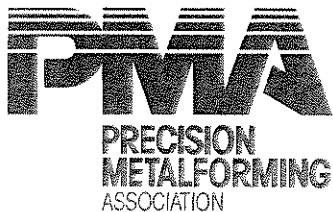
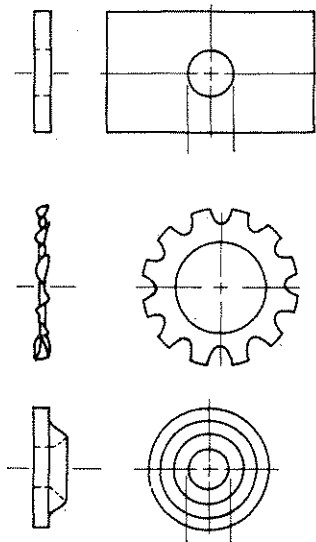


# FACTS ABOUT WASHERS

4th edition

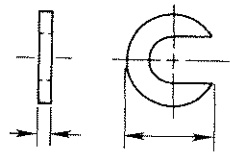


prepared by the Washer Division  
Precision Metalforming Association

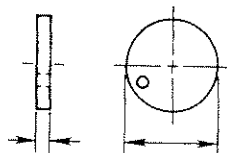


# Washers— Configurations unlimited!

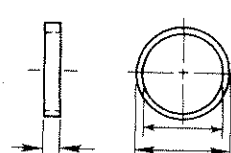
In a booklet of limited size, it is physically impossible to show or even list all the kinds of washers made by the members of the Washer Division of the Precision Metalforming Association. Types of washers include: tab, keyslot, eccentric, oval, and a host of others in endless combinations. A few of the more common types are shown here. If you require washers, members of the Washer Division can furnish them in any type, size, material or finish.



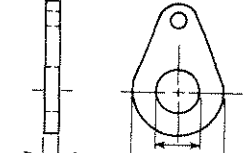
"C" Shape



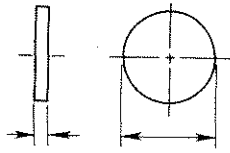
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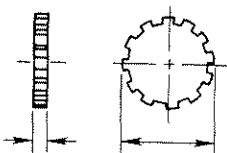
Machinery Bushing



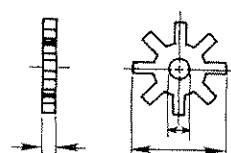
Retaining



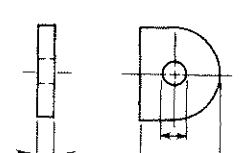
Disc



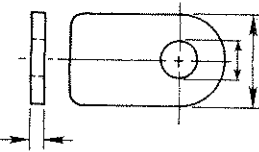
Star Disc



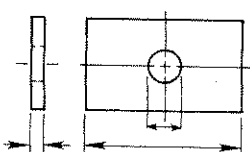
Star



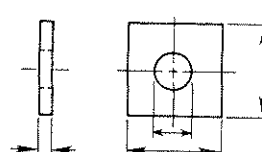
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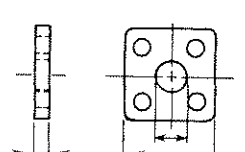
"D" Shape



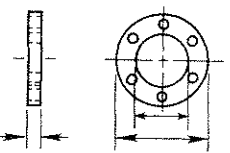
Rectangular



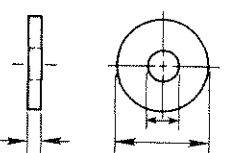
Square



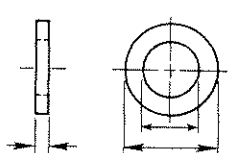
Flange



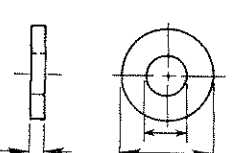
Flange



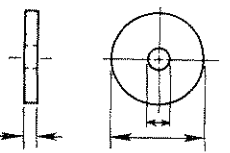
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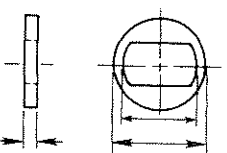
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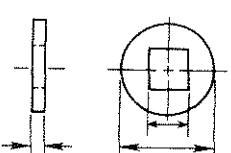
Standard Wrought



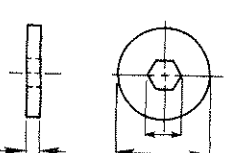
Wide Sidewall



Flattened Shaft



Square Hole



Hexagonal Hole

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## A Word About PMA...

The Precision Metalforming Association represents the \$30 billion metalforming industry of North America. Its over 1,100 member companies include leading producers of metal stampings, spinings, washers and precision sheet metal fabrications, as well as suppliers of equipment, materials and services to the metalforming industry.

Fourth Edition, 1992  
Prepared by The Washer Division, Precision Metalforming Association  
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## WASHER DIVISION

### FOREWORD

This publication is designed to help you by providing a single source of reference you can use when specifying and purchasing washers. Washers perform an important function in mechanical assemblies. Specifying the correct washer size, shape, material and mechanical characteristics will help ensure the integrity of your applications.

### ACKNOWLEDGEMENT

The WASHER DIVISION of the Precision Metalforming Association is pleased to present this booklet to members of all industries utilizing washers in their products. The Association has made every effort to assure that this work is as factual as possible at the time of printing. However, the Association is unable to assume any responsibility for its misuse or misinterpretation.

### SERVICES YOU CAN EXPECT FROM WASHER MANUFACTURERS

WASHER DIVISION members manufacture component parts rather than end products. They are manufacturing specialists. You can expect these services from a PMA WASHER DIVISION member:

**Design Assistance.** Assistance in feasibility of design and practical aspects of manufacturing. Early supplier involvement is a wise investment.

**Manufacturing Expertise.** A variety of equipment and techniques are available to produce your washers at the most economical cost.

**Controlled Delivery.** Your inventory costs are minimized by delivery just-in-time (JIT) for your scheduled requirements.

**Quality Control Systems.** Emphasis on statistical control of washer manufacturing processes produces washers to your specifications.

**Single Source Advantage.** Minimizing tooling and administrative costs and reduction in your supplier base are primary benefits of having a single source for washers.

# FACTS ABOUT WASHERS

## WHAT IS A WASHER?

Washers are vital components in fastening and assembly operations. A washer's shape and specifications are directly related to its application and the requirements of the end product it will be used in.

Washers perform many functions in addition to the common one of acting as a seat for bolts, nuts, screws and rivets. They also insulate, seal, lock, space, improve appearance, provide spring take-up, align, distribute loads, etc.

