BAL SEAL ENGINEERING, INC.

Custom components that drive tomorrow's technologies.®

Properties of standard Bal Spring® canted coil spring materials

Technical Report

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19650 Pauling
Foothill Ranch, CA
USA 92610-2610
t +1 949 460 2100
f +1 949 460 2300

Jollemanhof 16, 5th floor
1019 GW Amsterdam
The Netherlands
t +31 20 638 6523
f +31 20 625 6018

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

www.balseal.com

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1.0 Summary

Various types of canted coil spring materials are available from Bal Seal Engineering, Inc. Material selection depends primarily on the medium and operating temperature of the application.

This report describes physical, mechanical and chemical resistance properties of these materials at normal temperatures and after cooling from elevated temperatures.

2.0 Types of Spring Materials:

The following are standard and special spring materials available from Bal Seal Engineering, Inc. Mechanical properties are affected by temperature, diameter of wire, and degree of cold working. Typical physical properties at 70 °F (21 °C) are shown in Table 2.

2.1 BSE1 or BSE2 (Stainless Steel)

BSE1 or BSE2 is a chromium-nickel stainless steel. It can operate at temperatures –330 °F to +570 °F (–200 °C to +300 °C).

2.2 BSE3 or BSE4 (Stainless Steel)

BSE3 or BSE4 has a higher nickel content, which provides better corrosion resistance than BSE1 or BSE2. The suggested temperature range is –330 °F to +570 °F (–200 °C to +300 °C).

2.3 BSE5 (Stainless Steel)

This material has a lower carbon content than BSE3 or BSE4. The temperature range is –330 °F to +570 °F (–200 °C to +300 °C), with mechanical properties similar to BSE3 or BSE4.

2.4 BSE6 (Stainless Steel)

This material has the same composition as BSE5 except that it is melted in vacuum to reduce impurities.

2.5 BSE9 (Beryllium Copper Alloy)

This is a high-strength copper alloy. The operating temperature range is –420 °F to +250 °F (–250 °C to +175 °C).

2.6 BSE11 (Zirconium Chromium Copper Alloy)

This copper alloy has lower yield strength than BSE9, yet still exhibits excellent electrical conductivity. The maximum operating temperature is 392 °F (200 °C).

2.7 BSE12 (Copper Alloy)

This copper alloy has lower strength than BSE9, yet still exhibits excellent electrical conductivity. The maximum operating temperature is 392 °F (200 °C).

2.8 BSE17 (Nickel Alloy)

BSE17 is a nickel-based alloy that has higher corrosion resistance than BSE1 or BSE2, BSE3, or BSE4, and BSE5 stainless steel with a higher percentage of nickel. Operating temperature range is from –330 °F to +750 °F (–200 °C to +400 °C).

2.9 BSE18 (Nickel Alloy)

BSE18 offers the highest corrosion resistance of the standard spring materials. Its temperature range is –70 °F to 1250 °F (–60 °C to +677 °C).

2.10 BSE19 (Cobalt Nickel Alloy)

BSE19 is a nickel alloy used in corrosive environments and long service life applications. It maintains high mechanical properties and has a temperature range from –70 °F to +550 °F (–60 °C to +288 °C). This material is a noncorrosive metal and will cause galvanic corrosion when coupled with carbon steel, or BSE3 or BSE4, and thus is not recommended for use under such conditions.

2.11 BSE22 (Platinum Iridium Alloy)

This material has limited use as a spring and is considered a specialty material.

2.12 BSE26 (Titanium Alloy)

BSE26 has a temperature range of –300 °F to +600 °F (–200 °C to +315 °C). This material has higher corrosion resistance than BSE1 or BSE2 and BSE3 or BSE4 stainless steels, BSE17, and BSE18. The low mechanical properties can lead to deformation under relatively low compression forces of the material.

2.13 BSE29 (Copper Alloy)

This high-strength copper alloy has twice the conductivity as BSE9 with the advantage that it does not contain beryllium. The maximum operating temperature is 392 °F (200 °C).

2.14 BSE30 (Very High Conductivity Copper Alloy)

This material has higher conductivity than BSE11 and BSE12. It has slightly lower mechanical properties than BSE11 but slightly higher than BSE12. The maximum operating temperature is 392 °F (200 °C).

