COEFFICIENT OF THERMAL EXPANSION FOR VARIOUS MATERIALS AT DIFFERENT TEMPERATURES

Technical Report
TR-18 (Rev. F)

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1.0 Purpose

The purpose of this Technical Report is to show the coefficient of thermal expansion (CTE) for various metallic and non-metallic materials used in springs and seals made by Bal Seal Engineering Co.

2.0 Scope

The coefficient of thermal expansion is used to determine the rate at which a material expands as a function of temperature. 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 allows 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 (in.) per degree Fahrenheit or Celsius. The CTE data is calculated by the change in length divided by the quantity of the length at room temperature, multiplied by the change of temperature.

Coefficient of Thermal Expansion for Various Materials at Different Temperatures

4.0 Charts

4.1 Chart 1 Metals
inch / inch / deg F
(mm / mm / deg C)

STEELS								
	32° to 600°F	**(0° to 316°C)**	**32° to 400°F**	**(0° to 205°C)**	**32° to 200°F**	**(0° to 93°C)**	**32° to -100°F**	**(0° to -73°C**
303 SS	9.9 x 10-^{6}	(17.8 x 10^{-6})			9.6 x 10^{-6}	(17.3 x 10^{-6})	9.3 x 10^{-6}	(16.7 x 10^{-6})
304 SS	9.4 x 10-^{6}	(16.9 x 10^{-6})	9.2 x 10^{-6}	(16.6 x 10^{-6})	8.8 x 10^{-6}	(15.8 x 10^{-6})	8.2 x 10^{-6}	(14.8 x 10^{-6})
347 SS	9.5 x 10-^{6}	17.1 x 10^{-6})	9.4 x 10 $^{-6}$	(16.9 x 10^{-6})	9.3 x 10^{-6}	(16.7 x 10^{-6})	8.5 x 10^{-6}	(15.3 x 10^{-6})
410 SS	5.6 x 10-^{6}	(10.1 x 10^{-6})			5.5 x 10^{-6}	(9.9 x 10^{-6})		
416 SS	5.6 x 10^{-6}	(10.1 x 10^{-6})			5.5 x 10^{-6}	(9.9 x 10^{-6})		
440 SS	5.9 x 10^{-6}	(10.6 x 10^{-6})			5.6 x 10^{-6}	(10.1 x 10^{-6})	5.6 x 10^{-6}	(10.1 x 10^{-6})
13-8 PH SS							5.8 x 10^{-6}	(10.4 x 10^{-6})
15-5 PH SS			6.0 x 10^{-6}	(10.8 x 10^{-6})	6.0 x 10^{-6}	(10.8 x 10^{-6})	5.8 x 10^{-6}	(10.4 x 10^{-6})
17-4 PH SS Condition A	6.2 x 10^{-6}	(11.2 x 10^{-6})	6.0 x 10^{-6}	(10.8 x 10^{-6})	6.0 x10^{-6}	(10.8 x 10^{-6})		
17-4 PH SS Condition H900	6.3 x 10^{-6}	(11.3 x 10^{-6})	6.1 x 10^{-6}	(11.0 x 10^{-6})	6.0 x 10^{-6}	(10.8 x 10^{-6})		
17-7 PH SS Condition A	9.5 x 10^{-6}	(17.1 x 10^{-6})	9.0 x 10^{-6}	(16.2 x 10^{-6})	8.5 x 10^{-6}	(15.3 x 10^{-6})		
17-7 PH Condition H900	6.4 x 10^{-6}	(11.5 x 10^{-6})	6.3 x 10^{-6}	(11.3 x 10^{-6})	6.1 x 10^{-6}	(11.0 x 10^{-6})		
A286 SS	9.8 x 10^{-6}	(17.6 x 10^{-6})	9.4 x 10^{-6}	(16.9 x 10^{-6})	9.2 x 10^{-6}	(16.6 x 10^{-6})		
1020 CRS	7.0 x 10^{-6}	(12.6 x 10^{-6})	7.0 x 10^{-6}	(12.6 x 10^{-6})	7.0 x 10^{-6}	(12.6 x 10^{-6})		
4140 High Alloy Steel			13.7 x 10^{-6}	(24.7 x 10^{-6})	12.7 x 10^{-6}	(22.9 x 10^{-6})		
4340 High Alloy Steel			13.6 x 10^{-6}	(24.5 x 10^{-6})	12.4 x 10^{-6}	(22.3 x 10^{-6})		
H13 Tool Steel			11.5 x 10^{-6}	(20.7 x 10^{-6})				
H11 Tool Steel			11.5 x 10^{-6}	(20.7 x 10^{-6})				
Vasco T-250	5.6 x 10^{-6}	(10.1 x 10^{-6})						
Tungsten Carbide K801			2.7 x 10^{-6}	(4.9 x 10^{-6})			2.2 x 10^{-6}	(3.9 x 10^{-6})

