BAL SEAL ENGINEERING

Custom components that drive tomorrow's technologies.®

Coefficients of Thermal Expansion for Common Hardware and Sealing Materials

Technical Report

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1.0 Purpose

The purpose of this Technical Report is to provide information about the coefficient of thermal expansion (CTE) for common hardware materials used in engineering applications, and for the polymers used to manufacture Bal Seal® spring-energized seals.

2.0 Scope

When an object is heated or cooled, its length changes by an amount proportional to the original length and the change in temperature. The CTE is used for design purposes to determine if failure by thermal stress may occur. Understanding the relative expansion/contraction characteristics of materials is important for application success.

The CTE values are of considerable interest to design engineers. Plastics tend to expand and contract anywhere from six to nine times more than metals. The thermal expansion difference develops internal stresses and stress concentrations in the polymer, which can cause premature failure to occur.

3.0 Definition

The coefficient of thermal expansion is defined as the change in length or volume of a material for a unit change in temperature. The overall coefficient is the linear thermal expansion per degree Fahrenheit or Celsius. The CTE data is calculated by the change in length divided by the initial length at room temperature, divided by the change in temperature.

For example, a 6 inch length of 303 SS rod (CTE of 9.6 x10-6 in./in. °F at 75 °F) heated from 75 °F to 95 °F would expand by 0.001152 in. (9.6 x 10-6 in./in. °F * 6 in * 20 °F).

4.0 Thermal Expansion Tables

As systems heat up and cool down, it is important to ensure that all of the components—whether metal or plastic—remain the same size in relativity to each other, in order to avoid excess stresses or system failure caused by a discrepancy in sizes. Below are tables that showcase the coefficient of thermal expansion for common hardware materials at a range of temperatures.

4.1 Table: Thermal Expansion of Steels

<table>
<tr><th>Units $\frac{(\mu in)}{(in^* \, °F)} \left(\frac{(\mu m)}{(m^* \, °C)}\right)$</th><th>–100 °F (–73 °C)</th><th>32 °F (0 °C)</th><th>200 °F (93°C)</th><th>400 °F (205 °C)</th><th>600 °F (316 °C)</th></tr>
<tr><td>303 SS</td><td>9.3 (16.7)</td><td>9.6 (17.3)</td><td colspan="2">9.9 (17.8)</td></tr>
<tr><td>304 SS</td><td>8.2 (14.8)</td><td>8.8 (15.8)</td><td>9.2 (16.6)</td><td>9.4 (16.9)</td></tr>
<tr><td>347 SS</td><td>8.5 (15.3)</td><td>9.3 (16.7)</td><td>9.4 (16.9)</td><td>9.5 (17.1)</td></tr>
<tr><td>410 SS</td><td>—</td><td>5.5 (9.9)</td><td colspan="2">5.6 (10.1)</td></tr>
<tr><td>416 SS</td><td>—</td><td>5.5 (9.9)</td><td colspan="2">5.6 (10.1)</td></tr>
<tr><td>440 SS</td><td>5.6 (10.1)</td><td>5.6 (10.1)</td><td colspan="2">5.9 (10.6)</td></tr>
<tr><td>13-8 PH SS</td><td>5.8 (10.4)</td><td colspan="3">—</td></tr>
<tr><td>15-5 PH SS</td><td>5.8 (10.4)</td><td>6.0 (10.8)</td><td>6.0 (10.8)</td><td>—</td></tr>
<tr><td>17-4 PH SS Condition A</td><td>—</td><td colspan="2">6.0 (10.8)</td><td>6.2 (11.0)</td></tr>
<tr><td>17-4 PH SS Condition H900</td><td>5.8 (10.4)</td><td colspan="2">6.0 (10.8)</td><td>6.3 (11.3)</td></tr>
<tr><td>17-7 PH SS Condition A</td><td>—</td><td>8.5 (15.3)</td><td>9.0 (16.2)</td><td>9.5 (17.1)</td></tr>
<tr><td>17-7 PH Condition H900</td><td>—</td><td>6.1 (11.0)</td><td colspan="2">6.4 (11.5)</td></tr>
<tr><td>A286 SS</td><td>—</td><td>9.2 (16.6)</td><td>9.4 (16.9)</td><td>9.5 (17.0)</td></tr>
<tr><td>1020 Carbon Steel</td><td>—</td><td>6.5 (11.7)</td><td>7.11 (12.8)</td><td>7.7 (13.9)</td></tr>
<tr><td>4140 High Alloy Steel</td><td>—</td><td>6.8 (12.2)</td><td>7.61 (13.7)</td><td>8.1 (14.6)</td></tr>
<tr><td>4340 High Alloy Steel</td><td>—</td><td>6.8 (12.2)</td><td>7.61 (13.7)</td><td>8.1 (14.6)</td></tr>
<tr><td>H13 Tool Steel</td><td>—</td><td>5.8 (10.4)</td><td>6.3 (11.3)</td><td>6.4 (11.5)</td></tr>
<tr><td>H11 Tool Steel</td><td>—</td><td colspan="2">6.6 (11.9</td><td>6.9 (12.4)</td></tr>
<tr><td>Vasco T-250</td><td>—</td><td colspan="3">5.6 (10.1)</td></tr>
<tr><td>Tungsten Carbide K801</td><td>2.2 (3.9)</td><td colspan="2">2.7 (4.9)</td><td>—</td></tr>
</table>

