

# Materials Table

| Material   | Material Thickness (in) | Minimum Tensile Strength (psi) | Shear Strength (psi) | Maximum Recommended Operating Temp. (°F) | Modulus of Elasticity (psi) |
|--|-------------------------|--------------------------------|----------------------|--|-----------------------------|
| CARBON STEEL   |                         |                                |                      |  |                             |
| OIL TEMPERED<br>SAE 1070 - 1090  | .006 - .014             | 269,000                        | 153,000              | 250                                      | 30 X 10 <sup>6</sup>        |
|  | .0141 - .021            | 255,000                        | 145,000              |  |                             |
|  | .0211 - .043            | 221,000                        | 126,000              |  |                             |
|  | .0431 & larger          | 211,000                        | 120,000              |  |                             |
| HARD DRAWN<br>SAE 1060 - 1075  | .006 - .030             | 230,000                        | 130,000              |  |                             |
|  | .0301 - .110            | 181,000                        | 103,000              |  |                             |
|  | .1101 - .220            | 156,000                        | 89,000               |  |                             |
| AISI 302   |                         |                                |                      |  |                             |
| AMS-5866   | .002 - .022             | 210,000                        | 119,000              | 400                                      | 28 X 10 <sup>6</sup>        |
|  | .0221 - .047            | 200,000                        | 114,000              |  |                             |
|  | .0471 - .062            | 185,000                        | 105,000              |  |                             |
|  | .0621 - .074            | 175,000                        | 100,000              |  |                             |
|  | .0741 - .089            | 165,000                        | 94,000               |  |                             |
|  | .0891 & larger          | 155,000                        | 88,000               |  |                             |
| AISI 316   |                         |                                |                      |  |                             |
| ASTM A313 <sup>1</sup>   | .002 - .023             | 195,000                        | 111,000              | 400                                      | 28 X 10 <sup>6</sup>        |
|  | .0231 - .048            | 190,000                        | 108,000              |  |                             |
|  | .0481 - .061            | 175,000                        | 99,000               |  |                             |
|  | .0611 & larger          | 170,000                        | 97,000               |  |                             |
| 17-7 PH/CH900  |                         |                                |                      |  |                             |
| CONDITION CH900<br>AMS-5529  |                         | 240,000 <sup>2</sup>           | 137,000 <sup>2</sup> | 650                                      | 29.5 X 10 <sup>6</sup>      |
| A-286  |                         |                                |                      |  |                             |
| AMS-5810   |                         | 180,000 <sup>2</sup>           | 105,000 <sup>2</sup> | 1000                                     | 31 X 10 <sup>6</sup>        |
| Inconel <sup>5</sup> Alloy X-750   |                         |                                |                      |  |                             |
| Spring Temper AMS-5699 <sup>3</sup>  |                         | 220,000 <sup>2</sup>           | 125,000 <sup>2</sup> | 700                                      | 31 X 10 <sup>6</sup>        |
| No.1 Temper<br>Rc 35 Maximum<br>AMS-5699 <sup>1,3</sup>  |                         | 136,000 REF                    | 77,000               | 700                                      |                             |
| No.1 Temper AMS-5698   |                         | 155,000 <sup>2</sup>           | 88,000 <sup>2</sup>  | 1000                                     |                             |
| Inconel <sup>5</sup> Alloy 718   |                         |                                |                      |  |                             |
| AMS-5596 <sup>1</sup>  |                         | 180,000 <sup>2</sup>           | 102,000 <sup>2</sup> | 1300                                     | 29.6 X 10 <sup>6</sup>      |
| Elgiloy <sup>5</sup>   |                         |                                |                      |  |                             |
| AMS-5876 <sup>1,3</sup>  | ≤ 0.004                 | 300,000 <sup>2</sup>           | 171,000 <sup>2</sup> | 800                                      | 30 X 10 <sup>6</sup>        |
|  | .0041 - .019            | 290,000 <sup>2</sup>           | 165,000 <sup>2</sup> |  |                             |
|  | .0191 - .025            | 280,000 <sup>2</sup>           | 159,000 <sup>2</sup> |  |                             |
|  | .0251 - .100            | 270,000 <sup>2</sup>           | 154,000 <sup>2</sup> |  |                             |
| Beryllium Copper   |                         |                                |                      |  |                             |
| Temper TH02<br>ASTM B197 <sup>1</sup>  |                         | 185,000 <sup>2</sup>           | 128,000 <sup>2</sup> | 400                                      | 18.5 X 10 <sup>6</sup>      |
| NOTE: Additional materials available include Phosphor Bronze, C-276, 410 Stainless Steel, MONEL <sup>5</sup> K-500, MONEL <sup>5</sup> 400, Waspaloy and others. Please consult Smalley Engineering for further details. |                         |                                |                      |  |                             |
| <sup>1</sup> Referenced for chemical composition only.   |                         |                                |                      |  |                             |
| <sup>2</sup> Values obtained after precipitation hardening.  |                         |                                |                      |  |                             |
| <sup>3</sup> Conforms to NACE Standard MR-01-75.   |                         |                                |                      |  |                             |
| <sup>4</sup> Exceeding these temperatures will cause increased relaxation. Consult Smalley Engineering for High Temperature applications.  |                         |                                |                      |  |                             |
| <sup>5</sup> ELGILOY is a registered trademark of Combined Metals of Chicago. INCONEL and MONEL are registered trademarks of Special Metals Corporation. HASTELLOY is a registered trademark of Haynes International.    |                         |                                |                      |  |                             |

## Material Types

Selecting the proper material for an application requires a general knowledge of what is commonly available for use in Smalley flat wire products. Specifying the correct material can prevent additional cost and failure in operation. Carbon steel is the most commonly specified material. Stainless steels, although more costly than carbon steel, provide far superior corrosion resistance and have higher temperature operating limits.

## Carbon Steel

### Oil Tempered

SAE 1070-1090 high carbon tempered spring steel is a standard material for spiral retaining rings and wave springs. Tensile strength and yield strength are maximized as a result of the oil tempered martensitic structure.

### Hard Drawn

SAE 1060-1075 high carbon cold drawn spring steel is a standard material for snap rings. Hard drawn carbon steel has no scale as it receives its strength from the drawing process.

In either temper, carbon steel is best suited in applications having a protected environment as it corrodes if not lubricated or atmospherically sealed. Additional corrosion protection can be added with special finishes. Rings and springs are normally supplied with an oil dip finish providing protection during shipment and for shelf storage.

- Carbon steel is highly magnetic and can be a variety of different colors including blue, black and gray.

## Stainless Steel

### 302 Stainless Steel

302 is the standard stainless steel for spiral retaining rings. This widely used material is specified because of its combination of corrosion resistance and physical properties. 302 obtains its spring temper condition by cold working. Though it is categorized as being a nonmagnetic stainless, 302 becomes slightly magnetic as a result of cold working. It is not hardenable by heat treatment.

- 302 has a silver-gray color.

### 316 Stainless Steel

Nearly identical in physical properties and heat resistance to 302, 316 provides additional corrosion resistance, particularly against pitting, due to its molybdenum chemical content. 316 is generally used in food, chemical and sea water applications.

316 shows less magnetism than 302. However, as with 302, magnetism increases as the wire is cold reduced. This stainless grade is also not hardenable by heat treatment.

- 316 has a silver-gray color.

### 17-7 PH Condition CH900 Stainless Steel

Similar in corrosion resistance to type 302, this alloy is used almost exclusively for wave springs, yet offers both high tensile and yield strengths for special ring applications. In fatigue and high stress applications, 17-7 out performs even the finest grade of carbon steel.

Spring properties are achieved by precipitation hardening Condition C to Condition CH900.

As a result, the material may be subjected to a temperature of 650°F (343°C) without a loss of spring properties. 17-7 PH Condition CH900 exhibits magnetism similar to high carbon steel.

- After precipitation hardening, 17-7 has a blue, brown or silver color as a result of open-air heat treatment, although atmosphere controlled heat treatment provides a bright color.

# Material Types

## Super Alloys

### Inconel X-750\*



This nickel-chromium alloy is used most commonly in high temperature and corrosive environments. Two commonly specified tempers of Inconel are described below.

Most commonly, Inconel X-750 is precipitation heat treated to a

spring temper condition. In this state, it has temperature resistance to 700°F. The National Association of Corrosion Engineers (NACE) approves this hard temper to specification MR-01-75 (Rc50 maximum) for spiral retaining rings and wave/compression springs.

#1 temper, which requires a longer heat treatment than spring temper, has a lower tensile strength but provides temperature protection to 1000°F. Both spring temper and #1 temper may be heat treated in either an open air or atmosphere controlled furnace. Open air heat treatment may produce oxidation, which often results in a slight black residue. An atmosphere controlled environment eliminates oxidation and produces a component with no residue.

■ Rings and springs manufactured from this grade of Inconel have a blue/silver-gray color and exhibit no magnetism.

### A286 Alloy

In applications up to 1000°F, this alloy exhibits similar properties to Inconel X-750. Its spring temper condition is obtained by precipitation hardening. A286 may be heat treated similar to spring temper and #1 temper Inconel.

■ This material exhibits no magnetism and has a blue/silver-gray color.

### Elgiloy\*

Known for its excellent resistance to corrosive environments and use at elevated temperatures, this relatively new spring material is now readily available from Smalley. Commonly used in oil industry applications, Elgiloy shows improved reliability over other NACE approved materials by resisting sulfide stress cracking. Additionally, Elgiloy is said to out perform "over 600% better than 17-7 PH in load retention at 650°F and provide over 100% more cycles (in fatigue resistance) than carbon steel, without breakage."

■ Elgiloy exhibits no magnetism and is blue-brown in color as a result of heat treatment.

## Coppers

### Beryllium Copper Alloy #25

Normally specified in a hard temper, this alloy produces excellent spring properties due to a combination of low modulus of elasticity and high ultimate tensile strength. The alloy gains its physical properties by precipitation hardening. In contrast to other copper alloys, beryllium copper has the highest strength and offers remarkable resistance to loss of physical properties at elevated temperatures.

■ Beryllium copper is nonmagnetic. Its electrical conductivity is about 2-4 times as great as phosphor bronze

### Phosphor Bronze, Grade A

Phosphor bronze offers fair spring properties, fair electrical conductivity and is rated a step below beryllium copper in performance. It is purchased in a spring temper condition to maximize spring characteristics.

■ Phosphor bronze is hardenable only by cold working. This material is also nonmagnetic.

\*INCONEL X-750 is a registered trademark of Special Metals Corporation. ELGILOY is a registered trademark of Combined Metals of Chicago.

## Material Finishes

### Black Oxide

#### **MIL-DTL-13924, Class 1**

This finish provides a flat black finish. Black oxide is intended more for cosmetic appearance than for corrosion resistance.

### Zinc Plating

#### **Zinc Plate, ASTM B633, Type V, Fe/Zn 5, SC1 (Colorless)**

#### **Zinc Plate, ASTM B633, Type VI, Fe/Zn 5, SC1 (Colored Chromate)**

Zinc plating is used on carbon steel to increase the corrosion resistance of the product. Zinc plating is often used as a cost effective and ecologically friendly alternative to Cadmium plating. Our standard Zinc plating, Type V and Type VI, are RoHS compliant. The thickness level of the plating is controlled by the service condition number (SC number) which can be designated by the customer. Zinc plating does not guarantee coverage between the turns of multiple turn rings. The process does subject the ring to the possibility of hydrogen embrittlement. Smalley offers stainless steel as a preferable option to both cadmium and zinc plating.

### Oil Dip

This is the standard finish for all Smalley products produced from carbon steel. The oil provides resistance to corrosion in transport and normal storage. The oil dip finish should not be considered a permanent finish.

### Passivation

#### **AMS 2700, Method 1, Type 2, Class 3**

Passivation is an optional cleaning operation for stainless steel. It provides a bright finish and increased corrosion resistance. Passivation dissolves iron particles and other substances, which have become imbedded in the surface of stainless steel during production. If not dissolved, these foreign particles could promote rusting, discoloration or even pitting.

In theory, the corrosion resistance of stainless steel is due to the thin, invisible oxide film that completely covers the surface of the ring and prevents further oxidation. Removing the contaminants prevents breaks in the oxide film for optimum corrosion resistance.

### Zinc Phosphate

#### **MIL-DTL-16232, Type Z, Class 2**

This finish is sometimes referred to as "Parkerizing" and appears gray-black in color. The corrosion resistance of phosphate is superior to black oxide but inferior to cadmium plating or stainless steel. Phosphate can not be applied to stainless steel.

