SPRING MANUFACTURERS' RESEARCH ASSOCIATION

The Review of Customer Specifications by Spring Manufacturers

Report No. 139

by

H.H. Clark

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NOTE:

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THE REVIEW OF CUSTOMER SPECIFICATIONS BY SPRING MANUFACTURERS

by H. H. Clark

In the not too distant past in our country* spring specifications were not given the careful attention of the spring manufacturer that they receive today. Perhaps this may have been due to the then current tendency to regard the spring manufacturer as an artisan and to assign to him more functional responsibility than he receives today. With the foregoing in mind, it is understandable that it was more or less the custom to treat manufacturing tolerances lightly with the expectation that the products would be found satisfactory so long as they performed adequately in a functional sense. It can be appreciated also that in certain quarters manufacturers were optimistic as to their abilities to fabricate to close tolerances, while in others the reverse was true. In other words, the approach to manufacturing specifications and tolerances was far more subjective than it is today.

Today the spring manufacturer must treat manufacturing specifications with far more respect and consideration than in the past. There are a number of reasons for this increased emphasis on specifications, but in the ultimate they all boil down to a matter of economics. In the first place, a manufacturer can no longer afford to be optimistic as to his ability to make springs to specifications. The effect of today's current high wage rates on secondary or repair operations precludes anything but a realistic appraisal as to the inherent capabilities of equipment to hold tolerances. In the second place, the concept of quality control, which has gained such a foothold in most of the segments of industry served by spring manufacturers, makes it absolutely essential that manufacturing tolerances be realistic and be maintained. Most of us who have approached the quality control program have learned its essential virtues, which can be reduced succinctly to the thought that in the long run it is cheaper to build quality into the product than it is to eliminate culls through inspection. Since the matter of specification preview is so intimately connected with quality control, it might be profitable here to enumerate the procedure involved as a general rule in quality control certification and the program in its general broad outlines, even though most spring makers are fully conversant with the procedure.

QUALITY CONTROL PROCEDURES

In obtaining quality control certification, the usual first step in the procedure is to have a survey made of equipment and processing by the quality control representatives of the customer. The purpose of this survey is for the customer to judge whether or not the equipment is

* U.S.A.

capable of making springs in conformance with their blueprint specifications and to their quality requirements. Along with the inspection of equipment, as well as the tooling thereof, careful attention during the survey is paid to processing techniques to make sure that these are adequate to assure the ability to meet the requirements of the process standards of the customer. This part of the survey includes a study of heat treatment processes, furnaces and their control, together with hardness and load testing equipment, as well as such items as painting procedures, shotpeening, corrosion prevention coatings and their application.

After the equipment and processing survey is made and a favourable report is issued, pre-production samples are submitted and are inspected 100% by the customer, and specimens from these are fatigue tested if this is a requirement. At the time of submission of these samples, certification is made by the manufacturer that all parts shipped subsequently will conform with the quality level of the samples.

Assuming that the 100% inspection of the above samples disloses that the quality is adequate, the formality of receiving inspection of subsequent shipments will be waived. However, representatives of the quality control department of the customer will make spot checks from time to time of sufficient size to permit judgment of the quality level on a statistical basis, and reports are issued to all persons concerned, including, of course, the vendor. These reports include comparative records on an accumulative basis. They show the vendor the relative efficiency of his quality control, not only with respect to time but also with respect to the efforts of his competitors, in the instances where this is deemed advisable.

If there are difficulties disclosed as the result of these occasional quality control checks, but the difficulties are not of a nature which would make the parts unusable, the manufacturer is directed to correct the condition before making additional shipments. Depending upon the type of defects encountered and their significance, quality control representatives of the customers may call at the plant to assist in locating the trouble. On the other hand, if the statistical sampling indicates that the parts are not usable, the shipment is returned and the manufacturer is prevented from making future shipments until he assures the customer by submission of corrected samples that the difficulties have been overcome.

SPECIFICATION PREVIEWS

Obviously a spring manufacturer who takes part in quality programs of the general nature described above must review carefully the specifications applicable to the respective spring items involved. He should review the operations proposed to be followed to make sure that his equipment and tooling are adequate to produce parts within the tolerances specified and that his processing is otherwise adequate to meet the quality requirements of the customer, either as specified on blueprints or implicit therein.

A careful previewing of specifications may bring to light many things before pre-production samples are prepared. If it is found that the tolerances are too close to be met without expensive secondary operations being performed, the manufacturer is rendering both the customer and himself a disservice if he does not call attention to the situation. Frequently the close tolerances may have resulted from a misunderstanding or over-zealousness on the part of the designer, and wider tolerances, which the manufacturer would propose as a normal procedure requiring no secondary operations, would be quite acceptable. As a result of a preview of this nature, the manufacturer may find himself in a position to furnish the the item to the customer at a lower price than he would have quoted on the original specifications, which contributes toward the building of customer good will.

