THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

COMPARISON OF BRITISH AND FOREIGN STANDARD SPECIFICATIONS FOR SPRING MATERIALS

Report No. 418

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1. INTRODUCTION

This report collects together the articles presented in a monthly series in SRAMA's Newsletter, tabulating British and equivalent foreign standards for an exhaustive range of materials for wire springs.

The series appeared in the Technical section of the Newsletter between September 1986 and July 1987 and covered eleven material qualities whose major features, for ease of reference, were presented in tabular form for composition, tensile strength, formability and surface quality.

Wherever possible, to facilitate production of the report, the original text and format have been reproduced, which explains the lack of consistency in type-face and size (especially in the tables, some of which had to be reduced to fit the physical constraints of paper size). However, every effort has been made to excise repetitions and irrelevancies.

We hope that members will find this of value as a reference document, to be used as an extension of the information contained in SRAMA's "Spring Materials Selector".

Explanatory Notes:-

(a) The major features of the various national specifications listed should be sufficient for most purposes. For more detailed comparison, the up-to-date editions of the standards quoted should always be consulted since similar specifications do vary in minor details.

(b) Many spring users indicate their requirements by reference only to material composition rather than specifying the appropriate spring wire standard. Attention is drawn to the fact that the use of 'steel grade' numbers defines only the chemical composition and not the mechanical and metallurgical conditions.

2. COLD DRAWN CARBON STEEL SPRING WIRE

Carbon steel spring wire is by far the most important and widely used material for the manufacture of light helical springs. It derives its strength from a combination of heat treatment (Patenting) and cold working by drawing. These wires are produced to a variety of quality grades by rod selection, composition and the degree of control exercised on surface imperfections.

A. COMPOSITION

Wire Specification	Origin	Steel Grade	% C	% Si	% Mn	% S max	% P max	
BS 5216 1975	UK	NS	0.45-0.85	0.35 max	0.4-1.0	0.05	0.05	
		HS	0.45-0.85	0.35 max	0.4-1.0	0.05	0.05	
		ND	0.55-0.85	0.35 max	0.3-1.0	0.03	0.03	
		HD	0.55-0.85	0.35 max	0.3-1.0	0.03	0.03	
S201:1967	UK	___	0.55-0.85	0.1-0.35	0.3-1.0	0.03	0.03	
S202:1967	UK	___	0.55-0.85	0.1-0.35	0.3-1.0	0.025	0.025	
DEF106:1961	UK	___	0.75-0.85	0.3 max	0.5-0.7	0.02	0.02	
ASTM A227 1983	US	___	0.45-0.85	0.15-0.35	0.3-1.3	0.05	0.04	
ASTM A679 1983	US	___	0.65-1.0	0.1-0.4	0.2-1.3	0.05	0.04	
SAE J113:69	US	1	0.45-0.75	0.1-0.3	0.6-1.3	0.05	0.04	
		2	0.50-0.85	0.1-0.3	0.6-1.3	0.05	0.04	
SAE J271:72	US	___	0.7-1.0	0.1-0.3	0.2-1.3	0.04	0.04	
SAE J172:70	US	___	0.6-0.75	0.15-0.3	0.6-0.9	0.03	0.025	
DIN 17223	Germany	A	0.4-0.85	0.35 max	0.3-1.0	0.04	0.04	Cu 0.2
Part 1:1984		B*	0.4-0.85	0.35 max	0.3-1.5	0.04	0.04	Cu 0.2
SIS 141774: 1979	Sweden	1774-04	0.6-0.95	0.15-0.4	0.3-0.8	0.035	0.035	
		1774-05	0.6-0.95	0.15-0.4	0.3-0.8	0.035	0.035	
G 3521:1980	Japan	SW-A	0.39-0.86	0.15-0.35	0.3-0.9	0.04	0.04	
		SW-B	"	"	"	"	"	
		SW-C	"	"	"	"	"	

* The German DIN 17223 steel grade B specifies three carbon and manganese ranges within those quoted in the table to accommodate increases in section size.

Commentary:

The Japanese standard G3521 does not specify compositions but refers to G3506 which contains a series of 21 steels having more closely defined carbon contents, each of 0.07% range. The choice of carbon level is governed by the tensile strengths specified in G3521, the selection being made by the wire manufacturer.

The majority of the standards specify fairly wide carbon ranges but, in practice, wire manufacturers will select a somewhat tighter range depending on the type of patenting employed, the finished wire size and the required tensile strength.

B. **TENSILE STRENGTH**

Wire Dia (mm)	Strength Rm (N/mm^2)				
	BS 5216 Grade 1 (NS)	BS 5216 Grade 2 (NS,HS,ND,HD)	BS 5216 Grade 3 (HS,ND,HD)	S201	S202
0.10					
0.20		2340-2640	2640-2940	2317 min	2471 min
0.50		2060-2320	2320-2580	2162 min	2317 min
1.0		1790-2010	2010-2230	1853-2008	2008-2162
2.0	1370-1570	1570-1770	1770-1970	1699-1853	1853-2008
3.0	1250-1450	1450-1650	1650-1850	1544-1699	1699-1853
4.0	1170-1370	1370-1570	1570-1770	1390-1544	1544-1699
5.0	1110-1310	1310-1510	1510-1710	1390-1544	1544-1699
6.0	1050-1250	1250-1450	1450-1650	1235-1390	1390-1544
7.0	1010-1210	1210-1410	1410-1610	1081-1235	1235-1390
8.0	970-1170	1170-1370	1370-1570	1081-1235	1235-1390
9.0	940-1140	1140-1340	1340-1540	1081-1235	1235-1390
10.0		1120-1320	1320-1520	1081-1235	1235-1390
12.0		1060-1260	1260-1460		
15.0					
20.0					

Wire Dia (mm)	Strength Rm (N/mm^2)					
	DEF 106	ASTM A227		ASTM A679	SAE J113	
		Class I	Class II		Class 1	Class 2
0.10						
0.20	2625 min					
0.50	2625 min	1960-2240	2240-2520	2410-2670	1960-2240	2240-2520
1.0	2239-2394	1770-2040	2040-2310	2160-2390	1770-2040	2040-2310
2.0	2008-2162	1580-1810	1810-2040	1940-2150	1580-1810	1810-2040
3.0	1776-1930	1460-1680	1680-1900	1810-2000	1460-1680	1680-1900
4.0	1621-1776	1380-1590	1600-1900	1730-1910	1380-1590	1600-1900
5.0	1621-1776	1320-1510	1510-1700	1650-1830	1320-1510	1510-1700
6.0	1544-1699	1280-1470	1470-1650		1280-1470	1470-1650
7.0	1467-1622	1220-1410	1410-1600		1220-1410	1410-1600
8.0		1190-1370	1370-1550		1200-1380	1380-1560
9.0		1160-1340			1160-1340	1340-1530
10.0		1130-1310			1140-1320	1320-1510
12.0		1090-1260			1100-1270	1270-1450
15.0		1030-1190				
20.0						

Wire Dia (mm)	Strength Rm (N/mm^2)					
	SAE J271	SAE J172	DIN 17223: Part 1		SIS 14 17 74	
			Grade A	Grade B	1774-04	1774-05
0.10						2750-3100
0.20						2650-3000
0.50	2415-2670			2200-2470		2450-2750
1.0	2165-2400		1720-1970	1980-2220	1900-2200	2300-2550
2.0	1945-2150	1620-1758	1520-1750	1760-1970	1750-2000	2050-2250
3.0	1815-2005	1620-1758	1410-1620	1630-1830	1550-1800	1850-2050
4.0	1730-1910	1586-1724	1320-1520	1530-1730	1500-1750	1750-1950
5.0	1650-1830	1517-1655	1260-1450	1460-1650	1400-1650	1650-1850
6.0	1600-1775	1482-1620	1210-1390	1400-1580	1300-1500	1500-1700
7.0	1545-1720		1160-1340	1350-1530	1200-1400	1400-1600
8.0	1500-1675		1120-1300	1310-1480	1200-1400	1400-1600
9.0	1470-1650		1090-1260	1270-1440	1150-1350	1350-1550
10.0	1440-1610		1060-1230	1240-1400	1150-1350	1350-1550
12.0	1380-1550			1180-1340	1050-1250	1250-1450
15.0				1110-1260		
20.0				1020-1150		

Wire Dia (mm)	Strength Rm (N/mm^2) J.I.S G3521 Class A	Class B	Class C
0.10	2010-2350	2350-2700	2700-3040
0.20	1910-2210	2210-2500	2500-2800
0.50	1620-1910	1910-2210	2210-2500
1.0	1470-1720	1720-1960	1960-2210
2.0	1270-1470	1470-1720	1720-1960
3.0	1180-1370	1370-1570	1570-1810
4.0	1180-1370	1320-1570	1570-1770
5.0	1130-1320	1320-1520	1520-1720
6.0	1030-1230	1230-1420	1420-1620
7.0	980-1180	1180-1370	1370-1570
8.0	980-1180	1180-1370	1370-1570
9.0	930-1130	1130-1320	1320-1520
10.0	930-1130	1130-1320	1320-1520
12.0		1080-1280	1280-1470
15.0			
20.0			

Notes:- i) The UK defence standard DEF 106 specifies a reduction of area on tensile testing of greater than 35% for all wires above 1.2 mm diameter.

ii) The SAE J172 standard calls for 40% minimum R of A on all sizes.

iii) The German DIN 17223 specifies minimum reduction of areas as:1 mm to less than 4 mm wires - 40%; 4 mm to 7 mm wires 35%; 7 mm to 10 mm sizes, 30%.