Washers are indispensable to the function of virtually every machine or device with moving parts. Failure to properly specify the best type of washer can generate costs that far exceed the value of even the most expensive washer—a broken penny washer can shut down a million dollar machine!

Washers are available in almost limitless varieties. Any type of material that can be stamped can be made into a washer. Materials used in the manufacture of washers cover a broad range of metallics and non-metallics, including low and high carbon steels, stainless steel and steel alloys, copper based materials, beryllium copper, phosphor bronze, titanium, aluminum, fiber, mica, mylar, rubber, nylon, teflon, phenolic, etc. You name it, and a WASHER DIVISION member will be equipped to handle it!

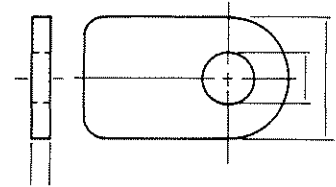
## MANUFACTURING METHODS

The primary method used to manufacture washers is stamping. Tools and manufacturing methods used in washer stamping processes are directly related to the customer's specifications and requirements. Additional processing may include many types of heat treating and surface coating, ranging from painting to plating with zinc or precious metals such as gold.

## THE SIX BASIC TYPES OF WASHERS

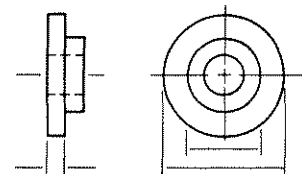
In order to define a washer with any degree of accuracy, an adjective must be used to place it in its proper category. Some of the basic categories are:

1. Flat washer
2. Shoulder washer
3. Tab washer
4. Lock washer
5. Countersunk washer
6. Spring washer



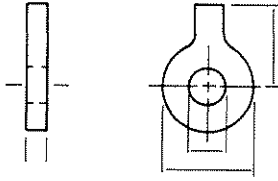
### Flat Washers

The most common category, "Flat Washer", includes an almost infinite number of configurations. Internal and external shapes may be round, symmetrically square, hexagonal, rectangular, etc., or non-symmetrical, depending on the function of the washer.



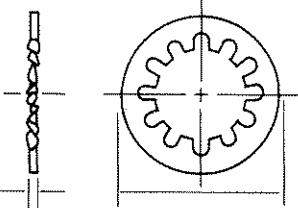
### Shoulder Washers

Shoulder washers, sometimes called "Step" or "Flange" washers, have in profile the appearance of a low crowned top hat. The category is rather unique since shoulder washers are used primarily in the electronic equipment industry as insulators, and are therefore made of non-conductive materials.



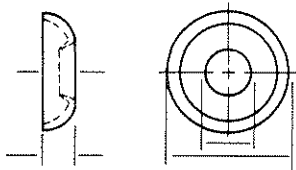
## Tab Washers

Tab washers are made in an almost infinite variety of configurations with internal and/or external notches and or tabs, single or multiple, formed and flat.



## Lock Washers

Lock washers are of course familiar to most of us in the conventional helical split and internal and external tooth types.



## Countersunk Washers

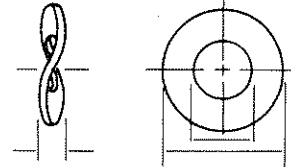
Countersunk washers come in a number of shapes: 90 degree countersunk, angle countersunk, flanged, unflanged, rolled flange, etc. Most people are familiar with the finishing type used for cosmetic purposes on many consumer products.

## Spring Washers

In bolted connections, spring washers absorb any looseness resulting from vibration or thermal expansion. They also eliminate side play in assemblies and are used with bearings to control end pressure and play. Vibration mountings also often use spring washers.

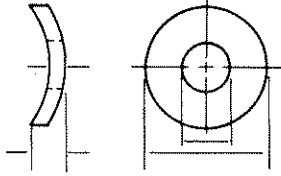
There are three basic types of spring washers: cylindrically curved; wave; and Belleville. There are a number of design variations within these basic configurations. Spring washers are economical, occupy little space, and generally weigh less than comparable wire springs. They are commonly used to apply a predetermined force on adjacent

members in an assembly, and are fabricated to meet close dimensional tolerances.



**Cylindrically Curved Washers...**are also known as “crescent”, “bowed” or “curved” washers. They have the most uniform spring constant over the widest deflection range of any of the three types. Their spring rate is approximately linear throughout the entire deflection range. This type of washer is best suited for applications that require flexibility, frequent load cycling and light loads—ranging from a few ounces to about 100 pounds. For cylindrically curved washers to function properly, the formed portion has to be free to slide.

**Wave Washers...**are sometimes referred to as “wave springs”, and usually have several curvilinear lobes. They are available in many sizes, and normally have three, four or six waves—although almost any number of waves is possible. By increasing the number of waves, the thickness can be reduced for a given load—but only at the expense of decreasing the amount of deflection and increasing the radial stress. Wave uniformity is important because the load/deflection rate doesn’t start until all waves are evenly loaded. The wave washer is an efficient device for obtaining loads when the load is static or the working range is small and the amount of axial space is limited. Normal load ranges are from a few pounds to about 100 pounds. Wave washers are often used as cushion spacers to take up variations in assembled parts.



**Belleville Spring Washers...**are often described as a conical or spherical spring. They have the form of a truncated cone or truncated sphere. Belleville washers have the smallest deflection ranges of any of the three types of spring washers. They also have the highest load capacity—ranging from pounds to tons.

This type of washer is used to solve spring problems of high loads, limited space and small deflections. Belleville washers are usually made from high carbon steel, spring-temper phosphor bronze, beryllium copper, or stainless steel.

# VALUE ANALYSIS IN DESIGN AND PROCUREMENT

Since a washer is a relatively simple mechanical component with a low cost compared to other parts in an assembly, there are frequently overlooked washer design and procurement factors which, properly considered, will result in substantial cost savings and minimize production line aggravations. Properly considered, they are guaranteed to give you parts at the most economical price, with minimized procurement cycles.

For example, check the application to find out if you are buying more washer than you need. The I.D. (inner diameter) of a washer is determined by the shaft size, screw diame-

ter, etc., on which the washer is used. If O.D. (outer diameter) size is not critical, reducing a 3/4 inch O.D. to a 5/8 inch O.D. would reduce the amount of material required by approximately 35 percent (depending on gauge) with a possible cost savings to the buyer of 15 percent. This is, of course, provided the part does not violate the "Wall Thickness Standard" (see WD 1002, page 14).

Other key factors to consider are described on the following pages. Use these factors to make sure you have the right information you need to avoid making uneconomical decisions!