Specification previews should not be confined to tolerances alone but should include a careful review of the material and processing phases of the specifications. Often the customer may specify materials and processes which are more expensive than the application requires. On the other hand, the customer frequently under-specifies where material and processing are concerned, with the result that he may be jeopardizing the quality of the end product unless he is placed in a position to benefit from the specification preview and subsequent advice of the spring manufacturer.

Perhaps it is significant to draw one observation from the foregoing remarks and that is -- it is not enough for the spring manufacturer to be wise and understanding as to the optimum capabilities of his own equipment and procedure. In addition, to obtain the maximum from a given buyer-seller arrangement, he should know as much as he possibly can as to the application of and the duty placed on his springs. Armed with all of this information, he then is in a position to preview specifications correctly and to make adequate recommendations as required.

RATE AND LOAD TOLERANCES

A few remarks as to the effect on load and rate tolerances of helical coil springs as dependent variables of the tolerances on the diameter of the material, on coil diameter, on number of coils, and on free height will illustrate one approach to specification preview. The effect of these dependent variables can be obtained through consideration for the rate of deflection of a helical coil spring of relatively low angle of helix from the following classic formula:

$$R = \frac{Gd^4}{8D^3N}$$

where d = bar or wire diameter

D = mean coil diameter

N = number of coils

In the case where the spring is coiled from a bar of a given length L equal to π DN, the rate formula can also be expressed as:

$$R = \frac{\pi G d^4}{8D^2 L}$$

In the consideration of the effects of variations, it is convenient to make use of the approximation $(1 \pm x)^n = 1 \pm nx$, where x is very small compared to unity. If x_d is the ratio of the bar diameter tolerance to the bar diameter, X_D and X_L the similar ratios affecting mean coil diameter and bar length respectively, the expected $\pm$ variation in the rate of deflection will be the following ratio:

$$X_R = 4X_d + 2X_D + X_L$$

Variation in free height will produce a variation in the nominal load at a given compressed height, in addition to the variations caused by the rate changes described above. If X_f is the ratio of the variation in free height to the nominal deflection under load, the possible variation in loading will then be

$$X_p = 4X_d + 2X_D + X_L + X_f$$

In considering the rate variation X_R it is to be appreciated that once springs have been put into production it is extremely difficult and costly to attempt correction. Therefore, the tolerance to be specified where rate is concerned should be constant with the expected variation X_R above, or conversely, the factors X_d, X_D and X_L should be adjusted so that X_R will substantially equal the tolerance specified.

Since X_p is always greater than X_R, one might conclude that the permissible tolerance on loading should be greater than that on rate of deflection. However, in certain instances, e.g., in the practical case of chassis suspension springs, tolerances on loading cannot in general be as great as calculated values of X_p indicate as being required. Indeed, in these particular springs the specified tolerance ratios X_p are usually lower than the computed rate tolerance ratios X_R.

Springs can be corrected for free height much more readily than for rate of deflection, and it is feasible therefore to maintain tolerances on loading within much closer relative value than those on rate. In the final analysis, the maintenance of close tolerance on loading becomes an economic problem subject to the law of diminishing returns. The problem is two-fold in that the excessive amount of re-working caused by very close load tolerances not only increases the direct cost of unit output but also engages finishing equipment which might otherwise be operating more productively. Of the two economic effects, the latter can be the more serious, as it is usual practice to provide sufficient finishing equipment to balance the output of the rest of the facilities. Under such conditions, excessively close load tolerances can bring about an unbalanced condition which effectively reduces plant output.

ESTIMATION OF YIELD

It is possible to estimate the yield of acceptable springs to be expected when the variables affecting bar diameter, coil diameter, number of coils or bar length and free height are unknown. In arriving at such an estimate, the simplest assumption is that the yield will follow the normal probability curve in which the frequency of occurrences Y_n, as ordinate value, in a series of n occurrences is related to the deviation x from the abscissa mean value, e.g., load tolerance ratio values, as follows:

$$Y_n = \frac{nh}{\pi} e^{-h^2 x^2}$$

In this equation the value h is a precision index controlling the shape of the curve. Out of the total number of occurrences, the proportionate number whose value lies between ordinate values of +x and -x can be obtained from an evaluation of the probability integral:

$$P_{hx} = \frac{2}{\pi} \int_o^{hx} e^{-h^2 x^2} d(hx)$$

Tables are available for the determination of values of hx corresponding to assigned probability values P_{hx}. If we assume a high value to P_{hx}, a value approaching unity, for the case where the limits are those indicated as necessary by the computations for X_R and X_P, the standard deviation σ can be determined from the following formula:

$$\sigma = X_P/hx\sqrt{2}$$

In this formula the value of hx to be used is that found from the assumed tabulated value of P_{hx}. Having obtained the standard deviation in this manner, the hx value corresponding to the permitted variation in rate X'_R or loading X'_P can be obtained from the similar equation:

$$hx = X'_P/\sigma\sqrt{2}$$

Then from the tabulated values of the probability integral, the value P_{hx} for the new value of hx as determined above can be obtained. This probability value represents the yield as a percentage of the inspection of an infinitely great number of springs within the assigned limits on rate or loading.