### Vapor Degrease/Ultrasonic Clean

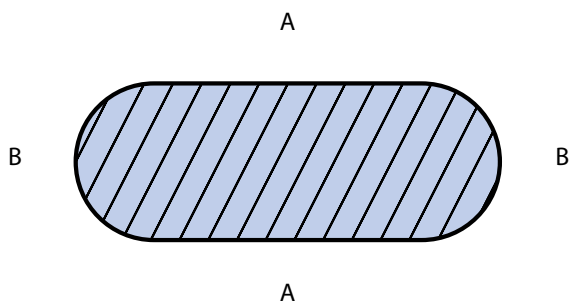
This is the standard cleaning and finish for all stainless steels. The process removes oil and other organic compounds from the material surface by use of a chlorinated solvent. The solvent effectively removes oil and grease from the exposed surfaces of the ring or spring. Ultrasonics are used in forcing the solvent to act between the turns of the ring.

### Vibratory Deburr/Hand Deburr

Though all circumferential surfaces and edges of Spirolox Rings are smooth, sharp corners are always present on the gap ends due to the cut-off operation. To break the sharp corners, achieving a blended/smooth surface finish, rings may either be vibratory or hand deburred to meet your specifications.

## Specifications

Federal, aerospace and other regulating agencies have prepared several specifications for sheet and strip materials, but few have been published for flat wire. Smalley procures its material to internally generated specifications. In addition to controlling tensile strength, rigid inspection procedures have been established to check for edge contour, physical imperfections, camber, cross-section and chemical composition.



## Ultimate Tensile Strength

To check the spring properties of wire, Ultimate Tensile Strength is the preferred test method over hardness because spring temper flat wire develops different hardnesses at various indentation points. As a result of cold rolling, the top and bottom surfaces ("A") become harder as they are more severely worked than the round edge areas ("B"). Tensile tests are more consistent as they evaluate the entire cross-section, not a single point as in a hardness test.



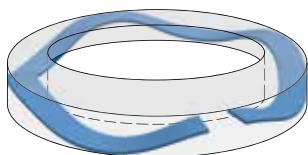
## Spring Design

### Defining the Spring Requirements

Although wave spring applications are extremely diverse, there is a consistently basic set of rules for defining spring requirements. Those requirements are used to select a stock/standard spring or design a special spring to meet the specifications.

### Working Cavity

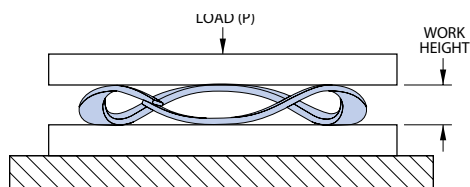
The working cavity usually consists of a bore the spring operates in and/or a shaft the spring clears. The spring stays positioned by piloting in the bore or on the shaft.



The distance between the loading surfaces defines the axial working cavity or work height of the spring.

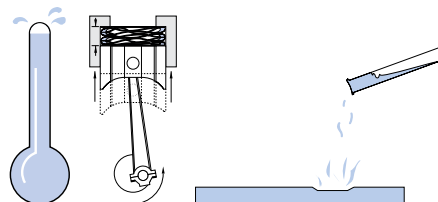
### Load Requirement

The load requirement is defined by the amount of axial force the spring must produce when installed at its work height. Some applications require multiple working heights, where loads at 2 or more operating heights are critical and must be considered in the design. Often minimum and/or maximum loads are satisfactory solutions, particularly where tolerance stack-ups are inherent in the application.



### Operating Environment

High temperature, dynamic loading (fatigue), a corrosive media or other unusual operating conditions must be considered in spring applications. Solutions to various environmental conditions typically require selection of the optimal raw material and operating stress.



### Standard Springs vs. Custom Springs

Finding the right spring can be as easy as selecting a standard catalog item. A Smalley engineer can help you choose from over 4,000 standard parts available from stock in carbon and stainless steel. Smalley's "no-tooling" method of manufacturing provides the utmost in flexibility and quality. Whether the requirement is for 1 spring or 1,000,000 consider Smalley for your custom spring requirements.

### Let Smalley Design Your Spring

Over 50% of Smalley's business is in the design and manufacturing of custom springs to suit individual applications. Whether it's a technical question, or the most complex spring design, Smalley engineers are always available and welcome the opportunity to assist you. Utilize the Application Checklist found in this catalog. Or at [www.smalley.com](http://www.smalley.com) we provide a simple procedure to e-mail us your known design parameters. An engineer will recommend a standard catalog item or provide you with design options for a custom spring.



# Spring Design

## Nomenclature

|                |  |
|----------------|--|
| b              | Radial Width of Material, in [(O.D. - I.D.)÷2] |
| D <sub>m</sub> | Mean Diameter, in [(O.D. + I.D.)÷2]            |
| E              | Modulus of Elasticity, psi                     |
| f              | Deflection, in                                 |
| H              | Free height, in                                |
| I.D.           | Inside Diameter, in                            |
| K              | Multiple Wave Factor, see Table 1              |
| L              | Length, Overall Linear, in                     |
| N              | Number of Waves (per turn)                     |
| O.D.           | Outside Diameter, in                           |

|    |                           |
|----|---------------------------|
| P  | Load, lb                  |
| S  | Operating Stress, psi     |
| t  | Thickness of Material, in |
| WH | Work Height, in (H-f)     |
| Z  | Number of Turns           |

### Multiple Wave Factor (K)

| N | 2.0-4.0 | 4.5-6.5 | 7.0-9.5 | 10.0 & Over |
|---|---------|---------|---------|-------------|
| K | 3.88    | 2.90    | 2.30    | 2.13        |

Table 1

## Single Turn Gap or Overlap Type Applications

1. Low-Medium Force
2. Low-Medium Spring Rate
3. Short Deflection
4. Precise Load/Deflection Characteristics

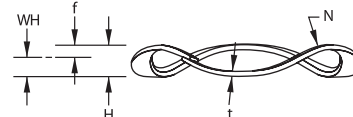
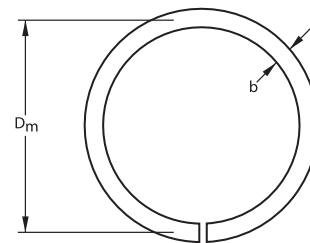
Single turn wave springs are the basic and most common wave spring product. They are used in the widest variety of spring applications due to their lower cost and simplified design configuration.

Single turn wave springs provide the most flexibility to designers. There are few restrictions in their design. They are specified in the majority of small axial and radial space constraint applications.

### Formulas:

$$\text{Deflection} = f = \frac{P K D_m^3}{E b t^3 N^4} * \frac{\text{I.D.}}{\text{O.D.}}$$

$$\text{Operating Stress} = S = \frac{3 \pi P D_m}{4 b t^2 N^2}$$



### Example: Smalley Part Number SSR-0200

Calculate free height and operating stress for Smalley part number SSR-0200 (Gap Type, Single Turn, Carbon Spring Temper Steel).

Where:

P = 34 lb  
 t = .024 in  
 b = .150 in  
 O.D. = 1.985 in  
 I.D. = 1.685 in  
 D<sub>m</sub> = 1.835 in  
 N = 4  
 E = 30x10<sup>6</sup> psi  
 K = 3.88  
 WH = .093 in

$$\text{Deflection} = f = \frac{(34)(3.88)(1.835)^3}{(30 \times 10^6)(.150)(.024)^3(4)^4} * \frac{1.685}{1.985} = .043 \text{ in}$$

$$\text{*Free Height} = H = (\text{W.H.} + f) = .093 + .043 = .136 \text{ in}$$

$$\text{Operating Stress} = S = \frac{(3)(\pi)(34)(1.835)}{(4)(.150)(.024)^2(4)^2} = 106,339 \text{ psi}$$

\*Calculated free height may not be the same as the actual springs measure due to variations in raw material and manufacturing process.

## Crest-to-Crest (Series Stacked)

### Applications

1. Low-Medium Force
2. Low-Medium Spring Rate
3. Long Deflection
4. Precise Load/Deflection Characteristics

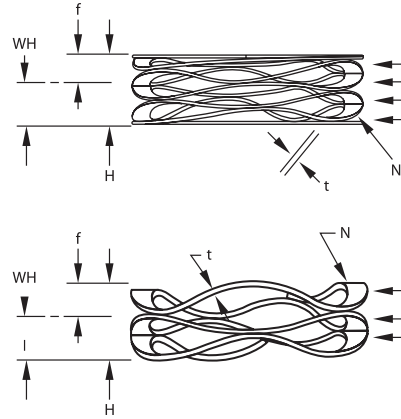
Crest-to-Crest flat wire compression springs are pre-stacked in series, decreasing the spring rate by a factor related to the number of turns.

#### Formulas:

$$\text{Deflection} = f = \frac{P K D_m^3 Z}{E b t^3 N^4} * \frac{I.D.}{O.D.}$$

$$\text{Operating Stress} = S = \frac{3 \pi P D_m}{4 b t^2 N^2}$$

Note:  
N must be in ½ wave increments  
Z = Number of active turns



## Nested Spirawave® (Parallel Stacked)

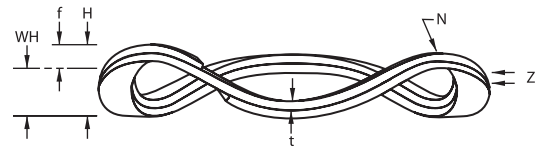
1. Higher Force
2. Higher Spring Rate
3. Short Deflection
4. Precise Load/Deflection Characteristics

Nested Spirawave Wave Springs are pre-stacked in parallel, increasing the spring rate by a factor related to the number of turns.

#### Formulas:

$$\text{Deflection} = f = \frac{P K D_m^3}{E b t^3 N^4 Z} * \frac{I.D.}{O.D.}$$

$$\text{Operating Stress} = S = \frac{3 \pi P D_m}{4 b t^2 N^2 Z}$$



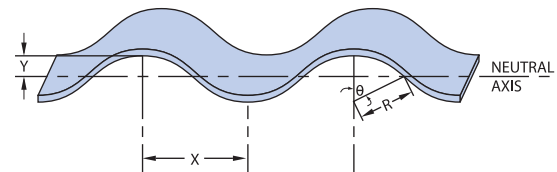
## Diameter Expansion

Nested & Crest-to-Crest Spirawaves Only: Multiple turn Spirawaves expand in diameter when compressed. The formula shown below is used to predict the maximum fully compressed diameter.

**Formula:** Maximum outside diameter at 100% deflection (solid height) = .02222 \* R \* N \* θ + b

Where:

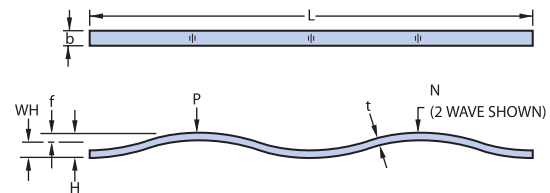
- R = Wave Radius =  $(4Y^2 + X^2) \div 8Y$
  - N = Number of Waves
  - θ = Angle, degrees =  $\text{ArcSin}(X \div 2R)$
  - b = Radial Wall
  - X = ½ Wave Frequency =  $\pi D_m \div 2N$
  - Y = ½ Mean Free Height =  $(H-t) \div 2$
- Where H = Per Turn Free Height



## Linear Springs

Linear Springs are a continuous wave formed (marcelled) wire length produced from spring temper materials. They act as a load bearing device having approximately the same load/deflection characteristics as a wave spring.

Forces act axially or radially depending on the installed position. Axial pressure is obtained by laying the spring flat in a straight line. Circular wrapping the spring (around a piston for example) produces a radial force or outward pressure.



**Formula:** Single wave linear spring where N=1

$$\text{Deflection} = f = \frac{P L^3}{4 E b t^3} \quad \text{Operating Stress} = S = \frac{3 P L}{2 b t^2}$$

**Formula:** 2 or more wave linear springs where N>1

$$\text{Deflection} = f = \frac{P L^3}{16 E b t^3 N^4} \quad \text{Operating Stress} = S = \frac{3 P L}{4 b t^2 N^2}$$



# Spring Design

## Stress

### Operating Stress

Compressing a wave spring creates bending stresses similar to a simple beam in bending. These compressive and tensile stresses limit the amount a spring can be compressed before it yields or “takes a set”. Although spring set is sometimes not acceptable, load and deflection requirements will often drive the design to accept some set or “relaxation” over time.

### Maximum Design Stress

**Static Applications** Smalley utilizes the Minimum Tensile Strength found in this catalog’s Materials section to approximate yield strength due to the minimal elongation of the hardened flat wire used in Smalley products. When designing springs for static applications we recommend the calculated operating stress be no greater than 100% of the minimum tensile strength. However, depending on certain applications, operating stress can exceed the minimum tensile strength with allowances for yield strength. Typical factors to consider are permanent set, relaxation, loss of load and/or loss of free height.