Commentary:

All countries offer more than one tensile range to cater for springs that are lowly stressed as well as for those where the operating stresses are high. In addition, the UK and Japan provide an extra class of material where the tensile strengths are relatively low to satisfy applications where material of high formability is needed. On the whole, the highest tensile

strengths are obtained from BS 5216 Grade 3, and the American standards A679 and J271.

The new German and ASTM standards now extend their sizes beyond 12 mm diameter and, in the case of the former, this is increased to 20 mm.

C. FORMABILITY

Specification	Torsion Test (mm)	Bend Test (180°)	Wrap Test (mm)	Wrap and Stretch Test (mm)
BS 5216 all qualities	>.4 to 10	3 to 6.5 on 2d >6.5 on 3d	<3 on 1d	—
S201	<5.1	>2.2*	<2.2	—
S202	<5.1	>2.2*	<2.2	—
DEF 106	all sizes	—	.5 to 2	—
A227 Class I	—	—	on 2d .5 to 2	
"	—	—	on 2 d >4 to 8	—
A227 Class II	—	—	on 2d .5 to 4	—
"	—	—	on 2d >4 to 8	—
A679	—	—	on 4d .5 to 3	—
	—	—	on 2d >3 to 5.2	—
J113	—	—	on 4d as A227	—
J271	—	—	.5 to 4	
			on 2d >4 to 7.9 on 4d	—
J172	—	—	—	—
DIN 17223	>.7 to 7	—	—	<.7 on 3d
Grades A and B	>7 to 10 Guidance only			(Grade B only)
SIS 1774-04 and -05	.5 to 5	>5 on 4d	<2.5 on 1d	—
G3521	<6	>6*	<6 on 1d	—

*S201, S202 and G3521 are subject to a 90° reverse bend test.

Commentary:

The majority of standards favour the wrap test as a means of assessing formability. None of the American standards uses the torsion test or the bend test as a method of determining formability, the SAE valve spring wire standard J172 having no requirements at all with respect to assessing formability.

D. SURFACE QUALITY

Specification	Deep Etch Test	Max Defect depth	Decarburisation			
			Complete	Partial	Gradient	Total
BS 5216 NS	all sizes					
HS	all sizes	3%	Nil	3%		3%
ND	all sizes	1.5%	Nil	1.5%		1.5%
HD	all sizes	Nil	Nil	Nil	Nil	Nil
S201	all sizes		Nil	1.5%		1.5%
S202	all sizes	Nil	Nil	Nil	Nil	Nil
DEF 106	all sizes	Nil	Nil	Nil	Nil	Nil
A227		*				
A679		*				
J113		3.5% or 0.25 mm whichever is smaller				
J271		*				
J172	all sizes	1%	Nil	0.025 to 0.037 mm depending on size		
DIN 17223		*				
Grades A & B SIS 1774-04		*				
and -05 G3521		*				

* only general statements that wire shall be free from harmful defects.

Commentary:

It is clear that the UK places more importance on the deep etch test than its foreign counterparts. It is also significant that few of the foreign standards quantify maximum allowable defect depths and, of the foreign standards examined, only J172 (a valve spring quality) places any restriction on surface decarburisation. When making this comparison, however, it should be noted that the high quality Grades C and D of DIN 17223 have not been included here since they are essentially music wire and are considered in Chapter 3 of this report.

3. MUSIC STEEL SPRING WIRE

Music steel spring wire is produced from steel having a higher carbon content than the general purpose patented cold drawn spring wires. It is characterised by its very high tensile strength and high surface quality and is particularly suitable for spring and wire form applications subjected to high stresses.

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C min max	%Si min max	%Mn min max	%S max	%P max
BS5216 1975	UK	M	0.70-1.00	0.35	0.25-0.75	0.03	0.03
ASTM A228:83	US	—	0.70-1.00	0.10-0.30	0.20-0.60	0.03	0.025
SAE J178:70	US	—	0.80-1.00	0.10-0.30	0.20-0.60	0.03	0.025
DIN 17223 Sheet 1:84	Germany	C and D	0.50-1.00	0.35	0.30-1.50	0.03	0.03
SIS 14-17-74:79	Sweden	17 74-06	0.60-0.95	0.15-0.40	0.30-0.80	0.035	0.035
JIS G3522:82	Japan	SWP - A	0.60-0.95	0.12-0.32	0.30-0.60	0.025	0.025
		SWP - B	0.60-0.95	0.12-0.32	0.60-0.90	0.025	0.025
		SWP - V	0.60-0.95	0.12-0.32	0.30-0.90	0.025	0.025

Note:- The copper content of wires to G3522 is specified as 0.20% max. for SWP-A and SWP-B wires. The valve spring wire SWP-V has a limiting value for copper of 0.15%. The standard G3522 does not specify the actual composition of wires but refers the reader to G3502 which includes a series of 18 steels having more closely defined carbon contents, each of 0.05% range.

Commentary:

The UK and US standards in general specify higher minimum carbon contents than do the German, Swedish and Japanese standards.

B. **TENSILE STRENGTH**

Wire Dia (mm)	Strength Rm (N/mm^2)					
	BS5216 M		A228 and J178	DIN 17223		SIS 1774-06
	Grade 4	Grade 5		Grade C	Grade D	
0.10	3020-3400	3400-3780	3000-3300		2800-3100	3150-3500
0.20	2760-3090	3090-3420	2700-3000		2800-3100	2900-3200
0.50	2440-2670	2670-2900	2400-2650		2480-2740	2650-2900
1.0	2240-2390	2390-2540	2150-2400		2230-2470	2400-2650
2.0	1970-2120	2120-2270	1950-2200	1980-2200	1980-2200	2150-2350
3.0	1850-2000	2000-2150	1800-2000	1840-2040	1840-2040	
4.0	1770-1920		1700-1900	1740-1930	1740-1930	
5.0			1650-1850	1660-1840	1660-1840	
6.0			1660-1800	1590-1770	1590-1770	
7.0				1540-1710	1540-1710	
8.0				1490-1660	1490-1660	
9.0				1450-1610	1450-1610	
10.0				1410-1570	1410-1570	
12.5				1330-1480	1330-1480	
16.0				1240-1390	1240-1390	
20.0				1160-1300	1160-1300	

Wire Dia (mm)	Strength Rm (N/mm^2)		
	G3522 SWP-A	G3522 SWP-B	G3522 SWP-V
0.10	2795-3089	3089-3383	
0.20	2599-2844	2844-3089	
0.50	2305-2550	2550-2795	
1.0	2059-2256	2256-2452	
2.0	1814-2010	2010-2206	1765-1912
3.0	1667-1863	1863-2059	1667-1814
4.0	1667-1814	1814-1961	1667-1814
5.0	1618-1765	1765-1912	1618-1765
6.0	1520-1667	1667-1814	1520-1667
7.0	1471-1618		
8.0	1471-1618		
9.0	1422-1569		
10.0	1422-1569		

Note:- The German DIN 17223 Sheet 1 standard specifies minimum reduction of area values as 1 mm to 3.8 mm wires 40%; 4 mm to 7 mm wires, 35%; 7.5 mm to 10 mm wires, 30%.

Commentary:

The British Grade 5 music wire has, in general, the highest tensile strength when compared with foreign standards for similar sized wires. Historically, music wires have been confined to sizes less than about 4 to 6 mm but both the Germans and Japanese have recently introduced 'music or piano' wires which extend to 20 mm diameter and 10 mm diameter respectively.