SAMPLE YIELD CALCULATION

The tolerances on the rates of deflection and on load are seldom specified broadly enough to take into account the full effects of the variations to be expected in bar diameter, coil diameter, bar length, and free length of the spring. Frequently the customer will agree to increasing the specified rate and load tolerances if the matter is properly presented. On the other hand, in certain instances, notably for chassis suspension springs as mentioned above, the customer usually cannot specify load tolerances as broad as they should be, even though he realizes that a cost premium results, and is resigned to paying it for the closer tolerances.

The following is an example of the yield to be expected in the production of a more-or-less typical suspension coil spring, of which the significant design items are:

I.D.	=	$4.50 \pm .031$ in.	(coil inside diameter)
d	=	$.545 \pm .004$ in.	(bar diameter)
D	=	$4.50 + .545 = 5.045$	(mean coil diameter)
R	=	125 ± 4 lb/in.	(rate of deflection)
L	=	$123 \pm .312$ in.	(active length of bar)
P	=	810 ± 25 lb.	(nominal load)

From the above data the tolerance ratios may be calculated as follows:

$$X_d = .004/.545 = .00735$$
$$X_D = .031/5.045 = .00615$$
$$X_L = .312/123 = .00254$$

Assuming that all springs will be within the above tolerances for bar diameter, coil diameter and bar length, the expected $\pm$ rate of deflection variation ratio will be:

$$X_R = 4 \times .00735 + 2 \times .00615 + .00254 = .04424$$

It is to be noted that the rate of deflection for this spring is required to be maintained within $\pm$ 4 lb. or within a rate variation ratio of .032, whereas the expected variation ratio as calculated above will be .04424. If we assume that the required rate tolerance will be maintained within three standard deviations the applicable hx value can be computed from the standard deviation formula as follows:

$$hx = X_R / \sigma \sqrt{2}$$

Substituting 3σ for X_R, the hx value will be 2.1213. The probability value P_{hx} for this value of hx will be found from tabular values to be 0.9972, close enough to unity to enable one to expect that substantially all values will fall within the limits of the expected ratio variation rate of .04424.

In this instance the standard deviation will be

$$\sigma = X_R/hx \sqrt{2} = .04424/2.125 \sqrt{2} = .01475$$

Considering the above standard deviation and the permitted rate variation of .032, the corresponding hx value will be

$$hx = X_R' / \sigma \sqrt{2} = .032/.01475 \sqrt{2} = 1.535$$

From tabulated values of the probability integral for a value of hx equals 1.535 we find a P_{hx} value of .9700. Ths indicates, that, although the permitted rate variation is less than it should be, nevertheless 97 percent of the springs should be within the prescribed limits.

However, with respect to load, conditions inherently are different than those affecting rate of deflection. In this illustrated case where the nominal load is 810 lb. and the rate is 125 lb/in., the nominal deflection is 810/125, or 6.48 in.

Assuming that the springs can be manufactured within a tolerance in free height of ±.12 in., the deflection variation ratio will be

$$X_f = .12/6.48 = .0185$$

The load variation ratio will then be

$$X_P = X_R + X_f = .04424 + .0185 = .06274$$

If we assume that 99.72 percent of the springs will come within the load variation ratio above, the corresponding hx value is 2.1213, and the standard deviation for the load is

$$\sigma = X_P/hx \sqrt{2} = .06274/2.125 \sqrt{2} = .02091$$

The permitted load variation in this instance is

$$X_P' = 25/810 = .03085$$

The hx value corresponding to the standard load deviation just above and the permitted load variation ratio will be

$$hx = X_p' / \sigma \sqrt{2} = .03085/.02091 \sqrt{2} = 1.041$$

From tabulated values again we find that for an hx value of 1.041 the corresponding P_{hx} value is .8580, and that it is reasonable to expect that 14 percent of the springs would have loads outside of the prescribed limits.

Time does not permit that calculations of this nature be made on every item for which cost estimates are prepared. However, the illustration should be of interest because it depicts the order and the nature of the variables which can be expected. In addition, studies along the lines of this sample calculation can be used to form the background of more generalized aids in the preview of specifications.

Effect of Load Tolerance on Yield

In the above sample yield calculation it was determined under certain assumptions that 85.80 percent of the springs manufactured would be found within an arbitrarily assigned load tolerance of ± 3.085 percent. In this illustration the standard deviation was determined to be .02091.

By using this standard deviation of .02091, calculating the corresponding hx values, and finding the respective P_{hx} values of the probability integral, one can plot the curve in Figure 1 from the values obtained. This curve shows the yield in terms of the springs which will be within an arbitrarily assigned ± tolerance on the load without resorting to rework operations.

