**PROPERTIES OF SELECTED MATERIALS AT CRYOGENIC TEMPERATURES**

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The design of systems for operation at cryogenic temperatures requires the use of material properties at these low temperatures. The properties at cryogenic temperatures can be much different than the room-temperature values. In addition, some properties can be strong functions of temperature. Property data at cryogenic temperatures are not easy to find. Many measurements were made at the National Institute of Standards and Technology (NIST) and other laboratories about 50 years ago. Some of the results were published in reports that are now out of print, which makes the results unavailable to most researchers. To correct that problem, NIST initiated a program to critically evaluate cryogenic material properties and to curve fit the available data for temperatures in the range of about 4 K to 300 K. The parameters for the curve fit, as well as a graph of the curve, are available on the websites:

For a broad range of subjects including materials and fluids <https://trc.nist.gov/cryogenics/>

 For materials [https://trc.nist.gov/cryogenics/materials/materialproperties.htm](https://trc.nist.gov/cryogenics/materials/materialproperties.htm%22%20%5Ct%20%22_blank)

Click on “Material Properties” to find the list of materials. The properties available include thermal conductivity, specific heat, linear thermal expansion, thermal expansion coefficient, and Young’s modulus. Not all properties are available for all materials. The materials currently in the database are ones commonly used in the construction of cryogenic hardware.

The tables presented here are the calculated values using the equations given on the website. In general the equations fit a single set of data to within about 1 % to 2 %, but often several sets of data are used in determining the best fit, in which case deviations can be significantly higher, such as 5 %. The website specifies the deviation of the fit relative to the experimental data for each property and each material. Uncertainties in the experimental data usually are in the range of 2 % to 5 %, and variations from sample to sample can also lead to similar uncertainties, especially in thermal conductivity. Some well-characterized materials, such as silicon, are used for standard reference materials. Thus, uncertainties in the experimental data for the thermal expansion coefficient of silicon are usually less than 0.2 %, and the standard deviation of the curve fit to the data is less than about 0.2 % over most of the temperature range

Copper referred to here is of very high purity 99.99% (4N or better) and may be considered oxygen-free (sometimes referred to as OFHC-oxygen free high conductivity). Values are given with respect to the RRR (Residual Resistivity Ratio) which correlates the thermal resistivity and electrical resistivity as the impurity effect and is primarily additive in resistivity. Higher RRR values indicate higher purity and lower electrical and thermal resistance leading to higher thermal conductivity. Standard high-purity copper such as grade 101 or 102 has an RRR value of approximately 100. Higher values may be obtained with considerable effort at minimizing trace impurities by special annealing techniques that can achieve an RRR of about 1000 or greater in some special instances. Specially obtained high RRR value copper is often used only when very low temperatures (< 40 K), and necessarily high thermal conduction at low temperature, are required.

Ti 15-3-3-3 has a nominal composition of 15% V, 3% Cr, 3% Sn, 3% Al, balance Ti. For the specific measurements documented by Canavan and Tuttle (Ref. 29), the exact composition is 14.88% V, 3.13% Cr, 2.88% Sn, 3.01% Al, bal. Ti. The composition for brass is 65% Cu, 32% Zn, 3% Pb which is free machining. The composition for BeCu is 2% Be, 0.3% Co, balance Cu.

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