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SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) HELICAL COMPRESSION AND EXTENSION SPRING TERMINOLOGY

Foreword—This document has *also been changed* to comply with the new SAE Technical Standards Board format.

1. ***Scope***—The following recommended practice has been developed to assist engineers and designers in the preparation of specifications for the major types of helical compression and extension springs. It is restricted to a concise presentation of items which will promote an adequate understanding between spring manufacturer and spring user of the major practical requirements in the finished spring. Closer tolerances are obtainable where greater accuracy is required and the increased cost is justified.

For the basic concepts underlying the spring design and for many of the details, see the SAE Information Report MANUAL ON DESIGN AND APPLICATION OF HELICAL AND SPIRAL SPRINGS, SAE HS J795, which is available from SAE Headquarters in Warrendale, PA 15096. A uniform method for specifying design information is shown in the TYPICAL DESIGN CHECK LISTS FOR HELICAL SPRINGS, SAE J1122.

Two types of helical springs are considered:

a. Hot coiled compression springs for general automotive use as well as for motor vehicle suspensions.
b. Cold wound compression and extension springs for general automotive use.

This recommended practice uses SI (metric) units in accordance with the provisions of SAE J916 JUN82.

2. ***References***

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE HS 84—Manual on Shot Peening
SAE J113—Hard-Drawn Mechnical Spring Wire and Springs
SAE J132—Oil-Tempered Chromium-Vanadium Valve Spring Quality Wire and Springs
SAE J157—Oil-Tempered Chromium—Silicon Alloy Steel Wire and Springs
SAE J172—Hard Drawn Carbon Steel Valve Spring Quality Wire and Springs
SAE J178—Music Steel Spring Wire and Springs
SAE J217—Stainless Steel 17-7 PH Spring Wire and Springs
SAE J230—Stainless Steel, SAE 30302, Spring Wire and Springs
SAE J271—Special Quality High-Tensile, Hard-Drawn Mechnical Spring Wire and Springs

SAE J316—Oil-Tempered Carbon-Steel Spring Wire and Springs
SAE J351—Oil-Tempered Carbon-Steel Valve Spring Quality Wire and Springs
SAE J461—Wrought and Cast Copper Alloys
SAE HS J795—SAE Manual on Design and Application of Helical and Spiral Springs
SAE J808—Manual on Shot Peening
SAE J916—Rules for SAE Use of SAE (Metric) Units
SAE J1122—Helical Springs: Specification Check Lists

3. Hot Coiled Springs

3.1 Materials and Heat Treatment—Round spring steel bars are available in carbon and alloy analyses. The bars are generally used in the "as rolled" condition (either commercial hot rolled or precision hot rolled), but they may be centerless ground before coiling.

The heat treatment necessary to develop the required physical properties of the material may be accomplished by direct quench immediately after coiling, or by allowing the coiled spring to cool to a temperature below the critical, then reheating to the required temperature and quenching; the quench is followed by tempering to produce the specified hardness.

Table 1 lists available materials. Their hardenability limitations dictate maximum bar size. For tensile and torsional properties, see MANUAL, SAE HS J795, Chapter 2, Table 2.21.

TABLE 1—MATERIALS FOR HOT COILED COMPRESSION SPRINGS

Materials	Specification	Max. Bar[1] Dia., mm
Carbon Steels	SAE 1085	10
	SAE 1095	10
Carbon Boron Steel	SAE 15B62H	25
Alloy Steels	SAE 5150 H	10
	SAE 5160 H	20
	SAE 9260 H	10
	SAE 51B60H	30
	SAE 4161 H	60
	SAE 6150 H	10

1. Based on a through hardened bar of 444 HB typical hardness ranges are 444 - 495 HB and 461 - 514 HB.

3.2 Shot Peening—Shot peening is used to increase the fatigue life of springs. It consists of subjecting the spring to a stream of metallic shot moving at high velocity. The peening action of the shot reduces the effect of surface defects and sets up beneficial stresses in a thin surface layer. It also results in cold working this layer. To be effective, the peening must reach the area of highest stress which for helical compression springs is the inside diameter of the coil.

The fatigue life of hot coiled springs is greatly impaired when the bar surface is afflicted by such flaws as impurities, cracks, seams, or decarburization, but it can be increased by the peening operation in the order of 4 to 1. Even the much better fatigue life attainable in hot-coiled springs with nearly perfect bar surface will be improved by peening in the order of more than 2 to 1. For further details see MANUAL, SAE HS J795, Chapters 1 and 4, also SHOT PEENING MANUAL, SAE HS 84 J808.

3.3 Presetting—Presetting (also called scragging, cold setting, or bulldozing) is an operation during the manufacturing process in which the spring is compressed beyond the yield point of the heat treated material. In preparation for this, the spring is coiled to a free length in excess of the designated free length. The yielding in the surface layers of the bar which occurs during presetting produces beneficial residual stresses, thus increasing the elastic limit and thereby reducing the chances of settling in subsequent service. The yielding causes the spring to take a permanent set, thus bringing it down to the designated free length. See also Preset Length, 3.6.3.

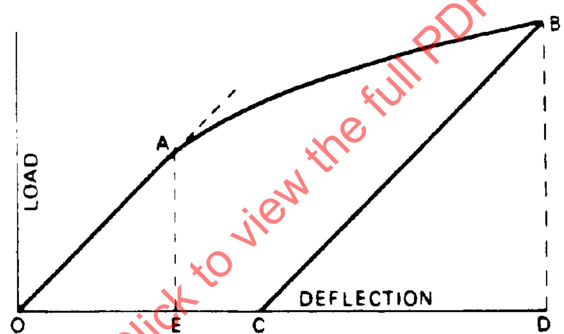

FIGURE 1—TYPICAL LOAD-DEFLECTION DIAGRAM OF HELICAL SPRING DURING PRESETTING

3.3.1 WARM SETTING—In order to reduce the "sag" of "settling" of helical suspension springs which occurs when they are subjected to vehicle loading over time, it has become common practice to warm set the spring at an elevated temperature (usually about 200 °C depending on the particular spring design). One theory holds that the major benefit of this operation results from an increase in the amount of strain hardening that occurs when the spring is stressed past the proportional limit (point "A" in Figure 1). Increasing the temperature lowers the proportional limit to some stress lower than point "A", and therefore if the spring is still stressed to point "B", the amount of strain hardening that occurs is greater. This increase in strain hardening will reduce the dynamic or static settling (load loss) that occurs over the useful life of the spring.

