VALVE SPRING WIRE TECHNICAL SERVICES BULLETIN

AMERICAN SPRING WIRE CORPORATION

NORTH AMERICA

Updated: June 20, 2014

OVERVIEW

American Spring Wire produces various sizes, shapes and grades of valve spring quality wire that are used for highly stressed, high cycle fatigue application, such as internal combustion engines. Each application requires its own size, shape, and mechanical properties to meet the needs of the design engineer to fulfill all the requirements of the spring.

This technical data bulletin will give the spring design engineer the ability to use the following information to assist in the spring design.

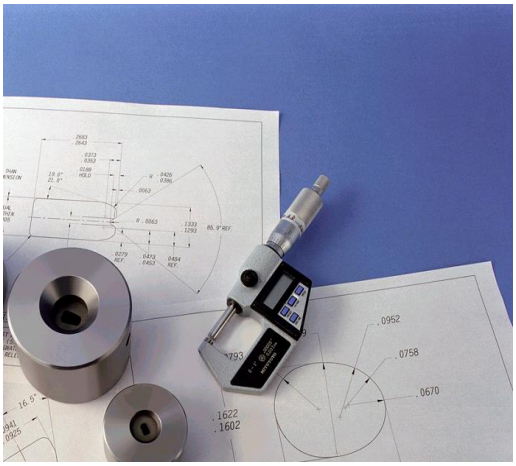
Raw Material Quality Characteristics

Rod Specifications

Raw material specifications – ASW has developed written specifications for the steel wire rod used for each of the various types of valve spring quality wire. These specifications include requirements for chemistry, surface quality, decarburization, inclusion content, microstructure, residual elements, mechanical handling and other important aspects of quality. All rod specifications are written by the ASW Technical Department and are fully controlled documents in our Quality System. A steel supplier must verify his capabilities before qualification as an approved source. Valve quality rod is purchased from a very few select sources from around the world.

Non-metallic Oxides

Inclusion content – All rods purchased for valve spring quality wire are made with the latest technology in cleanliness and inclusion control. Steelmaking includes inclusion morphology control to optimize the deformability and lessen the harmfulness of inclusions. ASW typically uses the max 't' method for rating inclusions. We also have the ability to measure to ASTM E 45.



Wire Quality Characteristics

Surface Removal Techniques

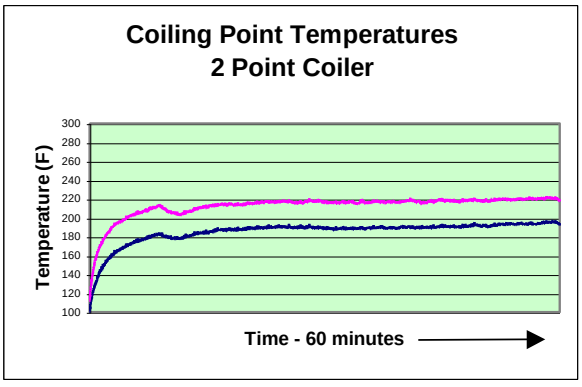
Surface removal – All valve spring quality wire produced at ASW undergoes a surface preparation process that involves removal of surface imperfections that come from the steel supplier. We have the option of using one of two different techniques.

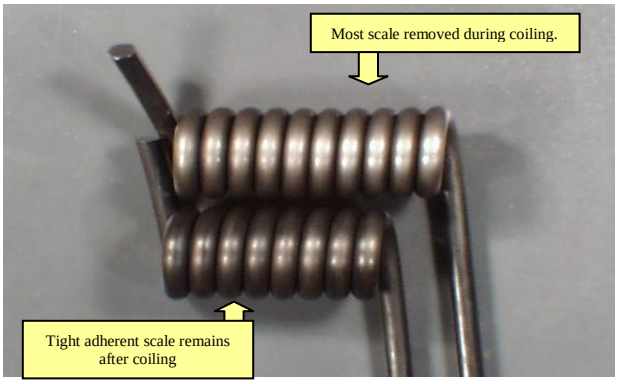
Shaving process – The shaving process is commonly used around the world for valve spring wire manufacture. This process uses a shaving die that peels away the surface layer of the steel. It leaves a hardened surface that requires a subsequent heat treating process to allow the wire to be drawn to the finish size. ASW uses an induction heat treating furnace in line after the shaving die to anneal this hardened layer.