**Dynamic Applications** When designing wave springs for dynamic applications, Smalley recommends that the calculation of operating stress not exceed 80% of the minimum tensile strength. Refer to the “Fatigue Stress Ratio” and Table 2 for further fatigue guidelines.

### Residual Stress/Pre-Setting

Increasing the load capacity and/or fatigue life can be achieved by compressing a spring beyond its yield point or “presetting”. Preset springs are manufactured to a higher than needed free height and load and then compressed solid. Both the free height and load are reduced and the material surfaces now exhibit residual stresses, which enhance spring performance.

## Fatigue

Fatigue cycling is an important consideration in wave spring design and determining precisely how much the spring will deflect can greatly impact the price of the spring. An analysis should include whether the spring deflects full stroke or only a few thousandths each cycle or possibly a combination of both as parts wear or temperature changes.

The fatigue guidelines in Table 2 provide a conservative approach and allow for calculation of cycle life between 2 work heights. Although these methods of fatigue analysis have proven to be a good approximation, testing is recommended whenever cycle life is critical.

### Formula:

$$\text{Fatigue Stress Ratio} = X = \frac{(\sigma - S_1)}{(\sigma - S_2)}$$

(refer to Table 2)

Where:  $\sigma$  = Material tensile strength

$S_1$  = Calculated operating stress at lower work height  
(must be less than  $\sigma$ )

$S_2$  = Calculated operating stress at upper work height

| Fatigue Guidelines |                      |
|--------------------|----------------------|
| X                  | Estimated Cycle Life |
| < .40              | Under 30,000         |
| .40 - .49          | 30,000 – 50,000      |
| .50 - .55          | 50,000 – 75,000      |
| .56 - .60          | 75,000 – 100,000     |
| .61 - .67          | 100,000 – 200,000    |
| .68 - .70          | 200,000 – 1,000,000  |
| > .70              | Over 1,000,000       |

Table 2

## Load/Deflection

A comparison of the actual spring rate to the theoretical (calculated) spring rate provides practical limits for the working range of the spring. Spring rate (P/f) can be calculated by manipulating the deflection equations. See formulas in the Spring Design section.

Figure 1 shows a graph of theoretical and tested spring rate. Typically, theoretical rate is accurate until the spring starts to bottom out or reach its “solid height”.

As a general rule, the calculated spring rate is linear through the first 80% of available deflection and for work heights down to 2 times the solid height. Although the spring can operate beyond this “linear” range, measured loads will be much higher than calculated.

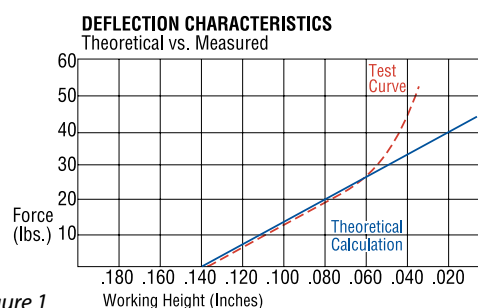


Figure 1

## Hysteresis

Wave springs exert a greater force upon loading and lower force upon unloading. This effect is known as hysteresis. The shaded area shows a graphic representation between the curves in Figure 2.

In a single turn spring, friction due to circumferential and radial movements are the prime causes. Crest-to-Crest and Nested Springs also contribute to the frictional loss

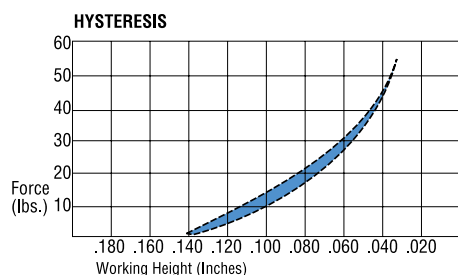


Figure 2

as adjacent layers rub against each other. Sufficient lubrication will minimize this effect.

## Design Guidelines

### Material Cross-Section

Material cross-section plays an important role in wave spring design. The most economical materials are those used in manufacturing Smalley standard springs and retaining rings. In addition, many other material cross sections are commonly used in special spring manufacture designs. Smalley engineering can provide assistance in selecting an economical alloy and cross section.

As a basic guideline, use our standard 'SSR'-Wave Spring series for cross-section/diameter relationships. Lighter material sections are usually acceptable. Heavier sections for a given diameter may be incorporated using the following information:

#### Special wave spring design criteria for selecting material cross-sections:

- Maximum material thickness = standard ('SSR-') thickness \* 2
- Maximum radial wall = material thickness (any value) \* 10
- Minimum radial wall = material thickness (any value) \* 3

For Overlap Type Wave Springs and multiple turn Spirawaves, the radial wall must be sufficient to prevent misalignment between adjacent layers. For springs with a narrow radial wall, radial misalignment can occur during handling or during operation if the spring is not contained or closely piloted.

Solutions to this problem include dimensioning the spring to pilot closely on the I.D. and/or O.D. or designing the spring as a single turn Gap Type.

### Diameters

Figure 3 illustrates two methods of specifying diameters. In either case, the spring diameter is developed to provide proper operation between the bore and the shaft.

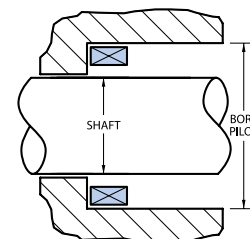


Figure 3a

Note: Smalley's manufacturing process of edgewinding controls either the O.D. or the I.D. The material radial wall is also tightly controlled. Therefore whenever possible, tolerance only one diameter and the radial wall instead of tolerancing both the O.D. and I.D.

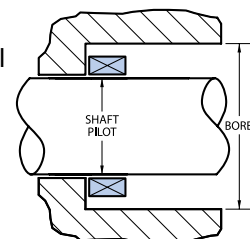


Figure 3b

### Bore Pilot

For springs that pilot in the bore as shown in figure 3a, the bore and shaft diameters should be included in the spring specifications. Commonly used requirements would read:

"Spring must pilot and operate in a (minimum bore) bore diameter."

"Spring must clear a (maximum shaft) shaft diameter."

The actual spring diameter is then developed at time of manufacture to provide the best fit and prevent binding due to expansion.

For Gap Type and Overlap Type Springs, the outside diameter can be specified because binding is not a concern. The outside diameter can be toleranced to provide a minimum clearance in the bore or provide cling in the bore, as do the Smalley Bearing Preload Springs.

### Shaft Pilot

For springs that pilot on a shaft as shown in Figure 3b, the inside diameter can be toleranced to provide a minimum clearance from the shaft. Since wave springs expand during compression, interference with the shaft is generally not a concern.

To insure proper operation, include shaft and bore diameters in the spring specifications. Commonly used requirements would read:

"Spring pilots over and clears a (maximum shaft) shaft diameter."

"Spring operates in a (minimum bore) bore diameter."

## Engineering Design

Spirolox Retaining Ring and Constant Section Ring applications, although diverse, can be analyzed with a straight forward set of design calculations. There are four main areas that should be considered in most applications.

1. Material Selection
2. Load Capacity
3. Rotational Capacity
4. Installation Stress

Smalley Application Engineers are available to provide immediate technical assistance.

The following pages of Spirolox Retaining Ring and Constant Section Ring engineering design have been developed from over 50 years of extensive testing and research into the various applications of retaining rings. The formulas are provided for the preliminary analysis of a ring application and the design of a Spirolox Retaining Ring.

Design engineers commonly associate the word “retaining ring” to a basic style or type of retaining device. In reality, retaining rings are nearly as diverse as their applications. Spirolox Retaining Rings offer a distinct alternative, and in many instances an advantage, over the more common retaining rings available on the market today. Some of the major distinctions are:

### Spiral Wound in Multiple Turns

Increases load capacity yet allows easy assembly by hand or as an automated process.

### 360° Retaining Surface

No gap – no protruding ears.

### Uniform Radial Section

Provides a pleasant appearance on the assembled product. Beneficial when radial clearance is limited.

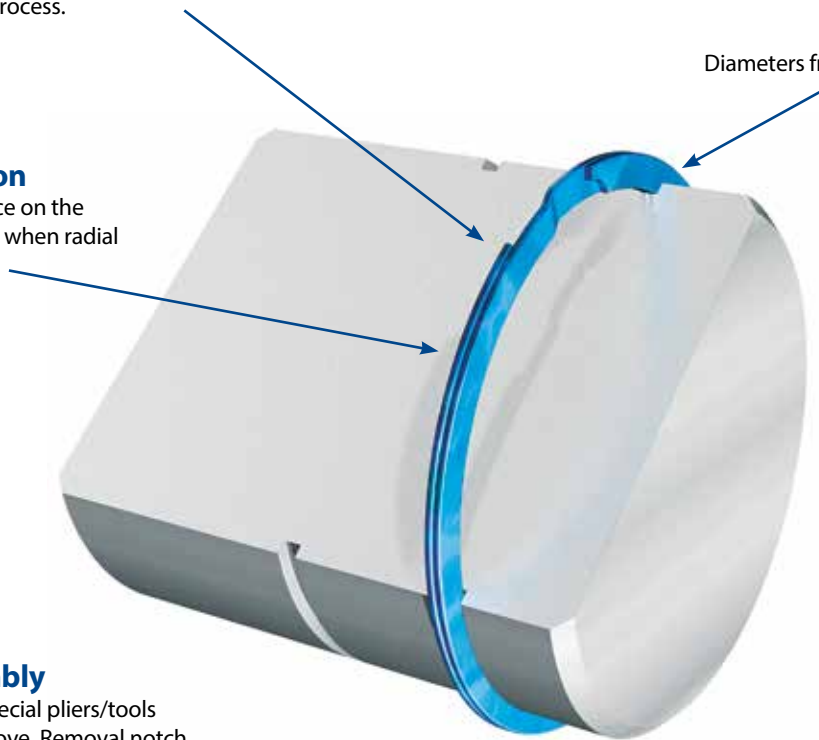
Diameters from .200" to 120"

### Simplified Assembly

Wind into groove. No special pliers/tools needed to install or remove. Removal notch provided for easy removal using a screwdriver.

### Design Flexibility

Ring thickness can be changed to accommodate most any application by either varying material thickness and/or number of turns. Standard rings meet military and aerospace specifications. Special designs are produced quickly and economically in many alloys.



## Load Capacity

Understanding the load capacity of a Spirolox Retaining Ring assembly requires calculations for both ring shear and groove deformation, with the design limitation being the lesser of the two.

The load capacity formulas do not take into account any dynamic or eccentric loading. If this type of loading exists, the proper safety factor should be applied and product testing conducted. In addition, the groove geometry and edge margin (i.e.; the distance of the groove from the end of the shaft or housing) should be considered.

When abusive operating conditions exist, true ring performance is best determined thorough actual testing.

### Ring Shear

Although not commonly associated as a typical failure of Spirolox Retaining Rings, ring shear can be a design limitation when hardened steel is used as a groove material. Ring thrust load capacities based on ring shear are provided within this catalog's tables of standard rings. These values are based on a shear strength of carbon steel with the recommended safety factor of 3.

#### Formula:

$$P_R = \frac{D T S_S \pi}{K}$$

Where:

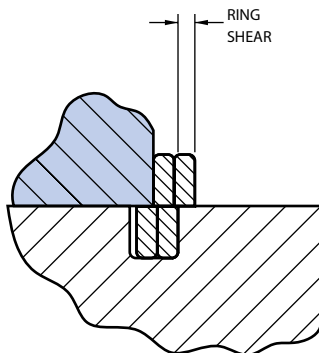
- $P_R$  = Allowable thrust load based on ring shear (lb)
- $D$  = Shaft or housing diameter (in)
- $T$  = Ring thickness (in)
- $S_S$  = Shear strength of ring material (psi)
- $K$  = Safety factor (3 recommended)

#### Example:

1. WH-550-S16
2. Safety factor = 3

$$P_R = \frac{5.500 (.072) 108,000 (\pi)}{3}$$

$$P_R = 44,787 \text{ lb}$$



The thrust load based on ring shear above, must be compared to the thrust load based on groove deformation to determine which is the limiting factor in the design.

### Groove Deformation (Yield)

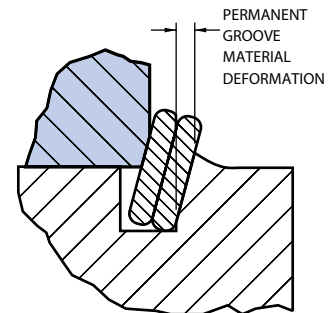
Groove deformation is by far the most common design limitation of retaining rings. As permanent groove deformation occurs, the ring begins to twist. As the angle of twist increases, the ring begins to enlarge in diameter. Ultimately, the ring becomes dished and extrudes (rolls) out of the groove. As a conservative interpretation, the following equation calculates the point of initial groove deformation. This does not constitute failure which occurs at a much higher value. A safety factor of 2 is suggested. Ring thrust load capabilities based on groove deformation are provided within this catalog's tables of standard rings.

