



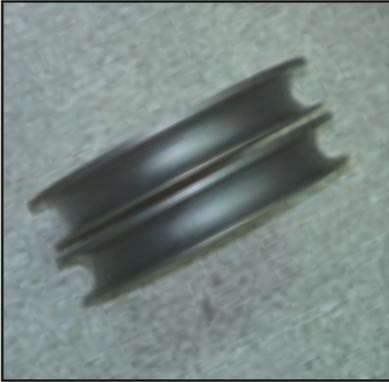
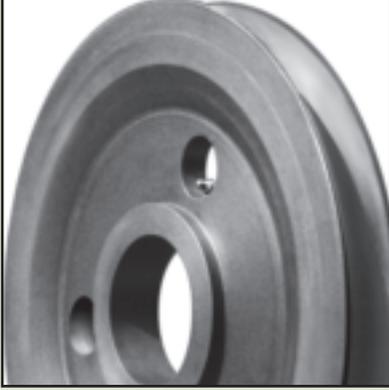
## Engineering Plastic Sheaves & Sheave Design

### Cast Nylon Sheaves for the Heavy Equipment Industry

Timco's cast nylon sheaves are increasingly found on a wide variety of lifting equipment. They often replace sheaves made of cast iron or steel. Today, Timco's sheaves can be found on nearly any type of crane including gantry, tower, rough terrain, crawler, truck, and pedestal cranes. They are also used in equipment for the wire drawing and cable stranding industries, on forklifts, telehandlers, manlifts, mobile drill rigs and in many other mechanical systems. Timco is the largest supplier of machined non-metallic sheaves in North America. We are proud to offer our customers sheaves of all sizes and designs.

Sheaves are grooved wheels or pulleys used with rope or chain to change the direction and point of application of pulling force. Timco's fabricated sheaves have considerable advantages over cast iron or steel sheaves. Benefits of using our sheaves are found on the following pages. This brochure also details design guidelines for cast nylon sheaves to improve your equipment's safety and efficiency. Selecting sheaves requires a knowledge of product specifications: type of belt or rope to be used, bearing size and type, and any dimensional restrictions. A worksheet to gather information to design a sheave is found on page 9. An experienced Timco sales engineer would be happy to assist you in your sheave design.

**TIMCO**



# Benefits of Using Timco Engineering Plastic Sheaves

## Extend Wire Rope Life

Wire rope (wire cable) is an important and highly stressed component in material handling equipment. The useful lifetime of wire rope is mostly determined by fatigue, Hertzian pressure between wire rope and sheave, and external conditions such as line pull, sheave diameter, groove profile and sheave material.

In contrast to most other machine components, wire rope must be replaced before it fails. In order to extend wire rope life, sheaves or sheave grooves made of Timco's cast nylon are used. Timco sheaves are very wear resistant and do not stress the outer strands of the rope nearly as much as steel sheaves. Standard wire rope rests in the groove of a steel sheave on point contacts only, resulting in high specific loads between the outer wires of the rope and the groove. Premature wire rope failure due to the breaking of individual wires in the outer strands can occur. This does not happen with sheaves made of Timco cast nylon.

The elasticity of Timco's sheaves results in a larger contact area between wire rope and sheave groove. The specific loading is greatly reduced, and the wire rope is under less stress. Timco sheaves provide a cushion in the groove contact area. The load bearing contact area on a Timco nylon sheave is 10 times larger than on a steel sheave.

Wear resistance, reduced specific loading and elasticity make our sheaves extend the life of the wire rope by up to 300%!

## Are Lighter Weight

The low weight of Timco sheaves can also increase their operational efficiency. The weight of our cast nylon sheaves is one-seventh the weight of steel sheaves. In heavy cranes with multiple reeving, the weight savings adds up quickly. The total axle load on a large mobile crane (which may use as many as 18 sheaves) can be reduced by almost 2,200 lbs by using Timco sheaves. The effect of the weight savings on the boom tip is magnified at low boom angles.

Timco cast nylon sheaves improve equipment efficiency, reduce load and stress, and are easier to handle.

## Improve System Safety

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Wire rope performance is often the key factor in the efficient and safe operation of large systems. Because the wire rope is less stressed when using Timco cast nylon sheaves, the entire lift system runs more safely.

Handling or installing Timco sheaves is significantly easier and safer than working with metal sheaves.