The yield curve of Figure 1 is significant in that it demonstrates what can be expected in reworking operations as tolerances on load vary. In the sample calculation, and from the curve, with the required load tolerance of ± 3.085 percent one would expect to encounter 14.20 percent of the springs outside of load tolerance, requiring rework operations. The curve indicates that if the ± 3.085 percent load tolerance is halved, the resulting rework operations would apply to more than three times the previous amount. Since there is an inverse linear relationship between the yield and the cost of reworking springs which are out of load tolerance, it is helpful in the cost estimating phase of specification review to have yield information available in a form which can be used readily. Our company uses just such data in the form of a curve in preparing cost estimates.

Standards and Specifications

In our country there are many standards and recommended practices relating to spring materials, to the springs themselves, and to the various manufacturing processes involved where both the materials and the springs are concerned. Most of the larger users and manufacturers of springs have their own published standards. In the more important items there is little discrepancy between the various proposed tolerances, but there would be less confusion if there were a more general acceptance of the specifications of the various technical societies who have given much time and effort to the development of standards which should be equitable to makers and users alike.

A partial list of the more important standards and recommended practices includes those of the following technical societies.

1. American Iron & Steel Institute.
2. Association of American Railroads.
3. American Society for Metals.
4. American Society for Testing Materials.
5. Fine Wire Manufacturers' Association.
6. Society of Automotive Engineers.
7. Spring Manufacturers Institute.

The recommended procedures of the above groups are well accepted. Some, as the names imply, are concerned with the application of springs to particular fields. Frequently the tolerances on functional requirements are not consistent with the tolerances required on the design variables. However, in most instances where there are inconsistencies, a compromise has been made in light of minimal functional needs on the one hand and manufacturing costs on the other.

As an example of the type of work which has been done by technical societies in our country to promote the acceptance of tolerances and practices within a large industrial field, the following recommended practices of the Society of Automotive Engineers are attached.

Appendix	Title
A	Helical Compression Springs, Hot Coiled for General Automotive Use.
B	Helical Compression Springs, Cold Coiled for General Automotive Use.
C	Helical Springs for Motor Vehicle Suspension

Generally speaking, the data published on springs by the above groups are subject to review at intervals to make sure that revisions are made frequently enough to maintain the recommended procedures in line with developments and improvements in manufacturing procedures. An adequate system for the review of the specifications of customers should contain provision for reference to updated versions of the standards and practices recommended by such institutions as those listed above.

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APPENDIX A

HELICAL COMPRESSION SPRINGS HOT COILED
FOR GENERAL AUTOMOTIVE USE-SAE J507 SAE Recommended Practice

Report of Spring Committee approved September 1949 and last revised June 1958

(The following recommended practice deals with hot coiled springs made from round steel bars of $\frac{3}{8}$ in. or larger diameter. The recommended practice furnishes a system of dimensional tolerances which serves to inform the user of practical manufacturing limits. Closer tolerances are obtainable where the accuracy is required and the increased cost is justified. Helical springs for suspension are covered in SAE Recommended Practice, Helical Springs for Motor Vehicle Suspension-SAE J509)

Diameter of Bar Stock - Tolerances for diameters of bar stock are given in Table 1.

Table 1 - Tolerances for Diameter of Bar Stock, In

BAR DIAMETER	TOLERANCE PLUS OR MINUS
Over 3/8 to 7/16 incl.	0.006
Over 7/16 to 5/8 incl.	0.007
Over 5/8 to 7/8 incl.	0.008
Over 7/8 to 1 incl.	0.009
Over 1 to 1-1/8 incl.	0.010
Over 1-1/8 to 1-1/4 incl.	0.011
Over 1-1/4 to 1-3/8 incl.	0.012
Over 1-3/8 to 1-1/2 incl.	0.014
Over 1-1/2 to 2 incl.	0.016

Coil Diameter. - Tolerances for coil diameters are given in Table 2.

Table 2 - Tolerances for Coil Diameters, In.

FOR SPECIFIED OR COMPUTED OUTSIDE DIAMETER	INSIDE OR OUTSIDE TOLERANCE, PLUS OR MINUS				
	FOR FREE SPRING HEIGHT				
	UP TO 10 INCLUSIVE	OVER 10 TO 18 INCL.	OVER 18 TO 26 INCL.	OVER 26 TO 34 INCL.	OVER 34 TO 42 INCL.
Up to 6 incl.	1/16	3/32	1/8	5/32	3/16
Over 6 to 8 incl.	3/32	1/8	3/16	1/4	1/4
Over 8 to 12 incl.	1/8	3/16	1/4	1/4	1/4

Spring Heights

All spring heights are measured after the spring has been deflected to its solid height to remove temporary recovery of free height.

Solid Height.

Solid height is the perpendicular distance between the plates of the testing machine 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 150% of the load beyond which no appreciable deflection takes place.

Maximum solid height, as tested, or nominal solid height, as computed, may be specified on the drawing. Nominal solid height is computed as total number of coils minus one-half coil, multiplied by bar diameter.