A second theory is that a more effective beneficial residual stress pattern is set up over the bar cross section, when a spring is warm set at elevated temperature.

It should be noted that a final (cold) presetting operation is still necessary.

In general, warm setting will decrease the load loss by more than 50%, depending on the working stress level.

3.4 Bar Diameter and Length—Round bars are hot rolled to any desired diameter between 9 and 100 mm. Table 2 shows the cross section tolerances for commercial hot rolled bars. Bars may be precision hot rolled with 50% of the tolerances in Table 2, or they may be centerless ground with 25% of the tolerances in Table 2.

Bars are commonly purchased in the exact length required to produce one spring. Tolerances for bar lengths are shown in Table 3.

TABLE 2—CROSS SECTION TOLERANCES FOR HOT ROLLED CARBON AND ALLOY STEEL ROUND BARS

Specified Diameter, mm Over	Specified Diameter, mm Thru	Tolerance, Plus and Minus, mm	Out of Round, mm
—	10	0.15	0.22
10	15	0.18	0.27
15	20	0.20	0.30
20	25	0.23	0.34
25	30	0.25	0.38
30	35	0.30	0.45
35	40	0.35	0.52
40	60	0.40	0.60
60	80	0.60	0.90
80	100	0.80	1.20

TABLE 3—LENGTH TOLERANCES FOR HOT ROLLED CARBON AND ALLOY ROUND STEEL BARS

Specified Diameter, mm Over	Specified Diameter, mm Thru	Length Tolerance, Plus Only, mm For Lengths, mm Over Thru	Length Tolerance, Plus Only, mm For Lengths, mm 1500 3000	Length Tolerance, Plus Only, mm For Lengths, mm 3000 —
—	25		12	20
25	50		16	25
50	100		25	40

3.5 Coil Diameter—The coil diameter can be expressed in terms of the mean coil diameter (D) which is used in the rate and stress formulae. However, coil diameter tolerances should be specified on either the inside diameter (ID) or the outside diameter (OD) of the coils, depending upon the importance of the respective dimensions to the user. Tolerances are shown in Table 4, based on coil diameter and spring length.

For motor vehicle suspension springs, it is customary to specify the ID in order to facilitate the coiling of a family of springs on a single arbor.

TABLE 4—COIL DIAMETER TOLERANCES

For Specified or Computer Outside Diameter, mm	Inside or Outside Diameter Tolerance, Plus and Minus, mm For Free Spring Length, mm Up to 250	Inside or Outside Diameter Tolerance, Plus and Minus, mm For Free Spring Length, mm Over 250 thru 450	Inside or Outside Diameter Tolerance, Plus and Minus, mm For Free Spring Length, mm Over 450 thru 650	Inside or Outside Diameter Tolerance, Plus and Minus, mm For Free Spring Length, mm Over 650 thru 850	Inside or Outside Diameter Tolerance, Plus and Minus, mm For Free Spring Length, mm Over 850 thru 1050
75.0 thru 110.0	0.8	1.3	2.5	3.6	4.6
Over 110.0 thru 150.0	1.3	2.5	3.6	4.6	5.6
Over 150.0 thru 200.0	2.5	3.6	4.6	5.6	6.6
Over 200.0 thru 300.0	3.6	4.6	5.6	6.6	6.6

3.6 Spring Lengths—Spring lengths are to be measured after preloading (see Preload Length, 3.6.4), as the distance parallel to the spring axis between the end surfaces, or else between two reference points specified on the spring drawing.

3.6.1 FREE LENGTH—Free length is the length when no external load is applied. When load is specified, free length is used as a reference dimension only. When load is not specified, free length tolerance equals ±(1.5 mm + 4% of free-to-solid deflection).

3.6.2 SOLID LENGTH (SEE ALSO NUMBER OF COILS, 3.7)—Solid length is the length when the spring is compressed with an applied load sufficient to bring all coils in contact; for practical purposes, this applied load is taken to equal approximately 150% of the load beyond which no appreciable deflection takes place.

3.6.3 PRESET LENGTH—In the presetting operation (see Presetting, 3.3), the spring is usually compressed solid. However, if the stress at solid length is so high that the spring would be excessively distorted, the presetting operation may only be carried to a specified preset length. If more than one preset compression is desired, this must be specified on the drawing. See Also MANUAL, SAE HS J795, Chapters 1 and 4.

3.6.4 PRELOAD LENGTH—Preloading is the operation of deflecting the spring to the preload length in order to remove temporary recovery of free length before the spring is checked for load and rate.

If the spring was preset during the manufacturing process to the solid length, the preloading may also be carried to the solid length, but it may be restricted to a preload length slightly greater than the solid length, provided the maximum deflection during subsequent service will not go below the preload length.

If the spring was preset to a specified preset length greater than the solid length, the preloading should be restricted to a preload length greater than the preset length.

However, the preload length must not exceed the minimum spring length possible in the mechanism for which the spring is designed. In suspensions, this is called the "length at metal-to-metal position." The metal-to-metal contact will occur in the suspension mechanism when rubber bumpers are disregarded. The spring deflection from the specified loaded length to the metal-to-metal position is called "clearance."

3.6.5 LOADED LENGTH—Loaded length is the length while the load is being measured; it is a fixed dimension, with the tolerance applied to the load.