Coefficient of Thermal Expansion for Various Materials at Different Temperatures

ALUMINUM AND OTHER ALLOYS								
	68° to 392°F	(20° to 202°C)	68° to 212°F	(20° to 100°C)	68° to -58°F	(20° to -50°C)	68° to -238°F	(20° to -150°C)
356	12.5 x 10^{-6}	(22.5 x 10^{-6})	11.9 x 10^{-6}	(21.4 x 10^{-6})	11.0 x 10^{-6}	(19.8 x 10^{-6})		
2014	13.1 x 10^{-6}	23.6 x 10^{-6})	12.5 x 10^{-6}	(22.5 x 10^{-6})	12.0 x 10^{-6}	(21.6 x 10^{-6})	10.9 x 10^{-6}	19.6 x 10^{-6})
2024	13.2 x 10^{-6}	(23.8 x 10^{-6})	12.6 x 10^{-6}	(22.7 x 10^{-6})	11.9 x 10^{-6}	(21.4 x 10^{-6})	10.8 x 10^{-6}	(19.4 x 10^{-6})
6061	13.5 x 10^{-6}	(24.3 x 10^{-6})	13.0 x 10^{-6}	(23.4 x 10^{-6})	12.1 x 10^{-6}	(21.8 x 10^{-6})		
7075	13.5 x 10^{-6}	(24.3 x 10^{-6})	12.9 x 10^{-6}	(23.2 x 10^{-6})	12.1 x 10^{-6}	(21.8 x 10^{-6})		
Magnesium			14.4 x 10^{-6}	(25.9 x 10^{-6})				
Aluminum Si-Bronze			16.6 x 10^{-6}	(29.9 x 10^{-6})	9.0 x 10^{-6}	(16.2 x 10^{-6})	8.1 x 10^{-6}	(14.6 x 10^{-6})
Titanium 6AL-4V	5.0 x 10^{-6}	(9.0 x 10^{-6})	4.8 x 10^{-6}	(8.6 x 10^{-6})			1.3 x 10^{-6}	(2.3 x 10^{-6})

4.2 Chart 2 Plastics and other non-metals
inch / inch / deg F
(mm / mm / deg C

PTFE AND PTFE BAL SEAL COMPOSITIONS								
	77° to 572°F	**(25° to 300°C)**	**77° to 392°F**	**(25° to 202°C)**	**77° to 212°F**	**(25° to 100°C)**	**77° to -58°F**	**(25° to -50°C)**
PTFE (plain)					79.6 x 10-6	(143.3 x 10-6)		
G (Graphite PTFE)					78.5 x 10-6	(141.3 x 10-6)		
GC (Graphite-Carbon PTFE)					76.2 x 10-6	(137.2 x 10-6)		
GFPA (Graphite-fiber-reinforced PTFE)					70.3 x 10-6	(126.7 x 10-6)		
GL-20					76.8 x 10-6	(132.2 x 10-6)		
SP-31 (Polymer-Filled PTFE)					77.2 x 10-6	(139.0 x 10-6)		

POLYMERS AND OTHER NON-METALLIC MATERIALS								
Halar			54.0 x 10^{-6}	(97.2 x 10^{-6})	44.0 x 10^{-6}	(79.2 x 10^{-6})		
Polyimide			78.0 x 10^{-6}	(140.4 x 10^{-6})				
Tefzel					52.0 x 10^{-6}	(93.6 x 10^{-6})		
Torlon Virgion Type 4203					17.0 x 10^{-6}	(30.6 x 10^{-6})		
Torlon w/30% Graphite Type 4301					5.6 x 10^{-6}	(10.1 x 10^{-6})		
Vespel SP-1 Virgin	30.0 x 10^{-6}	(54.0 x 10^{-6})					25.0 x 10^{-6}	(45.0 x 10^{-6})
Vespel SP-21	23.0 x 10^{-6}	(41.4 x 10^{-6})					25.0 x 10^{-6}	(45.0 x 10^{-6})
Nylon					50.0 x 10^{-6}	(90.0 x 10^{-6})		
Silicone Rubber			190.0 x 10^{-6}	(342.0 x 10^{-6})				
Mech. Carbons	1.2 to 2.5 x 10^{-6}	(2.16 to 4.5 x 10^{-6})						

5.0 References

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