

**OEM Corporation**

**GUIDELINES**

**FOR**

**DESIGN AND SPECIFICATION**

**OF**

**FAN SHAFTS**

**OEM Corporation  
Guidelines  
For  
Design and Specifications  
of  
Fan Shafts**

OEM Corporation specializes in the manufacture of high quality shafts for general purpose axial and centrifugal fans. OEM produces straight, centerless ground shafts up to 2 15/16" in diameter, straight, centerless ground tubular shafts up to 2" in diameter, and machined step shafts up to 4" in diameter. The following design guidelines have been developed based on OEM's years of experience in the manufacture of fan shafts, and are intended to provide OEM's customers with information on the design, material selection and specification of fan shafts that will result in most economical shaft design.

There are number of factors that need to be evaluated in the design of shafts for general purpose fans, which are covered in the second section of these guidelines, that lead to the selection of the fan shaft diameter and material selection for a particular application. OEM recommends the following specifications and drafting practices for general purpose fan shafts. Following these recommendations will result in the most economical fan shaft design and will minimize questions of interpretation of drawings.

The design specifications covered are:

1. Material Specifications
2. Shaft Diameter Tolerance
3. TIR Runout Tolerance, and Measurement
4. Surface Finish
5. Flat and Keyseat Specification, and Tolerance
6. Dimensioning Recommendations

**1. Material Specifications**

In most fan shaft application 1045 Steel has adequate mechanical properties to meet the requirements for safe shaft design, and selection of 1045 Steel will result in the most economical shaft design. The selection of higher strength materials will result in higher costs and should be avoided unless the additional yield strength is dictated by the shaft application. Because the availability of bar stock in all diameters and grades is sometimes limited OEM recommends specifying a range of materials that will allow OEM to provide the most economical material available.

The recommended material specification is:

Shaft Material shall be 1018 to 1060 Steel.

## 2. Shaft Diameter Tolerance

OEM recommends shaft diameter tolerances as shown below, and on the attached OEM dimensional chart.

<u>Nominal Size</u>	<u>and Tolerance</u>
5/8	.6248/.6238
3/4	.7498/.7488
1	.9998/.9988
1 3/16	1.1873/1.1863
1 7/16	1.4373/1.4363
1 11/16	1.6873/1.6863
1 15/16	1.9373/1.9363
2 3/16	2.1870/2.1855
2 7/16	2.4370/2.4355
2 11/16	2.6870/2.6855
2 15/16	2.9370/2.9355

## 3. Runout TIR

OEM recommends a specification tolerance on TIR of 0.002"/foot of shaft length. OEM checks and straightens shafts to this specification. The TIR is measured at the indicated wheel location or at the center of the shaft with the shaft supported in "V" blocks at the indicated bearing locations. It is recommended that the approximate wheel and bearing locations be indicated on the drawings as shown in Figure 1.

## 4. Surface Finish

OEMs' centerless grinding process provides an excellent surface finish suitable for pillow block bearing application. OEM can also provide shafts with improved surface finish for sleeve bearing application at additional cost. Recommendations for surface finishes at lower microinch values should be obtained from the bearing manufacturer. Contact OEM for quotations when specifying special surface finish requirements.

OEM recommends the following surface finish specification:

<u>Shaft Size</u>	<u>Surface Finish</u>
Under 1"	25 Microinch
1" to 1 1/32"	32 Microinch
1 1/16" to 1 11/16"	42 Microinch
1 15/16" and over	46 Microinch

## **5. Flat and Keyseat Specification and Tolerance**

### **Keyseats**

The length of a keyseat should be specified defining the usable keyseat length not including the cutter radius at the end(s) of the keyseat. The recommended length and position tolerance for keyseats is  $\pm 0.060$ "

The depth of the keyseat should be specified as the dimension from the bottom of the keyseat to the opposite side of the shaft, which can be accurately measured. The recommended tolerance on this keyseat dimension and keyseat width are shown on the attached OEM dimensional chart. The keyseat dimensions are based on the use of "Bar Stock" keys.