When nominal solid height is specified, tolerances in Table 3 apply.

Table 3 - Maximum Solid Height Above Nominal Solid Height, In.

NOMINAL SOLID HEIGHT	MAXIMUM DEVIATION OF SOLID HEIGHT ABOVE NOMINAL SOLID HEIGHT
Up 7 incl.	1/16
Over 7 to 10 incl.	3/32
Over 10 to 13 incl.	1/8
Over 13 to 16 incl.	5/32
Over 16 to 19 incl.	3/16
Over 19 to 22 incl.	7/32
Over 22 to 25 incl.	1/4

Free Height.

Free height is determined by placing a straightedge across the top of the spring and measuring the perpendicular distance from the plate on which the spring stands to the straightedge at the approximate centre of the spring.

If load is specified, free height should read "approximate" only, and may not be restricted by any tolerance.

If load is not specified:

Free height tolerance = ± (1/16 in. + 4% of free-to-solid deflection).

Permanent Set

Permanent set is the loss of free height after the spring has been compressed solid three times with the applied load specified under solid height determination, measured at the same point and in the same manner.

Permanent set shall not exceed 1/32 in. + 1/2% of free-to-solid deflection.

Loaded Height

Loaded height is the perpendicular distance between the plates of the testing machine when the specified load has been applied.

Variation in loaded height, with load fixed:

Loaded height tolerance = ± (1/16 in. + 3% of free-to-solid deflection).

Variation in load, with loaded height fixed:

Load tolerance = ± (1/16 in. + 3% of free-to-solid deflection) x rate.

These height tolerances are limited to springs with free height not over 36 in., not over six times free-to-solid deflection, and not less than 0.8 times outside diameter. Tolerances for springs outside these limits are subject to special agreement.

Load

Load is the force in pounds measured on the testing machine required to deflect the spring to the specified loaded height.

Rate

Rate is the average load increase per inch of spring deflection, determined between 20 and 60% of free-to-solid deflection, unless otherwise defined.

Nominal Solid Load

Nominal solid load is the product of rate and free-to-solid deflection. As it is the theoretical maximum load, it may be used for computing the corresponding stress. The solid load obtained by test should not be used in calculations, as it is usually different from the nominal figure.

Total Number of Coils.

Total number of coils shall not vary more than 5% from the number specified.

Uniformity of Pitch

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

Squareness of Ends

The ends of the bar shall be tapered to give the finished spring a reasonably firm bearing. The tip of the tapered bar shall be in approximate contact with the adjacent coil and shall not protrude more than 1/8 in. beyond the outside diameter of the spring.

Unless otherwise specified, the ends of any spring having an outside diameter to bar diameter ratio of 4 or more, and a free height to outside diameter ratio 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. Tolerances for springs outside these limits are subject to special agreement.

When stipulated, the bearing surface of the spring end shall be ground 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.

APPENDIX B

HELICAL COMPRESSION AND EXTENSION SPRINGS
COLD COILED FOR GENERAL AUTOMOTIVE USE-SAE J508 SAE Recommended Practice
Report of Spring Committee approved September 1949 and last revised June 1958.

(The following recommended practice deals with cold coiled springs made from round steel wire of 1/2 in. or smaller diameter. It furnishes a system of dimensional tolerances for springs of average quality as used for the majority of automotive applications. Springs can be made to closer tolerances at an increased cost; valve springs are a typical example. Again, springs can be made cheaper by omitting some tolerances).

Wire Diameter

Table 1 - Wire Diameter Tolerances, In

TYPE OF WIRE	WIRE DIAMETER	TOLERANCE, PLUS OR MINUS
Music Wire	Up to 0.026 inclusive	0.0003
	0.027 to 0.063 inclusive	0.0005
	0.064 to 0.250 inclusive	0.001
Carbon steel wire hard drawn or oil tempered	Up to 0.075 inclusive	0.001
	0.076 to 0.375 inclusive	0.002
	0.376 and larger	0.003
Valve spring quality and alloy steel wire	Up to 0.148 inclusive	0.001
	0.149 to 0.177 inclusive	0.0015
	0.178 to 0.375 inclusive	0.002
	0.376 and larger	0.003

Coil Diameter

Coil diameter tolerances can be specified on either the inside diameter or the outside diameter of the coils, depending upon the importance of the respective dimensions to the user. The tolerances to apply are functions of the ratio of mean diameter D of the coils to wire diameter d as given in Table 2. The tolerances are to be considered as manufacturing tolerances and do not take into account the effects of changes in diameter due to applied loads.