## Quality Control

The quality requirements of today's market vary immensely, ranging from commercially accepted standards and tolerances for standard washers to the most stringent requirements for many specialty products and engineered applications. WASHER DIVISION members are capable of meeting your requirements, including material warrants, statistical process control, documentation and certification of lot traceability, and zero defects.

To make sure you receive the best price for the quality you need, all quality requirements should be disclosed when you make a request for quotation. Be sure your quality requirements note allowable specification ranges (the plus or minus tolerance for a given dimension) for washer dimensions and materials. Most washer dimensions, such as the outside or inside diameter (O.D. or I.D.) have a range of tolerance that is acceptable.

## Statistical Process Control

Statistical Process Control (SPC) is a technique used in a manufacturing process, such as the stamping of a washer, that concentrates on preventing, rather than the detecting, the production of parts not made to specifications. It allows your washer manufacturer to demonstrate that the manufacturing process was in control when your washers were produced. Hence, the washers should meet your specified quality requirements.

SPC establishes what are known as control limits. Upper and lower control limits (UCL and LCL) are the limits that the manufactur-

ing process is capable of producing. A process that is under good control should yield control limits within the specification range you require.

With SPC, production processes are closely monitored at a predetermined frequency to detect trends or variations that may fall outside of established control limits. Corrections are made immediately if these trends or variations indicate the process is moving outside of control limits.

After a number of manufacturing runs of the same item, the washer manufacturer may have demonstrated that their processes are in control and continual tracking or monitoring may not be necessary. Your WASHER DIVISION supplier is capable of providing a wide range of services in the area of quality, and can be of invaluable assistance to you.

## The Fastener Quality Act and Washers

In November of 1990 the U.S. Congress passed and President Bush signed into law the **Fastener Quality Act** (P.L. 101-592), which requires that certain fasteners be tested and certified to meet their specifications before being sold in the United States. Some FQA requirements are confusing, leading a number of washer purchasers to mistakenly conclude that all washers must meet FQA tracking, testing and certification requirements. This is not the case.

According to Section 3(5) of the FQA, the only washers covered include:

- A "load-indicating washer"; or
- A washer specified by screw, nut, bolt, or

stud standards, when the screw, nut, bolt, or stud has "internal or external threads (and) bears a grade identification marking required by a standard or specification."

While the "load-indicating washer" language is clear, the second definition of a washer covered by the FQA is not. Consultation with government officials and washer industry experts has revealed that, at the time of this printing, no one is aware of a washer which is specified by a screw, nut, bolt, or stud standard. **Therefore, the only washers known to be covered by the FQA at the time of this printing are load-indicating washers.**

The question of what (if any) other washers will be covered by the FQA should be answered permanently in regulations issued by the National Institute of Standards and Technology some time in 1992. For up-to-date information on whether the washers you purchase are covered by FQA requirements, contact your PMA WASHER DIVISION supplier. Information may also be available from the Precision Metalforming Association (216-585-8800) or the National Institute of Standards and Technology (301-975-4500).

## Economics of Quantity

To obtain the most economical price, order the largest quantity possible for a single delivery. This amortizes set-up costs to your advantage and gives you the maximum price benefits on freight and secondary operations such as heat treating and plating. Whenever possible, advise your supplier of your annual estimated usage and projected program life. If you expect the part to have an annual use of 250,000, and will be purchased for about five years, the washer manufacturer will be able to plan on the most economical pricing basis.

## A Word About "Specials"

Your washer manufacturer is prepared to develop tooling for almost any "special" washer application you need. You may be able to save a significant amount of money, however, by determining if a slight deviation from specified dimensions will allow the manufacturer to supply a "standard" stock item, instead of building new tooling for a "special" order.

WASHER DIVISION members have catalogues of various part configurations, sizes,

material, etc., which are manufactured in large quantities and often stocked. Consequently, a washer which you consider unique to your requirements may already exist as a "house standard" with one or more WASHER DIVISION members. By consultation with them and/or their catalogues or listings, you may be able to avoid new tooling costs, long lead times, etc.

Any WASHER DIVISION company will be glad to help you determine whether a "house standard" or "special" will best suit your needs. Remember, your specifications determine the price you will pay for the part. A good rule to keep in mind is to only incorporate restrictions that are essential and critical to the washer's function.

## Information Needed Before Designing or Specifying Any Type of Washer

### Tolerances

Do not specify closer tolerances than required by the application. As a general rule, "The Tighter The Tolerances The More Expensive The Part." Washer tolerances should be specified in accordance with accepted industry standards (see WD 1001, page 13). Many companies can produce closer tolerances on typical production runs. Extremely close tolerances will necessitate costlier tooling, maintenance and set-up charges which are bound to affect the price. For closer tolerances, consult your WASHER DIVISION manufacturer.

### Material and Thickness

Specifying material that is readily available and within standard tolerances will result in significant savings. For example, if you specify .080 thick steel when .0747 and .0897 are standard gauges, you are asking for higher costs. Specify material tolerances according to the "Standard Sheet Metal Thickness Variations" on page 12. A WASHER DIVISION member will assist you in determining the correct material specifications for your application.

Another factor you must consider is the type of material used. Material selection should be based upon the application's requirements. For example, a corrosion resistant alloy used in place of a steel part plated to resist corrosion may provide you significant savings.

## Temper, Hardness and Heat Treating

Don't specify temper if hardness is of no importance. Tempers such as 1/4 or 3/4 hard in steel are costlier and more difficult to obtain. If possible, specify Commercial Quality, Low Carbon Steel for lowest possible cost.

Do not specify hardness ranges or other mechanical properties on heat treated parts with closer ranges than standard for the material. This information is currently available from your WASHER DIVISION manufacturer.

Allow as much of a spread on the hardness as possible. It may be possible to substitute Rockwell "C" 45-50 in place of Rockwell "C" 47-48. To lower costs, commercial case hardening tolerances for parts should not be any deeper than necessary—0.003 to 0.005 deep file hard is normally considered adequate. Greater depths (0.010 to 0.015 and deeper) are costlier and often not functionally necessary.

## Compatibility

Spring washers are frequently specified showing all physical dimensions, heat treating requirements and load requirements. Care must be exercised to make certain that the specifications are mutually compatible. In spring washers, the load is a function of the

cube of the thickness. Thus, close requirements for load will require very close thickness control on the material. If a close load specification isn't required, you will pay for close material control without getting comparable value. Without any consideration for other physical tolerances, a load tolerance of +/- 15 percent will require a +/- 0.0005 inch tolerance on a 0.010 inch thick washer.