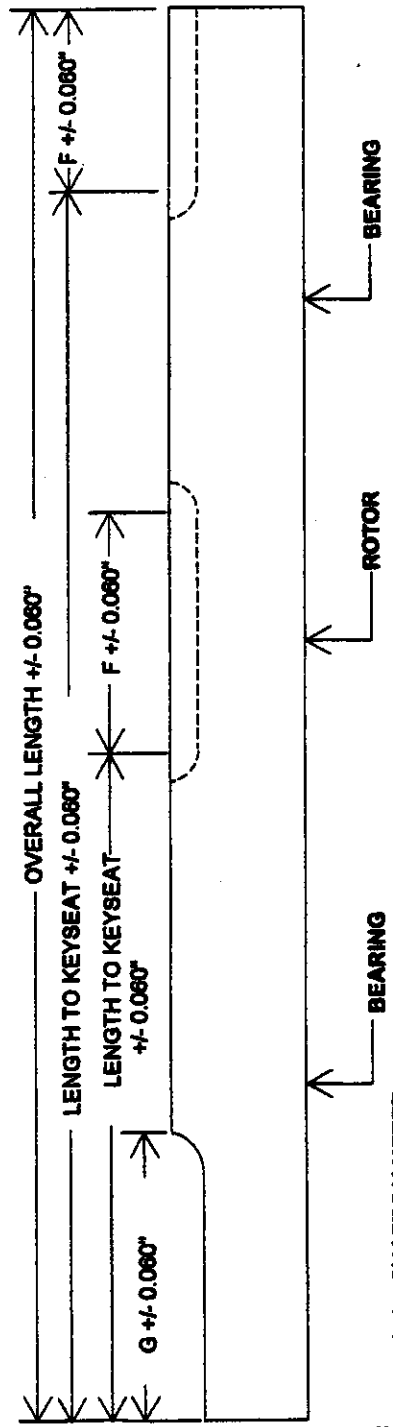
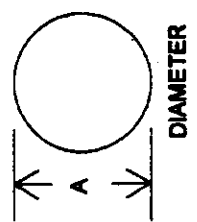
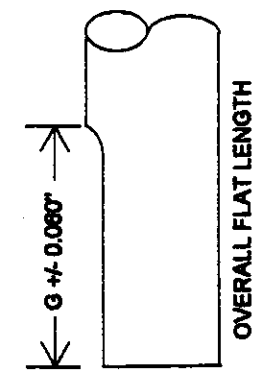
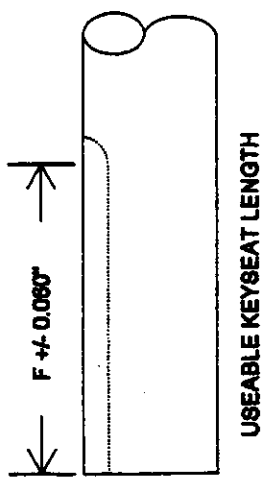
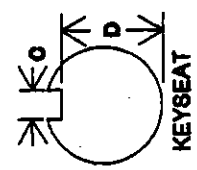
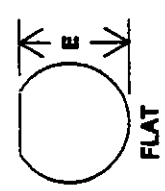
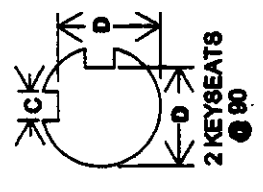
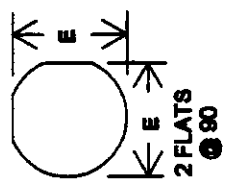
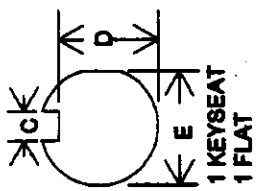
### **Flats**

The length of flats should be specified as the overall length of the flat including the radius at the end(s) of the flat. The recommended tolerance on the length and position of a flat is  $\pm 0.060$ "

The depth of the flat should be specified as the dimension from the bottom of the flat to the opposite side of the shaft, which can be accurately measured. The recommended tolerance on this dimension is shown on the attached OEM dimensional chart.

## **6. Drawing Dimensioning**

OEM recommends that the shaft drawing show the shaft dimensions and specifications as shown in figure 1. Using these guidelines will minimize questions of drawing interpretation between OEM and the customer.



NOTES:

1. A = SHAFT DIAMETER
2. C = KEYSEAT WIDTH
3. D = KEYSEAT DEPTH
4. E = FLAT DEPTH
5. F = USEABLE KEYSEAT LENGTH
6. G = OVERALL FLAT LENGTH
7. MATERIAL - 1018 TO 1080 STEEL
8. ALIGNMENT OF KEYSEATS OR FLATS NOT RADIALY RELATED
9. TIR AT ROTOR LOCATION OR CENTER = 0.002"/FI

**OEM CORPORATION**

SHAFT DRAWING  
RECOMMENDED DRAFTING PRACTICE

FIGURE 1

# OEM CORPORATION

## STANDARD SHAFT DIMENSIONS AND TOLERANCES

NOMINAL SHAFT DIAMETER	A SHAFT DIAMETER	C KEYSEAT WIDTH	D KEYSEAT DEPTH	E FLAT DEPTH	SURFACE FINISH MICROINCH
5/8	.6248/.6238	.1875/.1895	.514/.510	.605/.595	25
3/4	.7498/.7488	.1875/.1895	.644/.639	.730/.720	25
1	.9998/.9988	.250/.252	.857/.852	.980/.970	32
1 3/16	1.1873/1.1863	.250/.252	1.047/1.042	1.167/1.166	32
1 7/16	1.4373/1.4363	.375/.377	1.225/1.215	1.417/1.407	42
1 11/16	1.6873/1.6863	.375/.377	1.479/1.469		42
1 15/16	1.9373/1.9363	.500/.502	1.855/1.845		46
2 3/16	2.1870/2.1855	.500/.502	1.909/1.899		46
2 7/16	2.4370/2.4355	.625/.627	2.084/2.047		46
2 11/16	2.6870/2.6855	.625/.627	2.338/2.328		46
2 15/16	2.99370/2.9355	.750/.752	2.514/2.504		46

# Shaft Design Considerations For General Purpose Fans

There are a number design characteristics that need to be evaluated to determine the shaft size and material selection for a fan application. This discussion is limited to the design of straight solid shafts up to 2 15/16" in diameter with one fan wheel mounted between bearings, or mounted cantilever outboard of the bearings. The same general principles apply to other fan applications, however the process is more complex when dealing with multiple fan wheels on a single shaft, applications requiring step shafts, or for operation at high speeds or at elevated temperatures.