Grinding process - This proprietary process was developed by ASW and has been used successfully and exclusively by our company for over 40 years. It uses a rotary grinding method that is more cost effective than shaving and eliminates the need for additional processes required by shaving. A zinc phosphate is applied, in line, to the surface prepared wire.

Surface Quality

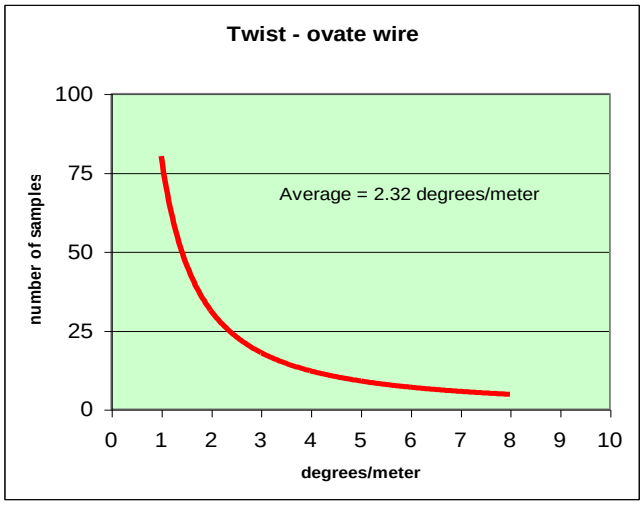
Surface quality oxide scale – ASW uses state of the art oil tempering technology to produce a desired oxide coating on the wire surface that aids in spring coiling performance. This oxide is important due to the higher tensile materials generating more heat during spring coiling. This oxide coating assists in lubricating the tooling on the spring coiler and reduces the friction thereby reducing coiler marks and improving the life of the tools on the spring coiler (see bottom left graph). At present we can supply this oxide on sizes from 0.110" - 0.315" (2.8 – 8.0 mm). The picture below compares a wrapped spring sample from our controlled atmosphere-tempering furnace, showing good tight adherent oxide scale to a spring where the oxide flakes off during spring coiling.

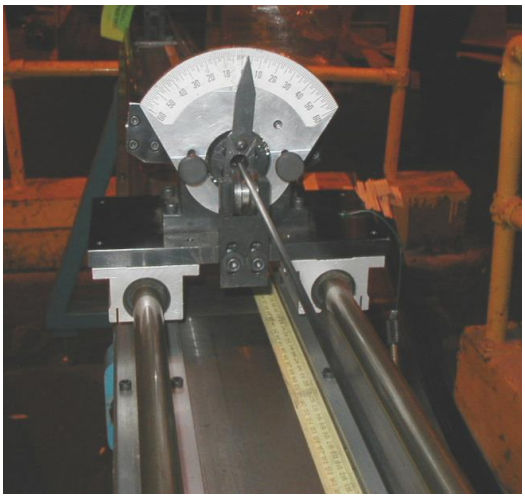




Shaped VSQ Wire

Ovate / Multi-Arc (MA)/ Elliptical wire – ASW has produced various different sizes of ovate and elliptical shaped wire. All wire is die drawn using shape dies produced by ASW at our Tooling Division. Each new size is drawn on CAD and this program is then applied to our wire EDM machine for close tolerance cutting of the dies. Special quality practices are implemented during the drawing and oil tempering of ovate and elliptical shaped wire to maintain the proper dimensions and control the straightness of the finish wire. Excess twist in the finish wire can cause many problems during spring coiling. ASW has implemented systems to monitor and control twist throughout the wire drawing and oil tempering operations. Since straightness is an important quality characteristic, we measure twist on both ends of every coil produced. Our twist capabilities on finished oil tempered wire are seen in the following chart.