3.0 Advantages and Limitations of Spring Materials

Table 1: Advantages and limitations of standard Bal Spring® materials

Material	Advantages	Limitations	Typical Applications
BSE1 or BSE2 (Stainless Steel)	• Low cost and readily available • Highest tensile strength of all standard Bal Spring materials	• Lower corrosion resistance than BSE3 or BSE4 and BSE5 • Mechanical properties change at elevated temperatures	• General service
BSE3 or BSE4 (Stainless Steel)	• Better corrosion resistance than BSE1 or BSE2 due to higher nickel and molybdenum content	• Mechanical properties lower than BSE1 or BSE2	• Food processing
BSE5 (Stainless Steel)	• Higher corrosion resistance than BSE3 or BSE4 due to lower carbon content	• Higher cost than BSE3 or BSE4	• Biomedical • Corrosive environments • Laboratory • Food processing
BSE6 (Stainless Steel)	• Very low impurities	• Limited availability • Higher cost than BSE5	• Body implants
BSE9 (Beryllium Copper Alloy)	• High-strength copper alloy	• Limited temperature range	• Parts requiring good electrical conductivity • EMI shielding • Electronics
BSE11 (Zirconium Chromium Copper Alloy)	• Excellent electrical conductivity • Lower cost than BSE9	• Lower strength than BSE9	• High-current applications
BSE12 (Copper Alloy)	• Excellent electrical conductivity	• Lower strength than BSE9 or BSE11	• High-current applications
BSE17 (Nickel Alloy)	• Higher corrosion resistance and operating temperature than BSE1 or BSE2, BSE3 or BSE4, and BSE5 stainless steels	• Limited availability	• Corrosive environments
BSE18 (Nickel Alloy)	• High resistance to stress cracking • High corrosion resistance • Resistant to cracking under NACE Level VII conditions • Compatible with hydrogen sulfide	• Wire size	• Petrochemical applications with hydrogen sulfide sour gas per NACE report MR-01-75

Table 1 continued on page 6

3.0 Advantages and Limitations of Spring Materials

Table 1: Advantages and limitations of standard Bal Spring® materials continued from page 5

Material	Advantages	Limitations	Typical Applications
BSE19 (Cobalt Nickel Alloy)	• Compatible with hydrogen sulfide • Nickel-based material with higher modulus of elasticity than all other stainless steel materials with higher mechanical properties than other stainless steel materials	• Galvanic corrosion can occur when coupled with dissimilar metals	• Body implant applications such as pacemakers • Petrochemical applications where corrosion resistance to hydrogen sulfide is necessary
BSE22 (Platinum Iridium Alloy)	• Excellent corrosion resistance	• Highest cost of all spring materials. • Increased weight loss in oxidizing atmospheres	• Medical electronics
BSE26 (Titanium Alloy)	• Compatible with biomedical fluids like proteins, peptides, and enzymes • Contains no chrome or nickel to affect these molecules	• Low tensile strength • Very high cost	• Certain biomedical applications such as those in which contact with fuming nitric acid is required
BSE29 (Copper Alloy)	• Good electrical conductivity and high-strength copper alloy	• Lower conductivity than BSE9, BSE11, and BSE30	• General service

4.0 Physical, Electrical, and Mechanical Properties of Spring Materials at Normal and After Elevated Temperatures

4.1 Physical and mechanical properties at 70 °F (21 °C)

Table 2 outlines ranges of physical, electrical, and mechanical properties of standard Bal Spring® wire materials based on a wide range of wire sizes included in each purchasing specification. Tensile modulus and yield strength are reference values.

