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Bench Guide to Barrel Springs

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In dealing with clock spring barrels, problems usually fall into three categories.

1. Damaged or missing barrel teeth
2. Anchorage of spring to barrel
3. Sizing replacement springs

Since the first two categories are well covered in repair manuals, this article will deal only with spring selection.

Formulas from a spring engineering manual will be used to determine proper spring length for a given thickness, and for selection of replacement springs, even if the original spring is missing or has been replaced with one of incorrect size. Example calculations are shown for each formula.

Springs are often reusable except for damage to the outer ends where they are anchored to their barrels. These springs can be shortened and re-punched after annealing about an inch beyond the damaged area. The following formulas will provide a means for determining whether sufficient length remains for eight or more days of operation.

For long springs, loss of an inch or two would not be critical; but for short springs (30–40 inches) it may be better to replace the spring rather than attempt a repair. In any case, a loss in the number of barrel turns can be readily checked.

SPRING SELECTION

This guide will progress through three stages:

1. Determination of proper width
2. Length determination assuming correct thickness
3. Determination of thickness and length assuming a missing spring

In these cases we are faced with the problem of selecting the proper spring for the barrel.

Width

The width of the spring is determined by the depth of the barrel, and should be such that the spring is free to move within the barrel without binding on the bottom face of the barrel or the barrel cap.

Generally, the spring width is about 0.030–0.050 inches less than the usable barrel depth to insure proper clearance. The width of the spring selected should be to the nearest 64th of an inch after clearance of about 1 mm or 0.030–0.050 inches is subtracted from the barrel depth.

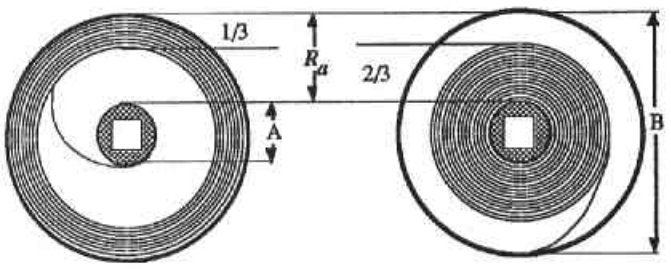
When determining barrel depth, care should be taken to measure from the bottom of the barrel cap groove to the bottom of the barrel.

Length

To obtain the maximum number of barrel turns, the spring edge area must occupy one half of the available area of the barrel. Available barrel area is determined by calculating total barrel area and subtracting the area occupied by the arbor.

Note that in Figure 1 (let down) and Figure 2 (fully wound), the area occupied by the spring is equal to half the vacant area and therefore occupies half the available area of the barrel. As a quick visual check to ascertain proper spring installation, note that the let down spring occupies approximately ⅓ of the available radius (R_a), and the fully wound spring occupies approximately ⅔ of the available radius (R_a). Available radius is the distance from the outside of the arbor to the inside of the barrel wall.

Figures 1 and 2.



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Expressed in symbols, spring length is calculated as follows: Since the area of a barrel is determined by barrel diameter, and given that area = πR^2 or $\pi D^2/4$; and $\pi/4 = 0.785$, therefore area = $0.785D^2$.

Formula I

$$Lt = \frac{1}{2}\left[\frac{\pi B^2}{4} - \frac{\pi A^2}{4}\right]$$

where:

L = spring length
B = barrel inside diameter
A = arbor outside diameter
t = spring thickness
π = 3.1416.

Since $\pi/4 = 0.785$, we can simplify Formula I to:

$$L = \frac{0.785(B^2 - A^2)}{2t} \quad \text{or} \quad L = \frac{B^2 - A^2}{2.55t}$$

Example I: Determination of length when correct thickness is known

Using a sample barrel of 1.75″ diameter with an arbor of .430″ diameter:

barrel area = $1.75^2(0.785)$ or 2.40 square inches

arbor area = $0.430^2(0.785)$ or 0.145 square inches

By subtracting the arbor area from the barrel area we determine the available area of the barrel.

available area = 2.40 − 0.145 = 2.255 square inches

Since spring thickness (t) multiplied by length (L) equals spring area, dividing the spring area (Lt) by the selected thickness determines the proper length.

