The SPRING CALCULATOR

CONNECTICUT SPRING CORPORATION
1841 BROAD ST. HARTFORD, CONN.

INTRODUCTION

•

The Spring Calculator accompanying this booklet is used constantly in design and calculation of rate and stress in coil springs made from round, square, or rectangular wire.

No attempt has been made in this booklet to give instructions in reading slide rule scales. If the reader is totally unfamiliar with slide rules, it is suggested that he buy an inexpensive "Beginners Slide Rule," and from the instruction book which accompanies it, he can quickly familiarize himself with the reading of the scales.

NOTATION

•

D: Mean Diameter of Spring (Inside diameter plus wire size, or outside diameter minus wire size)

d: Wire size

P: Load (In pounds)

F: Deflection of Spring (In inches)

Nt: Total number of Coils

Na: Number of Active Coils (See note below)

S: Maximum Unit Stress (In pounds per square inch)

L: Free Length of Spring

Ls. Solid Length of Spring (When compressed to point where all coils are touching)

G: Modulus of elasticity in shear

b: Breadth, or long dimension of rectangular wire

t. Thickness, or short dimension of rectangular wire

NOTE: In compression springs, the end coils are usually closed. In this case, for purposes of calculation the number of active coils should be taken as 1½ less than the total number of coils. For example, a spring containing 6 total coils would have 4½ active coils.

The

SPRING CALCULATOR

•

The Spring Calculator is a means for the solution of the two most important formulas relating to helical coil springs; the formula for load required to produce a deflection of one inch; and the formula for maximum unit stress generated under a given load.

The face of the calculator for "deflection" gives direct readings for springs of round steel wire, and is based on a modulus of 11,500,000. Auxiliary scales are provided for the conversion of the results to suit materials with a modulus differing from 11,500,000, and for the calculation of springs made from rectangular (or square) wire.

The face of the "stress" side of the calculator gives direct readings for springs formed from round wire; an auxiliary scale permits correction for the increased stress in the surface fibres of the wire nearest the axis of the spring according to the formula developed by A. M. Wahl, and a second auxiliary scale permits calculation of stress in wire of rectangular (or square) cross-section.

PROPER USE OF CALCULATOR

DEFLECTION

One side gives direct solution of the formula for deflection of helical coil springs. By setting *Wire Size* against *Mean Diameter* on the two upper scales, *Pounds Per Inch Deflection* (*or Rate*) will be found opposite *Active Coils* on the two lower scales.

Example 1. Find the rate of a spring with ¾″ outside diameter, wire size .0625, ends closed, 8 total coils.

> The *Mean Diameter* is .75 less .0625, or .6875. The Number of *Active Coils* is 8 minus 1½, or 6½. Against .0625 on Wire Size scale, set .6875 on *Mean Diameter* scale. Under 6½ on *Active Coils* scale, find 10.4 on *Pounds per Inch Deflection* scale.

If a material with a modulus differing from 11,500,000 is used, the rate is worked out as in Example 1, then the arrow under "G" is set on the result obtained, and under the figure for the modulus of the material in question will be found the rate.

Example 2. Assume that the spring in Example 1 is made of Brass. First determine the rate for steel as in Example 1. Place the arrow under "G" on the result (10.4 for steel). The modulus for brass is 5,000,000, so under the figure "5" will be found 4.5 lbs. which is the rate for the spring if made of brass. Or, to reverse the procedure:

Example 3. Find the size of Phosphor Bronze wire to be used in a spring with 11 active coils, a Mean Diameter of ½″, spring to deflect 1⅜″ under a load of 11 pounds.

1⅜″ deflection under 11 pound load is a rate of 8 pounds per inch deflection. Since Phosphor Bronze has a modulus of 6,250,000, set 6.25 on the "G" scale on 8 on Pounds per Inch Deflection scale. Under the arrow will be found 14.8. Place 11 (number of active coils) on this new value of 14.8 and over .5 on Mean Diameter, find .061 (Wire Size).

STRESS

The Stress side of the calculator is similar in operation; by setting *Wire Size* on *Mean Diameter* the *Stress* (in thousands of pounds per square inch) can be read directly under *Load*. To correct for the Wahl factor (See Page 11) figure the ratio D/d; place the arrow under *Ratio D/d* on the Stress first obtained, and under the figure for the ratio of D/d will be found the maximum unit stress.

Example 4. Find the maximum unit stress in a spring with D of .30; d of .060 and P of 20 pounds.

Against .30 on Mean Diameter scale set .060 on Wire Size scale. Under 20 on Load scale find 71,000 on Stress scale. Since ratio D/d is 5, set arrow under "Ratio D/d" on value just obtained and under 5 on this scale, find 93,000.