## Offer Corrosion and Weather Resistance

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Timco sheaves do not rust, and resist chemical and salt water corrosion. They are ideal for outdoor and marine applications as well as in other harsh environments.

## Last Longer Than Sheaves Made of Other Materials

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A unique combination of mechanical and impact properties, combined with its excellent wear resistance, allow Timco cast nylon sheaves to outlast their metallic counterparts.

Groove wear is caused either by mechanical overload (generally produced by point stress) or by slippage of the cable. The increased rope support provided by Timco's plastic sheaves reduces both mechanical overload and cable slippage, as well as stress caused by vibration.

Improved performance and long-lasting toughness make Timco cast nylon sheaves a cost effective choice.

## Provide Longer System Life

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In addition to its many other benefits, cast nylon also dampens vibrations. This is beneficial for the rope, bearings, shaft, housing, and other components of the system. The useful lifetime of all components in the reeving is extended. This means lower maintenance costs, less downtime, longer useful product life, and more profitability.

### Why Buy Your Sheaves From Timco?

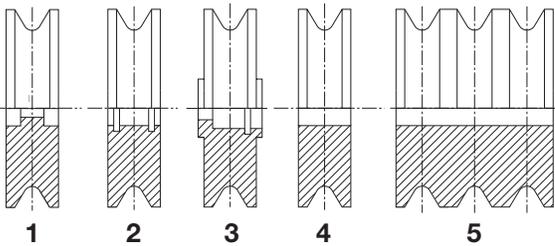
- 40 Years of Fabrication Experience
- ISO 9001:2000
- Offering Design, Fabrication and Assembly Services
- Rapid Prototyping
- Broad Range of Plastic Materials
- Engineering Solutions – Our Engineers Help You Design Your Part



# Sheave Design

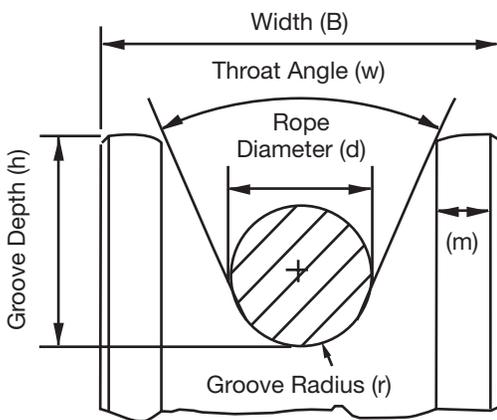
## Design of Bearing Seat and Sheave Groove

### Types of Bearing Seats



Due to the low coefficient of friction of cast nylon, sheaves can be installed without anti-friction bearings in applications with light loads (Type 4 and Type 5). Please refer to the section “Sheaves without bearings” later in this brochure. If the load in the bearing seat exceeds the maximum permissible load for running directly on the shaft, anti-friction bearings should be installed. Several installation methods are available (Types 1, 2 and 3).

The groove diameter of a cast nylon sheave should exceed the wire rope diameter by about 5%. This allows for the tolerance in the rope diameter and assures good support for the wire rope. The groove depth should be at least 1.5 times the rope diameter to prevent “jumping”. A groove angle (throat angle) of between 30° and 45° assures the best support for the wire rope. When using stranded cables, the root diameter should not be a whole number multiple of the length of lay of the cable.



- h = Groove depth (1.5 • d) minimum
  - w = Throat angle
  - d = Wire rope diameter
  - r = Groove radius (see Figure 1 or (d+5%) / 2)
  - m = Minimum flange width
  - B = Minimum width of sheave = d • 2.5
- Maximum permissible fleet angle is 4°

Rope Diameter (inches)	Groove Radius (inches)	m (inches)
1/8	0.066	0.079
1/4	0.131	0.118
3/8	0.197	0.177
1/2	0.263	0.197
5/8	0.328	0.236
3/4	0.394	0.276
7/8	0.459	0.276
1	0.525	0.315
1-1/4	0.656	0.394
1-1/2	0.788	0.433
1-3/4	0.919	0.492
2	1.050	0.492

Figure 1: Recommended Groove Dimensions

## Determining Line Pull

Certain calculations involving line pull ( $F_s$ ) and the wrap angle ( $\alpha$ ) must be completed when designing a sheave. For circumferential loads, the wrap angle  $\alpha$  influences the load on the groove and on the center bore or bearing. Wrap angle is defined as the angle formed between the entry and exit points of the wire rope on the sheave, as seen from the center of the sheave.