#### Formula:

$$P_G = \frac{D d S_y \pi}{K}$$

Where:

- $P_G$  = Allowable thrust load based on groove deformation (lb)
- $D$  = Shaft or housing diameter (in)
- $d$  = Groove depth (in)
- $S_y$  = Yield strength of groove material (psi), see Table 1
- $K$  = Safety factor (2 recommended)



#### Example:

1. WH-550-S16
2. Groove material yield strength = 45,000 psi
3. Safety factor = 2

$$P_G = \frac{5.500 (.074) 45,000 (\pi)}{2}$$

$$P_G = 28,769 \text{ lb}$$

#### Typical Groove material yield strengths

|                       |               |
|-----------------------|---------------|
| Hardened Steel 8620   | 110,000 psi   |
| Cold Drawn Steel 1018 | 70,000 psi    |
| Hot Rolled Steel 1018 | 45,000 psi    |
| Aluminum 2017         | 40,000 psi    |
| Cast Iron             | 10-40,000 psi |

Table 1

Since ring shear was calculated at 44,787 lb, the groove yields before the ring shears. Therefore 28,769 lb is the load capacity of the retaining ring.

# Ring Design

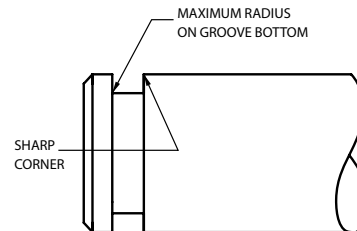
## Groove Geometry

### Groove Radius

To assure maximum load capacity it is essential to have square corners on the groove and retained components. Additionally, retained components must always be square to the ring groove in order to maintain a uniform concentric load against the retained part. The radius at the bottom of the groove should be no larger than Table 2 states.

| Shaft or Housing Diameter | Maximum Radius on Groove Bottom |
|---------------------------|---------------------------------|
| 1 inch and under          | .005 Max.                       |
| Over 1 inch               | .010 Max.                       |

Table 2



### Retained Component

The retained part ideally has a square corner and contacts the ring as close as possible to the housing or shaft. The maximum recommended radius or chamfer allowable on the retained part can be calculated with the following formulas.

Where:

- b = Radial wall (in)
- d = Groove depth (in)

#### Example:

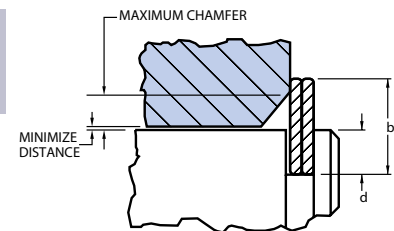
1. WH-100

Maximum Chamfer =  $.375(.075 - .021) = .020$  in

Maximum Radius =  $.5(.075 - .021) = .027$  in

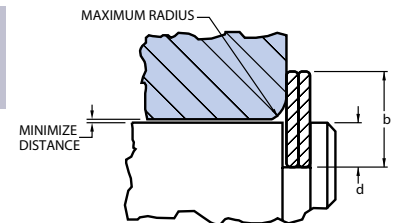
#### Formula:

Maximum Chamfer =  $.375(b - d)$   
(on retained component)



#### Formula:

Maximum Radius =  $.5(b - d)$   
(on retained component)



### Edge Margin

Ring grooves which are located near the end of a shaft or housing should have an adequate edge margin to maximize strength. Both shear and bending should be checked and the larger value selected for the edge margin. As a general rule, the minimum edge margin may be approximated by a value of 3 times the groove depth.

#### Formula:

##### Shear

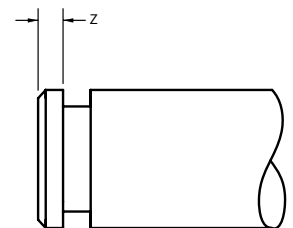
$$z = \frac{K 3 P}{S_Y D_G \pi}$$

##### Bending

$$z = \left[ \frac{K 6 d P}{S_Y D_G \pi} \right]^{1/2}$$

Where:

- z = Edge margin (in)
- P = Load (lb)
- D<sub>G</sub> = Groove diameter (in)
- S<sub>Y</sub> = Yield strength of groove material (psi), Table 1
- d = Groove depth (in)
- K = Safety factor (3 recommended)



#### Example:

1. VS-125

2. Groove material yield strength = 40,000 psi

3. Safety factor = 3

4. Load = 1,000 lb

##### Shear

$$z = \frac{3 (3) 1000}{40,000 (1.206) \pi}$$

$$z = .059 \text{ in}$$

##### Bending

$$z = \left[ \frac{3 (6) .022 (1000)}{40,000 (1.206) \pi} \right]^{1/2}$$

$$z = .051 \text{ in}$$

Therefore the minimum edge margin that should be used is .059 in

## Rotational Capacity

The maximum recommended RPM for all standard external Spirolox Retaining Rings are listed in the ring tables of this manual.

A Spirolox Retaining Ring, operating on a rotating shaft, can be limited by centrifugal forces. Failure may occur when these centrifugal forces are great enough to lift the ring from the groove. The formula below calculates the RPM at which the force holding the ring tight on the groove (cling) becomes zero.

Rapid acceleration of the assembly may cause failure of the retaining ring. If this is a potential problem, contact Smalley engineering for design assistance.

### Maximum RPM

#### Formula:

$$N = \left[ \frac{3600 V E I g}{(4\pi^2) Y \gamma A R_M^5} \right]^{1/2}$$

Where: N = Maximum allowable rpm (rpm)  
 E = Modulus of elasticity (psi)  
 I = Moment of inertia =  $(t \times b^3) \div 12$  (in<sup>4</sup>)  
 g = Gravitational acceleration (in/sec<sup>2</sup>), 386.4 in/sec<sup>2</sup>  
 V = Cling  $\div 2 = (D_G - D_I) \div 2$  (in)  
 D<sub>G</sub> = Groove diameter (in)  
 D<sub>I</sub> = Free inside diameter (in)  
 Y = Multiple turn factor, Table 3  
 n = Number of turns  
 γ = Material density (lb/in<sup>3</sup>), (assume .283 lb/in<sup>3</sup>)  
 A = Cross sectional area =  $(t \times b) - (.12)t^2$  (in<sup>2</sup>)  
 t = Material thickness (in)  
 b = Radial wall (in)  
 R<sub>M</sub> = Mean free radius =  $(D_I + b) \div 2$  (in)

| n | 1     | 2     | 3     | 4     |
|---|-------|-------|-------|-------|
| Y | 1.909 | 3.407 | 4.958 | 6.520 |

Table 3

#### Example:

1. WSM-150

$$V = (D_G - D_I) \div 2 = (1.406 - 1.390) \div 2 = .008 \text{ in}$$

$$I = (t \times b^3) \div 12 = (.024 \times .118^3) \div 12 = 3.29 \times 10^{-6} \text{ in}^4$$

$$A = (t \times b) - (.12)t^2 = (.024 \times .118) - .12(.024)^2 = .00276 \text{ in}^2$$

$$R_M = (D_I + b) \div 2 = (1.390 + .118) \div 2 = .754 \text{ in}$$

$$N = \left[ \frac{3600 (.008) 30,000,000 (3.29 \times 10^{-6}) 386.4}{(4\pi^2) 3.407 (.283) .00276 (.754)^5} \right]^{1/2}$$

$$N = 6,539 \text{ rpm}$$

### Self-Locking

This feature allows the ring to function properly at speeds that exceed the recommended rotational capacity. The self-locking option can be incorporated for both external and internal rings. The self-locking feature utilizes a small tab on the inside turn "locking" into a slot on the outside turn. Self-locking allows the ring to operate at high speeds, withstand vibration, function under rapid acceleration and absorb a degree of impact loading.



**To learn more about self-locking rings and their installation and removal, please visit: [www.smalley.com/LockingRings](http://www.smalley.com/LockingRings).**

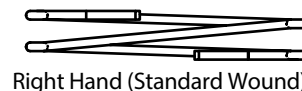
### Balanced

Smalley's balanced feature statically balances the retaining ring. A series of slots, opposite the gap end, account for the missing material in the gap. This characteristic is very useful when the balance of the assembly is critical and it is necessary to reduce eccentric loading.

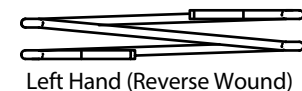


### Left Hand Wound

Smalley retaining rings are wound standard in a clockwise direction. In special applications it is sometimes favorable to have the retaining ring reverse, left hand wound.



Right Hand (Standard Wound)



Left Hand (Reverse Wound)