RECTANGULAR (OR SQUARE) WIRE

DEFLECTION

To figure the deflection rate of a spring of rectangular wire of breadth "b" and thickness "t", first proceed as for round wire, using "t" for Wire Size. Set the arrow under "Rect: Ratio b/t" on the result thus obtained, and under the value of the ratio b/t will be found the rate for the spring in question.

Square Wire is a special case of rectangular wire, the ratio b/t is 1, and the method described above is used.

NOTE: When rectangular (or square) wire is coiled into a spring of small diameter, "keystoning" takes place, distorting the rectangular cross-section into a trapezoid. This concentration of metal toward the axis of the spring has the effect of increasing the rate of the spring by decreasing its effective mean diameter. In cases of severe keystoning, the actual load required to produce one inch deflection may be 15% to 30% greater than calculated.

STRESS

A similar procedure is used; calculate Stress using "t" for Wire Size, and apply to this result, the ratio b/t as in calculating deflection.

Example 5. Find rate, and stress when compressed solid in a spring made from 1/8″ by 1/4″ rectangular stock; 7 total coils, ends closed and ground, outside diameter 1½″, free length 1⅝″, wound with long dimension perpendicular to axis.

Here,	D = 1¼″	Ratio b/t = 2
	b = ¼″	Ls = Nt x t = .875
	t = ⅛″	F = 1⅝ − .875 = .75
	Na = 5½″	

Using "t" for Wire Size on Deflection face of calculator, a value of 33 is found on Pounds per Inch Deflection scale. This value need not be read; its position can be marked with the sliding indicator. Set arrow under "Rect: Ratio b/t" on this value, and under 2 (the ratio b/t) will be found 150 Pounds per Inch Deflection.

Now turn to Stress face of the calculator. The load on the spring when compressed solid is the rate times the deflection, or 112 pounds. Again using "t" for "Wire Size" and the 112. for Load, a value on the Stress scale of 182,000. is obtained, and its position marked with the sliding indicator. Set arrow under "Rect: Ratio b/t" on this value, and under 2 (ratio b/t) will be found 73,000.

It may be noted that wire of rectangular cross-section with rounded edges is often used. This rounding off of the edges does not affect results to a noticeable degree. If the rounding off is such that the cross-section resembles a flattened oval, satisfactory results may be obtained by reducing "Ratio b/t" to 90% of its calculated value.

SQUARE AND RECTANGULAR VERSUS ROUND WIRE

It will be noted that a spring wound from square wire has a rate 43% higher than a spring of the same dimensions wound from round wire. This indicates that a square wire spring can be used where space is limited, particularly where both inside and outside diameters imposed limitations, and a high rate is desired.

However, most springs are used primarily as a means of storing energy, this energy to be returned when the load is released. From the viewpoint of storing a maximum amount of energy in a given space, the spring of square wire does not compare favorably with a spring of the same dimensions made from round wire. Given two springs of identical outside diameter, inside diameter, and solid length; one wound from square and the other from round wire, it will be found that the spring of round wire will store 27% more energy than the square wire spring, assuming that the maximum allowable unit stresses are the same. In terms of weight of steel, it will require over 60% more steel to absorb a given amount of energy in a spring of square wire than will be required in a spring of round wire. The conclusion to be drawn is that square wire is best adapted to springs where high rate is desired, space limited, and the required deflection small, i.e., the load more or less static.

Rectangular wire is sometimes useful in cases where solid length is limited and other space considerations permit its use. Proper combinations of breadth and thickness give great flexibility in designing a spring for a given rate and load, and often the use of rectangular wire provides the only means of solving a spring problem.

USE OF THE CALCULATOR IN SPRING DESIGN

In spring design there are usually three governing factors which determine the final design of the spring; namely, load at one or more specified lengths, space available, and type of service.

When designing a spring to fit a given set of conditions, it will usually be found advisable first to assume a mean diameter in conformity with space limitations, then by use of the rule, to calculate a wire size and number of coils which will give a rate consistent with load demands. As there are an unlimited number of combinations of wire size and number of coils, a wire size should be chosen which, multiplied by the number of coils, will produce a spring of solid length consistent with space limitations. For a well-proportioned spring, it is desirable to have a wire size of 1/5 to 1/8 the mean diameter; the wire size should never be greater than ⅓ the mean diameter.

It is then necessary to calculate the maximum unit stress under the greatest load to which the spring will be subjected. If this stress is above safe limits, it will be necessary to redesign the spring with an increased wire size, which will increase the rate of the spring unless mean diameter or number of coils is also increased.

Where space is not limited, it is usually more economical to increase the diameter and wire size; whereas if space is limited it may be necessary to use a higher grade of steel capable of withstanding the higher stress to be imposed. It must also be remembered that for springs subjected to infrequent flexions, or under static loads, it is safe to use stresses close to the elastic limit of the material, while springs subjected to rapidly repeated loads should be designed with lower working stress.