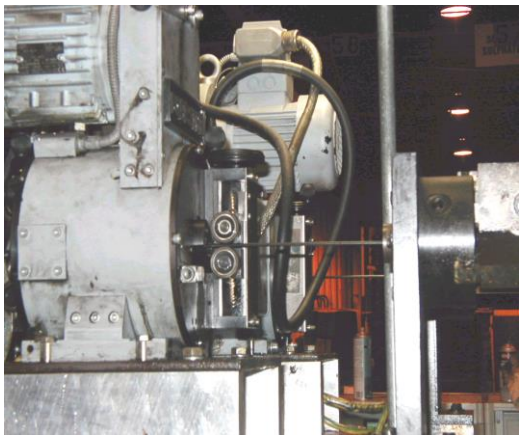




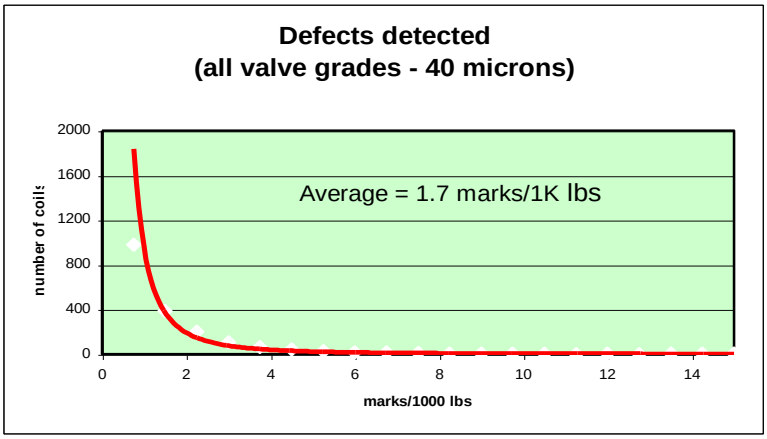
Finished ovate and elliptical shaped wire is measured for twist using a gage that is shown in the above right photo. This gage measures degrees of twist along a sample that is 5 meters in length. This test is an important measure for helping maintain the twist capability necessary for ovate wire.

Eddy Current Testing

Final eddy current inspection – All valve wire is processed through a final eddy current inspection. The purpose of this final test is to do a 100% surface test for the entire coil to detect and identify any mark or defect that is greater than 0.0015" (40 microns). Eddy current equipment consists of state of the art technology using Foerster Circograph and Defectomat equipment for detecting longitudinal and point defects. ASW uses an ultraviolet paint (UV) system for marking defects. UV paint cures immediately when exposed to the UV light source. This eliminates the problem of wet paint transferring to equipment and other rings in the coil. There is also a built in paintmark identification system using photocells. This system verifies that paint has been applied and we do not have an unpainted defect.



Continuous eddy current testing can be done for sizes of 0.110" – 0.315" (2.8 – 8.0 mm). All ovate and elliptical shaped wire can be tested using clearance compensation technology on the Circograph. On special profiles, a shaped encircling coil and guide system can be implemented. Current capabilities are seen in the following capability study.



Rotating Probe: Coverage of the wire surface is approximately 90% at 11,000rpm using 5mm probes on the Circograph.

Stationary coil: There is 100% coverage of the wire surface using the stationary coil.

ASW 90VN
Chrome-Silicon-Vanadium with Nickel Alloy

1) **Application:**

This specification defines the requirements of quenched and tempered (oil-tempered) and non-tempered, chromium-silicon-vanadium-nickel alloy spring steel wire intended for the manufacture of engine valve and other high stress, high fatigue cycle springs. This grade is designed for springs that are to be surface nitrided after oil tempering. Surface nitriding followed by shot peening increase the fatigue life of the valve spring. Gas nitriding will strengthen the spring by forming fine nitrides at the surface.