Table 2 - Coil Diameter Tolerances, In

MEAN COIL DIAMETER	DIAMETER TOLERANCE For D/d ratio 3 to 7.9.	PLUS OR MINUS For D/d ratio 8 to 15
1/8 or less	0.003	0.004
Over 1/8 to 1/4 inclusive	0.004	0.005
Over 1/4 to 1/2 inclusive	0.006	0.010
Over 1/2 to 1 inclusive	0.010	0.016
Over 1 to 2 inclusive	0.016	0.025
Over 2 to 4 inclusive	0.025	0.042
Over 4 to 8 inclusive	0.042	0.063

Free Length

When load with tolerance is not specified, it is advisable to specify the free length with tolerance. In the case of compression springs the free length is an over-all dimension measured parallel to the axis of the spring; for extension springs the free length refers to the length inside to inside of the hooks (over-all length minus two wire thicknesses). The tolerances to apply are functions of the ratio of mean diameter D of the coils to wire diameter d as given in Table 3.

Table 3 - Free Length Tolerances, In.

FREE LENGTH	FREE LENGTH TOLERANCE, For D/d ratio 3 to 7.9	PLUS OR MINUS For D/d ratio 8-15
1/2 or less	0.025	0.040
Over 1/2 to 1 inclusive	0.035	0.050
Over 1 to 2 inclusive	0.050	0.080
Over 2 to 4 inclusive	0.080	0.12
Over 4 to 8 inclusive	0.12	0.19
Over 8 to 16 inclusive	0.22	0.30
Over 16 to 32 inclusive	0.35	0.45

Solid Height

If spring is to be compressed nearly solid, the solid height should be specified as a maximum dimension without tolerance.

Load and Rate

Table 4 - Load and Rate[a] Tolerances %

NUMBER OF ACTIVE COILS	LOAD TOLERANCE PLUS OR MINUS	RATE TOLERANCE, PLUS OR MINUS
3 or less	15	10
Over 3 to 9 inclusive	10	8
Over 9 to 15 inclusive	8	6
Over 15	7	5

[a]The rate shall be determined between 20 and 60% of the total deflection obtained without exceeding the elastic limit of the spring.

Number of Coils.

In order to meet the requirements on load, rate, free length, solid height, and position of end hooks, it is often necessary to vary the number of coils by ± 10% for extension springs and by ± 5% for compression springs. Therefore the number of coils should be specified as an approximate figure for reference only.

Squareness of Ends.

The squareness of the ends of squared and ground compression springs as measured in the unloaded position is to be maintained within a limit of 3 deg. with the axis of the spring.

APPENDIX C

HELICAL SPRINGS FOR MOTOR VEHICLE SUSPENSION - SAE J509 SAE Recommended Practice

Report of Passenger - Car Division approved January 1938 and last revised by Spring Committee June 1958.

(This recommended practice deals with helical compression springs made from alloy steel bars which are coiled hot and are heat treated after coiling.

The scope of this recommended practice is restricted to a concise presentation of items which will promote an adequate understanding between spring maker and spring user of the major practical requirements in the finished spring).

Bar Diameter

The bars required for these springs are usually $\frac{1}{2}$ to $\frac{7}{8}$ in. in diameter. It is customary to specify the diameter as the decimal dimension which works out most advantageously for purposes of design. The bars are either centreless ground (diameter tolerance $\pm$0.002 in.) or precision hot rolled (diameter tolerance $\pm$0.004 in.).

The bars are commonly purchased in the exact length required to produced one spring. The lengths vary in practice from 10 to 15 ft and are subject to a tolerance of $+\frac{5}{8}-0$ in.

Coil Diameter

For purposes of dimensional control it is customary to specify the coil diameters of these springs in terms of the inside diameter. In general, the inside diameters vary from 3 to 6 in., and tolerances to apply are $\pm$ 1/32 in. for springs up to and including $4\frac{1}{2}$ in. inside dia, and $\pm$ 3/64 in. for springs above $4\frac{1}{2}$ in. inside dia.

Types of Spring Ends

Three types of ends are used:

1. A flat end formed from a tapered bar end. Grinding of the outboard bearing surface is not required if the tapering and coiling are performed adequately.

2. An untapered end coil formed substantially smaller than the central coils of the spring and in such fashion to have an outboard bearing surface perpendicular to the axis of the helix of the spring, the so-called "pig-tail" 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 1 in. 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.

Springs can be specified to have any combination of the three 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.

Spring seats and ends are usually so formed as to render approximately two-thirds to one coil inactive at each end.

Spring Heights

Spring heights are measured after preloading, as the distance parallel to the spring axis between two reference points specified on the spring drawing.

Solid Height

Solid height is the distance between the two reference points 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 150% of the load beyond which no appreciable deflection takes place.

Free Height

Free height is the distance between the two reference points under no load. It is used as an approximate dimension only.

Loaded Height

Loaded height is the distance between the two reference points while the load is being measured. It is a fixed reference dimension; tolerance is expressed in terms of load.

Preloading

Preloading is the operation of deflecting the spring to the solid height to remove temporary recovery before the spring is checked for load or rate. If the spring is designed to preclude deflection to the solid height by reason of excessive stresses, the drawing may specify that the preloading be confined to deflecting the spring at least to the metal-to-metal contact position defined under section on Clearance.