Table 2: Physical, electrical, and mechanical properties of standard Bal Spring® wire materials

Material	Min & Max Temp. Range °F (°C)	Density (Specific Gravity) lb/in³(gm/cc)	Electrical Resistivity µΩ-in (µΩ-cm)	Electrical Conductivity* %IACS	Ultimate Tensile Strength ksi (MPa)	Elongation at Break %	Tensile Modulus (Reference) lb/in² (GPa)	Yield Strength (Reference) ksi (MPa)
BSE1 or BSE2 (Stainless Steel)	–459 °F to 570 °F (–273 °C to 300 °C)	0.290 (8.03)	28.3 at 70 °F (72.0 at 21°C)	3%	272–355 (1875–2450)	1.9–3.2	28 x 10^6 (193)	245 (1690)
BSE3 or BSE4 (Stainless Steel)	–459 °F to 570 °F (–273 °C to 300 °C)	0.290 (8.03)	29.1 at 70 °F (74.0 at 21°C)	2.9%	215–275 (1482–1896)	1.9–3.2	28 x 10^6 (193)	218 (1503)
BSE5 (Stainless Steel)	–459 °F to 570 °F (–273 °C to 300 °C)	0.290 (8.03)	29.1 at 70 °F (74.0 at 21 °C)	2.9%	153–210 (1054–1448)	1.9–5.5	28 x 10^6 (193)	166 (1145)
BSE6 (Stainless Steel)	–459 °F to 570 °F (–273 °C to 300 °C)	0.290 (8.03)	29.1 at 70 °F (74.0 at 21 °C)	2.9%	153–210 (1054–1448)	1.9–3.2	28 x 10^6 (193)	166 (1145)
BSE9 (Beryllium Copper Alloy)	–459 °F to 351 °F (–273 °C to 177 °C)	0.29 (8.03)	4.21 at 70°F (10.7 at 21°C)	18%	110–135 (758–930)	1.5–3.5	18.5 x 10^6 (128)	115 (792)
BSE11 (Zirconium Chromium Copper Alloy)	–459 °F to 392 °F (–273 °C to 200 °C)	0.321 (8.89)	0.862 at 70 °F (2.19 at 21 °C)	78%	95–115 (648–793)	1.5–3.5	17 x 10^6 (117)	90 (620)
BSE12 (Copper Alloy)	–459 °F to 392 °F (–273 °C to 200 °C)	0.322 (8.91)	0.862 at 70 °F (2.19 at 21 °C)	78%	85–100 (586–689)	1.5–3.5	18.5 x 10^6 (128)	85 (586)
BSE17 (Nickel Alloy)	–459 °F to 1000 °F (–273 °C to 538 °C)	0.321 (8.89)	51.2 at 75 °F (130.0 at 24 °C)	1.4%	206–272 (1420–1875)	1.5–5.7	29.7 x 10^6 (205)	220 (1517)
BSE18 (Nickel Alloy)	–459 °F to 1202 °F (–273 °C to 650 °C)	0.299 (8.28)	48.0 at 122 °F (122.0 at 50 °C)	1.6%	190 min (1310 min)	1.7–4.0	31 x 10^6 (214)	195 (1345)
BSE19 (Cobalt Nickel Alloy)	–459 °F to 550 °F (–273 °C to 288 °C)	0.304 (8.43)	40.7 at 70 °F (103.3 at 21 °C)	1.8%	240 to 305 (1655–2103)	1.5–2.6	34.1 x 10^6 (235)	240 (1655)
BSE22 (Platinum Iridium Alloy)	–459 °F to 842 °F (–273 °C to 450 °C)	0.7807 (21.6)	12.2 at 70°F (31 at 21°C)	5.60%	246–276 (1696–1903)	1.5 min	37 x 10^6 (255)	195 (1345)
BSE26 (Titanium Alloy)	–459 °F to 572 °F (–273 °C to 300 °C)	0.163 (4.51)	19.6 at 70°F (49.8 at 21 °C)	3.4%	110–150 (758–1034)	1.5–2.6	15.2 x 10^6 (105)	108 (745)
BSE29 (Copper Alloy)	–459 °F to 356 °F (–273 °C to 180 °C)	0.318 (8.80)	1.69 at 70 °F (4.3 at 21 °C)	40%	110–130 (724–896)	1.5–4.5	19 x 10^6 (131)	110 (758)

* Conductivity values are percentages of standard alloy conductivity.

5.0 Chemical Compatibility of Standard Bal Spring® Materials

The following data describes general compatibility values. It is recommended that appropriate testing be done to verify such values.