# Ring Design

## Maximum Allowable RPM for Spirolox Retaining Rings — Imperial

| Part<br>NUMBER | VS    | WS    | WST   | WSM   | FSE   | Part<br>NUMBER | VS    | WS    | WST   | WSM   | FSE    | Part<br>NUMBER | VS     | WS     | WST    | WSM    | FSE    |
|----------------|-------|-------|-------|-------|-------|----------------|-------|-------|-------|-------|--------|----------------|--------|--------|--------|--------|--------|
| 334            | —     | 1,840 | 1,810 | 1,960 | —     | 146            | —     | 5,020 | —     | —     | —      | 25             | 45,227 | —      | —      | 36,651 | —      |
| 337            | 2,630 | 1,790 | —     | —     | 3,433 | 150            | 5,900 | 4,940 | 4,670 | 6,540 | 12,178 | 31             | 39,946 | —      | —      | 31,364 | —      |
| 343            | 3,500 | 1,750 | 1,690 | 1,880 | 3,334 | 156            | 7,720 | 5,343 | 5,160 | 6,110 | 9,004  | 37             | 31,161 | —      | —      | 23,025 | —      |
| 350            | 2,440 | 1,700 | 2,020 | 2,090 | 3,236 | 157            | —     | 5,240 | —     | —     | —      | 43             | 24,067 | —      | —      | 18,019 | —      |
| 354            | —     | 1,730 | 1,960 | 2,080 | —     | 162            | 7,220 | 4,880 | 4,690 | 5,750 | 9,118  | 46             | —      | —      | 28,820 | 21,450 | —      |
| 356            | 2,370 | 1,680 | —     | 1,970 | 3,528 | 168            | 6,590 | 4,930 | 4,110 | 5,260 | 8,595  | 50             | 28,030 | 24,650 | 20,780 | 20,600 | 32,573 |
| 362            | 2,270 | 1,660 | 1,860 | 1,890 | 2,970 | 175            | 6,200 | 4,510 | 3,930 | 4,970 | 8,101  | 56             | —      | —      | —      | —      | 32,410 |
| 368            | 2,210 | 1,600 | 1,860 | 1,890 | 2,890 | 177            | —     | 4,410 | 3,960 | 4,990 | —      | 53             | —      | 21,280 | —      | —      | —      |
| 374            | —     | 1,520 | —     | —     | —     | 181            | 5,700 | 4,290 | 4,170 | 4,720 | 8,470  | 55             | —      | 19,440 | 18,130 | 18,260 | —      |
| 375            | 2,120 | 1,530 | 1,790 | 1,860 | 2,964 | 187            | 5,380 | 4,240 | 3,850 | 4,540 | 6,440  | 56             | 21,060 | 18,520 | 17,270 | 17,400 | —      |
| 381            | 2,060 | 1,470 | —     | —     | 2,701 | 193            | 5,100 | 4,020 | —     | —     | 8,047  | 59             | —      | 17,290 | 15,200 | 15,390 | —      |
| 387            | 2,010 | 1,500 | 1,620 | 1,750 | 2,934 | 196            | —     | 3,860 | 3,320 | 4,730 | —      | 62             | 17,850 | 19,500 | 15,700 | 14,730 | 22,107 |
| 393            | 1,930 | 1,510 | 1,560 | 1,690 | 2,529 | 200            | 4,720 | 3,740 | 3,410 | 4,560 | 7,650  | 65             | —      | 16,270 | —      | —      | —      |
| 400            | 1,880 | 1,470 | 1,560 | 1,660 | 2,264 | 206            | 5,970 | 3,550 | 3,340 | 3,810 | 7,103  | 66             | —      | 16,510 | 15,600 | 13,860 | —      |
| 406            | —     | 1,400 | —     | —     | —     | 212            | 5,550 | 3,400 | 3,120 | 3,560 | 6,603  | 68             | 15,340 | 15,470 | 15,600 | 13,510 | 19,520 |
| 412            | 2,090 | 1,350 | —     | —     | 2,367 | 215            | —     | 3,490 | 3,120 | 3,450 | —      | 71             | —      | 13,050 | —      | —      | —      |
| 413            | —     | 1,380 | —     | —     | —     | 216            | —     | 3,370 | —     | —     | —      | 75             | 12,350 | 14,290 | 12,750 | 12,190 | 22,451 |
| 418            | —     | 1,360 | —     | —     | —     | 218            | 5,290 | 3,290 | —     | —     | 6,316  | 78             | —      | 12,960 | 11,590 | 11,110 | —      |
| 425            | 1,960 | 1,360 | 1,350 | 1,440 | 2,350 | 225            | 5,050 | 3,220 | 2,820 | 3,240 | 6,040  | 81             | 15,380 | 12,470 | 11,300 | 10,150 | 17,414 |
| 431            | —     | 1,300 | —     | —     | —     | 231            | 4,720 | 3,020 | 2,730 | 3,040 | 5,786  | 84             | —      | 10,770 | —      | —      | —      |
| 433            | —     | 1,300 | —     | —     | —     | 236            | —     | 2,870 | —     | —     | —      | 87             | 12,800 | 10,570 | 10,660 | 10,340 | 17,374 |
| 437            | 1,850 | 1,290 | 1,250 | 1,360 | 2,215 | 237            | 4,520 | 2,890 | 2,560 | 3,380 | 6,343  | 90             | —      | 9,180  | —      | —      | —      |
| 443            | —     | 1,230 | —     | —     | —     | 243            | 4,240 | 2,920 | 2,480 | 3,180 | 5,089  | 93             | 11,500 | 9,400  | 9,100  | 8,760  | 12,757 |
| 450            | 1,750 | 1,270 | 1,210 | 1,300 | 2,116 | 250            | 4,063 | 2,750 | 3,040 | 3,090 | 4,994  | 96             | —      | 8,920  | —      | —      | —      |
| 456            | —     | 1,280 | —     | —     | —     | 255            | —     | 2,600 | 3,430 | 2,920 | —      | 98             | —      | 9,530  | 6,980  | 8,640  | —      |
| 462            | 1,670 | 1,240 | —     | —     | 2,001 | 256            | 3,900 | 2,600 | —     | —     | 5,118  | 100            | 9,800  | 9,160  | 7,800  | 8,940  | 18,675 |
| 468            | —     | 1,220 | —     | —     | —     | 262            | 3,680 | 2,500 | 2,780 | 2,750 | 4,073  | 102            | —      | 9,070  | 7,400  | 8,500  | —      |
| 472            | —     | 1,180 | —     | —     | —     | 268            | 3,540 | 2,470 | 2,630 | 2,680 | 4,797  | 103            | —      | 8,080  | —      | —      | —      |
| 475            | 1,580 | 1,180 | 1,160 | 1,180 | 2,193 | 275            | 3,400 | 2,340 | 2,560 | 2,790 | 3,981  | 106            | 11,490 | 8,610  | 8,660  | 11,260 | 11,446 |
| 481            | —     | 1,140 | —     | —     | —     | 281            | 3,220 | 2,380 | —     | —     | 4,074  | 109            | —      | 7,350  | —      | —      | —      |
| 487            | 1,520 | 1,120 | —     | —     | 1,816 | 287            | 3,100 | 2,260 | 2,260 | 2,590 | 3,927  | 112            | 9,990  | 7,470  | 7,960  | 9,820  | 12,107 |
| 493            | —     | 1,090 | —     | —     | —     | 293            | 2,940 | 2,140 | 2,200 | 2,460 | 3,727  | 115            | —      | 6,700  | —      | —      | —      |
| 500            | 1,440 | 1,050 | 1,020 | 1,080 | 1,724 | 295            | —     | 2,160 | —     | —     | —      | 118            | 9,220  | 7,350  | 6,320  | 9,040  | 15,056 |
| 511            | —     | 1,000 | —     | —     | —     | 300            | 2,840 | 2,080 | 2,150 | 2,410 | 3,537  | 121            | —      | 6,340  | —      | —      | —      |
| 512            | —     | 1,020 | —     | —     | —     | 306            | 3,670 | 2,020 | 2,090 | 2,290 | 3,245  | 125            | 8,500  | 6,750  | 6,500  | 8,042  | 11,970 |
| 525            | 1,310 | 970   | 1,280 | 1,210 | —     | 312            | 3,030 | 1,980 | 1,990 | 2,240 | 3,853  | 128            | —      | 5,860  | —      | —      | —      |
| 537            | —     | 900   | —     | —     | —     | 314            | —     | 1,980 | —     | —     | —      | 131            | 7,880  | 6,310  | 5,800  | 8,280  | 13,786 |
| 550            | 1,190 | 890   | 1,170 | 1,120 | —     | 315            | —     | —     | 1,990 | 2,190 | —      | 134            | —      | 5,960  | —      | —      | —      |
| 551            | —     | 870   | —     | —     | —     | 318            | 2,930 | 1,930 | —     | —     | 3,731  | 137            | 7,030  | 6,110  | 6,000  | 7,430  | 11,008 |
| 562            | —     | 840   | —     | —     | —     | 325            | 2,790 | 1,870 | 1,900 | 2,100 | 3,557  | 140            | —      | 5,580  | —      | —      | —      |
| 575            | 1,090 | 820   | 1,100 | 1,030 | —     | 331            | 2,700 | 1,840 | —     | —     | 3,595  | 143            | 6,560  | 5,490  | 5,160  | 6,700  | 11,594 |

## Maximum Allowable RPM for Spirolox Retaining Rings — Metric

| Part<br>NUMBER | VSM   | ES  | DNS | FS    | Part<br>NUMBER | VSM   | ES    | DNS   | FS    | Part<br>NUMBER | VSM   | ES    | DNS   | FS     | Part<br>NUMBER | VSM    | ES     | DNS    | FS     |
|----------------|-------|-----|-----|-------|----------------|-------|-------|-------|-------|----------------|-------|-------|-------|--------|----------------|--------|--------|--------|--------|
| 165            | 1,000 | 795 | 753 | 1,201 | 70             | 3,402 | 2,315 | 2,982 | 4,411 | 34             | 7,398 | 7,982 | 7,763 | 10,847 | 6              | 51,561 | -      | -      | -      |
| 170            | 945   | 749 | 715 | 1,151 | 71             | -     | 2,309 | -     | -     | 35             | 7,004 | 7,485 | 7,628 | 11,685 | 7              | 39,742 | -      | -      | -      |
| 175            | 894   | 697 | 671 | 1,088 | 72             | 3,218 | 2,321 | 2,805 | 3,947 | 36             | 6,641 | 6,903 | 8,474 | 11,640 | 8              | 40,518 | -      | -      | -      |
| 180            | 848   | 657 | 636 | 1,030 | 75             | 2,949 | 2,152 | 2,537 | 3,648 | 37             | -     | 7,227 | -     | -      | 9              | 35,627 | -      | -      | -      |
| 185            | 898   | 631 | 601 | 1,115 | 77             | -     | -     | 2,379 | 3,467 | 38             | 5,994 | 7,174 | 7,556 | 10,520 | 10             | 31,833 | -      | -      | -      |
| 190            | 854   | 591 | 577 | 860   | 78             | 3,158 | 2,007 | 2,304 | 3,731 | 40             | 7,573 | 6,172 | 7,181 | 10,841 | 11             | 25,202 | -      | -      | -      |
| 195            | 813   | 569 | 551 | 880   | 80             | 3,025 | 1,981 | 2,576 | 3,747 | 42             | 6,888 | 5,715 | 6,546 | 8,972  | 12             | 30,875 | 22,153 | -      | -      |
| 200            | 775   | 534 | 518 | 837   | 82             | 2,900 | 1,895 | 2,425 | 3,574 | 45             | 6,021 | 5,158 | 5,740 | 7,861  | 13             | 26,805 | 20,094 | 22,915 | 31,185 |
| 205            | -     | -   | 495 | 1,068 | 85             | 2,703 | 1,825 | 2,333 | 3,476 | 46             | -     | 4,909 | 5,505 | 7,006  | 14             | 22,359 | 18,471 | 19,967 | 21,602 |
| 210            | 802   | 579 | 466 | 1,077 | 88             | 2,526 | 1,737 | 2,143 | 3,252 | 47             | -     | 5,570 | 5,283 | 7,232  | 15             | 19,625 | 14,543 | 17,836 | 24,273 |
| 220            | 734   | 530 | 425 | 932   | 90             | 2,443 | 1,721 | 2,029 | 2,731 | 48             | 5,309 | 5,744 | 5,075 | 7,881  | 16             | 17,364 | 14,149 | 18,132 | 29,110 |
| 230            | 674   | 482 | 527 | 854   | 92             | -     | -     | -     | -     | 50             | 4,901 | 4,084 | 5,651 | 7,885  | 17             | 14,958 | 15,923 | 15,677 | 19,841 |
| 240            | 622   | 444 | 486 | 735   | 95             | 2,174 | 1,509 | 1,777 | 2,598 | 52             | 6,057 | 3,616 | 5,251 | 7,318  | 18             | 13,439 | 12,233 | 16,195 | 22,605 |
| 250            | 575   | 413 | 451 | 726   | 98             | -     | -     | 1,659 | 2,377 | 53             | -     | 3,450 | -     | -      | 19             | 12,140 | 11,685 | 14,221 | 20,417 |
| 260            | 582   | 381 | 424 | 743   | 100            | 1,955 | 1,508 | 1,579 | 2,542 | 54             | -     | 3,295 | 4,842 | 6,811  | 20             | 11,066 | 10,810 | 12,948 | 18,532 |
| 270            | 541   | 354 | 390 | 718   | 102            | -     | -     | 1,530 | 2,746 | 55             | 5,380 | 3,360 | 4,680 | 6,576  | 21             | 15,326 | 9,641  | 12,475 | 16,896 |
| 280            | 505   | 328 | 363 | 714   | 105            | 2,082 | 1,399 | 1,435 | 2,640 | 56             | 5,238 | 3,215 | 4,525 | 6,354  | 22             | 13,341 | 10,397 | 11,421 | 13,523 |
| 290            | 472   | -   | 382 | 624   | 108            | -     | -     | 1,368 | 2,418 | 58             | 4,890 | 3,111 | 4,359 | 5,942  | 23             | -      | 9,652  | 10,495 | 14,213 |
| 300            | 443   | -   | 357 | 584   | 110            | 1,902 | 1,323 | 1,391 | 2,279 | 59             | -     | 2,982 | -     | -      | 24             | 11,035 | 8,479  | 10,825 | 19,083 |
| 310            | -     | -   | 342 | -     | 115            | 1,745 | 1,248 | 1,280 | 2,090 | 60             | 4,575 | 2,862 | 4,050 | 4,793  | 25             | 10,214 | 8,524  | 10,020 | 11,982 |
| 320            | -     | -   | 316 | -     | 120            | 1,606 | 1,176 | 1,175 | 1,694 | 61             | -     | 2,683 | -     | -      | 26             | 12,483 | 8,642  | 9,301  | 12,494 |
| 330            | -     | -   | 299 | -     | 125            | 1,483 | 1,092 | 1,088 | 1,778 | 62             | 4,323 | 2,884 | 3,738 | 5,490  | 27             | -      | 11,357 | 8,721  | 14,320 |
| 340            | -     | -   | 343 | -     | 130            | 1,374 | 993   | 1,017 | 1,647 | 63             | 4,220 | 2,773 | 3,691 | 5,071  | 28             | 10,648 | 10,259 | 8,609  | 15,229 |
| 350            | -     | -   | 322 | -     | 135            | 1,270 | 934   | 952   | 1,530 | 64             | -     | 2,780 | -     | -      | 29             | 9,973  | 9,765  | 8,060  | 18,016 |
| 360            | -     | -   | 305 | -     | 140            | 1,186 | 870   | 888   | 1,519 | 65             | 3,967 | 2,577 | 3,430 | 4,806  | 30             | 9,534  | 9,149  | 7,562  | 12,189 |
| 370            | -     | -   | 291 | -     | 145            | -     | 821   | 835   | 1,331 | 66             | -     | 2,526 | -     | -      | 31             | -      | 8,495  | -      | -      |
| 380            | -     | -   | 276 | -     | 150            | 1,022 | 755   | 788   | 1,470 | 67             | -     | 2,275 | 3,239 | 4,463  | 32             | 8,437  | 7,778  | 8,686  | 14,215 |
| 390            | -     | -   | 262 | -     | 155            | 961   | 891   | 733   | 1,379 | 68             | 3,602 | 2,486 | 3,201 | 3,945  | 33             | -      | -      | 8,205  | 9,511  |
| 400            | -     | -   | 251 | -     | 160            | 1,060 | 831   | 690   | 1,296 | 69             | -     | 2,438 | -     | -      |                |        |        |        |        |

## Installation Stress Analysis

The equations provided are used to check that the elastic stress limit of the ring material is not exceeded by stress due to installation. Standard parts that are assembled manually in the recommended shaft/bore and groove diameters do not require stress analysis. Special rings, or rings being assembled with special tooling, require stress analysis.