4.2 Table: Aluminum and other Alloys

<table>
<tr><th>Units $\frac{(\mu in)}{(in^{*}\ °F)}\left(\frac{(\mu m)}{(m^{*}\ °C)}\right)$</th><th colspan="2">−238 °F (−150 °C)</th><th colspan="2">−58 °F (−50 °C)</th><th colspan="2">68 °F (20 °C)</th><th colspan="2">212 °F (100 °C)</th><th colspan="2">392 °F (202 °C)</th></tr>
<tr><td>Al 356</td><td colspan="3">—</td><td colspan="2">11.0 (19.8)</td><td colspan="2">11.9 (21.4)</td><td colspan="3">12.9 (23.2)</td></tr>
<tr><td>Al 2014</td><td colspan="3">10.9 (19.6)</td><td colspan="2">12.0 (21.6)</td><td colspan="2">12.8 (23.0)</td><td colspan="3">13.6 (24.4)</td></tr>
<tr><td>Al 2024</td><td colspan="3">10.8 (19.4)</td><td colspan="2">11.9 (21.4)</td><td colspan="2">12.9 (23.2)</td><td colspan="3">13.7 (24.7)</td></tr>
<tr><td>Al 6061</td><td colspan="3">—</td><td colspan="2">12.1 (21.8)</td><td colspan="2">13.1 (23.6)</td><td colspan="3">14.0 (25.2)</td></tr>
<tr><td>Al 7075</td><td colspan="3">—</td><td colspan="2">12.1 (21.8)</td><td colspan="2">13.1 (23.6)</td><td colspan="3">14.0 (25.2)</td></tr>
<tr><td>Magnesium</td><td colspan="5">—</td><td colspan="2">14.5 (26.1)</td><td colspan="3">15.1 (27.2)</td></tr>
<tr><td>Aluminum Si-Bronze</td><td colspan="3">8.1 (14.6)</td><td colspan="2">9.0 (16.2)</td><td colspan="2">16.6 (29.9)</td><td colspan="3">—</td></tr>
<tr><td>Titanium 6AL-4V</td><td colspan="5">1.3 (2.3)</td><td colspan="2">4.8 (8.6)</td><td colspan="3">5.1 (9.2)</td></tr>
</table>

4.3 Plastics and other non-metals

Plastics tend to have CTE values anywhere from six to nine times more than those of metals. The difference in thermal expansion can potentially lead to the development of internal stresses and stress concentrations within the polymer, which can result in premature failure. Below are the CTE values for materials used in the manufacture of Bal Seal spring-energized seals, as well as some common plastic hardware materials.

4.4 Table: Polymers

Units (µin)/(in* °F) ((µm)/(m* °C))	–58 °F (–50 °C)	77 °F (25 °C)	212 °F (100 °C)	392 °F (202 °C)	572 °F (300 °C)
Halar	—	44.0 (79.2)	54.0 (97.2)	—	
Polyimide	—	28.0 (50.4)		—	
Tefzel	—	52.0 (93.6)	—		
Torlon Virgin Type 4203	—	17.0 (30.6)	—		
Torlon w/30% Graphite Type 4301	—	13.9 (25.0)	—		
Vespel SP-1 Virgin	25.0 (45.0)	30.0 (54.0)			
Vespel SP-21	—	23.0 (41.4)			
Nylon	—	50.0 (90.0)	—		
Silicone Rubber	—	190.0 (342.0)		—	
Mech. Carbons	—	1.2 to 2.5 (2.2 to 4.5)			
T (Virgin PTFE)	—	79.6 (143.3)	—		
TA (Modified PTFE)	—	66.7 (120.0)	—		
G (Graphite Filled PTFE)[1]	—	78.5 (141.3)	—		
GC (Graphite-Carbon PTFE)[1]	—	76.2 (137.2)	—		
GFP (Graphite-fiber -reinforced PTFE)[1]	—	70.3 (126.7)	—		
GL20 (Glass Filled PTFE)[1]	—	76.8 (132.2)	—		
SP31 (Polymer-Filled PTFE)[1]	—	77.2 (139.0)	—		
P41 (Virgin PEEK)	—	27.8 (50.0)	—		

1. Bal Seal Engineering proprietary blend

5.0 Reference

5.1 Conversion factors

Degrees Fahrenheit = (°C x 1.8) +32
Degrees Rankine = Degrees Fahrenheit +459.7
Degrees Centigrade = (°F –32)/1.8
Degrees Kelvin = Degrees Centigrade +273

5.2 Bal Seal Report – RMS-41 Fluoropolymers, UHMW Polyethylene and Other Plastics as Seal Materials

5.3 LNP Engineering Plastics (www.lnp.com)

5.4 Ref: engineering toolbox

5.5 matweb