C. **FORMABILITY**

Specification	Torsion Test	Bend Test (90^{o})	Wrap Test	Wrap & Stretch Test
BS5216 M	—	—	>0.2mm on 1d	—
A228 and J178	—	—	all sizes on 1d (J178 only)	<2.6mm on 3d extend to 3 times length
DIN 17223 Sheet 1	0.7 to 7mm >7 to 10mm guidance only	—	—	<0.7mm on 3d extend to 2 to 4 times the coiled length
SIS 17 74-06	0.5 to 5mm	>5mm (180^{o})	<2.5mm on 1d	
G3522	<6mm	>6mm	—	guidance only

Commentary:

Comparing the above standards, there would appear to be little common ground with respect to a preferred formability test. Clearly the bend test is least popular but, for small wire sizes, foreign standards seem to favour a wrap and stretch test.

D. SURFACE QUALITY

Specification	Deep Etch test	Max defect depth	Decarburisation			
			Complete	Partial	Gradient	Total
BS5216 M	all sizes	1.5%	Nil	1.5% Max		
A228	—	—	—	—	—	—
J178	all sizes	1%	—	1% Max	—	—
DIN 17223. Grade D	all sizes	1%	Nil	1.5% Max	—	—
SIS 17 74-06	—	—	—	—	—	—
G3522 SWP-A SWP-B	>1.0mm	0.02 to 0.08mm according to wire size	—	—	—	—
SWP-V	>1.0mm	0.01 to 0.03mm according to wire size	Nil	—	—	1.5% or 0.05mm Max

Commentary:

All standards (with the exception of A228) stipulate deep etch testing and specify maximum defect levels as a percentage of wire diameter or, in the case of the Japanese standard, as a dimension. For the SWP-A and SWP-B qualities, these dimensions equate to approximately 1% of the wire diameter. For the SWP-V wire, maximum defect levels equate to 0.5% of the wire diameter.

Limits on decarburisation at 1 to 1.5% are similar and none of the standards allows complete decarburisation. It is surprising, however, that the American A228 and Japanese G3522, SWP-A and B qualities do not specify limits on decarburisation.

4. PRE-HARDENED AND TEMPERED CARBON STEEL SPRING WIRE

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C Min Max	%Si Min Max	%Mn Min Max	%S Max	%P Max
BS 2803 1980	UK	095A65	0.55 0.75	0.30	0.60 1.20	0.05	0.05
		094A65	0.55 0.75	0.30	0.60 1.20	0.04	0.04
		093A65	0.55 0.75	0.30	0.60 1.20	0.03	0.03
ASTM A229: 83	US	-	0.55 0.85	0.15 0.35	0.30 1.20	0.05	0.04
ASTM A230: 83	US	-	0.60 0.75	0.15 0.35	0.60 0.90	0.03	0.025
SAE J316: 70	US	A	0.60 0.85	0.15 0.30	0.90 1.20	0.05	0.04
		B	0.60 0.75	0.15-0.30	0.60 0.90	0.05	0.04
SAE J351: 68	US	-	0.60-0.75	0.15 0.30	0.60 0.90	0.03	0.025
DIN 17223 Sheet 2: 64	Germany	FD	0.60-0.70	0.25	0.50 0.90	0.03	0.03
		VD	0.60-0.70	0.25	0.50 0.90	0.02	0.03
SIS 14-17-70; 85	Sweden	1770-03	0.65-0.80	0.15-0.40	0.50 0.80	0.035	0.035
G3560: 83	Japan	SWO-A	0.54-0.76	0.15-0.35	0.30-0.90	0.04	0.04
		SWO-B	0.64-0.86	0.15-0.35	0.30-0.90	0.03	0.03
G3561: 82	Japan	SWO-V					

Note: The compositions given for G3560 and G3561 encompass a series of carbon steels whose carbon, manganese, sulphur and phosphorous contents are more closely defined.

Commentary:

All the steels have carbon contents around the eutectoid composition, with the German steels having the narrowest range of carbon. As would be expected, the higher valve spring wires limit the sulphur and phosphorus

contents to lower levels. All qualities contain appreciable amounts of manganese to aid hardenability and, in the case of SAE J316, quote two manganese ranges depending on the final size of wire to be heat treated. For example, for wire sizes greater than 4.8mm, the high manganese range of 0.9 to 1.2% is specified.

B. TENSILE STRENGTH

(See overleaf)

Note: Specifications A230, J351, DIN 17223 FD and VD, and G3561 specify a minimum reduction of area of the tensile test piece, eg A230, J351 wires over 2.5mm diameter - 40% minimum; DIN 17223 FD and VD wires, a variable minimum R of A value ranging from 35% to 45% according to wire size: G3561 wires, < 4 mm 45% min, > 4 mm 40% min.

Commentary:

Comparing the 13 different pre-hardened and tempered tensile ranges, only the American ASTM and SAE specifications have identical tensile properties. Because of the variation in tensile properties among the other standards, care is needed when attempting to equate one wire standard with another. In general, the UK and German FD quality wires appear to have the nearest similarity regarding tensile strength. There would seem to be no consistent pattern with respect to the tensile strengths of valve spring quality wires when compared with their own national general purpose standards.

B. TENSILE STRENGTH (PRE-HARDENED AND TEMPERED CARBON STEEL)

Wire Dia (mm)	Strength Rm (N/mm^2)									
	BS 2803	A229 Class I and J316 Class I	A229 Class II and J316 Class II	A230 and J351	DIN 17223 FD	DIN 17223 VD	SIS 1770-03	G3560 SWO-A	G3560 SWO-B	G3561 SWO-V
0.25	1910-2170									
0.5	1860-2110	2050-2250	2230-2450							
1.0	1770-2000	1800-2000	2060-2280	1700-1850	1765-1961	1667-1814				
2.0	1630-1800	1600-1800	1820-2020	1650-1800	1618-1765	1520-1618	1600-1800	1569-1716	1716-1863	1618-1765
3.0	1540-1690	1500-1700	1690-1880	1600-1750	1520-1667	1432-1530	1550-1750	1471-1618	1618-1765	1569-1716
4.0	1480-1630	1400-1580	1600-1780	1580-1720	1480-1628	1402-1500	1500-1700	1422-1569	1569-1716	1569-1716
5.0	1430-1580	1350-1520	1520-1700	1520-1680	1402-1550	1344-1442	1450-1600	1373-1520	1520-1667	1520-1667
6.0	1380-1530	1300-1480	1480-1660	1500-1650	1402-1550	1344-1442	1400-1550	1324-1471	1471-1618	1471-1618
7.0	1350-1500	1280-1450	1450-1630	1450-1600	1363-1510	1304-1402	1350-1500	1226-1373	1373-1520	
8.0	1320-1470	1250-1430	1430-1610		1295-1442		1350-1500	1226-1373	1373-1520	
9.0	1300-1450	1220-1400	1410-1590		1295-1442		1300-1450	1226-1373	1373-1520	
10.0	1280-1430	1200-1380	1400-1580		1255-1402		1300-1450	1177-1324	1324-1471	
12.5	1240-1390	1140-1310	1350-1530		1255-1402		1250-1400	1177-1324	1324-1471	
14.0		1120-1300	1340-1520		1255-1402					
16.0		1120-1300	1320-1500							

C. FORMABILITY

Specification	Torsion Test	Bend Test (180°)	Wrap Test
BS 2803	1.5 to 10 mm	> 3 mm	1 to 3 mm on 1d
A229 }	-	-	< 4 mm on 1d
J316 }			> 4 mm to 8 mm on 2d
A230 }	-	-	< 4 mm on 1d
J351 }			> 4 mm to 6.5 mm on 2d
DIN 17223 FD	By agreement	-	-
VD	1 mm to 7.5 mm*	-	-
SIS 1770			
G3560	-	> 6 mm**	< 4 mm on 1d
			> 4 mm on 2d
G3561	2.0 to 6 mm*	-	< 4 mm on 1d
			> 4 mm on 2d

* Reverse torsion test

** 90° bend angle

Commentary:

The wrap test is the most common method of assessing formabi8lity, the bend test being the least popular. Both Germany and Japan favour a reverse torsion for valve spring quality wires. Only the UK applies all three methods of assessing formability.