To select a safe stress value, it is necessary to estimate the elastic limit of the raw material. The minimum tensile strength, as shown in the materials table of the catalog, can be used as a suitable estimate. As with any theoretical calculation, a closer analysis of the actual application may reveal that these stress values can be exceeded. However, particular consideration must be made to functional characteristics such as installation method, the number of times the ring will be installed and removed, thrust load and/or centrifugal capacity.

After forming, the ring's natural tendency is to return to its original state. This places the inner edge of the radial wall in residual tension and the outer edge in residual compression. To account for the residual stress in the ring when expansion is taking place, only 80% of the minimum tensile strength should be used to compare to the installation stress; see Table 4.

In special designs, where the installation stress exceeds the material's elastic limit, rings can be produced to diameters which will yield a predetermined amount during assembly. Once installed, the ring will have the proper cling (grip) on the groove.

## Installation Stress

### Formula:

#### For external rings

$$S_E = \frac{E b (D_S - D_I)}{(D_I + b)(D_S + b)}$$

#### For internal rings

$$S_C = \frac{E b (D_O - D_H)}{(D_O - b)(D_H - b)}$$

Where:

- $S_E$  = Stress due to expansion (psi)
- $S_C$  = Stress due to compression (psi)
- $E$  = Modulus of elasticity (psi)
- $b$  = Radial wall (in)
- $D_S$  = Shaft diameter (in)
- $D_H$  = Housing diameter (in)
- $D_I$  = Free inside diameter, minimum (in)
- $D_O$  = Free outside diameter, maximum (in)

| Application | Percent of Minimum Tensile Strength |
|-------------|-------------------------------------|
| Shaft       | 80%                                 |
| Housing     | 100%                                |

Table 4

**Example:** Compare theoretical installation stress to percent of minimum tensile strength.

1. WS-100-S02

$$S_E = \frac{28,000,000 (.075) (1.000 - .933)}{(.933 + .075)(1.000 + .075)}$$

$$S_E = 129,845 \text{ psi}$$

Minimum tensile strength of the ring material: 210,000 psi.

Using 80%, (Table 4), of 210,000 psi = 168,000 psi.

$$129,845 \text{ psi} < 168,000 \text{ psi}$$

Since the installation stress is less than 80% of the minimum tensile strength, permanent set is not expected.

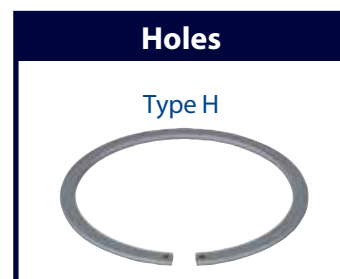
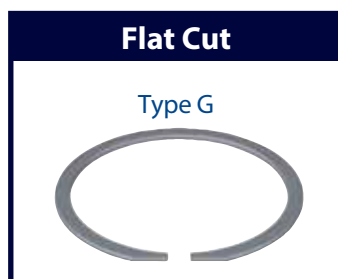
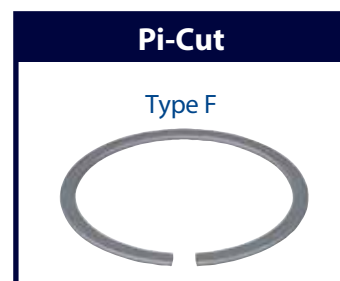
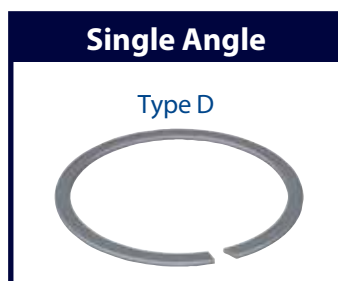
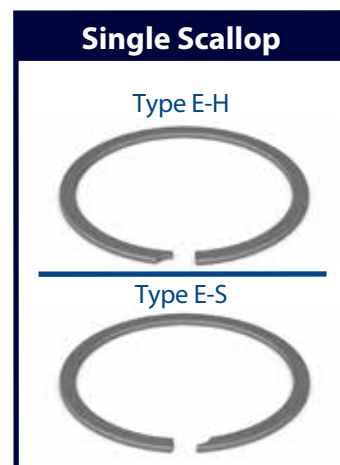
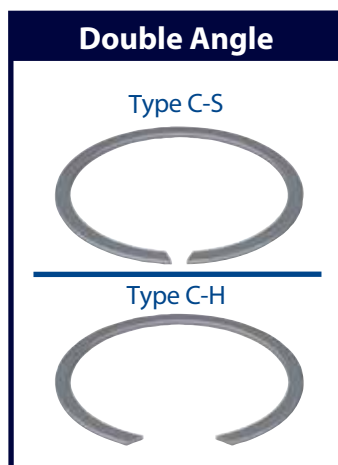
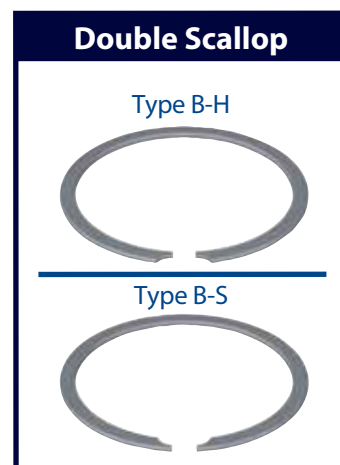
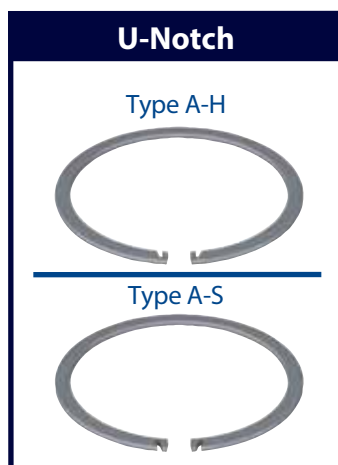
# End Configurations - Constant Section Rings Series

## End Configurations

Smalley offers 4 series of Eaton style snap rings from stock. Additional end types can be manufactured to meet your snap ring requirements. Inquire about the following end types:

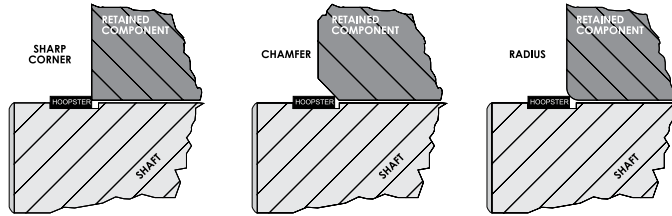
### Material Hardness

| Thickness<br>(Inch) | Hardness (Rc)<br>Min. |
|---------------------|-----------------------|
| Up to .022          | 46.0                  |
| Over .022 to .050   | 44.0                  |
| Over .050 to .078   | 42.0                  |
| Over .078           | 40.0                  |



## Ring Abutment

Unlike a conventional Spiral Retaining Ring or Snap Ring, the retained component in a Hoopster® Retaining Ring\* assembly may have a corner break. Thrust load is not sacrificed when the retained component has a broken corner because the moment arm is negligible in a Hoopster design.

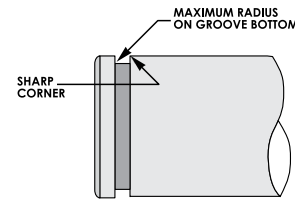


The 3 sketches above illustrate acceptable abutment practice.

## Groove Design and Geometry

Groove deformation is by far the most common design limitation of most retaining rings. Unlike a conventional retaining ring or snap ring that fails by deforming and twisting, the Hoopster Retaining Ring shows superior strength from its low profile and mechanical advantage over traditional retaining rings under load. With a Hoopster, there is no moment arm that twists the ring causing premature failure as with a conventional retaining ring.

The shallow groove specification of a Hoopster makes the groove wall a critical specification, to ensure the function of the ring. To obtain maximum load capacity from a Hoopster Retaining Ring, it is essential to have sharp corners on the groove. The maximum radius on the groove bottom should be no greater than 10% of the ring's radial wall. Maintaining a sharp corner on the top of the groove is just as critical.



**Formula:** Maximum Radius on Groove Bottom = .10b

Where: b = Ring radial wall

## Thrust Capacity

The shallow groove depth associated with a Hoopster, in combination with the groove material, are the controlling factors in determining thrust capacity. The Hoopster does not twist when loaded so pure thrust load based on the yield strength of the groove material maximizes the Hoopster's load carrying capacity.

**Formula:**

$$P_G = \frac{D d S_y \pi}{K}$$

Where:

- $P_G$  = Allowable thrust load based on groove deformation (lb)
- $D$  = Shaft or housing diameter (in)
- $d$  = Groove depth (in)
- $S_y$  = Yield strength of groove material (psi)
- $K$  = Safety factor (2 recommended)

### Typical Groove Material Yield Strengths

|                       |               |
|-----------------------|---------------|
| Hardened Steel 8620   | 110,000 psi   |
| Cold Drawn Steel 1018 | 70,000 psi    |
| Hot Rolled Steel 1018 | 45,000 psi    |
| Aluminum 2017         | 40,000 psi    |
| Cast Iron             | 10-40,000 psi |

Table 5

\*PATENT PENDING

# Springs Checklist

## Application Checklist

**Smalley Wave Springs**

**Custom Orders...Our Specialty**

**Fax to: 847.719.5999**

Quick Delivery on Custom Orders • No-Tooling-Cost • Precise Specifications • Engineering/Design Assistance  
Complete this application checklist and challenge Smalley's Engineering staff.

Name \_\_\_\_\_ Title \_\_\_\_\_ Date \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City/State/Zip Code \_\_\_\_\_ Country \_\_\_\_\_

Phone \_\_\_\_\_ Fax \_\_\_\_\_

Email \_\_\_\_\_

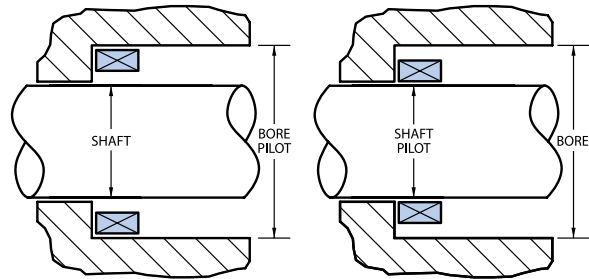
**Dimensions In:** ( ) Imperial Units ( ) Metric Units

Operates in \_\_\_\_\_ bore diameter

Inside diameter clears \_\_\_\_\_ shaft

Specify which diameter the spring should pilot closest to:

( ) Bore ( ) Shaft



### Load Deflection (Select One)

#### Group A

Min - Max Load @ Work Height ( ) lb @ in ( ) N @ mm

Free Height \_\_\_\_\_ Approximate

#### Group B

Min - Max Load @ Work Height ( ) lb @ in ( ) N @ mm

Min - Max Load @ Work Height ( ) lb @ in ( ) N @ mm

Free Height \_\_\_\_\_ Approximate

#### Group C

Free Height \_\_\_\_\_ (min) — \_\_\_\_\_ (max)

# of Waves \_\_\_\_\_ Material Thickness \_\_\_\_\_

Radial Wall \_\_\_\_\_

### Sketch

### Material

Consider the environment:

Temperature \_\_\_\_\_ °  
( ) F ( ) C

Corrosive Media \_\_\_\_\_

\*Carbon Steel ( )

\*17-7 PH/CH900 Stainless ( )

302 Stainless Steel ( )

316 Stainless Steel ( )

Inconel X-750 ( )

Other \_\_\_\_\_ ( )

### Finish

\* Oil dipped ( )  
(Carbon Steel)

\* Vapor degreased ( )  
and ultrasonic cleaned  
(Stainless Steel)

Passivate ( )

Black Oxide ( )

Phosphate Coat ( )

Vibratory Deburr ( )

Other \_\_\_\_\_ ( )

### Fatigue: Specify estimated cycle life

( ) Static Application

( ) 10<sup>6</sup> Cycle Life

( ) Under 10<sup>5</sup> Cycle Life

( ) Over 10<sup>6</sup> Cycle Life

( ) 10<sup>5</sup> Cycle Life

**Quantity:** Prototype \_\_\_\_\_

Production \_\_\_\_\_

**Application:** (Description)

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

\*Denotes standard material or finish.

## Application Checklist

Custom Orders...Our Specialty

### Rings Checklist

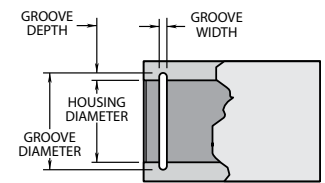
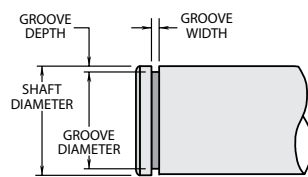
Fax to: 847.719.5999

Quick Delivery on Custom Orders • No-Tooling-Cost • Precise Specifications • Engineering/Design Assistance  
Complete this application checklist and challenge Smalley's Engineering staff.