3.7 Number of Coils—Total number of coils (N_t) are counted tip to tip, active number of coils (N) are specified as the number of working coils at free length. With increasing load, N may progressively decrease due to the "bottoming out" effect. If no appreciable bottoming out occurs, the relationships between N and N_t are as shown in Table 5 which also gives the formulae for nominal solid length.

Since nominal solid length may be exceeded somewhat by actual solid length due to manufacturing variations, a frequent practice is to specify nominal solid length together with a maximum solid length, as shown in Table 6.

TABLE 5—FORMULAE FOR TOTAL COILS AND FOR NOMINAL SOLID LENGTH

End Configuration	Total Coils (N_t)	Nominal Solid Length (L_s)
Both ends taper rolled	N + 2	$1.01\ d\ (N_t - 1) + 2t$
Both ends with tangent tail	N + 1.33	$1.01\ d\ (N_t + 1)$
Both ends with pigtail	N + 1.50	$1.01\ d\ (N_t - 1.25)$
Taper rolled plus tangent tail	N + 1.67	$1.01\ d\ N_t + 1$
Taper rolled plus pigtail	N + 1.75	$1.01\ d\ (N_t - 1) + t$
Tangent tail plus pigtail	N + 1.42	$1.01\ d\ N_t$

where

d = bar diameter
t = tip thickness of taper rolled bar
1.01 = factor used to compensate for the cosine effect of the coil helix angle

The bracketed term in the solid length formula for springs with two pigtail ends may vary between (N_t – 0.90) and (N_t – 1.60), depending on the pigtail details.

TABLE 6—SPRING SOLID LENGTH TOLERANCES

Nominal Solid Length, mm Over	Nominal Solid Length, mm Thru	Maximum Deviation of Solid Length Above Nominal Solid Length, mm
—	175	1.5
175	250	2.5
250	325	3.0
325	400	4.0
400	475	4.8
475	550	5.5
550	625	6.5

3.8 Spring Ends—Four types of ends are used (Figure 2):

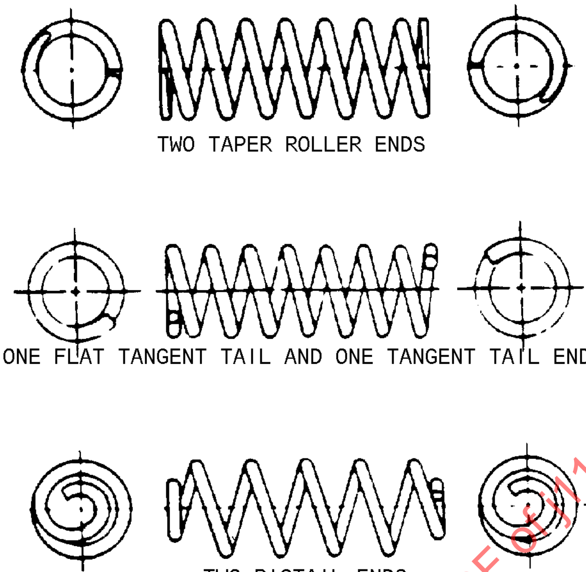

FIGURE 2—TYPICAL ENDS FOR HOT COILED COMPRESSION SPRINGS

1. A flat end formed from a tapered bar end. The bar end is usually tapered for a length equal to 2/3 coil and to a tip thickness of approximately 1/3 of the bar diameter. When the spring is coiled, the tip shall be in approximate contact with the adjacent coil and shall not protrude beyond the outside diameter by more than 20% of the bar diameter.
   When stipulated, the bearing surface of the spring end shall be ground perpendicular to the axis of the spring helix in order to produce a firm bearing. The actual ground bearing surface shall not be shorter than two-thirds of the mean coil circumference, nor narrower than half the width of the hot tapered surface of the bar. However, this grinding is usually not required if the tapering and coiling operations are performed adequately.
2. An untapered end coil formed substantially smaller than the central coils of the spring and in such a fashion as to have an outboard bearing surface perpendicular to the axis of the spring helix, the so-called "pigtail" end.
3. An untapered end coil formed as a helix having a pitch substantially equal to the bar diameter. To facilitate coiling, a straight end portion about 25 mm long is permitted to project tangent to the helix of this end construction, the so-called "tangent tail" end. The use of this type of end requires a spring seat formed at the same pitch of helix as that of the spring end.
4. An untapered end coil formed perpendicular to the axis of the spring helix for a circumference of at least 220 deg, the so-called "flat tangent tail" end. To facilitate coiling, a straight end portion about 25 mm long is permitted to project tangent to the outer circumference.

Springs can be specified to have any combination of the four types of ends. The combination of two tangent tail ends may involve a complex arrangement for indexing the spring seats, unless the design of every spring is adjusted to an identical number of total coils. Springs for general automotive use generally have two flat tapered ends. Spring ends and seats are usually so formed as to render approximately two-thirds to one coil inactive at each end.

3.9 Squareness of Ends—Unless otherwise specified, the tapered ends of any spring having an outside diameter to bar diameter ratio of 4 or more, and a free length to outside diameter of 4 or less, shall not deviate more than 3 deg from the perpendicular to the spring axis, as determined by standing the spring on its end and measuring the angular deviation of the outer helix from a perpendicular to the plate on which the spring is standing. In the case of a tangent tail end, the spring must stand on a seat with matching helical ramp. Tolerances for springs outside these limits are subject to special agreement.

3.10 Load—Load is the force in newtons (N) measured on the load testing machine required to deflect the spring to the specified loaded length. It is to be measured during compression of the spring (compression load) and not during release of the spring (release load), unless otherwise specified.

With loaded length fixed, the usual tolerance for motor vehicle suspension springs is expressed in terms of load equivalent to a deflection of ±5 mm at the nominal rate. Where the demand for greater accuracy warrants the cost of additional presetting or other operations, the load tolerance may be specified as low as ±1.50 mm at the nominal rate.