Specification	Deep Etch Test	Max Defect Depth	Decarburisation			
			Complete	Partial	Gradient	Total
BS 2803 NS	All sizes	3% or 0.2 mm	0.8% or 0.05 mm	1% or 0.06 mm	rem	4% or 0.25 mm
HS	All sizes	2% or 0.15 mm	Nil	0.75% or 0.05 mm	rem	3% or 0.2 mm
ND	All sizes	1% or 0.1 mm	Nil	0.375% or 0.03 mm	rem	1.5% or 0.12 mm
HD	All sizes	Nil	Nil	Nil	0.5% or 0.01 mm	0.5% or 0.01 mm
A229	-	-	-	-	-	-
A230	All sizes	General statement	Nil	< 0.04 mm	-	-
J316	-	3.5% or 0.25 mm	0.5%			2% on < 6 mm wire 0.125 mm on > 6 mm wire
J351	All sizes	General statement	Nil	0.025 mm on < 4.8 mm wire 0.0375 mm on > 4.8 mm wire	-	-
DIN 17223 FD	-	General statement	-	-	-	-
VD	All sizes	General statement	Nil	0.005 mm max to 0.03 mm max depending on wire size		
SIS 14-17-70						
G3560	All sizes	General statement		General Statement		
G3561	All sizes	0.01 mm ≤ 2 mm wire 0.5% on > 2 mm wire	Nil			1.5% or 0.05 mm

N.B. The defect and decarburisation levels specified are qualified, "whichever is the smaller"

Commentary:

Within the British standard there are four quality grades compared with two in the German standard. The remaining standards only define one quality. Foreign standards for general purpose spring wire tend to specify quality only in the broadest terms - if at all! More specific information is provided for the high quality valve spring wires but this is not as comprehensive as that given for the British ND and HD qualities.

Materials having broadly similar compositions which could be used as pre-hardened and tempered spring steel wire include the following:-

UK - En 42

US - SAE/AISI 1060, 1070, 1078

Germany - WkSt 1.1230, 1.1250, 1.1231, Ck67

France - XC65, XC70

Italy - C70

5. 1% CHROME-VANADIUM OIL HARDENED AND TEMPERED SPRING WIRE

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C min max	% Si min max	% Mn min max	% S max	% P min max	% Cr min max	% V min
BS 2803 1980	UK	735A50	.46 .54	.10 .35	.60 .90	.035	.035	.80 1.10	0.15
ASTM A231:83	US		.48 .53	.15 .35	.70 .90	.040	.040	.80 1.10	0.15
ASTM A232:77	US		.48 .53	.20 .35	.70 .90	.035	.020	.80 1.10	0.15
SAE J132 1974	US		.48 .53	.20 .35	.70 .90	.035	.020	.80 1.10	0.15
SIS 14-22 30	SW	22 30	.48 .55	.15 .40	.70 1.00	.035	.035	.90 1.20	0.10 - 0.2
JIS G3565:86	Japan	SWOCV-V	.45 .55	.15 .35	.65 .95	.025	.025	.80 1.10	.15 - .25

B. **TENSILE STRENGTH**

Wire Diameter (mm)	Strength R_m (N/mm^2)					
	BS 2803	A231	A232	J132	14-22-30	G3565
0.5		2060-2260	2070-2240	2070-2240		
1.0	1970-2120	1940-2100	1930-2100	1930-2100		
2.0	1780-1930	1780-1930	1760-1900	1760-1900	1600-1800	1570-1720
3.0	1670-1820	1660-1800	1640-1780	1640-1780	1550-1750	1570-1720
4.0	1580-1730	1580-1720	1565-1700	1565-1700	1500-1700	1520-1670
5.0	1530-1680	1520-1640	1500-1640	1500-1640	1450-1600	1470-1620
6.0	1490-1640	1460-1600	1460-1600	1460-1600	1400-1550	1470-1620
7.0	1450-1600	1420-1560	1430-1565	1430-1565	1350-1500	1420-1570
8.0	1430-1580	1400-1540	1400-1540	1400-1540	1350-1500	1370-1520
9.0	1400-1550	1380-1520	1380-1520	1380-1520	1300-1450	1370-1520
10.0	1380-1530	1360-1500	1360-1500	1360-1500	1300-1450	1370-1520
12.5	1360-1510	1320-1460	1320-1455	1320-1455	1250-1400	

Note:- Specifications A231, A232, J132 and G3565 specify minimum reduction of area values on wires above 2.0mm diameter, e.g. 45% minimum R of A up to but not including 4.0mm. Above 4mm a 40% minimum is stipulated.

C. **FORMABILITY**

Specification	Torsion Test	Bend Test (180^{O})	Wrap Test
BS 2803	1.5 to 10 mm	>3 mm	1 to 3mm on 1d
A 231	-	-	<4mm on 1d 4 to 8mm on 2d
A 232	-	-	<4mm on 1d 4 to 8mm on 2d
J 132	-	-	<4mm on 1d 4 to 8mm on 2d
14-22-30	-	>4 mm	up to 4mm on 2d
G 3565	<6 mm	>6 mm*	<4mm on 1d >4mm on 2d

* 90° bend angle

D. **SURFACE QUALITY**

Specification	Deep etch Test	Max. Defect Depth	Complete	Decarburisation		Total
				Partial	Gradient	
BS 2803 HS	All sizes	2% or 0.15mm	NIL	.75% or .05mm	rem	3% or .2mm
ND	" "	1% or 0.10mm	NIL	.375% or .03mm	rem	1.5% or .12mm
HD	" "	NIL	NIL	NIL	0.5% or 0.01mm	0.5% or .01mm
A231	" "	3.5% or 0.25mm	-	-	-	-
A232	" "	NIL	NIL	.025mm up to 4.88mm .038 above 4.88mm		
J132	" "	NIL	NIL	(as A232)		
14-22-30	—	Free from harmful defects	—	-	-	-
G3565	" "	.01mm up to 2mm 0.5% for 2 to 6mm 0.7% or .06mm for wire above 6mm	NIL			1.5% or 0.05mm max

N.B. The defect and decarburisation levels specified are qualified, "whichever is the smaller".

Commentary:

The German standards authority (DIN) does not publish a specification for oil hardened and tempered 1% CrV spring wire. Materials having broadly similar compositions which can be classed as such include the following steel grades:

Germany	- 50 CrV4, Wk.St. 1.8159
UK	- 735A50, En 47
US	- SAE/AISI 6150
France	- 50 CV4
Japan	- SUP10, SWOCV-V
Sweden	- 22-30

6. SILICON-CHROME PRE-HARDENED AND TEMPERED SPRING WIRE

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C min	%C max	%Si min	%Si max	%Mn min	%Mn max	%S max	%P max	%Cr min	%Cr max
BS2803 1980	UK	685A55	0.5	0.6	1.2	1.6	0.5	0.8	0.025	0.03	0.5	0.8
ASTM A401:77	US		0.51	0.59	1.2	1.6	0.6	0.8	0.04	0.035	0.6	0.8
SAE J157:70	US		0.51	0.59	1.2	1.6	0.6	0.8	0.04	0.035	0.6	0.8
JIS G3566:86	Japan	SWOSC-V	0.5	0.6	1.2	1.6	0.5	0.8	0.025	0.025	0.5	0.8

Commentary:

The chemical composition of the above four specifications are, for all practical purposes, the same, but attention is drawn to the slight differences in the sulphur and phosphorus contents between the specifications. With modern steel making practice, it is unlikely that the maximum levels quoted for the U.S. standards will be achieved.

B. TENSILE STRENGTH

Wire Dia (mm)	Strength Rm (N/mm^2) BS2803 Range 1	BS2803 Range 2	A401	J157	G3566
0.5					
1.0	1950-2100	2100-2250	2050-2230	2050-2230	
2.0	1830-1980	1980-2130	1970-2140	1970-2140	1910-2060
3.0	1750-1900	1900-2050	1880-2050	1880-2050	1860-2010
4.0	1680-1830	1830-1980	1820-1990	1820-1990	1810-1960
5.0	1630-1780	1780-1930	1770-1940	1770-1940	1760-1910
6.0	1590-1740	1740-1890	1740-1910	1740-1910	1710-1860
7.0	1560-1710	1710-1860	1710-1880	1710-1880	1660-1810
8.0	2540-1690	1690-1840	1690-1850	1690-1850	1660-1810
9.0	1520-1670	1670-1820	1660-1830	166011830	
10.0	1500-1650	1650-1800	1640-1810	1640-1810	
12.5	1460-1610	1610-1760	1600-1770	1600-1770	

Note: Specifications A401, J157 and G3566 specify minimum reduction of area values, e.g. A401 and J157 - 2.3mm to 3.4mm, 45% R of A min, > 3.4mm, 40% R of A min. G3566 - 3.5mm and smaller, 45% R of A min, > 3.5mm, 40% R of A min.

Commentary:

The UK is the only major country having two tensile ranges for silicon-chrome spring wire. The two American specifications have identical tensile strengths and are very similar to those for the Range 2 British material. The tensile strengths for Japanese wires are somewhat lower.