2) **Chemical Composition (wt %):**

C	Si	Mn	P	S	Cr	V	Ni	Cu	O –Ti – Al
0.56-0.61	1.80-2.10	0.70-1.00	0.015 max	0.015 max	0.85-1.05	0.05-0.15	0.20-0.40	.05% max	.003% max each

3) **Mechanical Properties:**

Tensile and dimensional properties of the O.T. wire are shown in table below. Modifications of the mechanical properties may be made as agreed upon between purchaser and supplier, provided that they are noted on all documents and tags pertaining to the material.

Tensile strength within an individual coil may not vary by more than 50 N/mm^2 (7 KSI)
Yield strength minimum will be 90% of the minimum required tensile strength.

Wire diameter		Tensile strength		Size tolerance		Out-of-Round		% RA
mm	(inches)	N/mm^2	(PSI)	mm	(inches)	mm	(inches)	min.
2.80-3.99	(0.110-0.157)	2082 – 2179	(302 – 316,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	45
4.00- 4.99	(0.1575-0.196)	2034 – 2130	(295 – 309,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	45
5.00-5.99	(0.1965-0.235)	1978 – 2089	(287 – 303,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	40
6.00-6.99	(0.236-0.275)	1930 – 2034	(280 – 295,000)	+/-0.040	(+/-0.0016")	0.040	(0.0016")	40
7.00-8.00	(0.2756-0.315)	1882 – 1986	(273 – 288,000)	+/-0.040	(+/-0.0016")	0.040	(0.0016")	40

4) Wrap test should be performed on an arbor with diameter that is 2 times the wire diameter

5) Cleanliness – The thickness of non-deformable inclusions (such as ASTM E-45 Type B&D) present in the outer 1/3 of a longitudinal rod sample cross section shall be measured and counted to the following categories. The max T method shall be used .(ASW method QC10016.win)

	Percent of Fields	
	80% minimum	**100%**
Maximum Inclusion thickness	**≤ 5 microns**	**≤ 15 micron**

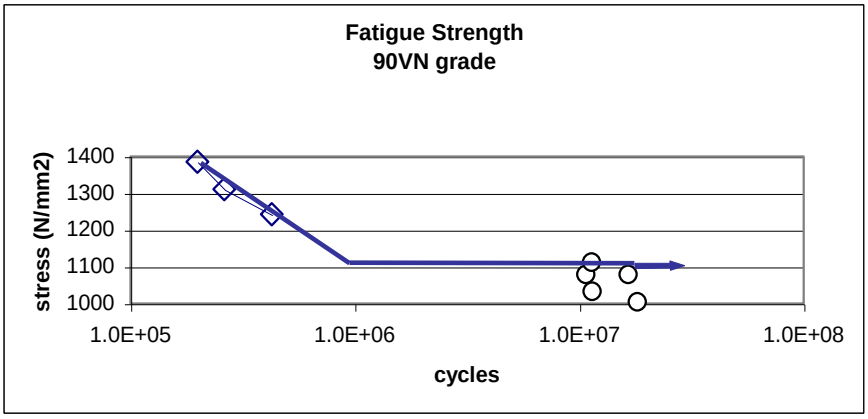
Testing shall be done on 10% of the coils from each heat.

6) Surface quality – Visual inspection of the end sample of a finished coil shall show no surface imperfection whose depth is greater than 0.0008" (20 microns).