By dividing available area of 2.255 square inches by 2, we determine the correct spring edge area.

$$Lt = \frac{2.255}{2} = 1.127 \text{ square inches, so } L = \frac{1.127}{t}$$

If we choose a spring of .016″ thickness, the calculation is as follows:

Area ÷ thickness = spring length

1.127 ÷ .016 = 70.4 inches

If the movement requires greater torque and we select a spring of .018″ thickness, we arrive at the following spring length:

area ÷ thickness = spring length

1.127 ÷ .018 = 62.6 inches

For a given thickness, any deviation from the proper length will adversely affect the number of turns available from the barrel. However, a slightly longer spring is less detrimental than a shorter one.

When a spring is missing, or it appears that an improper substitution has been made, Formula II can be used to determine thickness. After the thickness has been determined, Formula I can be used to determine the proper length.

Formula II

Given:

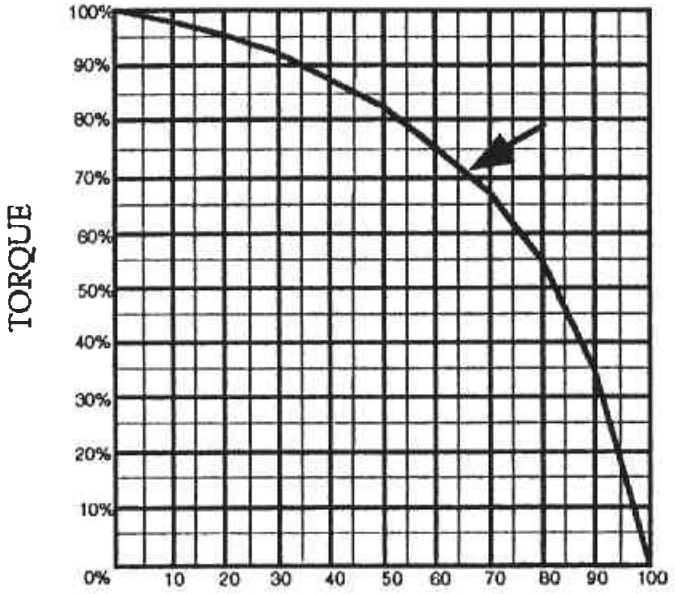
$$n = \frac{\sqrt{2(A^2 + B^2)} - (A + B)}{2.55t}$$

where:

n = number of turns a spring can produce from fully wound to fully let down
B = inside diameter of barrel
A = outside diameter of arbor
t = thickness of spring

Clocks are designed to use only about 65% of the turns available from the barrel, since at this point the torque has dropped to about 70% of maximum at the fully wound condition. (See Figure 3.) Therefore, when determining proper spring length in the example which will follow, n used in Formula II will have to be divided by ⅔ (multiplied by 3/2).

Figure 3.



Typical Torque Curve

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Example II: Sizing a missing spring for an 8-day clock

Using Formula II,

$$n = \frac{\sqrt{2(A^2 + B^2)} - (A + B)}{2.55t}$$

which can be rearranged to

$$t = \frac{\sqrt{2(A^2 + B^2)} - (A + B)}{2.55n}$$

and Formula I

$$L = \frac{B^2 - A^2}{2.55t}$$

The number of turns for 8 days running can be determined as follows:

In 8 days the center wheel must make $8 \times 24 = 192$ turns. Since center wheels are generally driven by the second wheels, the number of turns of the barrel in this example will be:

$$n_{8\text{ days}} = 192\left(\frac{\text{2nd pinion teeth}}{\text{barrel teeth}} \times \frac{\text{center pinion teeth}}{\text{center wheel teeth}}\right)$$

Using typical values of $192(8/64 \times 16/64) = 6$ turns of barrel for 8 days. Remembering that only about 2/3 of the available turns are used, we must substitute $6 \div 2/3 = 6 \times 3/2$ or 9 for n in Formula II in order to select a spring of proper thickness. Referring to the barrel and arbor dimensions of Example I and using 9 for n in Formula II (rearranged)

$$t = \frac{\sqrt{2(A^2 + B^2)} - (A + B)}{2.55n}$$

where:

$n = 9$
$A = 0.430$
$B = 1.75$
$A^2 = 0.185$
$B^2 = 3.06$

$$t = \frac{\sqrt{2(0.185 + 3.06)} - (0.430 + 1.75)}{2.55(9)}$$

Therefore,

$$t = \frac{\sqrt{6.49} - 2.18}{2.55(9)} = 0.016$$

When using 0.016 for t in Formula I which is:

$$L = \frac{B^2 - A^2}{2.55t}, \quad \text{therefore}$$

$$L = \frac{3.06 - 0.185}{2.55(0.016)} = 70.4 \text{ inches},$$

which agrees with the length obtained in Example I.