The following formula determines the actual load based on line pull and wrap angle:

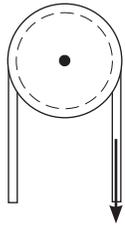
$$F_{res} = 2 \cdot F_s \cdot \sin \left\{ \frac{\alpha}{2} \right\}$$

## Groove Pressure

Two criteria must be observed, but as a general rule, if the D:d ratio (sheave tread diameter : wire rope diameter) is 18:1 or greater, the calculations for groove pressure can be ignored. The calculated value of the maximum continuous service load ( $p'$ ) resulting from the use of the formulas given below, must be equal to or less than the values given in *Figure 3* and *Figure 4*.

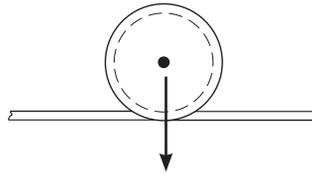
1. Sheave under circumferential load, or sheave under point load.

### Circumferential Load



Line pull  $F_s$

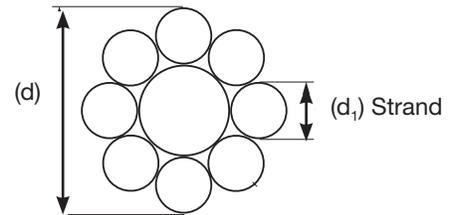
### Point Load



Load  $F$  (Wheel Pressure)

2. Stranded wire rope, or armored cable

### Open Stranded Cable



## Open Cable, circumferential load

$$p' = p'_e \cdot \sqrt{\frac{X}{Z}} \quad \text{with } p'_e = 650 \cdot \sqrt{\frac{[(2 \cdot r) - d_1] \cdot F_{res}}{2 \cdot r \cdot d_1 \cdot D}} \quad \text{in psi}$$

- $d_1$  = Strand diameter in inches
- $D$  = Root diameter of sheave in inches
- $X$  = Correction factor taken from *Figure 2*
- $r$  = Groove radius in inches
- $F$  = Load (wheel pressure) in lbs
- $F_{res}$  = Total load in lbs (see previous page)
- $Z$  = Number of strands

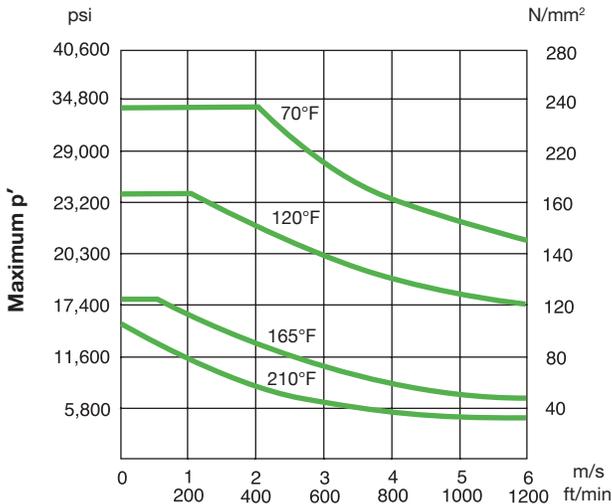


Figure 3: Maximum Continuous Loading  $p'$  for Circumferential Loads

## Open Cable, point load

$$p' = p'_e \cdot \sqrt[3]{\frac{X}{Z}} \quad \text{with } p'_e = 505 \cdot \sqrt[3]{\left[1 - \frac{d_1}{2 \cdot r} + \frac{d_1}{D}\right] \cdot \frac{F}{(d_1)^2}} \quad \text{in psi}$$

Specific Pressure ( $P_e$ ) (in psi)	Correction Factor ( $X$ )
$\leq 7,250$	$Z$
22,000	6
43,500	4
$\leq 62,250$	2.5