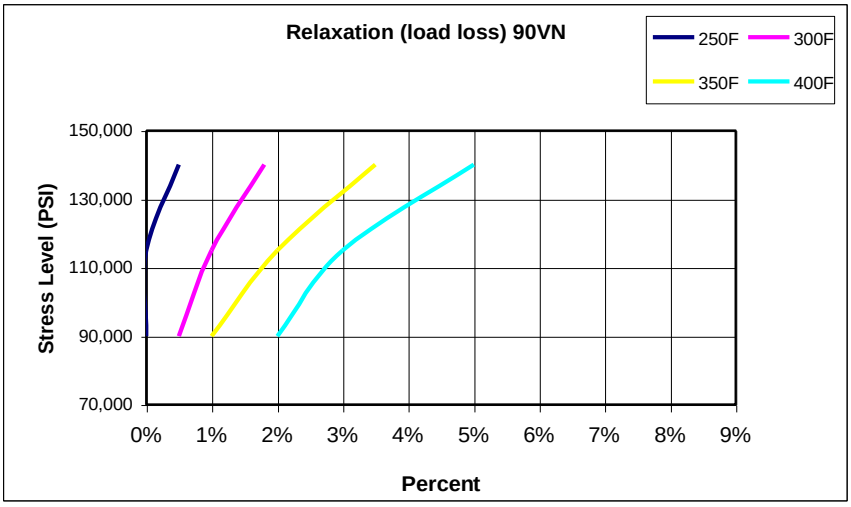
7) Decarburization – Complete decarburization is not allowed. Partial decarburization can exist to a depth of ½% of the wire diameter or 0.001" (25 microns), whichever is less.

8) Eddy current testing - Wire diameters of 0.110 - 0.315" (2.8 – 8.0mm) shall be double eddy current tested at finish, with a rotary probe and stationary coil, for defects 40 microns (0.0015") and deeper. Defects shall be painted in such a way that the customer can identify and segregate marked sections.

9) Rotating bending fatigue test results based on 0.1575" (4.0 mm) wire at 310 KSI (2140 N/mm^2) tensile. The value of 1110 N/mm^2 = 161 KSI.



10) Spring relaxation test results - These relaxation graphs were developed by compressing springs to selected lengths (stresses) and holding at temperature for 24-hours. Spring relaxation properties are very dependent on spring manufacturing variables, especially in the hot-set operation. This should be taken into consideration when applying this data.



11) Spring heat treatments – It is important that the springs are stress relieved immediately after coiling at a temperature of 425°C for 20-30 minutes. After grinding and a light shot peen, the springs may be surface nitrided at 400 - 425°C for a length of time depending on the desired depth of the nitriding. The higher the nitriding temperature, the greater the decrease in core hardness. After nitriding, the springs should go through a final shot peen operation.

ASW 9MV
Chrome-Silicon-Vanadium Alloy

1) **Application:**

This specification defines the requirements of quenched and tempered (oil-tempered) and non-tempered, chromium-silicon-vanadium alloy spring steel wire intended for the manufacture of engine valve and other high stress, high fatigue cycle springs.

2) **Chemical Composition (wt %):**

C	Si	Mn	P	S	Cr	V	Cu	O –Ti – Al
0.60-0.68	1.30-1.60	0.50-0.80	0.015 max	0.015 max	0.60-0.80	0.08-0.15	0.05 max	.003% max each

3) **Mechanical Properties:**

Tensile and dimensional properties of the O.T. wire are shown in table below. Modifications of the mechanical properties may be made as agreed upon between purchaser and supplier, provided that they are noted on all documents and tags pertaining to the material.

Tensile strength within an individual coil may not vary by more than 50 N/mm^2 (7 KSI)

Yield strength minimum will be 90% of the minimum required tensile strength.

Wire diameter		Tensile strength		Size tolerance		Out-of-Round		% RA
mm	(inches)	N/mm^2	(PSI)	mm	(inches)	mm	(inches)	min.
2.80-3.99	(0.110-0.157)	2060 - 2160	(299 - 313,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	45
4.00- 4.99	(0.1575-0.196)	2010 - 2110	(292 - 306,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	45
5.00-5.99	(0.1965-0.235)	1960 - 2060	(284 - 299,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	40
6.00-6.99	(0.236-0.275)	1910 - 2010	(277 - 292,000)	+/-0.040	(+/-0.0016")	0.040	(0.0016")	40
7.00-8.00	(0.2756-0.315)	1860 - 1960	(270 - 284,000)	+/-0.040	(+/-0.0016")	0.040	(0.0016")	40

4) Wrap test should be performed on an arbor with diameter that is 2 times the wire diameter

5) Cleanliness – The thickness of non-deformable inclusions (such as ASTM E-45 Type B&D) present in the outer 1/3 of a longitudinal rod sample cross section shall be measured and counted to the following categories. The Max T method shall be used. (ASW method QC10016.win)

	Percent of Fields	
	80% minimum	**100%**
Maximum Inclusion thickness	**≤ 5 microns**	**≤ 15 micron**

Testing shall be done on 10% of the coils from each heat.