Thickness

While torque (or strength) varies directly with width for a given thickness (a 1″ wide spring will deliver twice the torque of a ½″ wide spring of the same thickness), torque varies theoretically (and closely in practice) as the square of the thickness.

Thus, a .015″ thick spring compared with a .010″ thick spring would deliver:

$$\frac{.015^2}{.010^2} = \frac{15^2}{10^2} = \frac{225}{100} \text{ or 2.25 times more torque.}$$

Table 1 below illustrates this relationship. Using the above example of spring thicknesses of .015″ and .010″, torques would be 10.52 and 4.88 inch-pounds respectively; 10.52/4.88 = 2.156, slightly less than the theoretical 2.25 shown in the calculation. The reduction of actual from theoretical torque can be attributed mainly to sliding friction between spring coils. Use of a high quality mainspring grease will minimize loss of torque due to friction.

TABLE 1. Torque for a Typical 1″ Wide Spring When Fully Wound

Thickness	Torque
0.010	4.88
0.011	5.89
0.012	6.91
0.013	8.02
0.014	9.22
0.015	10.52
0.016	11.85
0.017	13.21
0.018	14.68
0.019	16.22
0.020	17.88
Inches	Inch-pounds

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The repairman should keep in mind that the use of a stronger spring should not be done as a substitute for installing bushings and polishing the pivots, if necessary, to insure that the movement is in good running order. In the normal range of clock springs, increasing the thickness just .001″ increases the torque approximately 15%.

To determine the torque for a particular spring using Table 1, keep in mind that the torque is directly proportional to the spring's width. As an example, consider a ¾″ width spring of .015″ thickness. The strength for a fully wound spring would be ¾ × 10.52, or 7.89 inch-pounds of torque. By referring to Figure 3 we determine that the torque, after the barrel has turned 65% of its turns, is approximately 70% of 7.89, or 5.52 inch-pounds.

Arbor Replacement

Should it be necessary to replace the winding arbor, its diameter should be 15 to 25 times the thickness of the spring. It has been found practically and experimentally that a lower ratio may cause undue high stress and possible breakage, while a higher ratio reduces the torque and number of turns obtainable.

Practical Method for Determining Number of Barrel Turns Required

A convenient way to determine the number of barrel turns required for a given time period, 8 days in this example, follows:

1. Assemble the barrel, second wheel, and center wheel between the plates.
2. Assemble the hour cannon and reduction gearing on the front of the movement, then mount the hour hand.
3. With the hour hand at the 12 position, make a pencil mark on the barrel tooth entering the second wheel pinion.
4. Slowly turn the barrel through *one revolution* while counting the number of hours the hand advances.
5. Divide 192 (number of hours in 8 days) by the number of hours the hand has advanced. The result will be the number of revolutions the barrel must make for 8 days running.

Example:

Hour hand moves ahead 32 hours. . .

$$\frac{192}{32} = 6 \text{ revolutions in 8 days or } \frac{3}{4} \text{ revolution per day.}$$

This method is less tedious and not so prone to error as counting teeth and making calculations. An error of one tooth of barrel rotation, or a few minutes of hand rotation, would not be significant.

Acknowledgment

We are grateful to Associated Spring, Barnes Group Inc. for permission to use information and figures from their Design Handbook, Engineering Guide to Spring Design, 1987 Edition © 1987 Barnes Group Inc.

About the Authors

L. Raymond "Ray" Wood has been a commercial airline pilot for 31 years. For the past 15 years he has been actively engaged in clock repair and restoration as both hobby and business. He is a member of Chapter #3.

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MEMBERS IN THE NEWS

The March 1, 1993 edition of *The New Yorker* reported in its "Talk of the Town" column that NAWCC member Marvin Schneider was named City Clock Master of New York City by the former Mayor David Dinkins. It is a well-deserved honor, since Schneider has worked hard for many years to put life back into the city's public clocks.

Before receiving the official title, he had already been taking care of the enormous clock on top of the former New York Life Building. Each of the building's four clockfaces measures twelve feet in diameter, and each has a six-foot minute hand and a four-foot hour hand. Schneider uses a three-quarter-horsepower motor to rewind the clock's inner workings, which use over two thousand pounds of pig iron. Schneider's ingenuity in clock repair may be appreciated through his handling of a missing pin in the bronze Sun Clock, located above the corner of Chambers Street and Broadway. He substituted the pin with a paper clip. Schneider's reward for his restoration work comes when he sees people quicken their pace at the sound of one of the city's clocks striking the hour.