C. FORMABILITY

Specification	Torsion Test	Bend Test (180^{o})	Wrap Test
BS2803	1.5 to 10mm	>3mm	1mm to 3mm on 1d
A401	—	—	<4mm on 1d 4 to 8mm on 2d
J157	—	—	<4mm on 1d 4 to 8mm on 2d
G3566	<6mm	>6mm*	<4mm on 1d >4mm on 2d

* 90° bend angle

Commentary:

The only test which is common to the four specifications is the wrap test. There is no requirement for a torsion or bend test in the American standards.

D. **SURFACE QUALITY**

Specification		Deep Etch test	Max defect depth	Decarburisation Complete	Partial	Gradient	Total
BS2803	HS	all sizes	2% or 0.15mm	Nil	.75% or .05mm	rem	3% or .2mm
	ND	" "	1% or 0.1mm	Nil	.375% or .03mm	rem	1.5% or .12mm
	HD	" "	Nil	Nil	Nil	0.5% or 0.01mm	0.5% or .01mm
A401		" "	3.5% or .25mm	——	——	——	——
J157		——	3.5% or .25mm	0.5% max	1.5% max	——	2% max
G3566		all sizes	.01% upto 2mm, .5% for 2 - 6mm, .7% for over 6mm	Nil			1.5% or 0.05mm

NB The defect and decarburisation levels specified are qualified "whichever is the smaller".

Commentary:

It should be noted that the British standard specifies three quality grades, whereas the foreign stardards define only one. The allowable maximum defect and decarburisation levels in American specifications are more generous than those for wire produced to Japanese or British standards.

Materials having broadly similar compositions which can be classed as silicon-chrome spring steels include the following:-

UK	- 685A55, En 48A
US	- SAE/AISI 9254
Germany	- 67SiCr5, Wk.St. 1.7103
France	- 60SC7
Japan	- SWOSC-V, SUP12

The German (DIN) and the Swedish (SIS) standards authorities do not publish specifications for oil hardened and tempered silicon-chrome spring wire.

7. STAINLESS STEEL SPRING WIRE

Stainless steel spring materials develop their high strength by cold working. Although essentially austenitic, these materials can become weakly magnetic due to the transformation of austenitic to a martensite-type structure as a result of the cold drawing process. This transformation is dependent on the actual composition of the material and, where applications demand "non-magnetic" stainless steel springs, care is required in selecting a suitable material composition which will remain austenitic on cold drawing.

This section is devoted to straight 18-8 type stainless steels.

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C Max	%Si Max	%Mn Max	%S Max	%P Max	%Cr	%Ni	%N Max
BS2056 1983	UK	302S26	0.12	1.0	2.0	0.03	0.045	17-19	7.5-10.0	
S205 1969	UK	—	0.15	0.2-1.0	0.5-2.0	0.025	0.035	17-19	7.5-9.0	
ASTM,A313 1981	US	302	0.15	1.0	2.0	0.03	0.045	17-19	8-10.0	0.1
		304	0.08	1.0	2.0	0.03	0.045	18-20	8-10.5	0.1
		305	0.12	1.0	2.0	0.03	0.045	17-19	10.5-13.0	
SAE,J230 1971	US	30302	0.15	1.0	2.0	0.03	0.045	17-19	8.0-10.0	
DIN 17224 1982	Germany	1.4310	0.12	1.5	2.0	0.03	0.045	16-18	6.0-9.0	
SIS 14-23-31 1972	Sweden	2331-06	0.12	1.0	2.0	0.03	0.045	17-19	7.0-9.5	
J.I.S G4314 1984	Japan	SUS302	0.15	1.0	2.0	0.03	0.045	17-19	8.0-10.0	
		" 304	0.08	1.0	2.0	0.03	0.045	18-20	8.0-10.5	
		" 304NI	0.08	1.0	2.5	0.03	0.045	18-20	7.0-10.5	0.1-0.2

Commentary:

In general, European standards contain only one grade of straight 18-8 type stainless steel whereas the American and Japanese include three. Unlike the European standards, the US and Japan offer nitrogen-stabilised material. Compared with other compositions under review, the German wires tend to be somewhat lower in Cr and Ni which will promote more rapid work hardening on cold drawing, along with a greater likelihood of the wire becoming 'magnetic'.

B. TENSILE STRENGTH

Wire Dia (mm)	Strength Rm (N/mm^2)									
	BS2056:302S26		S205	A313		J230	DIN 17224	SIS 14-23-31	JIS G4314	
	G1	G2		302 & 304	305	30302	1.4310	23 31-06	Class A (WPA) SUS 302, 304,304NI	Class B (WPB) SUS 302, 304,304NI
0.10	1880-2160	2160-2400		2240-2450	1690-1895	2240-2450	2200-2450	2110 min	1618-1863	2157-2403
0.25	1880-2060	2060-2300	2150 min	2205-2415	1690-1895	2205-2415	2100-2350	2010 min	1569-1814	2059-2305
0.50	1720-1960	1960-2200	2050 min	2070-2275	1620-1825	2070-2275	2000-2250	1960 min	1569-1814	1961-2206
1.0	1620-1860	1860-2100	1850-2050	1895-2095	1620-1825	1850-2070	1900-2150	1760 min	1471-1716	1863-2108
2.0	1430-1670	1670-1910	1650-1850	1695-1895	1450-1655	1695-1895	1700-1950	1670 min	1324-1569	1667-1912
3.0	1230-1470	1470-1710	1550-1750	1530-1745	1345-1550	1530-1745	1500-1750	1570 min	1177-1422	1471-1716
4.0	1230-1470	1470-1710	1400-1600	1415-1620	1240-1450	1415-1620	1500-1750	1470 min	1177-1422	1471-1716
5.0		1370-1610	1300-1500	1295-1515	1105-1310	1280-1475	1400-1650	1470 min	1079-1324	1373-1618
6.0		1370-1610	1200-1400	1205-1415	1035-1240	1205-1415	1400-1650	1270 min	1079-1324	1373-1618
7.0		1280-1520	1100-1300	1160-1365	965-1170	1110-1325	1300-1550	1270 min	981-1226	1275-1520
8.0		1280-1520	1100-1300	1070-1280	930-1140	965-1170	1300-1550	1270 min	981-1226	1275-1520
9.0		1230-1470	1000-1200	1035-1240	930-1140		1250-1500			1128-1373
10.0		1230-1470	1000-1200	1000-1205	895-1105		1250-1500			981-1226
12.0				930-1150	895-1105					883-1128

Note:- DIN 17224 stipulates a minimum of 40% R of A for wires over 1.5mm.

Commentary:

The national standard having the highest tensile strength over the complete size range is the German DIN 17224, which could be attributed to the leaner alloy content. The tensile strengths of the British Grade 2, the Swedish and the Japanese Class B wires are very similar.

Both Japan (Class A wire) and the USA (305 wire) recognise the need for spring wires of lower tensile strength where increased formability would aid spring manufacture.

C. **FORMABILITY**

Specification	Torsion Test	Bend Test (180°)	Wrap Test	Reverse Bend Test	Wrap and Stretch Test
BS2056:302S26	—	>3mm on 2d >6mm on 3d	<3mm on 1d	—	—
S205	<2mm	—	<3mm	>3mm	—
A313:302,304 and 305	—	—	<4mm on 1d >4mm on 2d	>0.6mm	<4.5mm
J230	—	—	<4mm on 1d > 4mm on 2d	—	<2.5mm
DIN 17224	>1.5mm	—	—	—	<1.5mm
SIS 14-23-31	—	—	<4mm	—	—
G4314	<4.0mm	—	—	—	—

Commentary:

The torsion test is used only to reveal surface defects and not as a measure of formability. The most common test for formability is the wrap test and is used in all standards except the Japanese specification. The United Kingdom is the only country specifying a bend test for stainless steel wires not surprising considering the practical difficulties in undertaking such a test on a routine basis.

D. **SURFACE QUALITY**

Specification	Deep Etch Test	Max. Defect Depth (mm)
BS2056:302S26	—	(note 1)
S205	all sizes	(note 2)
A313	—	—
J230	—	(note 1)
DIN 17224	—	(note 2)
SIS 14-23-31	—	(note 1)
G4314	—	(note 2)

Note 1:- No quantitative data is given, only general statements to the effect that the material should be free from harmful defects.

Note 2:- Visual examination after torsion testing but again no quantitative defect levels quoted.

Commentary:

The loss of carbon at the surface of stainless steel wires has no significant effect on the properties and therefore no decarburisation requirement is specified. On the other hand, stainless wires are probably more prone to surface defects than conventional carbon and low alloy spring steel wires, yet none of the standards has attempted to quantify an acceptable surface defect level.