Acids

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Acetic Acid	A	A	A	INA	A	A
Benzoic Acid	A	A	A	INA	INA	INA
Boric Acid	A	A	A	INA	INA	A
Chlorosulphonic Acid	NR	NR	A	INA	INA	NR
Chromic Acid	NR	NR	NR	INA	INA	A
Citric Acid	A	A	A	INA	INA	A
Formic Acid	A	A	A	INA	A	INA
Hydrofluoric Acid	NR	NR	A	INA	INA	NR
Hydrochloric Acid	NR	NR	A	NR	NR	INA
Nitric Acid 10%	A	A	A	NR	A	A
Nitric Acid 100%	A	A	NR	NR	A	A
Phosphoric Acid	A	A	A	A	A	INA
Sulfuric Acid	A	A	A	A	A	INA
Tartaric Acid	A	A	A	INA	INA	INA

A= Acceptable NR= Not recommended INA= Information not available

Alcohols

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Butyl Alcohol	A	A	A	INA	A	INA
Ethanol, Anhydrous	A	A	A	INA	A	A
Isopropyl Alcohol	A	A	A	INA	A	A
Methanol	A	A	A	INA	A	INA
Propanol	A	A	A	INA	A	INA

Aqueous Solutions

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Beer	A	A	A	INA	INA	INA
Chloride Salts	A	A	A	INA	A	A
Chlorinated Water	NR	A	A	INA	INA	A
Sea Water	A	A	A	A	A	A
Tap Water	A	A	A	A	A	A

A= Acceptable NR= Not recommended INA= Information not available

Fluorocarbon Solvents

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Freon F-12	A	A	INA	INA	INA	INA
Carbon Tetrachloride	A	A	A	INA	INA	A
Chlorine Gas	A	A	A	INA	INA	INA
Chlorobenzene	A	A	A	INA	INA	INA
Chloroform	A	A	A	INA	INA	A
Ethylene Glycol	A	A	A	INA	INA	INA
Methylene Chloride	A	A	A	INA	INA	INA
Sodium Chloride	A	A	A	INA	A	A
Sodium Chromate	A	A	INA	INA	INA	INA
Sodium Hydrochloride	A	A	A	INA	INA	INA
Trichloroethylene	A	A	A	INA	INA	INA

A= Acceptable NR= Not recommended INA= Information not available

Petroleum-Based Liquids

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Acetone	A	A	A	INA	A	INA
Acetonitrile	A	A	A	INA	A	INA
Benzene	A	A	A	INA	INA	A
Gasoline	A	A	A	INA	INA	INA
Jet Fuel	A	A	A	INA	INA	A
Kerosene	A	A	A	INA	INA	A
Methyl Ethyl-Ketone	A	A	INA	INA	INA	INA
Mineral Oil	A	A	A	INA	INA	INA
Naphtha	A	A	A	INA	INA	INA
N-Hexane	A	A	A	INA	INA	INA
Oleum	A	A	A	INA	INA	INA
Stoddard Solvent	A	A	NR	INA	INA	INA
Toluene	A	A	A	INA	INA	INA
Xylene	A	A	A	INA	INA	INA

A= Acceptable NR= Not recommended INA= Information not available

Biomedical

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Proteins	INA	INA	INA	INA	INA	A
Peptides	INA	INA	INA	INA	INA	A
Enzymes	INA	INA	INA	INA	INA	A
Monoclonal Antibodies	INA	INA	INA	INA	INA	A
Synthetic Oligo-Nucleotides	INA	INA	INA	INA	INA	A
Implant Applications	INA	INA	INA	INA	INA	A

Miscellaneous

Type	BSE1 or BSE2 (Stainless Steel)	BSE3 or BSE4, BSE5, BSE6 (Stainless Steel)	BSE17 (Nickel Alloy)	BSE18 (Nickel Alloy)	BSE19 (Cobalt Nickel Alloy)	BSE26 (Titanium Alloy)
Ammonia	A	A	A	INA	INA	A
Ammonium Hydroxide	A	A	A	INA	INA	A
Bromine Gas	NR	NR	A	INA	INA	INA
Carbon Dioxide	A	A	A	INA	INA	A
Fluorine Gas	NR	NR	NR	INA	INA	INA
Hydrogen	A	A	A	INA	A	A
Hydrogen Sulfide	A	A	A	A	A	INA
Nitrogen	A	A	NR	INA	INA	A
Oxygen	NR	NR	A	A	A	NR

A= Acceptable NR= Not recommended INA= Information not available