In the springs for general automotive use, the load tolerance (with loaded length fixed) typically equals ±(1.50 mm + 3% of free-to-solid deflection) × nominal rate. This tolerance is limited to springs where the free length does not exceed 900 mm, does not exceed six times the free-to-solid deflection, and is not less than 0.8 times the OD.

3.11 Rate—Rate is the change of load per unit length of springs deflection (N/mm).

In the springs for motor vehicle suspension, the rate is expressed in terms of the load increase per 25 mm deflection (N/25 mm). It is therefore determined as one-half the difference between the loads measured 25 mm above and 25 mm below the specified loaded length. Tolerance is ±3% with centerless ground or with precision rolled bars, and ±4% when commercial hot rolled bars are used.

In the springs for general automotive use, the rate is determined between 20 and 60% of the total deflection unless otherwise defined. Typical tolerance is ±5%. In non-critical applications, this may be increased to ±10%.

3.12 Direction of Coiling—For most applications, the direction of coiling is unimportant; however, right hand coiling is preferred because most spring manufacturers are so equipped. When direction of coiling is important, as in the case of concentrically nested springs, it must be specified or each component spring, maintaining opposite directions for adjacent springs. For tangent tail springs, the direction of coiling must conform with the installation conditions.

3.13 Uniformity of Pitch—The pitch of coils in a compression spring must be sufficiently uniform so that when the spring is compressed, unsupported laterally, to a length representing a deflection of 80% of the nominal free-to-solid deflection, none of the coils must be in contact with one another, excluding the inactive end coils. This requirement does not apply when the design of the spring calls for variable pitch, or when it is such that the spring cannot be compressed to solid length without lateral support.

3.14 Shaped and Variable Rate Coils—Many newer motor vehicle applications require specially shaped suspension coil springs, or springs with variable output characteristics. The coils which are specially shaped usually exhibit a partially conical or barrel form in order to satisfy restricted height, tire clearance, or other suspension requirements. In some cases, the ends of the spring may be offset in order to provide off center loading for suspension strut applications.

With regard to variable output characteristics, some springs are designed to provide a variable rate and corresponding frequency change, for improved height control, ride and handling. The variable rate characteristic is achieved by designing and producing the spring with very specific oil spacing such that active coil segments "bottom out" against a spring seat or against each other as the spring is deflected, thereby decreasing the effective number of active coils and increasing the rate. This effect is achieved with the greatest material and space efficiency if the bar is conically tapered over the length of the coils which bottom out. It should be pointed out, however, that special equipment is required to conically taper the bars. Also, it is important to not that coil-to-coil or coil-to-seat contact can cause undesirable noise.

3.15 Concentricity of Coils—At free length, the center of all coils must be concentric with the spring axis within 1.5 mm. This axis is the straight line connecting the centers of the end coils.

4. Cold Wound Springs

4.1 Material—Round wire sizes and tolerances may be found in the individual wire specifications, such as:

Music Wire		SAE J176
Carbon Steel Spring Wire	- Oil Tempered	SAE J316
	- Hard Drawn	SAE J113
	- Special Quality High Tensile Hard Drawn	SAE J271
	- Valve Spring Quality Oil Tempered	SAE J351
	- Valve Spring Quality Hard Drawn	SAE J172
Chromium Vanadium Wire - Valve Spring Quality		SAE J132
Chromium Silicon Alloy Steel Wire		SAE J157
Stainless Steel Wire, SAE 30302		SAE J230
Stainless Steel Wire, 17-7 PH		SAE J217
Phosphor-Bronze Wire,	SAE CA510	SAE J461
Beryllium-Copper Wire,	SAE CA172	SAE J461
Brass Wire,	SAE CA260	SAE J461
Silicon-Bronze Wire,	SAE CA655	SAE J461

4.2 Shot Peening—Shot peening is used to increase the fatigue life of springs. It consists of subjecting the spring to a stream of metallic shot moving at high velocity. The peening action of the shot reduces the effect of surface defects and sets up beneficial stresses in a thin surface layer. It also results in cold working this layer. To be effective, the peening must reach the area of highest stress which for helical compression and extension springs is the inside diameter of the coil.

Even when the wire surface is virtually flawless, the fatigue life of the cold-wound spring can be increased by peening in the order of more than 2 to 1. See MANUAL, SAE HS J795, Chapter 1, also SHOT PEENING MANUAL, SAE HS 84 J808.

4.3 Presetting—The need for presetting depends upon the design stresses, the application and its conditions and requirements. Then use of presetting is most beneficial when design stresses are at or near the yield point, and settling prevents the spring from performing as required.

Presetting is an operation that is performed during the manufacturing of helical compression springs in which the spring is compressed beyond the yield point of the material. The yielding of the surface layers of the wire which occurs during the presetting produces beneficial residual stresses, thus increasing the elestic limit of the spring and thereby reducing the chances of settling in subsequent service. The spring is coiled to a free length in excess of the designated free length. The yielding causes the spring to take a permanent set, thus bringing it down to the required free length.

The presetting operation may be performed at ambient temperature, called cold setting, or at some elevated temperature, called either heat setting or hot pressing. Heat setting consists of compressing the spring on a fixture, subjecting the compressed spring to a temperature higher than the desired operating temperature for a time suitable to insure complete penetration of the heat, and then cooling to room temperature before releasing.

Hot pressing consists of heating the spring in its free or relaxed position to some temperature for sufficient time to insure complete penetration; then, while the spring is at the temperature, it is compressed to some height below the installed or operating position and released.

4.4 Coil Diameter—Coil diameter tolerances can be specified on either the inside diameter (ID) or the outside diameter (OD) of the coils, depending upon the importance of the respective dimensions to the user. Tolerances are functions of the "Spring Index", which is the ratio of mean coil diameter (D) to wire diameter (d). They are to be considered as manufacturing tolerances and do not take into account the effects of changes in diameter due to applied loads. See Figure 3 and Figure 4.