Stainless steel wires having broadly similar compositions include the following:

UK - 302S26, 302S25, En 58A, S205

US - S302, S304, S305, 30302

Germany - Wk.St. 1.4300, 1.4310, X12CrNi 177, X12CrNi188

Sweden - 14-23-31, 14-23-33

Japan - SUS 301, 302, 304

France - Z6CN18.09, Z10CN18.09

8. MOLYBDENUM-BEARING STAINLESS STEEL SPRING WIRE

Stainless steels containing molybdenum are similar in many respects to the 'austenitic' 18/8 type stainless steels, although the additional molybdenum somewhat improves their corrosion resistance. The addition of 2 to 3% molybdenum to the straight 18/8 variety of stainless enhances corrosion resistance under most conditions but especially where exposure to sulphuric acid, organic acids, halogen salts and sea water is encountered.

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C Max	%Si Max	%Mn Max	%S Max	%P Max	%Cr	%Ni	%Mo
BS2056 1983	UK	316S42	0.07	1.0	2.0	0.03	0.045	16.0-18.5	9.5-13.5	2.0-2.5
ASTM, A313 1981	US	316	0.08	1.0	2.0	0.03	0.045	16.0-18.0	10.0-14.0	2.0-3.0
DIN 17224 1982	Germany	1.4401	0.07	1.0	2.0	0.03	0.045	16.5-18.5	10.5-13.5	2.0-2.5
SIS 14 23 47 1985	Sweden	47-04	0.07	1.0	2.0	0.03	0.045	16.0-18.5	10.5-14.0	2.0-2.5
JIS G4314 1984	Japan	SUS 316	0.08	1.0	2.0	0.03	0.045	16.0-18.0	10.0 14.0	2.0-3.0

Note:- The German steel grade 1.4401 is also designated as X5 Cr Ni Mo 1810.

Commentary:

All steel compositions are very similar, with the British standard having the leanest alloy content. The United States and Japanese steel compositions are identical, allowing higher percentages of molybdenum than their European counterparts.

B. **TENSILE STRENGTH**

Wire Dia (mm)	Strength R_m (N/mm^2)				
	BS2056 316S42	A313 316	DIN 17224 1.4401	SIS 14 23 47 23 47-04	G 4314 SUS316
0.10	1680-1920	1690-1895	1650-1900	1700 min	1618-1863
0.25	1640-1880	1690-1895	1600-1850	1650 min	1569-1814
0.50	1600-1840	1620-1825	1600-1850	1600 min	1569-1814
1.0	1580-1820	1620-1825	1500-1750	1500 min	1471-1716
2.0	1460-1700	1450-1655	1350-1600	1400 min	1324-1569
3.0	1260-1500	1345-1550	1200-1400	1350 min	1177-1422
4.0	1260-1500	1240-1450	1200-1400	1200 min	1177-1422
5.0	1100-1340	1105-1310	1100-1350	1200 min	1079-1324
6.0	1100-1340	1035-1240	1100-1350	1100 min	1079-1324
7.0	1030-1270	965-1170	1050-1300	1100 min	981-1226
8.0	1030-1270	930-1140	1050-1300	1100 min	981-1226
9.0	860-1100	930-1140			
10.0	860-1100	895-1105			
12.0		895-1105			

Note:- DIN 17224 specifies a minimum of 40% reduction of area on tensile testing for wires over 1.5mm diameter.

Commentary:

There does not appear to be any consistent pattern within the strength values quoted to suggest one national specification is significantly higher than another. From a practical stand-point the differences between the various standards are insignificant.

C. **FORMABILITY**

Specification	Torsion Test	Bend Test (180°)	Wrap Test	Reverse Bend Test	Wrap and Stretch Test
BS2056:316S42	—	>3mm on 2d >6mm on 3d	<3mm on 1d	—	—
A313:316	—	—	<4mm on 1d >4mm on 2d	>0.6mm	<4.5mm
DIN 17224:1.4401	>1.5mm	—	—	—	<1.5mm
SIS 14 23 47-04	—	—	<4mm	—	—
G4314:SUS316	<4mm	—	—	—	—

Commentary:

The formability requirements given for molybdenum-bearing stainless steels are precisely the same as those given for straight 18/8 type stainless steel wires. The wrap test is the most popular method of assessing formability of wire. Where a torsion test is specified, it is not used to gauge formability but rather to reveal surface imperfections in the material.

D. **SURFACE QUALITY**

Specification	Deep Etch Test	Max Defect Depth (mm)
BS2056:316S42	——	(note 1)
A313:316	——	——
DIN 17224:1.4401	——	(note 2)
SIS 14 23 47-04	——	(note 1)
G4314:SUS316	——	(note 2)

Note 1: Only general statements are given in the standards to the effect that wires should be free from harmful defects.

Note 2: Visual examination is required after torsion testing but no quantitative defect levels are given.

Commentary:

In view of the fact that stainless steel wires are more prone to surface imperfections than carbon steels, it is surprising that none of the standards includes a deep etch test to reveal defects, nor specifies acceptable levels of defects.

In addition to the steels considered in this comparison, there are a number of other materials having broadly similar compositions:

UK - 315S16 (En 58H), 316S16 (En 58J)

US - Wk.St. 1.4404 (X2CrNiMo1810), 1.4410 (G-X10CrNiMo18), 1.4408 (G-X6CrNiMo1810)

Sweden - 14 23 48, 14 23 43, 14 23 53

Japan - SUS 32TB, SUS 316L

France - AFNOR Z6CND17.11, Z2CND17.12

9. 17/7 PH STAINLESS STEEL SPRING WIRE

Precipitation hardening 17/7PH stainless steel wire is strengthened by a combination of cold working and thermal treatment after spring coiling. The material possesses good corrosion resistance and is particularly useful where high working stresses are encountered.

A. COMPOSITION

Wire Specification	Origin	Steel Grade	%C max	%Si max	%Mn max	%S max	%P max	%Cr	%Ni	%Al
BS2056 1983	UK	301S91	0.09	1.0	1.0	0.03	0.045	16-18	6.5-7.75	0.75-1.50
DTD 5086 1969	UK	—	0.09	1.0	1.0	0.025	0.035	16-18	6.5-7.75	0.75-1.50
ASTM A313:81	US	631	0.09	1.0	1.0	0.03	0.04	16-18	6.5-7.75	0.75-1.50
SAE J217: 70	US	—	0.09	1.0	1.0	0.03	0.04	16-18	6.5-7.75	0.75-1.50
AMS 5678A:81	US	—	0.09	1.0	1.0	0.03	0.04	16-18	6.5-7.75	0.75-1.50
DIN 17224:82	Germany	1.4568	0.09	1.0	1.0	0.03	0.045	16-18	6.5-7.75	0.75-1.50
G.4314 1984	Japan	SUS 631J1	0.09	1.0	1.0	0.03	0.04	16-18	7.0-8.5	0.75-1.50

Commentary:

All compositions are very similar except for the Japanese material in which the nickel content is somewhat higher.

B. TENSILE STRENGTH

Wire Dia (mm)	Strength Rm (N/mm^2)							
	BS2056:301S81		DTD 5086		A313 type 631, J217 and AMS 5678A		DIN 17224 :1.4568	G4314, SUS 631J1
	as drawn	after HT*	as drawn	after HT*	as drawn -nominal	after HT*	as drawn*	as drawn*
0.10								1961-2206
0.25	1880-2110	2230-2530			2035	2310-2515	1950-2200	1912-2157
0.50	1820-2050	2170-2470	1800-	2150-	2000	2275-2480	1850-2100	1814-2059
1.0	1770-2000	2120-2420	1750-2050	2150-2450	1895	2205-2415	1800-2050	1765-2010
2.0	1630-1860	1930-2210	1650-1950	2000-2300	1760	2015-2220	1600-1850	1569-1814
3.0	1500-1730	1800-2080	1500-1800	1850-2150	1625	1875-2080	1400-1650	1373-1618
4.0	1460-1690	1760-2040	1350-1700	1700-2000	1560	1765-1970	1400-1650	1373-1618
5.0	1400-1630	1680-1950	1350-1700	1700-2000	1530	1740-1945	1300-1550	1275-1520
6.0	1380-1610	1660-1930	1300-1650	1650-1900	1470	1670-1875	1300-1550	1275-1520
7.0	1350-1580	1600-1870	1250-1550	1550-1850	1470	1670-1875		
8.0	1330-1560	1530-1800	1250-1550	1550-1850	1425	1620-1825		
9.0	1270-1500	1470-1740	1250-1550	1550-1850	1425	1620-1825		
10.0	1270-1500	1470-1740	1250-1550	1550-1850	1425	1620-1825		
12.0					1400	1585-1795		
15.0					1400	1585-1795		

* Details of the precipitation heat treatment are given in each of the standards. The majority specify 480° +/- 10°C for 1 to 2 hours, although the Japanese specify 470° +/- 10°C for 1 hour. For the German & Japanese steels, the as-drawn values are increased by 260-400 and 245 min respectively.