EXTENSION SPRINGS

In the case of extension springs which have the coils laid close together when under no load, it is possible to build initial tension into the spring. This initial tension represents the load which must be applied to the spring before the coils begin to separate, and after enough load has been applied to offset the initial tension the spring will thereafter deflect under additional load in accordance with the values obtained from the Spring Calculator.

The maximum amount of initial tension which may be built into a spring in ordinary manufacturing practice is a function of the wire size and of the ratio of the mean diameter to the wire size, and may be ascertained by use of the chart on Page 12 of this booklet.

It must be remembered that the initial tension value must be added to the load produced by deflection when calculating the maximum unit stress in an extension spring.

MODULUS OF ELASTICITY IN SHEAR

This Spring Calculator gives direct readings for material with a modulus of 11,500,000. This value will be found satisfactory for most types of spring steel. In fact, commercial tolerances in wire size and mean diameter of the spring outweigh small variations in the modulus. The following table gives values of G for various materials commonly used in springs:

Music Wire	11,500,000
Oil Tempered Wire	11,500,000
Hard Drawn M. B.	11,200,000
Stainless Steel 18-8	9,700,000
Monel Metal	9,250,000
Phosphor Bronze	6,000,000
Beryllium Copper	6,100,000
Brass	5,000,000

PERMISSIBLE UNIT STRESS

	Safe Working Stress
Music Wire under .020	110,000
Music Wire over .020	90,000
Valve Spring Wire	70,000
Oil Tempered Wire	70,000
Hard Drawn M. B. (Premier or equivalent)	65,000
Stainless 18-8	65,000
Beryllium Copper	45,000
Monel Metal	40,000
Phosphor Bronze	35,000
Brass Spring Wire	30,000

The maximum working stresses given are based on the assumption that the spring works from no-load to full-load. If, as is often the case and almost invariably the case with valve springs, the spring works in a range between part load and full load, the upper limit of the working stress may be increased. We suggest consulting your spring-maker for details.

SOME SPRING FORMULAS

To find solid length of spring (ends closed and ground):

Multiply total coils by wire size.

To find solid length (ends not ground):

Multiply total coils by wire size and add one wire size.

Number of active coils in compression springs with ends closed should be taken as $1\frac{1}{2}$ less than total number of coils.

$$\text{Rate (Pounds required to deflect spring 1 inch)} = \frac{G\ d4}{8\ D3\ Na}$$

$$\text{Unit Stress} = \left[\frac{2.55\ Pd}{d\ 3}\right] K$$

The two formulas immediately above are those on which the Spring Calculator is based In the Stress formula, "K" is

the curvature correction factor obtained from the formula developed by A. M. Wahl:

$$K = \left[\frac{4C-1}{4C-4} + \frac{.615}{C}\right] \qquad \text{Where } C = \frac{D}{d}$$

and represents the increased stress found in the surface fibres of the wire nearest the axis of the spring. It has been our experience that when the stress calculated with this fact exceeds the elastic limit of the material, the spring will take a permanent set, but that its future usefulness is not necessarily impaired thereby. In other words, after a load has been applied which gives the spring a permanent set, the spring can later be subjected to repeated loads fairly close in value to the load which gave it a permanent set, without injury.

