Selected data for common materials on the Vapor Box project

Quantities that use the Mathematica "Quantity" functionality have the first letter in *script*.

The abbreviation for stainless steel 316 is SS.

```
(* some abbreviations for units *)
gpcc = Quantity["Grams" / "Centimeters"^3];
jpkgk = Quantity[1.0, "Joules" / ("Kilograms" "Kelvins")];
wpmk = Quantity["Watts" / ("Meters" "Kelvins")];
```

Typical density of 316 stainless steel from [1]

[1] https://www.azom.com/properties.aspx?ArticleID=863
This page is also available at https://web.archive.org/web/20190225005937/https://www.azom.-com/properties.aspx?ArticleID=863

In[173]:=
```
ρSS = 8. gpcc;
```

Density of mullite from [2]. We assume the ceramic heaters are made of mullite.

[2] https://accuratus.com/mullite.html.
This page is also available at https://web.archive.org/web/20190225005700/https://accuratus.com/mul lite.html

```
ρMullite = 2.8 gpcc ;
```

Specific heat of stainless steel from the same azom.com page as above. I arbitrarily chose the lowest value.

```
cSS = 490 jpkgk;
```

Specific heat capacity of Mullite, from [3]. The multiplying a constant value for *c*Mullite, taken to be the highest encountered in the experiment, by the *c*MulliteTFactor allows a more sophisticated analysis that takes into account the lower specific heat capacity at lower temperatures.

[3] Hildmann, Bernd, and Hartmut Schneider. "Heat Capacity of Mullite-New Data and Evidence for a High-Temperature Phase Transformation." Journal of the American Ceramic Society 87, no. 2 (2004): 227–234.

```
(* Temperature is in Kelvin *)
cMulliteT[T_] := Quantity[
     a + 10^-5 b T + 10^4 c T^-2 + 10 d T^-0.5 + 10^6 e T^-3, "Joules" / ("Grams" "Kelvins")] /.
   {a → 1.588 16, b → -1.225 4, c → -2.224 0, d → -1.114 2, e → 2.487} // Evaluate;
cMullite = cMulliteT[950];
(*worst case scenario for highest specific heat *);
cMulliteTFactor[TK_] := cMulliteT[TK] / cMullite
```

Emissivity of stainless steel is estimated as 0.3, similar to that reported on page 61 of [4], for SS 316, “as received”, on first heating.
Coated and uncoated ceramic heater emissivities are from the Watlow High Temperature Heaters brochure, [5], page 439.

[4] Thermal radiative properties of selected materials / by W.D. Wood, H.W. Deem, and C.F. Lucks ; to Office of the Director of Defense Research and Engineering.
Columbus, Ohio : Defense Metals Information Center, Battelle Memorial Institute, 1962.

[5] https://transition.watlow.com/downloads/en/catalogs/high-temp.pdf
Also available at https://web.archive.org/web/20190225011854/https://transition.watlow.com/downloads/en/catalogs/high-temp.pdf

In[191]:=
```
ϵSS = 0.3;
ϵCeramicHeaterHighEmissivity = 0.85;
ϵCeramicHeaterUncoatedSurfaces = 0.6; (* at 800C *)
```

The temperature factor for the resistance of Kanthal wire. From [5], using data for Kanthal A.

[5] https://www.kanthal.com/globalassets/kanthal-global/products/resistance-heating-wire-and-strip/materials-physical-and-mechanical-properties-chart_alkrothal-nikrothal.pdf
Also available at https://web.archive.org/web/20190224231336/https://www.kanthal.com/globalassets/kanthal-global/products/resistance-heating-wire-and-strip/materials-physical-and-mechanical-properties-chart_alkrothal-nikrothal.pdf

In[22]:=
```
ρElTemperatureFactorKanthal[Tc_] :=
  Interpolation[{{20, 1}, {250, 1.01}, {500, 1.03}, {800, 1.05},
     {1000, 1.06}, {1200, 1.06}}, InterpolationOrder → 1][Tc];
```

```
materialLib[ρ_, c_, k_, ϵ_] := <|"ρ" → ρ, "c" → c, "k" → k, "ϵ" → ϵ, "s" → ρ c|>;
materialLib["SS"] := materialLib[ρSS, cSS, ı, ϵSS];

materialLib["CeramicHeater"] :=
  materialLib[ρMullite, cMullite, ı, ϵCeramicHeaterHighEmissivity];
materialLib["CeramicHeaterUncoated"] :=
  materialLib[ρMullite, cMullite, ı, ϵCeramicHeaterUncoatedSurfaces];
materialLib["Arbitraryϵ0.1"] := materialLib[ı, ı, ı, 0.1];
materialLib["Arbitraryϵ0.2"] := materialLib[ı, ı, ı, 0.2];
```

Thickness of sheet metal gauges

In[168]:=

```
sheetGage[{"SS", g_}] := sheetGageSS[g];

sheetGageSS["16th"] := Quantity[0.062 5, "Inches"];
```