Commentary:

The three standards have identical tensile strengths but the as-drawn tensile strengths show differences from country to country, in excess of 100N/mm² in some cases. The strength values for the German and Japanese wires are generally lower than those quoted in British specifications. Only the DIN standard requires a minimum reduction in area of 40% after tensile testing on wires over 1.5mm diameter.

C. **FORMABILITY**

Specification	Torsion Test	Bend Test (180°)	Wrap Test	Reverse Bend Test	Wrap and Stretch Test
BS2056:301S81	—	>3mm on 2d >6mm on 3d	<3mm on 1d	—	
DTD5086	<2mm		<3mm	>3mm	
A313:type 631	—	—	<4.1mm on 1d >4.1mm on 2d	—	<4.5mm
J217	—	—	all sizes on 1d	—	<3mm
AMS 5678A	—	—	all sizes on 1d	—	<3.1mm
DIN 17224	>1.5mm	—	—	—	<1.5mm
G4314	<4mm	—	—	—	—

Commentary:

Although the torsion test is specified in three of the standards it is not primarily intended to measure the ductility of the material but rather as a test to reveal surface defects in the wire. Most standards favour a wrap test as an indication of formability. With two of the foreign standards there is no provision for measuring formability on large diameter wires.

D. **SURFACE QUALITY**:

Specification	Deep Etch Test	Max Defect Depth
BS2056:301S81	—	(Note 1)
DTD 5086	all sizes	1.5% or 0.025mm whichever is smaller
A313:type 631	all sizes	(Note 1)
J217	—	(Note 1)
AMS 5678A	—	(Note 1)
DIN 17224	—	(Note 2)
G4314	—	(Note 2)

Note 1:- No quantitative information is given, only general statements such as 'free from harmful defects' are specified.

Note 2:- Visual examination after torsion testing but no quantitative values given.

Commentary:

Since the carbon content of stainless steels is very low, there is no requirement for specifying decarburisation levels. It is surprising that only two of the standards stipulate deep etch testing as a means of revealing surface defects.

Materials having broadly similar compositions which are classified as 17/7PH steels include the following:

UK	- 301S81, DTD 5086
US	- Type 631, J217, AMS 5678A
Germany	- Wk.St. 1.4568, X7CrNiAl177
Japan	- SUS 631, SUS 631J1
International	- ISO 683/XVI Type 2

10. SPRING BRASS AND COPPER-NICKEL SPRING WIRE

Although not as widely used as phosphor-bronze material, spring brasses find application where material costs are a first consideration. They possess excellent electrical conductivity and good all-round corrosion resistance. In certain environmental conditions, such as damp atmospheres containing ammonia, cold drawn brass wires may be sensitive to "season cracking".

Copper-nickel (also known as "Nickel Silver" and "German Silver") is more expensive and is principally used in telecommunications and optical industries. It is silvery-white in colour and has good resistance to corrosion.

Both spring brass and copper-nickel develop their strength from cold working and cannot be hardened by thermal treatments.

A. COMPOSITION

Wire Specification	Origin	Grade	% Cu	% Zn	% Ni	% Mn
BS 2873:1969	U.K.	CZ 107	64.0/ 67.0	Rem.		
		NS 106	60.0/ 65.0	Rem.	17.0/ 19.0	0.05/ 0.5
ASTM B134:86	USA	C 27000	63.0/ 68.5	Rem.		
B206:86		C 76400	58.5/ 61.5	Rem.	16.5/ 19.5	
DIN 17682:79	Germany	CuZn36 (2.0335)	63.5/ 65.0	Rem.		
		CuNi18 Zn20 (2.0740)	60.0/ 63.0	Rem.	17.0/ 19.0	0.5 max
JIS H3270:86	Japan	C 7521	61.0/ 67.0	Rem.	16.5/ 19.5	0.5 max

Note:- The German DIN standard 17682 does not specify compositions but refers to other standards for this information e.g. CuZn36 - DIN 17660 and CuNi18Zn20 - DIN 17663. The numbers given in parenthesis below the German grades are alternative Werkstoff material designations.

Commentary:

The compositions for the brasses are very similar from country to country. On the other hand, the USA seems to favour a slightly lower copper content for their copper-nickel alloy. The Japanese do not include a spring brass in their national specifications.

B. **TENSILE STRENGTH**

Specification	Grade	Condition	Wire diameter (mm) over	up to	Tensile Strength R^m (N/mm^2) min	max
BS 2873:69	CZ 107	0	0.5	10.0	320	-
		1/2 H	0.5	10.0	460	620
		H	0.5	10.0	620	740
		EH		2.5	740	820
		EH	2.5	6.0	700	770
	NS 106	0, 1/2 H, H	by agreement			
ASTM B134:86	C27000	H00	0.5		345	450
		H01			425	530
		H02			545	650
		H03			635	740
		H04		12.0	700	810
		H06		9.5	790	890
		H08		6.3	830	-
ASTM B206:86	C76400	H01			510	640
		H02			635	760
		H04			770	885
		H08	0.5	0.65	900	-
			0.65	1.60	860	
			1.60	3.0	830	
			3.0	6.0	830	
DIN 17682:79	CuZn36		0.3	0.8	750	930
			0.8	1.5	700	850
			1.5	3.0	650	770
			3.0		by agreement	
	CuNi18 Zn20		0.3	0.8	860	1040
			0.8	1.5	830	980
			1.5	3.0	800	920
			3.0		by agreement	
JIS H3270:86	C7521	0	0.5		373	520
		1/2 H	0.5	5.0	520	686
		H	0.5	5.0	667	

Note: The wire condition is also referred to as the temper grade in the Japanese and ASTM standards. It should be noted that the various designations for wire condition/temper grade do not necessarily equate to the same tensile strength from country to country.

In the current ASTM standards for copper-based alloys, a new series of temper designations has been introduced and these equate to the old designations as given below:-

New temper grades	Old temper grades
O61	Annealed
H00	Eighth-hard
H01	Quarter-hard
H02	Half-hard
H03	Three-quarter-hard
H04	Hard
H06	Extra-hard
H08	Spring-hard
H10	Extra-spring hard

C **FORMABILITY**

Specification	Grade	Wrap test condition	Wrap test size	Bend Test condition	Bend Test size	Tensile Property condition	Tensile Property %El(min)
BS 2873:69	CZ107	H,EH	<6mm			O	35%
ASTM B206	C76400			H08	<6.5mm	H08	5-9% (depending on size)
DIN 17682	CuZn 36	all	<1.5 mm	all	all		
	CuNi18 Zn20	all	<1.5 mm	all	all		

Commentary:

The British and German standards favour a wrap test for assessing formability but this is often limited to smaller wire sizes. There appears to be little consistency between the various national standards regarding formability testing in that the UK has no requirements placed on the copper-nickel alloy nor the USA on formability of spring brass.

The DIN standard specifies a modified wrap test which involves stretching the helix after wrapping.

D. SURFACE QUALITY

Only DIN 17682 makes reference to the required surface quality of the wires and stipulates that defects and scores should be limited to a maximum of 1% of the wire diameter and not more than 0.006mm. The British and Japanese standards make only general statements that wires shall be free from harmful defects without any further qualification.

None of the American ASTM specifications makes any reference to surface quality.

11 PHOSPHOR BRONZE SPRING WIRE

Copper-based spring wires represent a group of materials which, due to their good electrical conductivity and appreciable resistance to corrosion, find wide application in electrical equipment. Almost invariably these materials develop their mechanical strength from cold working by drawing. They do not, however, develop the strength values attainable with ferrous materials and this feature must be recognised when designing springs from copper based materials.

Phosphor-Bronze wires are the most widely used of the copper-based alloys.

A. COMPOSITION

Wire Specification	Origin	Grade	% Cu	% Sn	% P
BS 2873:1969	U.K.	PB 102	Rem.	4.5/6.0	0.02/0.40
		PB 103	Rem.	6.0/7.5	0.02/0.40
ASTM B 159:86	USA	C51000	Rem.	4.2/5.8	0.03/0.35
		C52100	Rem.	7.0/9.0	0.03/0.35
DIN 17682:79	Germany	Cu Sn 6 (2.1020)	Rem.	5.5/7.0	0.01/0.35
		Cu Sn 8 (2.1030)	Rem.	7.5/8.5	0.01/0.35
JIS H3270:86	Japan	C5102	Rem.	4.5/5.5	0.03/0.35
		C5191	Rem.	5.5/7.0	0.03/0.35

Note:- The DIN standard 17682 does not specify compositions but refers to another standard for this information - DIN 17662. The numbers in parenthesis immediately below the German grade designations refer to the corresponding Werkstoff material numbers.

