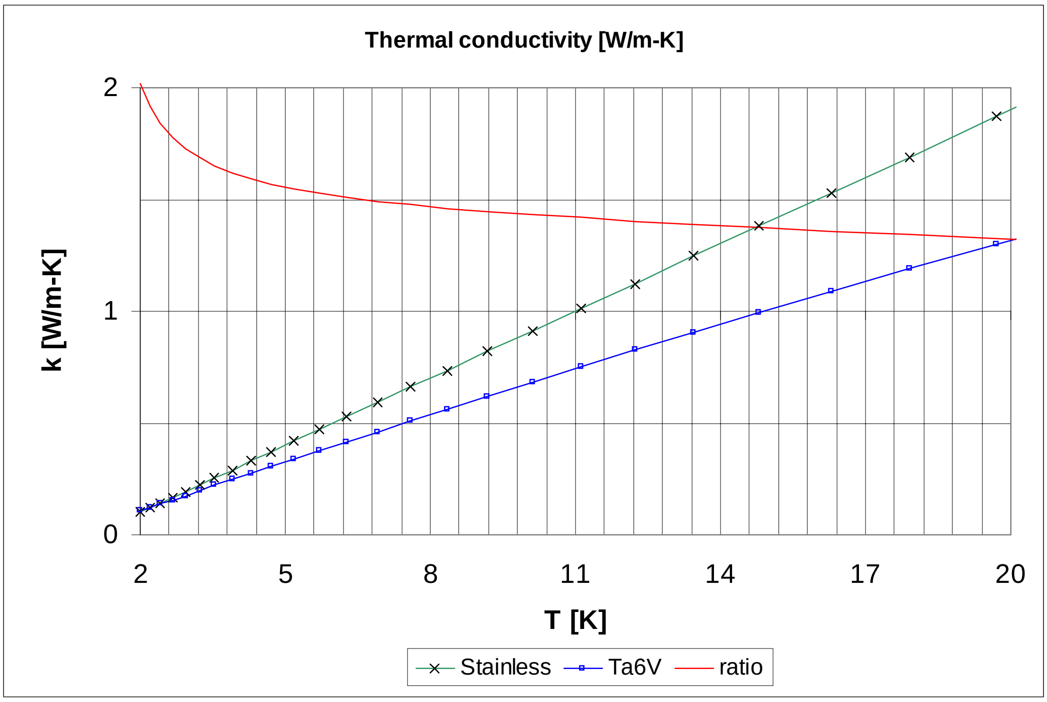
Kti *Ess/Eti < Kss → titanium is effectively a better insulator

So in all this criterion effectively compares the thermal conductance of both materials normalised with regard to stiffness.

The assumed stiffness for stainless steel at T<15 K is 225 GPa and for Titanium 115 GPa (+10% stiffness added to compensate for drop in temperature, effectively this change in stiffness cancels out in the weighting function)

The results

Hereafter a plot is given with the conductivity's and the ratio (Kti*Ess)/(Eti*Kss)



Thermal conduction compared (ratio)

From the graph it becomes clear that since the ratio is above 1 throughout the temperature range 4-15 K at these temperatures, stainless steel is the better thermal insulator. At about 2 Kelvin (cross-over in thermal conduction) the ratio is about 2, which is the ratio of both stiffnesses (stainless steel is about twice as stiff as titanium)

Conclusion

Therefore the conclusion is that stainless steel is the better choice of material for the instrument supports in the temperature range 4 K to 15 K.