## Flatness

As a recommended guideline, do not specify flatness greater than 0.010 T.I.R. (total indicator reading) per inch of outside diameter unless absolutely necessary for part function (see WD 1003, page 15). To do so may require expensive secondary operations such as grinding, flattening on special tooling, etc. On heat treated parts, overly stringent flatness requirements may require special heat treat fixturing or additional straightening or grinding operations, which are very expensive.

## Concentricity

The I.D. and the O.D. shall be concentric within the tolerance range of the I.D. as specified (see WD 1001, page 13).

### Purpose or Function

- 1.) Thrust
- 2.) Spring
- 3.) Lock
- 4.) Spacer
- 5.) Tension/compression
- 6.) Load
- 7.) Cup
- 8.) Wear application
- 9.) Special application
- 4.) Thickness
- 5.) Height/Space limitation/requirement
- 6.) Load and/or deflection requirement consistent with stress limitations
- 7.) Tolerance requirement
- 8.) Edge requirement
- 9.) Burr
- 10.) Die break

### Material Characteristics

- 1.) Corrosion resistance
- 2.) Spring properties—static loading, dynamic loading, heat-treat hardened, roll hardened
- 3.) Magnetic
- 4.) Non-magnetic
- 5.) Ferrous
- 6.) Nonferrous

### Dimensional Characteristics

- 1.) O.D. space limitation/requirement
- 2.) I.D. space limitation/requirement
- 3.) Concentricity

### Finish

- (A) Plating requirement
  - 1.) Corrosion resistance v. corrosion resistant material
  - 2.) Appearance
  - 3.) Free of steel contamination
  - 4.) Oxidation control
  - 5.) Identification
  - 6.) Mechanical v. electro plating for heat-treated parts to avoid hydrogen embrittlement
- (B) Heat treatments
  - 1.) Spring property
  - 2.) Wear resistance—case hardened or hardening of heat-treated alloys

## **Burrs**

Burrs are ragged, usually sharp, protrusions on edges of metal stampings. Designers and specifiers of washers commonly fail to define an acceptable burr condition, or to allow it to be covered by vague standard nomenclature in the drawing block such as, "break all sharp edges," "burr free," etc. (see WD 1004, page 16).

Deburring is an important element of cost and may, if not carefully defined, result in costs to you exceeding the basic value of the part itself. The first rule is that if parts do not require deburring, the drawing or specification should clearly state, "Normal stamping burrs acceptable." A normal stamping burr is generally defined as 10% of stock thickness.

The most broadly used method of reducing burrs is tumbling or vibratory deburring. However, these methods do not completely eliminate burrs. Rather, they roll over and smooth the sharp ragged protrusion of the burr, reducing the percentage of the protrusion, but not completely eliminating it. This is the most common method of reducing burrs and should be clearly specified (if required) by the drawing note or specification, "condition for handling" or "production tumble deburr for handling."

## **Surface Finish**

Do not specify a surface finish on the part better than is provided on the starting material unless absolutely necessary. Such speci-

cations may require expensive secondary grinding or lapping operations. For example, if you specify the starting material as hot rolled, and then specify an RMS finish of 16, a secondary operation becomes mandatory even though it may have no functional value.

## **Finish Coatings**

Washers can be covered with a wide variety of coatings, paints, and other materials for improved appearance or corrosion resistance. Due to the shape of washers, however, batch coating methods may not completely coat some parts. The washer may have spots, blemishes, etc., but will be perfectly adequate from a functional viewpoint. If full and complete coating coverage is required, then individual wiring or racking may be required.

Individual wiring or racking in the coating process will increase the price of a washer. To dramatize the difference in cost, please bear in mind that a given part costing \$5.00/m to cad plate by "lot batch" production may cost \$30.00/m to plate by individual wiring or racking—a ratio of 6 to 1!

## **Conclusion**

Discuss your needs with your washer manufacturer. A WASHER DIVISION member can offer invaluable assistance in furnishing the right washer for your requirement. Use these guidelines to obtain the optimum part at the most economical price!

# WASHER INQUIRY SHEET

Complete this Washer Inquiry Sheet by identifying the type of washer you require, along with its specifications and tolerances. Then, fax or mail it to your washer manufacturer for a prompt response and quote.

To: _____	From: _____
Company: _____	Company: _____
Address: _____	Address: _____
_____	_____
_____	Phone: _____
_____	Telefax: _____

Flat Washer

Shoulder Washer

Tab Washer

Lock Washer

Countersunk Washer

Cylindrically Curved Washer

Wave Washer

Belleville Spring Washer

Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

	Specifications/ Dimensions	Tolerances (+/-)
Outside Diameter		
Inside Diameter		
Concentricity		
Thickness		
Flatness		
Material:		
Type		
Hardness		
Plating/ Coating		
Heat Treat		
Grinding		
Quality		
Quantity		
Delivery		
Price		

# METRIC CONVERSION CHART

As the world moves to a global economy and marketplace for our products and services, the use of metric measurements is fast replacing traditional decimal/inch specifications. To assist you in understanding metrics, here are some of the most commonly used conversion factors.

TO CONVERT From	To
Millimeters x .03937	= Inches
Centimeters x .3937	= Inches
Square Centimeters x .155	= Square Inches
Meters x 3.2808	= Feet
Kilometers x .6214	= Miles
Inches x 2.54	= Centimeters
Inches x 25.4	= Millimeters
Square Inches x 6.452	= Square Centimeters
Feet x .3048	= Meters
Miles x 1.609	= Kilometers
Liters x 1.0567	= Quarts
Liters x .2642	= Gallons
Quarts x .946	= Liters
Gallons x 3.784	= Liters
Grams x .0353	= Ounces
Grams x .002205	= Pounds
Kilograms x 2.205	= Pounds
Newtons x .2248	= Pounds (Force)
Newton-Meters x .7376	= Pound-Feet
Newton-Meters x 8.851	= Pound-Inches
Gram-Centimeters x .0139	= Ounce-Inches
Ounces x 28.35	= Grams
Pounds x 453.6	= Grams
Pounds x .4536	= Kilograms
Pounds (Force) x 4.448	= Newtons
Pound-Feet x 1.3558	= Newton-Meters
Pound-Inches x .113	= Newton-Meters
Ounce-Inches x 72	= Gram-Centimeters