HELPFUL HINTS

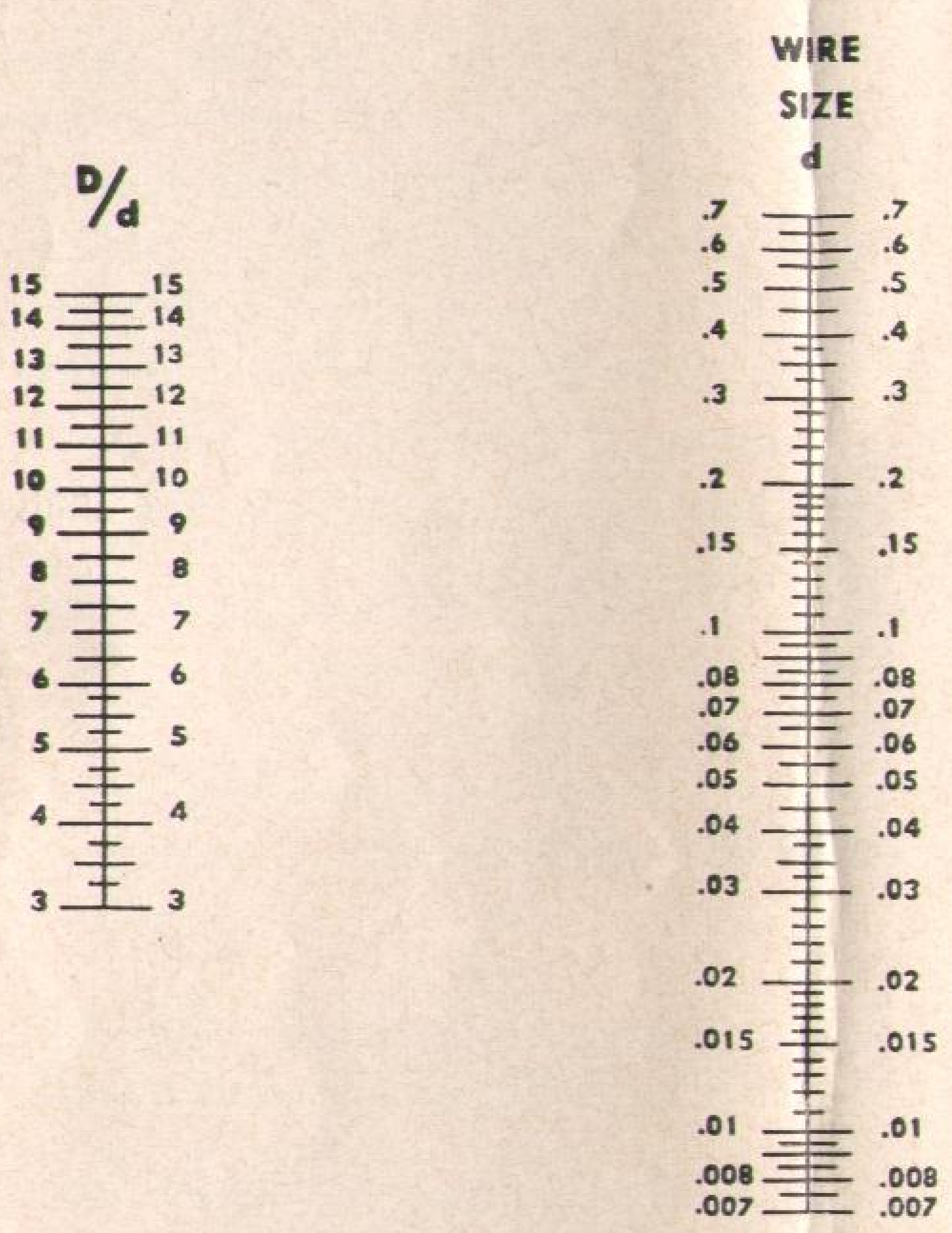
When ordering send, if possible, the part into which the spring is to be assembled—along with blueprints and specifications.

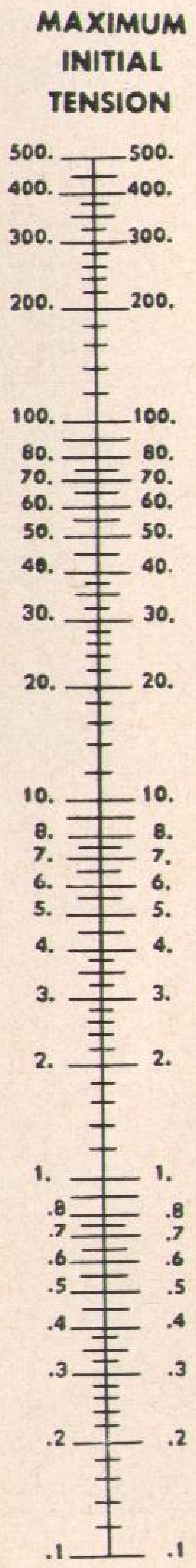
Always specify whether steel, brass, bronze, etc.—whichever material is required.

If the spring is to work over a rod or shaft, or in a hole or socket—give the dimensions in your specifications.

If the springs you require are to be subjected to shock, severe vibration, or present any unusual problems, consult our engineers. When in doubt, let us design your spring—it may be less expensive—it can't be more.

CHART FOR DETERMINING MAXIMUM INITIAL TENSION WHICH CAN BE BUILT INTO EXTENSION SPRINGS.





To use the chart, calculate the ratio D/d. Then lay a straight-edge (transparent celluloid is best) so that it connects the value of D/d on the left-hand scale with the value of the wire size on the middle scale. The amount of initial tension is then read on the right-hand scale, in pounds of pull required to bring the spring to the point where the coils begin to separate.

For example, a spring with D/d ratio of 6, wire size .080, can be wound with a maximum initial tension of approximately 9 pounds.

This represents the maximum initial tension; the spring can be wound with less than this maximum amount, or with no initial tension whatever. This initial tension can be held to fairly close limits, it being easier to hold close limits when the tension is close to the maximum than when the tension is nearer the zero value.