4.5 Spring Lengths—Spring lengths of compression springs are overall dimensions measured parallel to the axis of the spring.

Spring lengths of extension springs are measured inside to inside of the hooks (overall length minus two wire diameters).

4.5.1 FREE LENGTH—Free length is the length under no load. When load is specified, free length is used as a reference dimension only. When load is not specified, free length is specified for control and inspection purposes by using Figure 5 for compression springs and Figure 6 for extension springs.

The tolerances in Figure 3 are based on the number of active coils (N), the free length (L_o), and the spring index (D/d). With these parameters known, the N/L_o value is established on the abscissa, and the tolerance is found by multiplying the corresponding ordinate value by L_o. Round off the index to the nearest whole number and interpolate when this is an odd number. The tolerances shown in Figure 5 are for springs with ends closed and ground. For springs with the ends closed but not ground, multiply by 1.7.

4.5.2 SOLID LENGTH (SEE ALSO NUMBER OF COILS, 4.6)—In compression springs, this is the length with all active coils closed, to be specified as a maximum dimension allowing the manufacturer any tolerance required by the variations in wire size, total coils, and the amount of grind at the ends; platings and coatings increase the wire diameter and must be considered.

For springs with ground ends, the maximum solid length is the total number of coils times the wire diameter; for springs with ends not ground, the solid length is the total number of coils plus one, times the wire diameter.

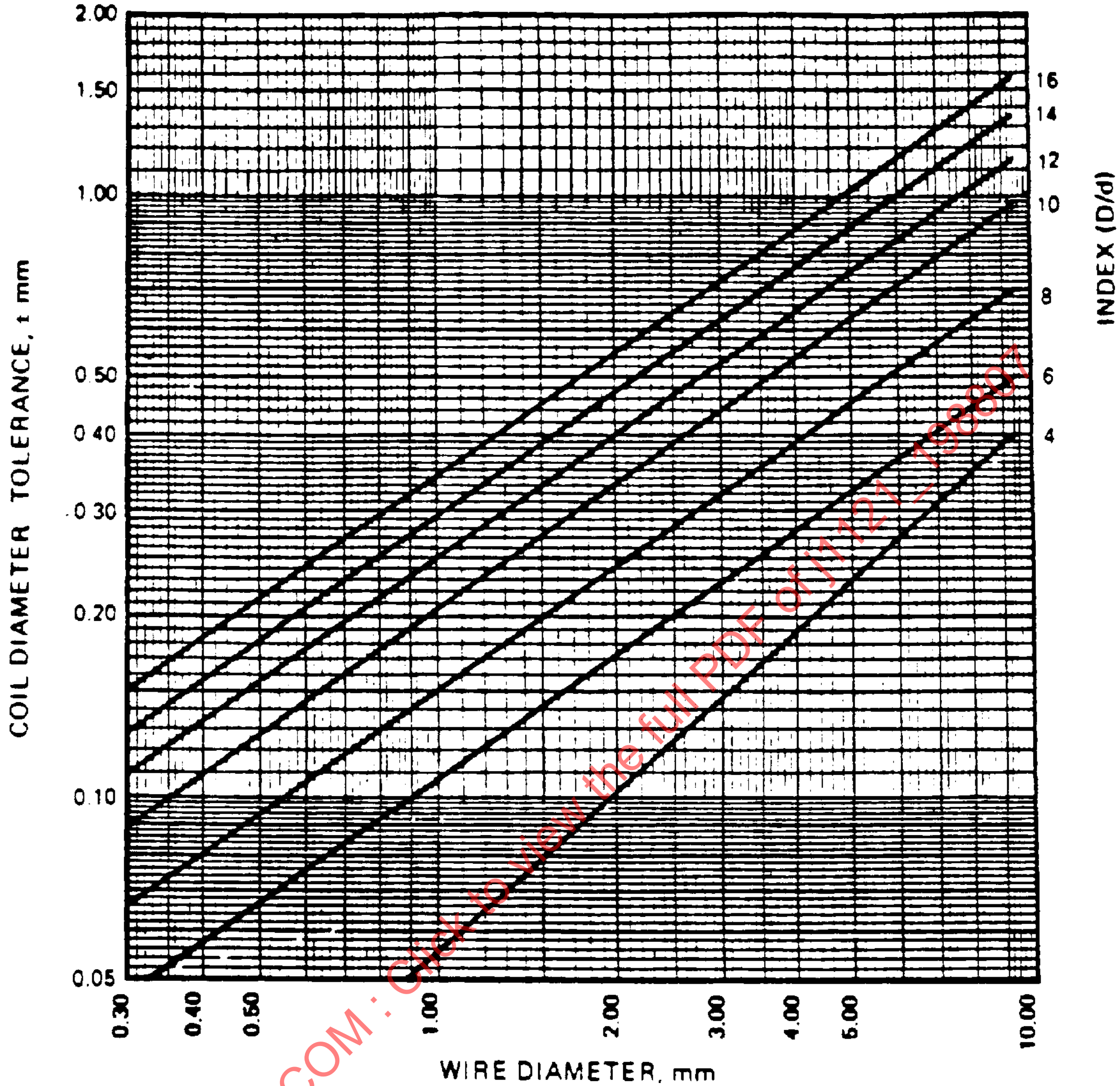

FIGURE 3—COIL DIAMETER TOLERANCE - COMPRESSION AND EXTENSION SPRINGS FOR WIRE SPRINGS FOR WIRE DIAMETERS 0.30 TO 9.50 mm. ROUND OFF INDEX TO NEAREST WHOLE NUMBER. INTERPOLATE WHEN THE ROUNDED-OFF VALUE IS AN ODD NUMBER. USE TOLERANCE FOR 0.30 mm WIRE DIAMETER WHEN WIRE DIAMETER IS LESS THAN 0.30 mm.