# STANDARD SHEET METAL THICKNESS VARIATION

GAUGE NO.	STEEL			ALUMINUM	STAINLESS	COPPER BRASS	GALVANIZED STEEL
	Gauge Factor	Decimal Tolerances	Hot Rolled				
2			X	.250 ± .013	—	(1/4) .2576 ± .009	—
3			X	—	—	* .2294 ± .009	—
1/4			X	—	—	—	—
4	(15/64)	.238 - .262	X	.190 ± .009	—	* .2043 ± .007	—
5	(7/32)	.216 - .241	X	—	—	(3/16) .1819 ± .007	—
6	(13/64)	.201 - .230	X	.160 ± .008	—	(5/32) .1620 ± .007	—
7	(3/16)	.186 - .212	X	—	.172 ± .007	* .1443 ± .007	—
8	(11/64)	.172 - .197	X	.125 ± .005	* .156 ± .007	(1/8) .1285 ± .006	* .1681 ± .008
5/32		.157 - .178	X	—	—	—	—
		.149 - .166	X	—	—	—	—
9		.139 - .152	X	.100 ± .004	.140 ± .006	.1144 ± .006	* .1532 ± .008
10		.128 - .142	X	—	.125 ± .005	.1019 ± .006	* .1382 ± .008
1/8		.113 - .132	X	—	—	—	—
11		.113 - .121	X	.090 ± .004	.109 ± .005	.0907 ± .006	.1233 ± .008
12		.098 - .116	X	.080 ± .004	.093 ± .004	.0808 ± .006	* .1084 ± .008
13		.083 - .104	X	—	.078 ± .004	.0720 ± .005	* .0934 ± .008
14		.068 - .089	X	.063 ± .004	* .070 ± .003	.0641 ± .005	.0785 ± .008
15		.061 - .078	X	—	.062 ± .003	.0571 ± .005	* .0710 ± .006
16		.054 - .070	X	.050 ± .004	* .056 ± .003	.0508 ± .005	.0635 ± .006
17		.049 - .059	X	—	.050 ± .003	.0453 ± .004	* .0575 ± .005
18		.042 - .055	X	.040 ± .003	.043 ± .003	.0403 ± .004	* .0516 ± .005
19		.038 - .046	X	—	.037 ± .002	.0359 ± .0035	* .0456 ± .005
20		.033 - .042	X	.032 ± .0025	* .034 ± .002	.0320 ± .0035	.0396 ± .004
21		.026 - .037	X	—	.031 ± .002	* .0285 ± .0035	* .0366 ± .004
22		.021 - .029	X	.025 ± .0025	* .028 ± .0015	.0253 ± .003	* .0336 ± .004
23		.021 - .029	X	—	.025 ± .0015	* .0226 ± .003	* .0306 ± .004
24		.018 - .024	X	.020 ± .002	.021 ± .0015	.0201 ± .003	.0276 ± .004
25		.020	X	—	.018 ± .0015	.0179 ± .003	* .0247 ± .004
26		.017 - .019	X	.016 ± .0015	* .017 ± .0015	.0159 ± .003	.0217 ± .003
27		.015 - .017	X	—	.015 ± .0015	* .0142 ± .0025	* .0202 ± .003
28				* .012 ± .0015	* .014 ± .0015	.0126 ± .0025	.0187 ± .003
29				—	* .012 ± .0015	* .0113 ± .0025	* .0172 ± .003
30				—	* .010 ± .0015	.0100 ± .0025	.0157 ± .003
31				—	—	—	.0142 ± .003

\* Items marked with an asterisk (\*) are not readily available as a warehouse stock item. The heavier thicknesses of brass and copper are usually stocked in the common fractions.  
 Source: Compilation of mill tolerances

# Workmanship Acceptance Standards

**subject: O.D. and I.D. tolerances and concentricity**

**scope:** To establish common practice for specifying tolerances of outside and inside diameters and concentricity of washers.

## O.D. and I.D. tolerances (decimal inches)

O.D.	+	-
.062 to .311	.000	.005
.312 to .374	.008	.005
.375 to .625	.015	.005
.626 to .922	.015	.007
.923 to 2.750	.030	.007
2.751 to 5.000	.045	.010
5.001+	.065	.010
I.D.		
.032 to .124	.000	.005
.125 to .249	.008	.005
.250 to .625	.015	.005
.626 to 1.500	.030	.007
1.501 to 2.625	.045	.010
2.626+	.065	.010

The above tolerances are based on ANSI B18.22

## concentricity (decimal inches)

I.D. Range	Concentricity in T.I.R.
.032 to .124	.005
.125 to .249	.013
.250 to .625	.020
.626 to 1.500	.037
1.501 to 2.625	.055
2.626+	.075

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**Precision Metalforming Association**  
 27027 Chardon Road, Cleveland, Ohio 44143

DATE:

2-1-92

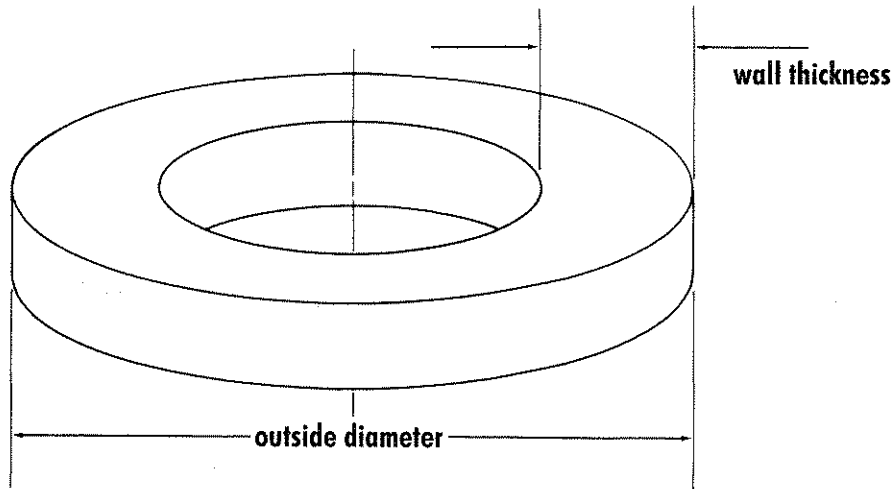
DATA SHEET NO.

WD 1001

# Workmanship Acceptance Standards

**subject:** wall thickness

**scope:** Establish common practice for specifying acceptable limits for wall thickness on flat washers.



wall thickness table

O.D. range		minimum wall thickness	
inches	millimeters	inches	millimeters
.1875 — .375	4.76 — 9.5	.0625	1.6
.375 — 1	9.5 — 25	.09375	2.4
1 — 2	25 — 51	.125	3.2
2 — 3	51 — 76	.1875	4.76
3 — 5	76 — 127	.25	6.35
<b>For:</b>		<b>Minimum wall:</b>	
low carbon steel annealed 1050 high carbon steel annealed copper alloys-all tempers aluminum alloys-all tempers		2 times metal thickness but not less than above chart	
stainless steel annealed blue steel* pre-tempered high carbon steel*		3 times metal thickness but not less than above chart	

\* Note: Contact your WASHER DIVISION member for exceptions. Special tooling or set-up procedures sometimes permit less wall. There is a limit of up to .020 inch maximum thickness of blue steel and pre-tempered high carbon steel.