Name \_\_\_\_\_ Title \_\_\_\_\_ Date \_\_\_\_\_  
 Company \_\_\_\_\_  
 Address \_\_\_\_\_  
 City/State/Zip Code \_\_\_\_\_ Country \_\_\_\_\_  
 Phone \_\_\_\_\_ Fax \_\_\_\_\_  
 Email \_\_\_\_\_

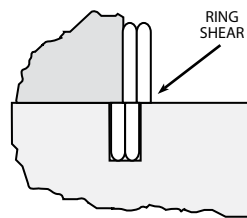
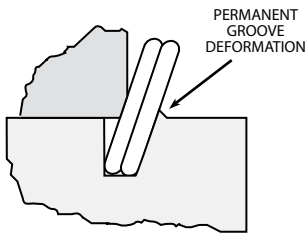
### Dimensions In: ( ) Imperial Units ( ) Metric Units

Housing Diameter \_\_\_\_\_  
 Shaft Diameter \_\_\_\_\_  
 Groove Diameter \_\_\_\_\_  
 Groove Width \_\_\_\_\_  
 RPM \_\_\_\_\_



Ring Radial Wall \_\_\_\_\_ Ring Thickness \_\_\_\_\_

### Thrust Capacity



#### 2. Ring Shear

Occurs when maximum capacity is limited by the retaining ring (groove material is hardened)

If thrust is a consideration specify:

Groove Material \_\_\_\_\_

Load Capacity \_\_\_\_\_ ( ) lb ( ) N

#### 1. Groove Deformation

Occurs when maximum capacity is limited by the groove material (groove material is soft)

### Finish

\* Oil dipped ( )  
 (Carbon Steel)  
 \* Vapor degreased ( )  
 and ultrasonic cleaned  
 (Stainless Steel)  
 Passivate ( )  
 Black Oxide ( )  
 Phosphate Coat ( )  
 Vibratory Deburr ( )  
 Other \_\_\_\_\_ ( )

### Material

Consider the environment:  
 Temperature \_\_\_\_\_ °  
 ( ) F ( ) C  
 Corrosive Media \_\_\_\_\_  
 \*Carbon Steel ( )  
 \*302 Stainless Steel ( )  
 \*316 Stainless Steel ( )  
 Inconel X-750 ( )  
 A-286 ( )  
 Other \_\_\_\_\_ ( )

**Quantity:** Prototype \_\_\_\_\_

Production \_\_\_\_\_

**Application:** (Description)

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

### Sketch

\*Denotes standard material or finish.



# Laminar Rings Checklist

## Application Checklist Custom Orders...Our Specialty

### Laminar Rings Checklist

Fax to: 847.719.5999

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Complete this application checklist and challenge Smalley's Engineering staff.

Name \_\_\_\_\_ Title \_\_\_\_\_ Date \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City/State/Zip Code \_\_\_\_\_ Country \_\_\_\_\_

Phone \_\_\_\_\_ Fax \_\_\_\_\_

Email \_\_\_\_\_

### Series

(see pages 103 - 109 for more information)

#### A. Single-Turn Ring Sets

(Imperial - YH, YHK, YS, or YSK) ( )

(Metric - QH, QHK, QS, or QSK) ( )

#### B. Double-Turn Ring Sets

(Imperial - YHD, YHKD, YSD, or YSKD) ( )

(Metric - QHD, QHKD, QSD, or QSKD) ( )

### Material

#### Standard

#### \*Maximum Recommended Operating Temperature

|                              | °F  | °C  | ( ) |
|------------------------------|-----|-----|-----|
| Carbon Steel (SAE 1070-1090) | 250 | 120 | ( ) |
| 302 Stainless Steel          | 400 | 200 | ( ) |

#### Special

#### \*Maximum Recommended Operating Temperature

|                               | °F       | °C      | ( ) |
|-------------------------------|----------|---------|-----|
| 17-7 PH/CH900 Stainless Steel | 650      | 343     | ( ) |
| A286 Alloy                    | 1000     | 538     | ( ) |
| 316 Stainless Steel           | 400      | 204     | ( ) |
| Inconel X-750                 | 700-1300 | 370-700 | ( ) |
| Elgiloy                       | 800      | 427     | ( ) |
| Other _____                   |          |         |     |

### Quantity (sets):

Prototype \_\_\_\_\_

Production \_\_\_\_\_

### Application: (Description)

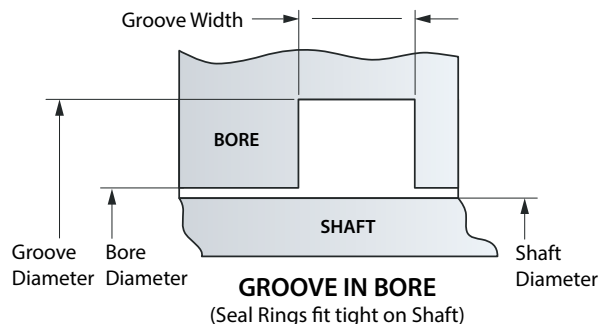
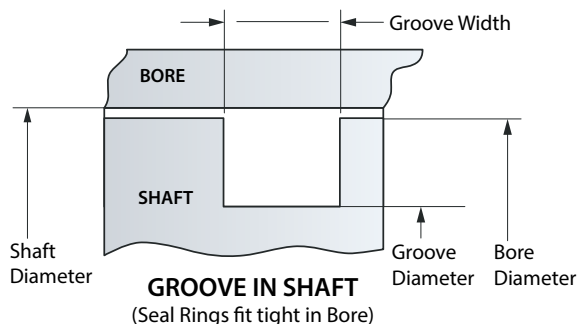
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

### Sketch

### Dimensions In: ( ) Imperial Units ( ) Metric Units

Bore Diameter \_\_\_\_\_ Shaft Diameter \_\_\_\_\_

Groove Diameter \_\_\_\_\_ Groove Width \_\_\_\_\_



Smalley Steel Ring offers **free** samples of catalog retaining rings, constant section rings and wave springs to test in your application.

## Shipping Address

*Telephone number required for samples*

**FAX OR EMAIL NOW!**  
847.719.5999 • info@smalley.com

Name \_\_\_\_\_  
Company \_\_\_\_\_  
Address \_\_\_\_\_  
City/State/Zip Code \_\_\_\_\_ Country \_\_\_\_\_  
Phone \_\_\_\_\_ Fax \_\_\_\_\_  
Email \_\_\_\_\_

## Shipping Method

All samples are sent out by US Mail. For expedited delivery, please provide a valid UPS or FedEx account number and specify the service to bill. Please call Smalley at 847.719.5900 to request other delivery methods.

☐ **Regular US Mail:** *(free)*

☐ **UPS:** Account number for charges *(required)* \_\_\_\_\_  
☐ Ground ☐ Overnight ☐ 2nd Day

☐ **FedEx:** Account number for charges *(required)* \_\_\_\_\_  
☐ Overnight ☐ 2nd Day

## Specific Sample

Please provide us with the part number you would like to test and the requested material:

Smalley Part Number: \_\_\_\_\_ ☐ Carbon Steel ☐ Stainless Steel

Smalley Part Number: \_\_\_\_\_ ☐ Carbon Steel ☐ Stainless Steel

## Assorted Samples

☐ Please send me a sample bag of assorted Smalley retaining rings and wave springs.

**Smalley reserves the right to authorize all sample requests.**

# How To Order

## Specifying Smalley Part Numbers

Smalley ring and spring part numbers consist of three steps. Please use the following guide to correctly identify your part number:

### WHT-50-PA-S02

- Specifies type of material (see Table 3)
- Specifies the type of finish to be applied on the material (see Table 2)
- Specifies series and housing/shaft diameter (see Tables 1a & 1b)

# 1

### Step 1: Base Part Numbers

#### Select Series...

**TABLE 1a: Retaining Ring Series**

| SERIES                         | # TURNS | INTERNAL | EXTERNAL |
|--------------------------------|---------|----------|----------|
| Light Duty                     | 1       | VH       | VS       |
| Light Duty*                    | 1       | VHM      | VSM      |
| Medium Duty                    | 2       | WH       | WS       |
| Medium Heavy Duty              | 2 or 3  | WHT      | WST      |
| Heavy Duty                     | 2       | WHM      | WSM      |
| Constant Section               | 1       | FHE      | FSE      |
| Constant Section (Eaton Style) | 1       | XAH      | XAS      |
| Constant Section (Eaton Style) | 1       | XDH      | XDS      |
| Aerospace*                     | 2       | EH       | ES       |
| DIN Series*                    | 2       | DNH      | DNS      |
| Constant Section*              | 1       | FH       | FS       |
| Hoopster                       | 1       | HH/HHU   | HS       |
| Hoopster*                      | 1       | HHM/HHMU | HSM      |
| WaveRing                       | 2       | WHW      | WSW      |

\* Metric Series

**TABLE 1b: Wave Spring Series**

| SERIES                        | PREFIX |
|-------------------------------|--------|
| Standard Single-Turn          | SSR    |
| Bearing Preload*              | SSB    |
| Narrow Section Single-Turn    | SSR-N  |
| Shim                          | SSRS   |
| Crest-to-Crest                | C      |
| Crest-to-Crest with Shim End  | CS     |
| Crest-to-Crest*               | CM     |
| Crest-to-Crest with Shim End* | CMS    |
| Wavo                          | RW     |

\* Metric Series

### Then Specify Part Diameter

See the product tables for a complete listing of available diameters in stock. Below are some base part number examples:

|                |  |
|----------------|--|
| <b>WH-100</b>  | 1.000" Medium Duty Internal Ring               |
| <b>WSM-150</b> | 1.500" Heavy Duty External Ring                |
| <b>C150</b>    | 1.500" Crest-to-Crest Wave Spring              |
| <b>CS125</b>   | 1.250" Crest-to-Crest Wave Spring w/ Shim Ends |
| <b>RW-0237</b> | 2.375" Wavo Spring                             |

## 2

### Step 2: Finish

To prevent corrosion, carbon steel has an oil dip finish. Stainless steel parts are vapor degreased and go through an ultrasonic cleaning process. To specify a special finish on retaining rings or wave springs add the appropriate suffix to the part number preceding the material suffix. For standard materials, there is no designation necessary.

**TABLE 2: Finish**

| STANDARD  |             |
|---|-------------|
| Finish  | Designation |
| Carbon Steel — Oil Dip                              | None        |
| Stainless Steel — Vapor Degrease & Ultrasonic Clean | None        |

| SPECIAL          |             |
|------------------|-------------|
| Finish           | Designation |
| Passivation      | <b>PA</b>   |
| Black Oxide      | <b>BA</b>   |
| Phosphate Coat   | <b>PS</b>   |
| Cadmium Plate    | <b>CD</b>   |
| Vibratory Deburr | <b>DV</b>   |

Example: WH-100-**PA**-S02 1.000" Medium Duty Housing Ring, with **passivation** in 302 stainless steel

## 3

### Step 3: Material

To specify the material, add the appropriate designation below to the end of the part number.

**TABLE 3: Material**

| STANDARD                               |             |
|--|-------------|
| Material                               | Designation |
| Carbon Steel SAE 1070-1090             | None        |
| 302 Stainless Steel (Retaining Rings)  | <b>S02</b>  |
| 316 Stainless Steel (Retaining Rings)  | <b>S16</b>  |
| 17/7 PH Stainless Steel (Wave Springs) | <b>S17</b>  |

| SPECIAL          |             |
|------------------|-------------|
| Material         | Designation |
| Inconel X-750    | <b>INX</b>  |
| A286             | <b>A86</b>  |
| Beryllium Copper | <b>BEC</b>  |
| Phosphor Bronze  | <b>PHB</b>  |
| Elgiloy          | <b>LGY</b>  |

Examples: VH-50 0.500" Light Duty Housing Ring in **Carbon Steel**  
 VS-100-**S02** 1.000" Light Duty Shaft Ring in **302 Stainless Steel**  
 C050-M5-**INX** 0.500" Crest-to-Crest Wave Spring in **Inconel X-750**

*Note: Custom wave springs can be manufactured in 302 & 316 stainless steel, retaining rings can be manufactured in 17-7 PH stainless steel upon request.*

### Packaging

Smalley has the flexibility to package retaining rings and wave springs using a variety of methods to simplify your assembly process. Standard packaging is based on the diameter. As a general rule for both retaining rings and wave springs:

- 15/16" and under diameters are bulk packaged.
- 13/8" and over diameters are generally tube (coin) packaged in lengths 10" to 18".