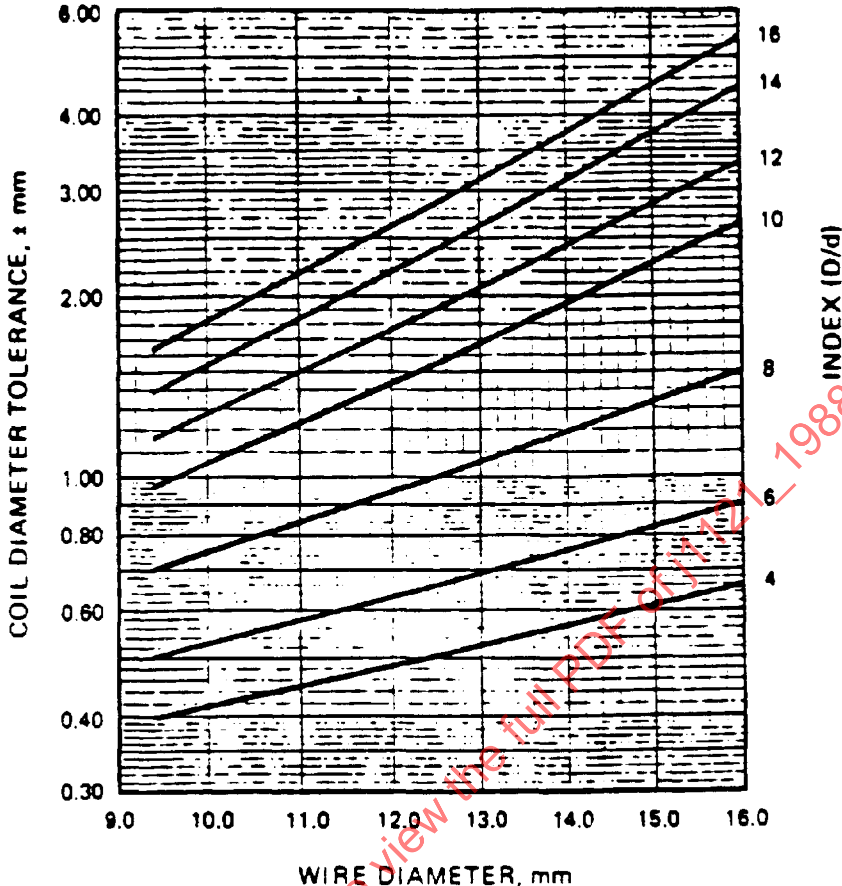

FIGURE 4—COIL DIAMETER TOLERANCE - COMPRESSION AND EXTENSION SPRINGS FOR WIRE DIAMETERS 9.5 TO 16.0 mm. ROUND OFF INDEX TO NEAREST WHOLE NUMBER. INTERPOLATE WHEN ROUNDED-OFF VALUE IS ODD NUMBER.

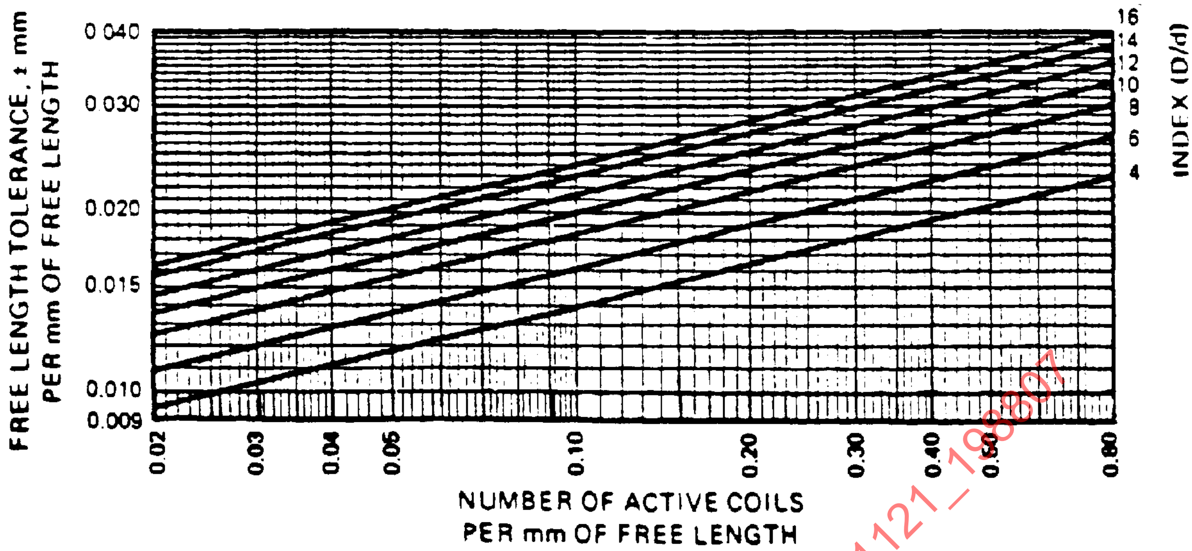

FIGURE 5—FREE LENGTH TOLERANCE - COMPRESSION SPRINGS. ROUND OFF INDEX TO NEAREST WHOLE NUMBER. INTERPOLATE WHEN ROUNDED-OFF VALUE IS ODD NUMBER. THESE ARE TOLERANCES FOR SPRINGS WITH ENDS CLOSED AND GROUND. FOR SPRINGS WITH ENDS CLOSED BUT NOT GROUND, MULTIPLY BY 1.7.