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DATA SHEET NO.  
WD 1002

# Workmanship Acceptance Standards

**subject:** flatness

**scope:** Establish common practice for specifying acceptable limits for flatness on flat washers.

## Measuring variation from flatness

Variation from flatness is measured by laying the part on a surface plate with the convex side up and measuring the maximum rise. The "roll over" on the edges of the washer is not to be measured.

Outside Diameter (inches)	Flat within T.I.R.
.000 — 1.000	.010
1.001 — up	.010/inch

Note: Washer faces shall be parallel within 0.002/inch.

Parts that are relatively thin in relation to their outside diameter may be subjected to the following pressure when measuring flatness.

Material Thickness (inches)	Outside Diameter (inches)	Pressure (ounces)
.001 — .005	.000 — up	2
.006 — .010	.500 — up	4
.011 — .020	1.000 — up	8
.021 — .030	2.000 — up	16
.031 — .040	3.000 — up	24

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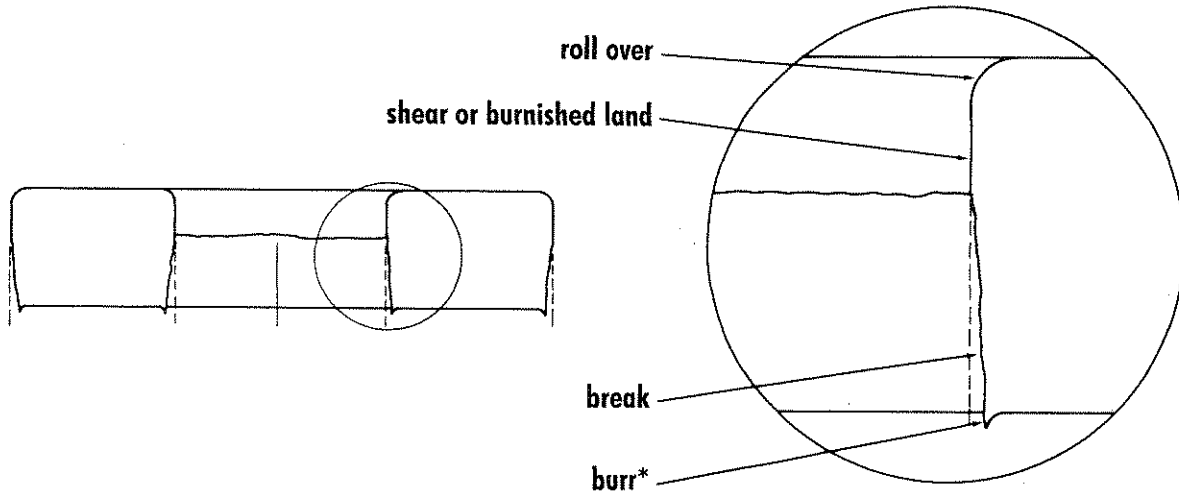
DATE:  
2-1-92

DATA SHEET NO.  
WD 1003

# Workmanship Acceptance Standards

**subject: burrs**

**scope:** Establish common practice for specifying acceptable limits for burrs on flat washers.



Requirement	Material Thickness (inches)	Allowable burr (inches)
When deburring is not specified	.001 — .004	.0005
	.005 — up	10% of thickness
When deburring is specified such as "must be burr free"	.001 — .004	.0003
	.005 — .030	.0005
	.031 — up	2% of thickness

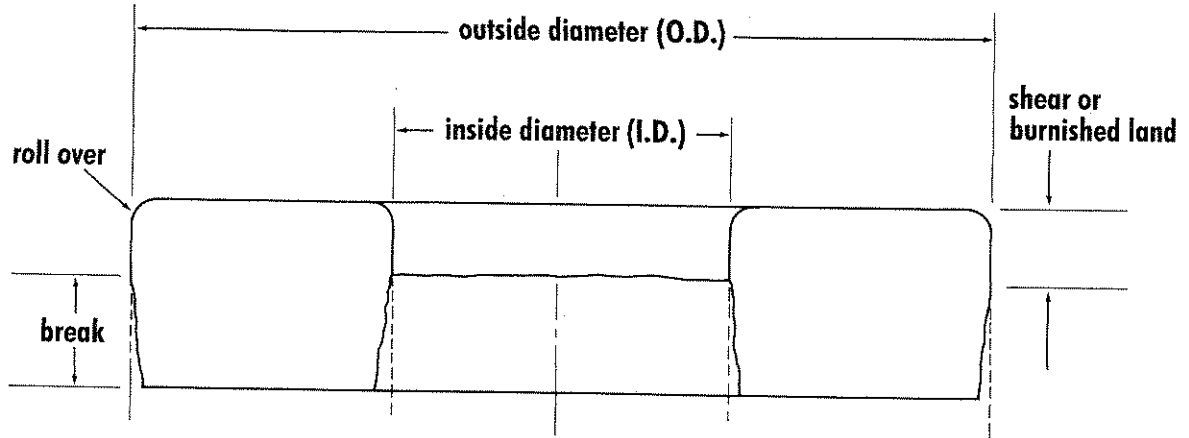
\*Burrs are ragged, usually sharp, protrusions on edges of metal stampings.

WASHER DIVISION of the <b>Precision Metalforming Association</b> 27027 Chardon Road, Cleveland, Ohio 44143	DATE: 2-1-92
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# Workmanship Acceptance Standards

**subject:** measuring washer dimensions

**scope:** Establish common inspection parameters.



**Feature Size:** This is to be measured only in the cut portion of the hole and the cut portion of the outside diameter.

**Shear or Burnished Land:** This is a burnished area which is approximately one third of material thickness.

**Break:** This is an area which is tapered about three degrees. This area has a rougher surface than the cut area.

**Roll Over:** This is a natural consequence of the punching process and the mechanical properties of the material being punched and the die application techniques employed.

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DATA SHEET NO.  
WD 1005

# Workmanship Acceptance Standards

**subject: methods of measurement**

**scope:** Establish common practice for measurement of washers.

**Outside Diameter (O.D.):** Use micrometer at shear or burnished land.

**Inside Diameter (I.D.):** Use plug gauges.

**Thickness:** Use micrometer measurement exclusive of burr.

**Flatness (for flat washers only):** Washer must pass between two parallel surfaces whose distance is equal to the allowable material tolerance plus the allowed flatness tolerance.