### Placing An Order

Smalley customer service representatives are available to assist you and guide you through the ordering process. For standard catalog rings and springs, Smalley's customer service department can assist with pricing, ordering and delivery information. Contact Smalley customer service at:



**847.719.5900**



**847.719.5999**



**sales@smalley.com**

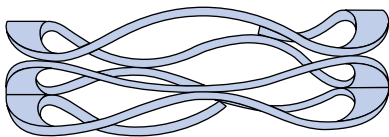
# Glossary

**Bore Diameter:** (See housing diameter)

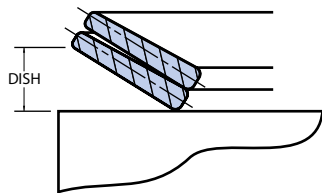
**Centrifugal Capacity (N):** A mathematical expression for determining the speed (in revolutions per minute, rpm) at which a retaining ring will lose cling on the groove.

**Cling:** A value that signifies the amount of “interference fit” between a retaining ring and its groove.

**Crest-To-Crest:** Term used to identify a Smalley Flat Wire Compression spring in a “Series” configuration, having a sinusoidal waveform. The wave contour in each 360° turn provides a peak to valley relationship that decreases spring rate proportionally to the number of turns.

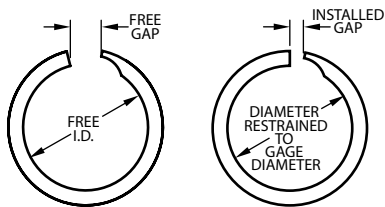


**Dish:** This ring dimension is the height difference in the ring cross section's axis of symmetry between O.D. and I.D. as illustrated below:



**Edgewinding:** Smalley's manufacturing method of circle coiling rectangular section flat wire on edge.

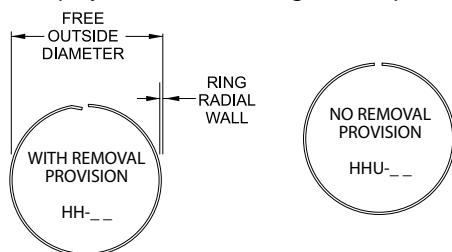
**Free Gap:** The distance between the “Free Ends” of a ring or spring as it rests in its free state.



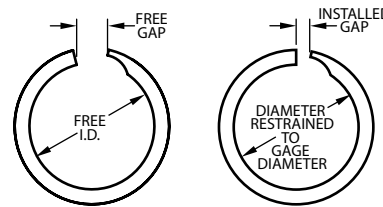
**Hardness:** The resistance of a material to plastic deformation, usually by indentation.

**Helix:** (see pitch)

**Hoopster:** Term used to identify the style of retaining ring with minimal radial projection and shallow groove depth.



**Housing Diameter (DH):** Also referred to as “bore” diameter. This dimension represents the inside diameter of the assembly where an internal retaining ring is installed.

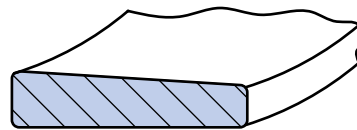


**Hydrogen Embrittlement:** A condition where hydrogen is absorbed within the internal grain structure of metal tending to make it susceptible to cracking and failure, particularly under sustained loads. Environments such as hydrogen sulfide (H2S) or processes such as electroplating or pickling can induce hydrogen embrittlement.

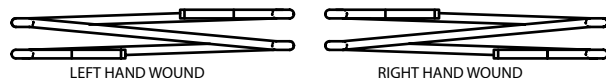
**Installed Gap:** (see Free Gap) This ring dimension is the distance between the ring ends while the ring is restrained at a specific gage diameter. Recommended as a more precise method of control over a free gap.

**Installation Stress (SC) or (SE):** Mathematical expression based on a radial strain. Useful in determining how far a Spirolox Retaining Ring can be expanded or contracted during installation.

**Keystone:** Derived from the definition of a “wedge” shaped stone. This term, illustrated below, refers to the “wedge” shaped cross section as a result of edgewinding flat wire.

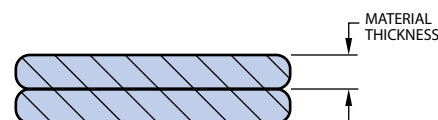


**Left Hand Wound:** Also referred to as “reverse wound”, design term signifying the counter-clockwise winding direction of a pitched coil.

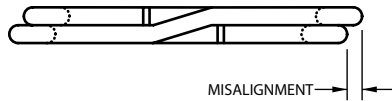


**Linear Spring:** Term used to identify a straight length of flat wire having a sinusoidal waveform. Used as a compression spring in both axial and radial applications.

**Material Thickness (t):** Also referred to as “wire” thickness. This dimension, as illustrated below, is useful in determining the overall ring thickness.

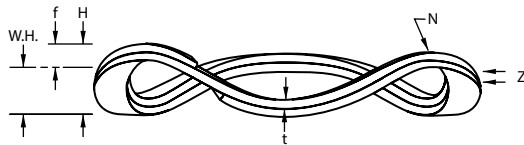


**Misalignment:** Also referred to as “skew”, this ring dimension is the radial variance of a multiple turn retaining.



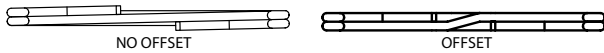
**Modulus of elasticity (E):** A measure of the rigidity of a material.

**Nested:** Term used to identify a Smalley Flat Wire Compression Spring in a “Parallel” configuration, having a sinusoidal waveform. The wave contour in each 360° turn matches (nests), increasing the spring rate proportionally to the number of turns.



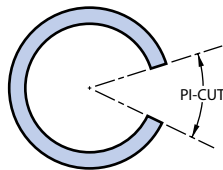
**Number of Turns (n):** The number of 360° turns of flat wire formed in a retaining ring or wave spring.

**Offset:** As illustrated below, this design feature is a bend in the material at the gap. This provides flat and parallel surfaces for ease of installation.

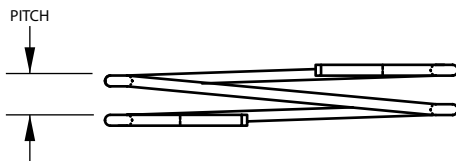


**Permanent Set:** A ring that has been expanded or contracted to a point where its elastic properties have been exceeded and does not return to its original diameter is said to have taken “permanent set”.

**Pi-Cut Ends:** Term signifying a particular ring design where the ends have been cut in an angular direction from the center of the ring as illustrated below.



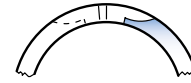
**Pitch:** Also referred to as helix, this ring dimension is the distance between two adjacent layers of the retaining ring.



**Radial Wall (b):** Width of a retaining ring when measured from inside to outside edge.

**Radius Notch:** (see Removal Notch)

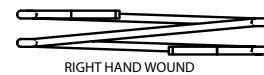
**Removal Notch:** Also referred to as a “radius notch” or “scallop”, this standard Spirolox Retaining Ring design feature is used to facilitate removal of the ring from its groove by means of a screwdriver or similar type tool.



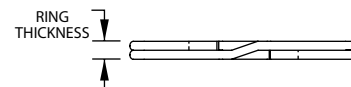
**Residual Stress:** Stress induced by a cold working process such as edgewinding. It may or may not be beneficial, depending upon the application.

**Reverse Wound:** (see left hand wound)

**Right Hand Wound:** Design term signifying the clockwise direction that a Spirolox Retaining Ring is normally wound. (also see Left Hand Wound)



**Ring Thickness (T):** Total thickness of an edgewound retaining ring. It may be determined by multiplying the material thickness by the number of turns and adding in the keystone value.



**Rod Diameter:** (see shaft diameter)

**Safety Factor (K):** Mathematical constant used in many design formulas to account for theoretical inaccuracies.

**Scallop:** (see Removal Notch)

**Shaft Diameter (DS):** This dimension represents the outside diameter of the assembly where an external retaining ring is installed.

**Shear Strength (SS):** An index of the quality of a material through a mathematical expression which divides the force required to shear a material by its cross-sectional area.

**Stress Relieve:** Low temperature heat treatment for removing any residual stresses induced by edgewinding and/or forming.

**Tensile Strength:** An index of the quality of a material through a mathematical expression which divides the material's load capacity in tension by its original cross-sectional area. Particularly accurate for spring steels, as there is only a small difference between ultimate tensile strength and yield strength.

**Thrust Load Capacity (PG) or (PR):** Overall capacity of an assembly to withstand a given value of thrust load in pounds. The limitation being the lesser of two mathematical calculations: ring thrust load capacity (PR) or groove thrust load capacity (PG).

**Yield Strength (Sy):** The stress at which a material exhibits initial plastic deformation.

**WAVO:** Single turn round wire wave spring.





## Notes

[illegible]

[illegible]

# Interchange Listing

| SMALLEY® | SPIROLOX®<br>SERIES | MILITARY<br>MIL-DTL-27426 | AEROSPACE<br>AS3219 | METRIC<br>AEROSPACE<br>MA 4035 | EUROPEAN<br>SPECIFICATION<br>DIN  | WALDES<br>TRUARC | EATON | INDUSTRIAL<br>RETAINING<br>RING | OTHER<br>RINGS   | ANDERTON |
|----------|---------------------|---------------------------|---------------------|--------------------------------|---|------------------|-------|---------------------------------|------------------|----------|
| VH       | UR                  | ---                       | ---                 | ---                            | <div>Groove Interchange Only</div> <div>Use a Smalley Retaining Ring to fit into the same groove of these stamped Retaining Rings (circlips).</div> |                  |       |                                 |                  |          |
| VS       | US                  | ---                       | ---                 | ---                            |   |                  |       |                                 |                  |          |
| WH       | RR                  | /3                        | AS4299<br>AS3217    | ---                            |   |                  |       |                                 |                  |          |
| WS       | RS                  | /1                        | AS4299<br>AS3218    | ---                            |   |                  |       |                                 |                  |          |
| WHT      | RRT                 | ---                       | ---                 | ---                            | ---   | ---              | NAN   | ---                             | UHB              | ---      |
| WST      | RST                 | ---                       | ---                 | ---                            | ---   | ---              | XAN   | ---                             | USC              | ---      |
| WHM      | RRN                 | /4                        | AS4299<br>AS3215    | ---                            | ---   | N5000<br>5008    | IN    | 3000<br>4000                    | HO<br>HOI<br>UHO | N1300    |
| WSM      | RSN                 | /2                        | AS4299<br>AS3216    | ---                            | ---   | 5100<br>5108     | EN    | 3100<br>4100                    | SH<br>SHI<br>USH | N1400    |
| DNH      | ---                 | ---                       | ---                 | ---                            | DIN 472   | ---              | ---   | ---                             | DHO              | D1300    |
| DNS      | ---                 | ---                       | ---                 | ---                            | DIN 471   | ---              | ---   | ---                             | DSH              | D1400    |
| EH       | ---                 | ---                       | ---                 | MA 4017                        | ---   | ---              | ---   | ---                             | ---              | ---      |
| ES       | ---                 | ---                       | ---                 | MA 4016                        | ---   | ---              | ---   | ---                             | ---              | ---      |
| FH       | ---                 | ---                       | ---                 | ---                            | DIN 472   | ---              | ---   | ---                             | DHO              | D1300    |
| FS       | ---                 | ---                       | ---                 | ---                            | DIN 471   | ---              | ---   | ---                             | DSH              | D1400    |
| XAH      | ---                 | ---                       | ---                 | ---                            | ---   | ---              | NAN   | ---                             | UHB              | ---      |
| XAS      | ---                 | ---                       | ---                 | ---                            | ---   | ---              | XAN   | ---                             | USC              | ---      |
| XDH      | ---                 | ---                       | ---                 | ---                            | ---   | ---              | ND    | ---                             | HN               | ---      |
| XDS      | ---                 | ---                       | ---                 | ---                            | ---   | ---              | XD    | ---                             | SNL              | ---      |
| XNH      | ---                 | ---                       | ---                 | ---                            | ---   | ---              | IN    | ---                             | UHO              | ---      |
| XNS      | ---                 | ---                       | ---                 | ---                            | ---   | ---              | EN    | ---                             | USH              | ---      |

## Notes

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# WHERE CAN I FIND MORE THAN JUST WORLD-CLASS PRODUCTS?

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**Ask Smalley.** Around the globe, Smalley products have earned a reputation for unsurpassed precision and performance. Our commitment to customer service is no different.

Whether it is providing customized supply chain solutions worldwide, meeting your JIT delivery requirements, or sending you free product samples for your critical test purposes, our customer service professionals know exactly what engineers expect. And we deliver, again and again. See for yourself.

Shelli  
Smalley Engineer





# SMALLEY

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Smalley also has representatives who can provide Spanish and Portuguese language support: [americas@smalley.com](mailto:americas@smalley.com)