There are four design characteristics that need to be evaluated for determination of the fan shaft diameter and material requirement.

- A. Critical Speed
- B. Torsional Stiffness
- C. Combined Torsion and Bending Stress
- D. Bearing Selection for Adequate Bearing Life

In addition to the above design characteristics there is one area that is often overlooked in the physical design of the fan, and that is the location of the driven pulley to the drive side bearing. For fans the predominate factor in determining the fan shaft size is the load on the drive side bearing. The load on the drive side bearing can be minimized by mounting the pulley as close to the bearing as is practical. In addition to reducing the load on the bearing the bending moment on the shaft is also reduced. It is good general practice to design the fan assembly to keep the driven pulley as close as practical to the drive side bearing.

## 1. Shaft Critical Speed

The shaft, fan wheel, and pulley assembly will have natural frequency dependent on the weight and location of the components. Operation at this natural frequency, called the critical speed, will allow the assembly to vibrate excessively do to even a small unbalance in the rotating assembly, and can lead to fan failure. The shaft design should be such that the maximum operating speed is no more than 80% of the critical speed.

Typical general purpose fans use self aligning cartridge or pillow block bearing and the shaft can be considered as supported at the ends rather than fixed. For this condition the critical speed of the shaft can be calculated from the following formula for fans where the fan wheel is mounted between bearings. ( this equation assumes the deflection of the shaft do to the weight of the pulley is negligible.)

$$N_c = 1,550,500 \frac{D^2}{L\sqrt{LW}}$$

D= Shaft Diameter-inches

L= Shaft Length Between Bearings-inches

W= Weight of Fan Wheel-lb

N<sub>c</sub>= Critical Speed-RPM

For cantilever shaft the critical speed can be calculated from:

$$N_c = 187.7\sqrt{1/y}$$

y= Maximum Shaft Deflection-inches

In designs where the maximum operating speed is close to 80% of the critical speeds determined using the above formulas it is recommended that more detailed methods of calculating shaft critical speeds be used.

## 2. Torsional Stiffness

The shaft diameter should be large enough to limit the twist in the shaft to a maximum of one degree in a length of 20 times the shaft diameter. The shaft size required to meet this condition can be calculated from:

$$D = 4\sqrt[3]{P/N}$$

D= Shaft Diameter-inches

P= Transmitted Horsepower

N= Speed- RPM

Except for fan designs requiring long small diameter shafts the torsional stiffness requirements will usually be met when the shaft size is based on bearing life or critical speed.

## 3. Combined Torsion and Bending Moment

The minimum shaft diameter required to limit the stress from the combined torsion and bending load to safe levels can be calculated from:

$$D = \sqrt[3]{5.1/s \sqrt{(1.5M)^2 + (63000P/N)^2}}$$

D= Shaft Diameter-inches

s= Maximum Allowable Shear Stress-psi

M= Maximum Bending Moment-inch-pounds

N= Speed- RPM

The maximum allowable shear stress for shaft material is taken as 13.5% of the ultimate tensile strength. (for shafts with flats and/or keyseats.)

1018Steel--Allowable shear stress= 8600psi  
1045Steel--Allowable shear stress= 12000psi

The shaft size required for safe stress levels is generally much less than that required for adequate bearing life or safe operating speed, so the use of steels with allowable shear stress higher than 1018 steel is an unnecessary cost.

#### 4. Bearing Life

The bearing size and type required to provide adequate L10 bearing life is dependent on; the load on the bearing from belt pull and the fan wheel weight, the operating speed and the load rating of the bearing. The load on the drive side bearing from the belt pull is the predominate factor in determining the bearing size and type required to provide adequate L10 bearing life. The bearing manufacturers handbooks define the methods of calculating belt pull, bearing load, and the L10 life.

General purpose fans are usually designed to have an L10 life in the range of 20,000 to 80,000 hours, and in most applications the desired bearing life will be the determining factor for the shaft size selection.

#### Summary

All of the above factors should be evaluated in the process of designing the shaft for fan applications, even though the bearing size required or the critical speed are the most predominate factors leading to the shaft diameter selection. It is also recommended that more detailed methods, such as FEA analysis, of evaluating these characteristics be used on critical applications.

#### References:

Machinery Handbook, 23rd Edition, Industrial Press  
Fan Engineering, Buffalo Forge Co., Buffalo, NY  
Rodyn Vibration Corp. 1932 Arlington Blvd., Suite 223,  
Charlottesville, Va. 22903  
Tel. 804-296-3175