**Burr:** Use a dial indicator as it has a minimum amount of pressure, will not crush the burr, and gives the most accurate reading.

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DATA SHEET NO.  
WD 1006

# Workmanship Acceptance Standards

subject: dimensioning symbols

Characteristics	American ANSI Y14.5	Canadian CSA B78.2
straightness		same
flatness		same
roundness (circularity)		same
cylindricity		same
profile of a line		same
profile of a surface		same
parallelism		same
perpendicularity (squareness)		same
angularity		same
position		same
concentricity (coaxiality)		same
symmetry		same
maximum material condition		same
diameter		same
circular runout		same
total runout		none
datum identification		
reference dimension	(5,000)	same
basic dimension		same
regardless of feature size		none
projected tolerance zone		same
datum target		same
part symmetry	none	

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 2-1-92

DATA SHEET NO.  
 WD 1007

# WASHER STANDARDS SOURCES

**ANSI — American National Standard Institute**  
11 West 42nd Street  
New York, NY 10036  
Phone: 212-642-4900  
Fax: 212-302-1286

ANSI B18.22M-1981  
Plain washers, metric  
ANSI B18.22.1-1965  
Plain washers  
ANSI/ASME B18.21.1-1990  
Lock washers  
ANSI/ASME B18.21.2M-1990  
Lock washers, Metric  
ANSI/SAE AIR 1754  
Aerospace washers, thermal compensating  
ANSI/SAE AS 1715 A  
Aerospace washers, flexible  
ANSI/SAE AS 1736  
Aerospace washers, rigid

ANSI/SAE AS 3326  
Aerospace washers, self-locking  
ANSI/SAE MA 1784  
Aerospace washers  
ANSI/SAE MA 4037  
Aerospace washers, key  
ANSI/SAE MA 4038  
Aerospace washers, key  
ANSI/SAE MA 4039  
Aerospace washers, key  
ANSI/SAE MA 4040  
Aerospace washers, key

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**ASME — American Society of Mechanical Engineers**  
Order Department  
22 Law Drive  
P.O. Box 2300  
Fairfield, NJ 07007-2300  
Phone: 800-321-2633  
Fax: 201-882-1717

B18.13-1987  
Screw and washer assemblies  
B18.13.1M-1991  
Screw and washer assemblies, metric

FAP-1-1990  
Quality assurance program for fastener  
manufacturers and distributors

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**ASTM — American Society for Testing & Materials**  
1916 Race Street  
Philadelphia, PA 19103  
Phone: 215-299-5400

F 436  
Steel washers, hardened  
F 606  
Through hardened carburized hardness  
test  
F 844  
Steel plain flat washers, unhardened  
F 959  
Direct tension indicator (DTI) washers for  
structural fastening

Standards are available separately, or as  
printed in ASTM publication Fasteners —  
Volume 15.08 (contains 76 fastener  
standards).

**DIN —Deutsches Institut fur Normung e.V.**  
**English translations available through the American National Standards Institute (ANSI).**  
**See address above.**

- DIN 93 (July, 1974)  
Tab washers with long tab
- DIN 125, Part 1 (March, 1990)  
Product grade A washers with a hardness up to 250 HV, designed for use with hexagon head bolts and nuts
- DIN 125, Part 2 (March, 1990)  
Product grade A washers with a hardness from 300 HV, designed for use with hexagon head bolts and nuts
- DIN 126 (March, 1990)  
Product grade C washers, designed for use with hexagon head bolts and nuts
- DIN 127 (October, 1987)  
Spring lock washers with square ends or tang ends
- DIN 128 (October, 1987)  
Curved and wave spring lock washers
- DIN 137 (October, 1987)  
Curved and wave spring washers
- DIN 267, Part 15 (November, 1983)  
Fasteners; technical delivery conditions; prevailing torque type nuts
- DIN 267, Part 26 (October, 1987)  
Fasteners; technical delivery conditions; steel spring washers for bolt/nut assemblies
- DIN 432 (November, 1983)  
External tab washers (locking tab washers)
- DIN 433, Part 1 (March, 1990)  
Product grade A washers with a hardness up to 250 HV, designed for use with cheese head screws
- DIN 433, Part 2 (March, 1990)  
Product grade A washers with a hardness up to 300 HV, designed for use with cheese head screws
- DIN 435 (December, 1989)  
Square taper washers for use with I sections
- DIN 462 (September, 1973)  
Machine tools; internal tab washers for slotted round nuts for hook spanner according to DIN 1804
- DIN 463 (July, 1974)  
Tab washers with long and short tap at right angles
- DIN 526 (May, 1973)  
Safety cups for cheese head screws according to DIN 84
- DIN 1440 (July, 1974)  
Washers; type medium for bolts
- DIN 1441 (July, 1974)  
Washers; type coarse for bolts
- DIN 6319 (April, 1987)  
Spherical washers and conical seats
- DIN 6340 (April, 1987)  
Washers for clamping devices
- DIN 6796 (October, 1987)  
Conical spring washers for bolt/nut assemblies
- DIN 6797 (July, 1988)  
Toothed lock washers
- DIN 6798 (July, 1988)  
Serrated lock washers
- DIN 6799 (October, 1981)  
Lock washers (retaining washers) for shafts
- DIN 6906 (December, 1972)  
Lock washers for screw assemblies
- DIN 6913 (October, 1987)  
Spring lock washers with safety ring
- DIN 6916 (October, 1989)  
Round washers for high-strength structural steel bolting
- DIN 6917 (October, 1989)  
Square taper washers for high-strength structural bolting of steel I sections
- DIN 7349 (July, 1974)  
Plain washers for bolts with heavy clamping sleeves
- DIN 7697 (November, 1970)  
Self locking counter nuts
- DIN 7980 (October, 1987)  
Spring lock washers with square ends for cheese head screws
- DIN 7989 (July, 1974)  
Plain washers for steel construction
- DIN 65209 (December, 1988)  
Aerospace; washers, countersunk
- DIN 65363 (December, 1987)  
Aerospace; lock washers for flight control rods
- DIN 65456 (December, 1987)  
Aerospace; washers for flight control rods, with hole for bonding
- DIN 65553 (August, 1987)  
Aerospace, shims, without hole, for anchor nuts with MJ thread
- LN 9016 (April, 1980)  
Aerospace; washers, bevelled
- LN 9025 (April, 1980)  
Aerospace; washers

LN 9028 (April, 1980)  
Aerospace; counterbored washers  
LN 9424 (August, 1987)  
Aerospace; lockwire, drawn,  
corrosion-resisting; dimensions, masses  
LN 29558 (June, 1974)  
Serrated lockring for temperatures  
up to 260°C

LN 29559 (October, 1967)  
Serrated lockring for temperatures up  
to 700°C, corrosion resistant  
LN 29905 (April, 1980)  
Aerospace; washers, self-aligning

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## ISO — International Standards Organization

Available through the American National Standards Institute (ANSI).