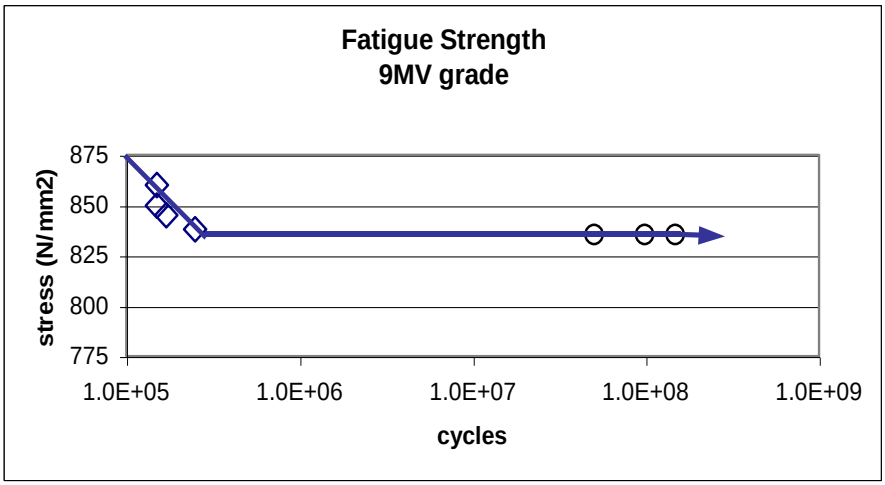
6) Decarburization – Complete decarburization is not allowed. Partial decarburization can exist to a depth of ½% of the wire diameter or 0.001" (25 microns), whichever is less.

7) Surface quality – Visual inspection of the end sample of a coil shall show no surface imperfection whose depth is greater than 0.0008" (20 microns).

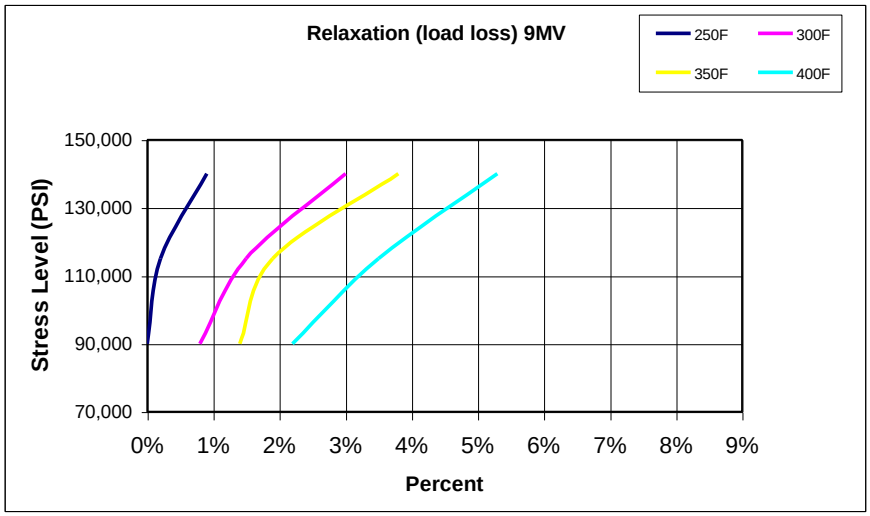
8) Grain size – the finished oil-tempered wire will have a fine prior austenitic grain size of ASTM 10 or finer.

9) Eddy current testing - Wire diameters of 0.110 - 0.315" (2.8 – 8.0mm) shall be double eddy current tested at finish, with a rotary probe and stationary coil, for defects 40 microns (0.0015") and deeper. Defects shall be painted in such a way that the customer can identify and segregate marked sections.