Commentary: In general the compositions of the various grades of phosphor bronze are very similar.

B. **TENSILE STRENGTH**

Specification	Grade	Condition	Wire Diameter (mm) over	up to	Tensile Strength R_m (N/mm^2) min	max
BS 2873	PB 102	0	0.5	10.0	340	-
		1/2H	0.5	10.0	540	700
		H	0.5	10.0	700	850
		EH		2.5	850	-
		EH	2.5	6.0	800	-
	PB 103	0	0.5	10.0	370	-
		1/2H	0.5	10.0	590	740
		H	0.5	10.0	740	900
		EH		2.5	900	-
		EH	2.5	6.0	850	-
ASTM B159:86	C51000	061		14.0	295	400
		H01		14.0	415	525
		H02		14.0	550	670
		H03		14.0	660	795
		H04			745	880
		H08		0.6	1000	
			0.6	1.6	930	
			1.6	3.0	890	
			3.0	6.0	850	
			6.0	10.0	830	
			10	16.0	720	
	C52100	061		6.0	365	470
		H01		6.0	510	625
		H02		6.0	655	795
		H03		6.0	780	930
		H04		6.0	860	1035
DIN 17682:79	Cu Sn 6 and Cu Sn 8		0.1	0.3	1050	1230
			0.3	0.8	1000	1180
			0.8	1.5	950	1100
			1.5	3.0	900	1020
			3.0		by agreement	
JIS H3270:86	C5102	0	0.5	-	304	422
		H	0.5	5.0	637	
	C5191	0	0.5	-	314	461
		1/2H	0.5	5.0	637	785
		H	0.5	5.0	834	

Note:- The wire condition is also referred to as the temper grade in the Japanese and ASTM standards. It should be noted that the various designations for wire condition/temper grade do not necessarily equate to the same tensile strength from country to country.

In the current ASTM standards for copper-based alloys, a new series of temper designations has been introduced and these equate to the old designations as given below:-

New temper grades	Old temper grades
O61	Annealed
H00	Eighth-hard
H01	Quarter-hard
H02	Half-hard
H03	Three-quarter-hard
H04	Hard
H06	Extra-hard
H08	Spring-hard
H10	Extra-spring hard

C. **FORMABILITY**

Specn.	Grade	Wrap Test condtn	Wrap Test Size	Bend Test condtn	Bend Test size	Tensile Property condtn	Tensile Property elongatn
BS 2873	PB 102	H, EH	<6mm			0	40% on 100mm
	PB 103	H, EH	<6mm			0	50% on 100mm
ASTM B 159	C51000			H08	<6.5mm	H08	5 to 9% on 50mm depending on size
DIN 17682	CuSn6&8	all	<1.5mm	all	all		
JIS H3270	C5102	H	<1.5mm				
	C5191	1/2H, H	<1.5mm				

Commentary:

Most standards favour a wrap test as a means of assessing formability but this is often limited to the smaller wire sizes. As with other DIN standards, the Germans specify a modified wrap test which involves stretching the coiled helix after forming.

D. **SURFACE QUALITY**

Only DIN 17682 makes reference to the required surface quality of the wires and stipulates defects and scores should be limited to a maximum of 1% of the wire diameter and not more than 0.006mm. The British and Japanese standards make only general statements that wires shall be free from harmful defects, without any further qualification.

The American ASTM specification makes no reference to surface quality.

12 COPPER BERYLLIUM SPRING WIRE

Within the group of copper-based alloys, copper beryllium has the highest strength derived from its ability to be hardened by cold working followed by a simple thermal treatment. Its use is recommended where the working stresses encountered in service could not be tolerated by other copper-based alloys. Although much more expensive than the other materials in this group, copper beryllium wire finds wide application in instruments and electrical components.

A. COMPOSITION

Wire Specification	Origin	Grade	% Cu	% Be	% Ni+Co	% Co
BS 2873:1969	UK	CB 101	Rem	1.70/ 1.90	0.05/ 0.40	
ASTM: B197:85	USA	C17200	Rem	1.80/ 2.0	0.2min	
DIN 17682:79	Germany	CuBe2 (2.1247)	Rem	1.80/ 2.10		
		CuCoBe (2.1285)	Rem	0.4/ 0.70		2.0/ 2.8
JIS H3270:86	Japan	C1720	Rem	1.80/ 2.0	0.2min	

Note:- The DIN standard 17682 does not specify compositions but refers to another standard for this information, viz:- CuBe2 and CuCoBe - DIN 17666. The numbers in parenthesis immediately below the German grade designations refer to the corresponding Werkstoff material numbers.

Commentary:

In general the compositions of the various grades are very similar but the Germans include a low beryllium variety which contains a significant amount of cobalt. However, this low beryllium alloy is not capable of achieving the same high tensile strength as the standard 2% Be alloy.

B TENSILE STRENGTH

Specification	Grade	Condition	Wire Diameter (mm) over	up to, incl	Tensile Strength R_m (N/mm^2) min	max	
BS 2873:69	CB 101	W	0.5	10.0	390	-	
		W(H)		3.0	770	-	
		WP	0.5	10.0	1050	-	
		W(H)P		3.0	1240	-	
ASTM B197:85	C17200	TB00			400	540	
		TF00			1105	1310	after h.t
		TD01			620	795	
		TH01			1205	1415	after h.t.
		TD02			760	930	
		TH02			1275	1480	after h.t
		TD03		2.0	895	1070	
		TH03		2.0	1310	1585	after h.t
		TD04		2.0	965	1140	
		TD04		2.0	1345	1585	after h.t
DIN 17682:79	CuBe2	F42	0.1	3.0	420	550	as drawn
		F120			1200	1300	after h.t
		F65			650	800	as drawn
		F125			1250	1400	after h.t
		F80			800	950	as drawn
		F135			1350	1450	after h.t
		F95			950	1150	drawn
		F140			1400	1550	after h.t
	CuCoBe	F25	0.1	3.0	250	370	drawn
		F65			650	800	after h.t
		F50			500	650	drawn
		F75			750	900	after h.t
		F60			600	750	drawn
		F80			800	1000	after h.t
JIS H3270:86	C1720	0	0.5	-	392	539	annealed
			0.5		1098	1324	after h.t
		1/4H	0.5	5.0	618	804	drawn
			0.5	5.0	1206	1422	after h.t
		3/4H	0.5	5.0	834	1069	drawn
			0.5	5.0	1304	1589	after h.t

Note:- The wire condition is also referred to as the temper grade in the Japanese and ASTM standards. It should be noted that the various designations for wire condition/temper grade do not necessarily equate to the same tensile strength from country to country.

In the current ASTM standard for copper beryllium alloys, a new series of temper designations has been introduced which equate to the old designations as given over:-

New temper grades	Old temper grades
TB00	Annealed (A)
TD01	Quarter-hard (1/4H)
TD02	Half-hard (1/2H)
TD03	Three-quarter-hard (3/4H)
TD04	Hard (H)
TF00	Annealed then pptn hardened (AT)
TH01	1/4 hard " " " (1/4HT)
TH02	1/2 hard " " " (1/2HT)
TH03	3/4 " " " " (3/4HT)
TH04	Hard " " " (HT)

C. **FORMABILITY**

Specification	Grade	Wrap Test Condition	Wrap Test size	Bend Test Condition	Bend Test size
BS2873	CB101	W(H)	<1.5mm		
ASTM B 197	C17200	all tempers,	all sizes		
DIN 17682	CuBe2	all	<1.5mm	all	all
	CuCoBe	all	<1.5mm	all	all

Commentary:

The standards favour a wrap test as a means of assessing formability but often only for the smaller wire sizes. As with other DIN standards, the Germans specify a modified wrap test which involves stretching the coiled helix after forming. It should be noted the Japanese standard has no tests specified for assessing formability.

D. **SURFACE QUALITY**

Only DIN 17682 makes reference to the required surface quality of the wires and stipulates that defects and scores should be limited to a maximum of 1% of the wire diameter and not more than 0.006mm. The British and Japanese standards make only general statements that wires shall be free from harmful defects without any further qualification.

The American ASTM specification makes no reference to surface quality.