See address above

ISO 887:1983  
Plain washers for metric bolts, screws and  
nuts- General plan  
ISO 1891:1979  
Bolts, screws, nuts and accessories—  
Terminology and nomenclature  
ISO 4759-3:1977  
Tolerances for fasteners— Part 3: Washers  
for metric bolts, screws and nuts with  
thread diameters from 1 up to and  
including 50mm-Product grades A and C  
ISO 6525:1983  
Plain bearings—Ring type thrust washers  
made from strip—Dimensioning and  
tolerances  
ISO 6526:1983  
Plain bearings— Pressed bimetallic half  
thrust washers- Features and tolerances  
ISO 7089:1983  
Plain washers— Normal series—Product  
grade A  
ISO 7089:1983  
Plain washers, chamfered— Normal  
series—Product grade A

ISO 7091:1983  
Plain washers— Normal series—Product  
grade C  
ISO 7092:1983  
Plain washers— Small series— Product  
grade A  
ISO 7093:1983  
Plain washers— Large series— Product  
grades A and C  
ISO 7094:1983  
Plain washers— Extra large series—  
Product grade C  
ISO 7415:1984  
Plain washers for high-strength structural  
bolting, hardened and tempered  
ISO 7416:1984  
Plain washers, chamfered, hardened and  
tempered for high strength structural  
bolting  
ISO 8738:1986  
Plain washers for clevis pins—Product  
grade A

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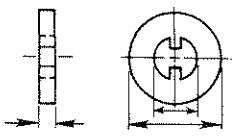
## SAE—Society of Automotive Engineers

400 Commonwealth Drive  
Warrendale, PA 15096-0001  
Phone: (412)776-4841  
Fax: (412)776-5760

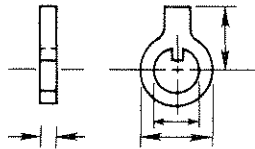
HS1582  
Manual on design and manufacture of  
cone disk springs, belleville springs, and  
spring washers  
J174  
Torque tension test procedures for  
steel threaded fasteners  
J238  
Nut and conical spring washer assemblies

J429  
Mechanical and material requirements for  
externally threaded fasteners  
J773b  
Conical spring washers  
J924  
Thrust washers: Design and applications

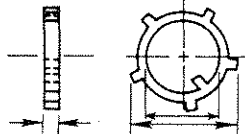
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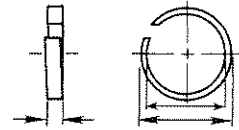
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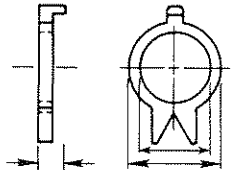
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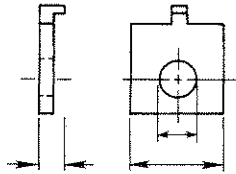
Multiple Internal/  
External Tab



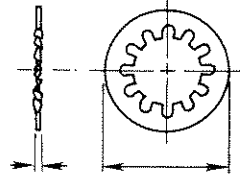
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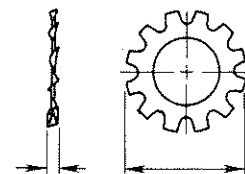
Tab  
Lockwasher



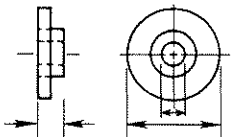
Tab  
Lockwasher



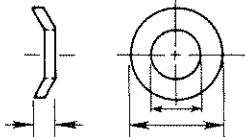
Lock



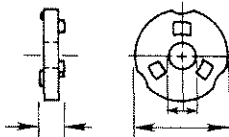
Lock



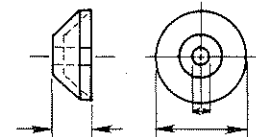
Shoulder



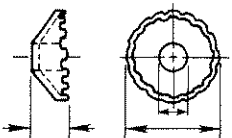
Beveled O.D.



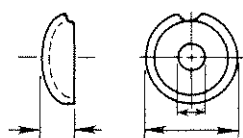
Special



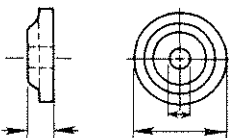
Beveled  
Cup



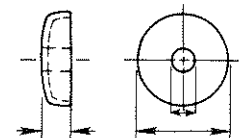
Serrated  
Tooth Cup



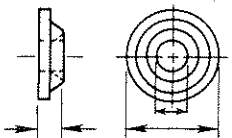
Electrical  
Contact



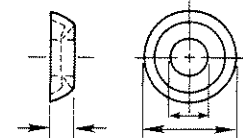
Spring  
Retainer



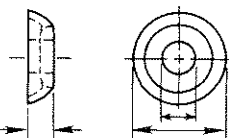
Cup or  
Retainer



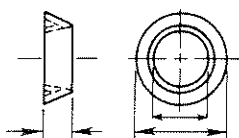
Finishing



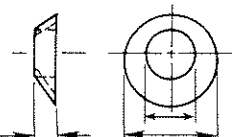
Finishing



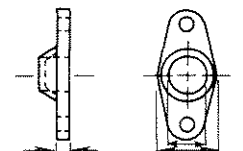
Dimpled



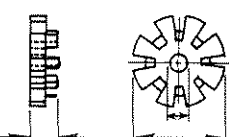
Countersunk



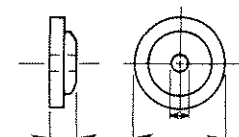
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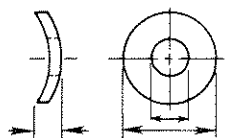
Countersunk



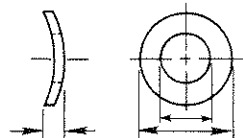
Centering



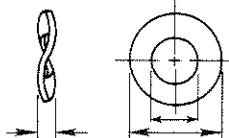
Centering



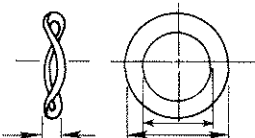
Belleville  
Spring



Spherical  
Spring



Cylindrically  
Curved Spring



Wave Spring

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