10) Rotating bending fatigue test results based on 0.1575" (4.0 mm) wire at 282 KSI (1946 N/mm^2) tensile. The value of 835 N/mm^2 = 121 KSI.



11) Spring relaxation test results - These relaxation graphs were developed by compressing springs to selected lengths (stresses) and holding at temperature for 24-hours. Spring relaxation properties are very dependent on spring manufacturing variables, especially in the hot-set operation. This should be taken into consideration when applying this data.



12) All other quality characteristics are to ASTM A877.

ASW 9BV
Chrome-Silicon Alloy

1) **Application:**

This specification defines the requirements of quenched and tempered (oil-tempered) and non-tempered chromium silicon alloy spring steel wire intended for the manufacture of engine valve and other high stress, high fatigue cycle springs.

2) **Chemical Composition (wt %):**

C	Si	Mn	P	S	Cr	Cu	O –Ti – Al
0.51-0.59	1.30-1.55	0.60-0.75	0.015 max	0.015 max	0.60-0.70	0.05 max	.003% max each

3) **Mechanical Properties:**

Tensile and dimensional properties of the O.T. wire are shown in table below. Modifications of the mechanical properties may be made as agreed upon between purchaser and supplier, provided that they are noted on all documents and tags pertaining to the material.

Tensile strength within an individual coil may not vary by more than 50 N/mm^2 (7 KSI)
Yield strength minimum will be 90% of the minimum required tensile strength.

Wire diameter		Tensile strength		Size tolerance		Out-of-Round		% RA
mm	(inches)	N/mm^2	(PSI)	mm	(inches)	mm	(inches)	min.
2.80-3.99	(0.110-0.157)	1930 – 2030	(280 – 295,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	45
4.00- 4.99	(0.1575-0.196)	1860 – 1960	(270 – 285,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	40
5.00-5.99	(0.1965-0.235)	1830 – 1930	(265 – 280,000)	+/-0.030	(+/-0.0012")	0.030	(0.0012")	40
6.00-8.00	(0.236-0.315)	1760 – 1860	(255 – 270,000)	+/-0.040	(+/-0.0016")	0.040	(0.0016")	40

4) Wrap test should be performed on an arbor that is the same diameter as the wire, for sizes 0.177" (4.5 mm) and smaller and two times the diameter for sizes larger than 0.177" (4.5 mm).

5) Surface quality – Visual inspection of the end sample of a coil shall show no surface imperfection whose depth is greater than 0.0008" (20 microns).

6) Cleanliness – The thickness of non-deformable inclusions (such as ASTM E-45 Type B&D) present in the outer 1/3 of a longitudinal rod sample cross section shall be measured and counted to the following categories. The Max T method shall be used. (ASW method QC10016.win)

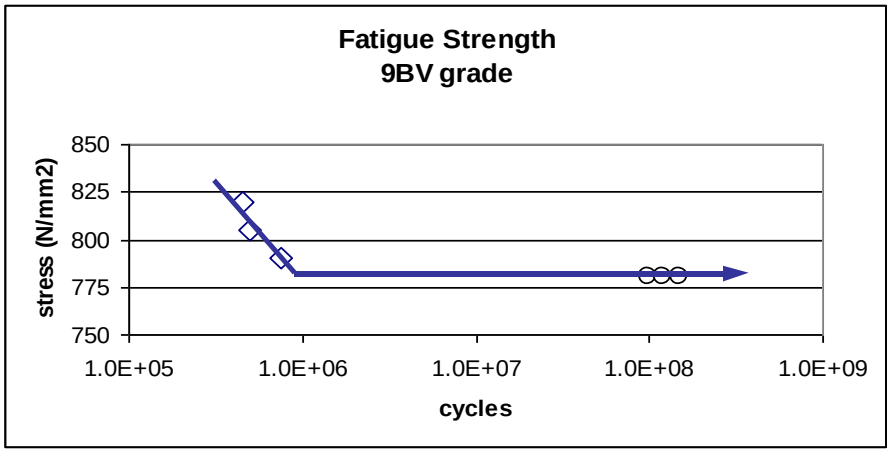
	Percent of Fields	
	80% minimum	**100%**
Maximum Inclusion thickness	**≤ 5 microns**	**≤ 15 micron**

Testing shall be done on 10% of the coils from each heat.

