



Coefficients of Thermal Expansion for Common Hardware and Sealing Materials

Technical Report
TR-18 (Rev. 01; 10-14-21)

19650 Pauling
Foothill Ranch, CA
USA 92610-2610
O +1 949 460 2100
F +1 949 460 230

VIDA Building, 1st Floor
Kabelweg 57
1014 BA Amsterdam
The Netherlands
O +31 20 638 6523
F +31 20 625 601

Suite 901, Chinachem
Century Tower
178 Gloucester Road,
Wanchai, Hong Kong
O +852 28681860
F +852 22956753

www.balseal.com



Contents

- 1.0 Purpose 3
- 2.0 Scope 3
- 3.0 Definition 3
- 4.0 Thermal Expansion Tables 4
 - 4.1 Table: Thermal Expansion of Steels 4
 - 4.2 Table: Aluminum and other Alloys 5
 - 4.3 Plastics and other non-metals. 6
 - 4.4 Table: Polymers 6
- 5.0 Reference 7

The information, descriptions, recommendations and opinions set forth herein are offered solely for your consideration, inquiry, and verification and are not, in part or in whole, to be construed as constituting a warranty, expressed or implied, nor shall they form or be a part of the basis of any bargain with Bal Seal Engineering, LLC. If any sample or model was shown to or provided by Buyer/User, such sample or model was used merely to illustrate the general description and type of goods. Such use is not to be construed as a warranty that the goods will conform to the sample or model. Furthermore, THE IMPLIED WARRANTY OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE AND ALL OTHER WARRANTIES, IMPLIED OR EXPRESSED, ARE EXCLUDED AND SHALL NOT APPLY. This document provides product options for further investigation by Buyers/Users having technical expertise. The Buyer/User, through its own analysis and testing, is solely responsible for making the final selection of the products and for assuming that all performance, safety and warning requirements for the application are met. It is recommended that Buyers/Users run evaluation testing under actual service conditions to determine whether proposed Bal Seal Engineering products are suitable for the intended purpose. Nothing contained herein or in any of our literature shall be considered a license or recommendation for any use that may infringe patent rights. (LE-17)

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 9.6×10^{-6} in./in. °F at 75 °F) heated from 75 °F to 95 °F would expand by 0.001152 in. (9.6×10^{-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 relative 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

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

4.2 Table: Aluminum and other Alloys

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

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 $\frac{(\mu\text{in})}{(\text{in} \cdot ^\circ\text{F})}$ $\left(\frac{(\mu\text{m})}{(\text{m} \cdot ^\circ\text{C})}\right)$	-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 = ($^{\circ}\text{C} \times 1.8$) +32

Degrees Rankine = Degrees Fahrenheit +459.7

Degrees Centigrade = ($^{\circ}\text{F} -32$)/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