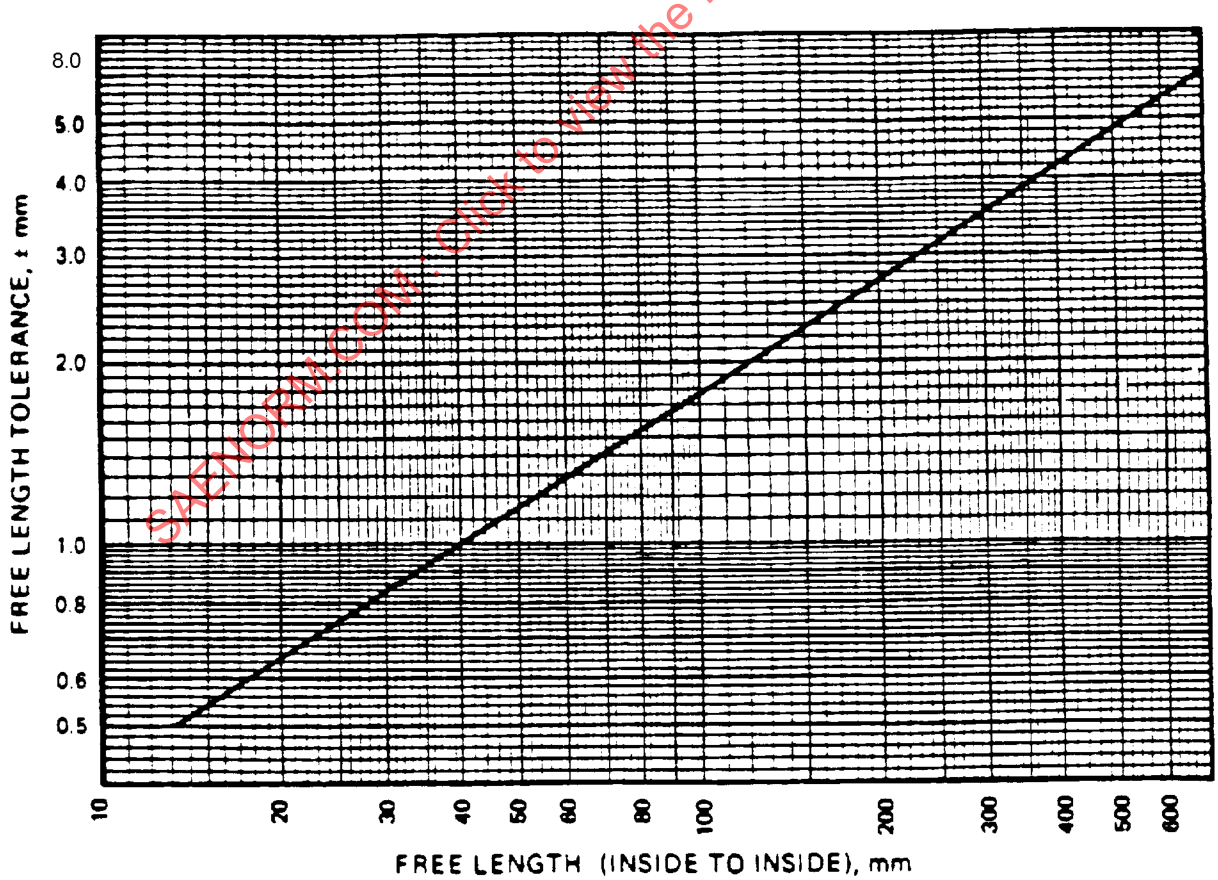

FIGURE 6—FREE LENGTH TOLERANCE - EXTENSION SPRINGS

4.5.3 PRESET LENGTH—After the compression spring has been coiled to a free length in excess of the designated free length, it is compressed solid or to a specified preset length; this produces yielding, which results in bringing the spring to the designated free length. If more than one preset compression is desired, it must be specified on the drawing. See also MANUAL, SAE HS J795, Chapters 1 and 4.

4.5.4 LOADED LENGTH—This is the length while the load is being measured. It is a fixed reference dimension, with the tolerance applied to the load.

4.5.5 MAXIMUM EXTENDED LENGTH—Extension springs normally do not have a definite stop to their deflection, therefore the drawing specifications should include a statement of the maximum extended length which must be attained without encountering permanent set.

4.6 Number of Coils—In compression springs, it is often necessary to vary the number of coils in order to meet the requirements on load, rate, free length, and solid length. Therefore, the number of coils should be specified as an approximate figure. For reference only, the tolerance for the number of coils is given in Table 7 compression springs and in Table 8 for extension springs. It is expressed in degrees as a function of the number of active coils.

TABLE 7—NUMBER OF COILS TOLERANCE OF COMPRESSION SPRINGS

Active Coils	Tolerance, ± deg
3 - 10	45
For each additional 10 coils, add	30

TABLE 8—NUMBER OF COILS TOLERANCE OF EXTENSION SPRINGS

Active Coils	Tolerance, ± deg Close Wound	Tolerance, ± deg Open Wound
3	30	90
4 - 10	45	90
For each additional 10 coils, add	15	30

In extension springs, either the number of coils in the body of the spring or the length over the coils may be specified, but only as an approximate figure. In computing the length over coils, it should be recognized that there is always one more wire diameter in the length than the number of coils in a close-wound spring.