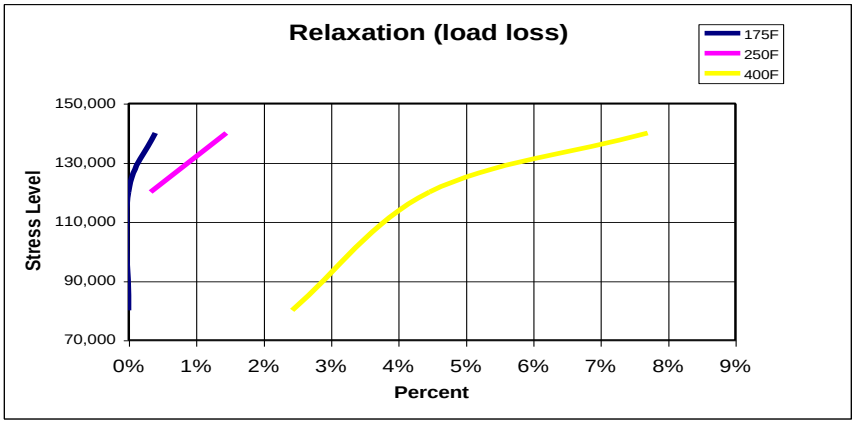
7) Decarburization – Complete decarburization is not allowed. Partial decarburization can exist to a depth of ½% of the wire diameter or 0.001" (25 microns), whichever is less.

8) Eddy current testing - Wire diameters of 0.110 - 0.315" (2.8 – 8.0mm) shall be double eddy current tested at finish, with a rotary probe and stationary coil, for defects 40 microns (0.0015") and deeper. Defects shall be painted in such a way that the customer can identify and segregate marked sections.

9) Rotating bending fatigue test results based on 0.1575" (4.0 mm) wire at 282 KSI (1964 N/mm^2) tensile. The value of 780 N/mm^2 = 113 KSI.



10) Spring relaxation test results - These relaxation graphs were developed by compressing springs to selected lengths (stresses) and holding at temperature for 24-hours. Spring relaxation properties are very dependent on spring manufacturing variables, especially in the hot-set operation. This should be taken into consideration when applying this data.



11) All other quality characteristics are to ASTM A877.

Spring Processing
Using Valve Quality Wire

Spring Coiling

This coiling operation is critical to the final quality of the spring. The points and arbor on the machine must be maintained so that mechanical marks are not induced into the wire surface. Additionally, if a single point coiler is used in processing "High Tensile" wires, extra care must be taken to avoid deformation and heat build on the inside diameter, as these conditions can lead to "Stress Cracking".

Stress Relieving

Immediately after the spring is coiled a thermal treatment must be applied. This is necessary to remove the majority of the residual coiling stresses, which also lead to stress cracking. The temperature can range from 700°F (370°C) to 800°F (425°C), depending on the chemistry of the wire.

Grinding

The grind operation squares the ends and develops the proper loads for the spring. Care must be taken to prevent the ends from overheating which could lead to reduced hardness of the material, and a change in the "rate" of the spring.

Shot Peen

The purpose of this process is to induce a compressive stress into the surface of the wire. This is essential for long term durability of dynamically loaded springs. When using "High Tensile" wire, this operation may have to be modified to obtain the required "Almen" reading, and surface condition. After shot peen, the spring must again be subjected to a stress relief, but at a lower temperature, 400°F (200°C) to 450°F (230°C).

Heat Setting

When a spring requires a very low load loss relaxation property, this operation may be added. The spring is heated and then quenched under load. This may replace the stress relief after the shot peen operation.

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ASWVSWTSB
8/07

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