Clearance

Clearance is the spring deflection possible in the vehicle from the specified loaded height to the spring height attained at the metal-to-metal contact position, disregarding rubber bumpers.

Load and Rate

Load and rate are the terms usually employed to describe the capacity of a suspension coil spring. They are to be measured in terms of the forces exerted by the spring during compression of the spring (compression loads), and not during release of the spring (release loads).

Load

Load is the force in pounds measured on the testing machine required to deflect the spring to the specified loaded height. Tolerance is expressed in terms of load equivalent to a deflection between ± 1/16 to ± 3/16 at the nominal rate, depending upon the nature of the installation .

Rate

Rate is half the difference between the loads measured 1 in. above and 1 in. below the specified loaded height. Tolerance is ± 3% with centerless ground bars and ± 4% with precision rolled bars.

Surface Treatment

After heat treatment, but before presetting, the springs are shot peened in a manner to assure adequate shot impingement intensity and coverage for optimum fatigue life. In order to retard corrosion, it is customary to apply an enamel finish to the springs.

Spring Specifications

In preparing spring drawings or specifications, the following items should be regarded as mandatory requirements:

- Bar diameter and tolerance
- Inside diameter and tolerance
- Loaded height as a fixed reference dimension
- Load and tolerance
- Rate and tolerance
- Type of ends
- Material
- Hardness range
- Surface treatment and finish

It is helpful to include in the specifications the following items for purposes of guidance:

- Approximate free height
- Bar length and tolerance
- Total number of coils
- Height at metal-to-metal contact position
- Solid height

There is an incipient wide variation in the ductility of the iterial itself and eventually it may be desirable to use a steel more onsistent in this respect.

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MR. CLARK There is some movement in the U.S.A. toward standard spring sizes, in fact some Companies produce an assortment of springs which you can buy in any hardware store in a similar manner to buying wood screws. On the engineering side there are a number of standard-size springs which are used in the engineering business. Additionally, the Ordnance Department of the U.S. Government are attempting to rationalise the number of spring designs.

DR. STUMPP A similar position exists in Germany and we are trying to establish a list of standard size springs in order to avoid the inconvenience of making five or ten springs for a particular customer. The idea here will be to persuade the customer to use a spring size selected from our standard list and thereby reduce the cost to the customer and the inconvenience to the spring manufacturer.

MR. GODDET The problem of standard size springs was studied in France years ago. A list of standard size springs was drawn up, but unfortunately, was not adopted but I am sure we can find copies of our recommendations and that these can be supplied to delegates for discussion on a future occasion.

HERR HUHNEN About two years ago I had the opportunity to meet spring manufacturers from Eastern Germany, and I was told that in Eastern Germany they have lists of standard sized springs mainly for use in the agricultural, tool making and other industries where the spring dimensions were not of such prime importance. Approximately 60 per cent of the springs used were of standardised size. All small quantities could therefore be obtained from the standard sized spring lists.

DR. STUMPP I think it would be most desirable for us to produce a list of standard sized springs on a European basis. Whether or not we should be successful would remain to be seen.

MR. CLARK We have found particularly with ordnance springs that it is necessary to have a very long list of sizes to meet all contingencies and the danger here from a design point of view is that some compromise might have to be made with regard to say machine design in order that a standard sized spring can be fitted.

HERR WATERSTRADT I would like to add to what Herr Huhnen has said. In Eastern Germany the list of standard sized springs amounts to about 1400 to 1500 types, and it is obvious that all these sizes cannot be stocked. Some springs have still to be made to customers requirements. In Western Germany we vizualise a list of standard sized springs made from wire of 0.5 to 10/12 millimetres in diameter. We imagine that such a list would constitute between 350 and 400 types and in fact at the present time we are working on this and to help us to formulate our ideas we would be very pleased if the French manufacturers could supply us with their document on standard sized springs.

MR. GODDET I would like to add further to what I have said previously. When we were rationalising the various spring designs we endeavoured to keep a definite relationship between flexibility and the dimensions. This resulted in some 730 different spring designs, but even so it was found that designers had still to make large compromises in order to use selected springs from this list. Incidentally, all these springs were made from wire sizes between 0.5 and 10 millimetres.

MR. MUHR I am aware of the situation which exists regarding the automobile manufacturers and quality control, but I would like to ask Mr. Clark whether there is any document available on this subject which is particularly directed towards the smaller consumers.

MR. CLARK If I understand the question correctly, it is to the possibility of extending quality control to the smaller firm. So far, this system of quality control applies only to the larger concerns.

MR. PETERSEN My Company are at the present time arranging to send our own personnel to such large concerns as General Motors and Ford to learn their own methods of quality control. This does vary from one Company to another.

MR. DUDEK Could Mr. Clark say what quality standard is used when one is not specified by the customer.

MR. CLARK In my Company we would work to the S.A.E. specifications but if the customer is more familiar with the Spring Manufacturers' Institute we might work to those. It is much better if you can quote some accepted standard rather than give your own ideas.