4.7 Spring Ends—In compression springs, there are four typical end configurations (Figure 7):

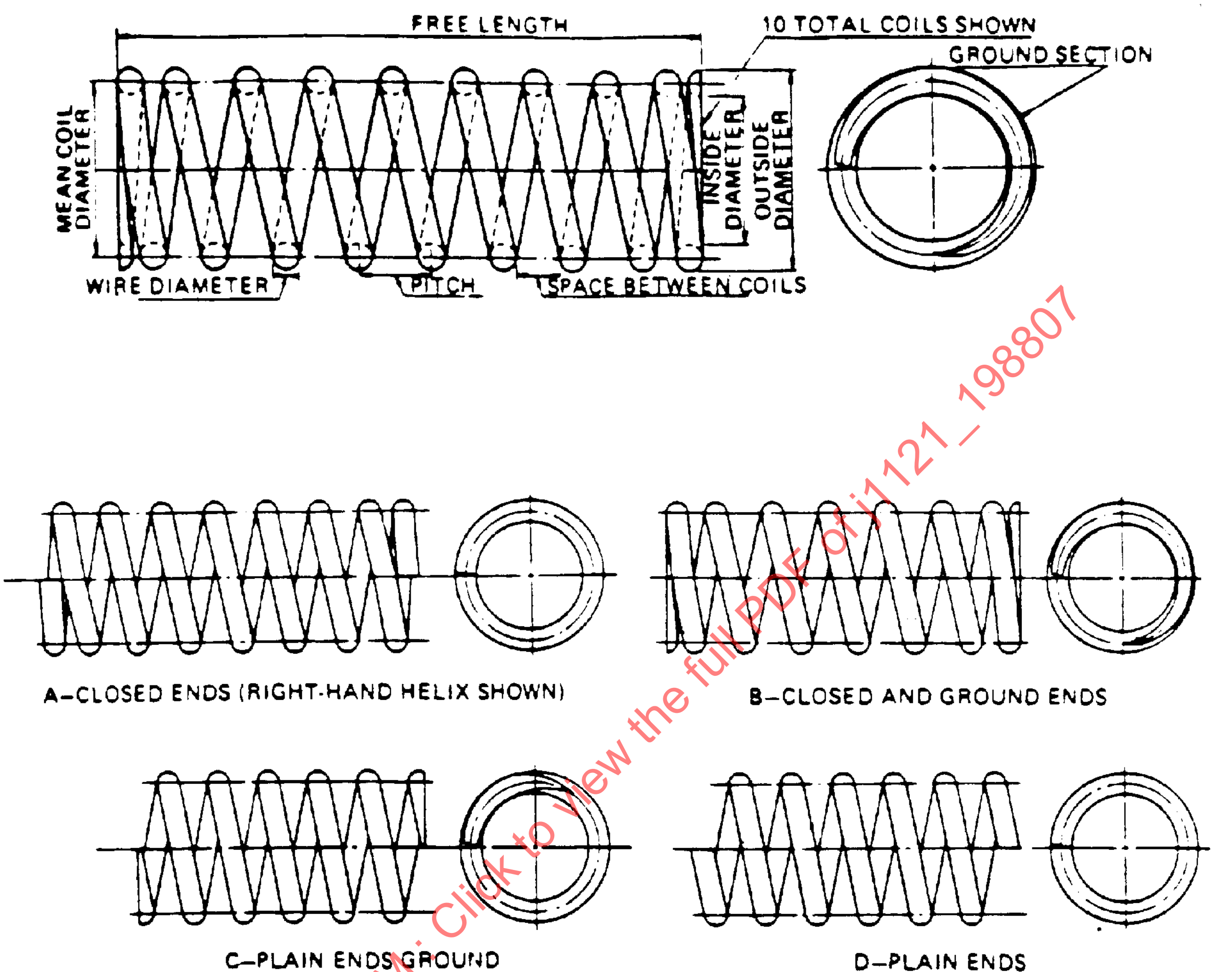

FIGURE 7—TYPICAL ENDS OF HELICAL COMPRESSION SPRINGS

1. Plain end (with the end coil having the same pitch as all other coils);
2. Plain end ground (the end surface being ground perpendicular to the spring axis);
3. Closed end (with the tip of the wire contacting the adjacent coil);
4. Closed and ground end (the closed end being ground perpendicular to the spring axis).

The unground ends may be used for reasons of economy, but they give eccentric loading with some increase in maximum spring wire stress and space required. The plain ends similarly produce eccentric loading and additionally present a handling problem due to springs tangling together.

In extension springs, many types of hooks, loops, eyes, etc. are used (see MANUAL, SAE HS J795, Figure 3.3). Details such as hook opening restraint of the loop within the body diameter should be specified on the drawing. The position of hooks relative to each other can be in line, at right angles, or at any other angular position as required. If this relative position is important, the spring drawing should emphasize the importance by a statement as well as by pictorial representation. Sharp bends in forming the end hooks should be avoided because they produce stress concentrations.

4.8 Squareness of Ends—In compression springs with closed and ground ends, the squareness of the ends, as measured in the unloaded position, is to be maintained within a limit of 3 deg with the axis of the spring.

4.9 Load—Load is the force in newtons (N) measured on the load testing machine required to deflect the spring to the specified loaded length.

For compression springs, the load is to be measured during compression of the spring (compression load) unless otherwise specified. Tolerances are shown in Figure 8 as functions of the nominal free length tolerance (Figure 5) and the deflection from free length to loaded length. Round off the percent load tolerance values to the next larger whole number. Interpolate when this is an odd number and when it is between 8 and 20%.

For extension springs, the load is to be measured during extension of the spring. Tolerances are computed as the product of the appropriate tolerance factor from Figure 9A and the appropriate multiplying factor from Figure 9B.

Cold coiled extension springs may be wound with tension between the coils so that a load must be applied to separate them, the so-called initial tension in the spring.

4.10 Rate—Rate is the change of load per unit length of spring deflection (N/mm). The rate is to be determined between 20 and 60% of the total deflection. Tolerances depending on the number of active coils are given in Figure 10.

4.11 Direction of Coiling—For most applications, the direction of coiling is unimportant; however, right hand coiling is preferred because most spring manufacturers are so equipped.

4.12 Uniformity of Pitch—The pitch of coils in a compression spring must be sufficiently uniform so that when the spring is compressed, unsupported laterally, to a length representing a deflection of 80% of the nominal free-to-solid deflection, none of the coils must be in contact with one another, excluding the inactive end coils. This requirement does not apply when the design of the spring calls for variable pitch, or when it is such that the spring cannot be compressed to solid length without lateral support.