MR. PETERSEN In partial answer to the question, Ford's have recently introduced a zero quality control level which in effect means that one part failing in a particular consignment would subject the whole shipment to rejection.

MR. CLARK As far as suspension springs are concerned we have been working to this zero quality control level for about a year now and believe you me life is miserable.

DR. OTZEN I was very pleased to see in your paper graphs which indicated the percentage yield of suitable springs and how very small tolerance requirements lead to high reject figures. I would be pleased to know whether you have any further graphs to show how percentage rejects vary for different classes of material or whether there is any general information which is readily available dealing with these points.

MR. CLARK I know of no published information dealing with a yield for different bar diameters and coil diameters. This sort of information we obtain during our routine quality inspection, but this is not published and is therefore not readily available.

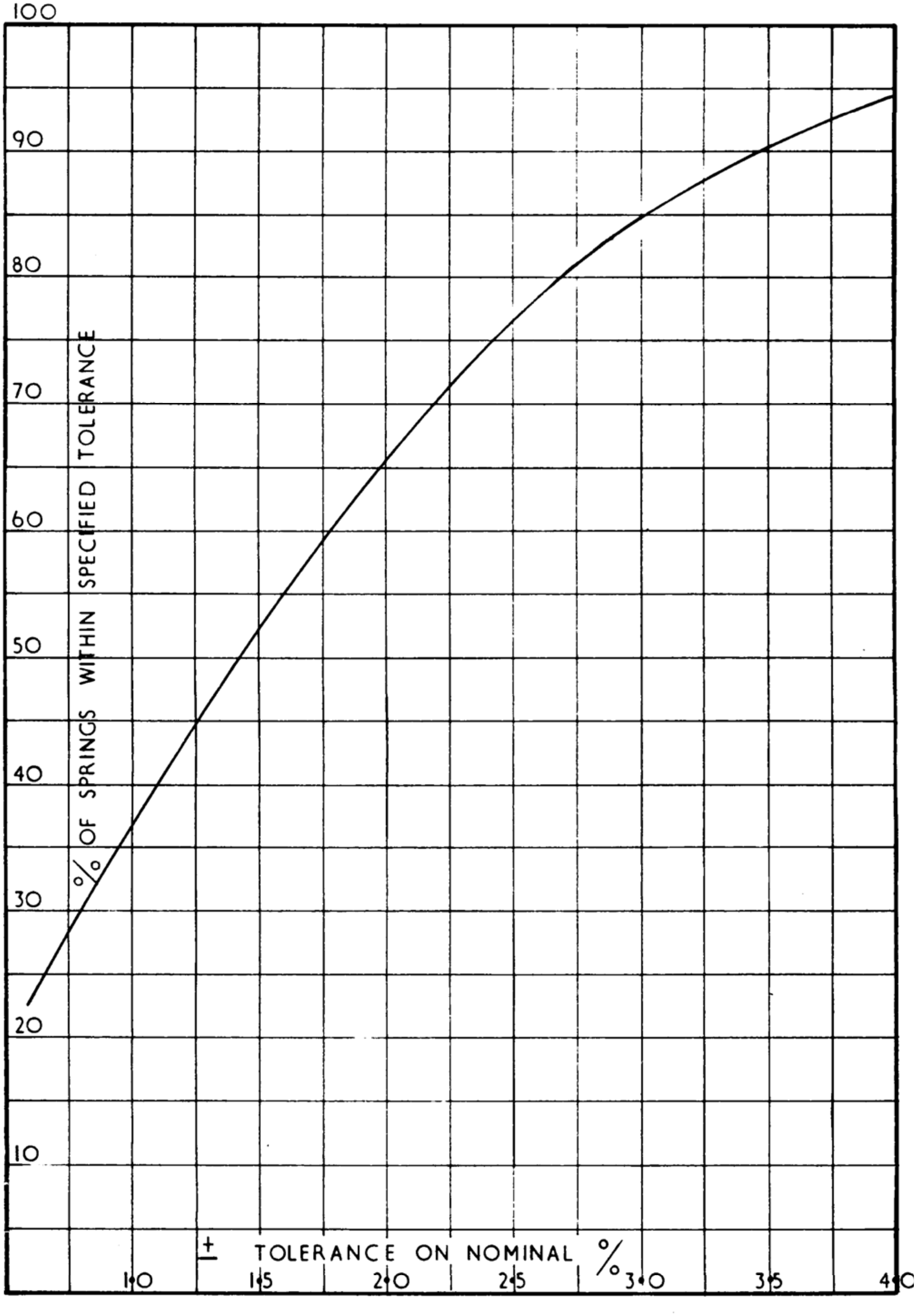

FIG. 1

EFFECT OF TOLERANCE ON YIELD OF PRODUCTION RUN
OF TYPICAL SUSPENSION COIL SPRING WITHOUT
REWORK OPERATIONS