Figure 2

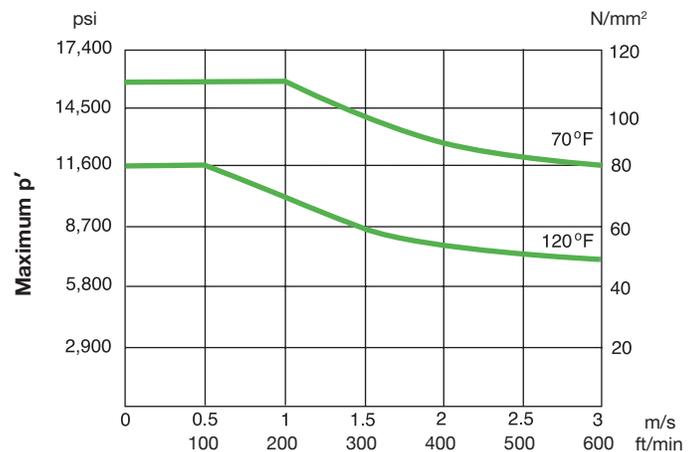


Figure 4: Maximum Continuous Loading  $p'$  for Point Loads

## Armored cable, point contact

- $p'$  = Expected area pressure between cable and groove  
 $a$  =  $(2/d) - (1/r)$   
 $b$  =  $2/D$   
 $d$  = Cable OD in inches  
 $D$  = Root diameter of sheave in inches  
 $F$  = Load (wheel pressure) in lbs  
 $r$  = Groove radius in inches  
 $\cos v$  =  $(a-b) / (a+b)$   
 $z$  = Auxiliary value from *Figure 5*

$$p' = \frac{765}{z} \cdot \sqrt[3]{(a + b)^2 \cdot F} \quad \text{in psi}$$

Auxiliary value z for various angles										
v	90 - 85°	84 - 75°	74 - 65°	64 - 55°	54 - 45°	44 - 35°	34 - 25°	24 - 15°	14 - 5°	4 - 0°
z	1.0	1.007	1.030	1.065	1.124	1.211	1.346	1.541	2.109	0

Figure 5

## Armored cable, circumferential load

There is no specific calculation for this application. Please contact our engineers if your application calls for these conditions.

## Bearing press fit tolerance

Minimum recommended press fit for bearing seat with needle roller or ball bearing. For other roller bearings and bronze bushings, multiply the press fit undersize by 1.6. Tolerance should be +/- 0.002 (+/- 0.05 mm).

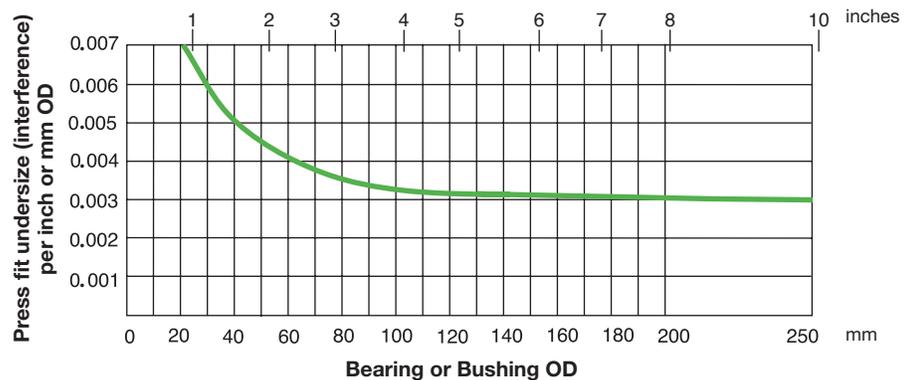


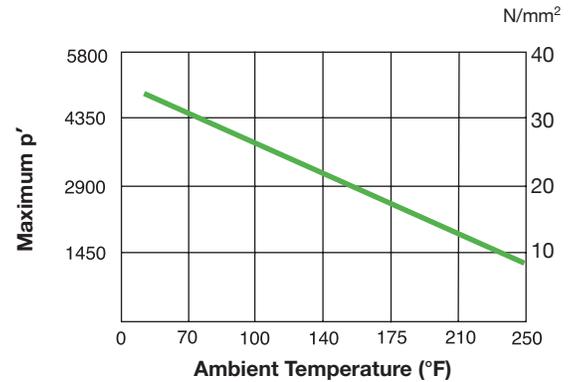
Figure 6

## Center bore pressure

Besides the pressure between cable and groove, the pressure between center bore and bearing outer race must be calculated for the proper sheave design.

$$p = \frac{F_{res}}{d_1 \cdot L \cdot Y}$$

- $d_1$  = Bearing OD in inches (or mm)
- $F_{res}$  = Total load in lbs (or N)
- $Y$  = Number of bearings
- $L$  = Bearing load carrying width in inches (or mm)



**Figure 7: Maximum continuous center bore pressure p vs. temp.**

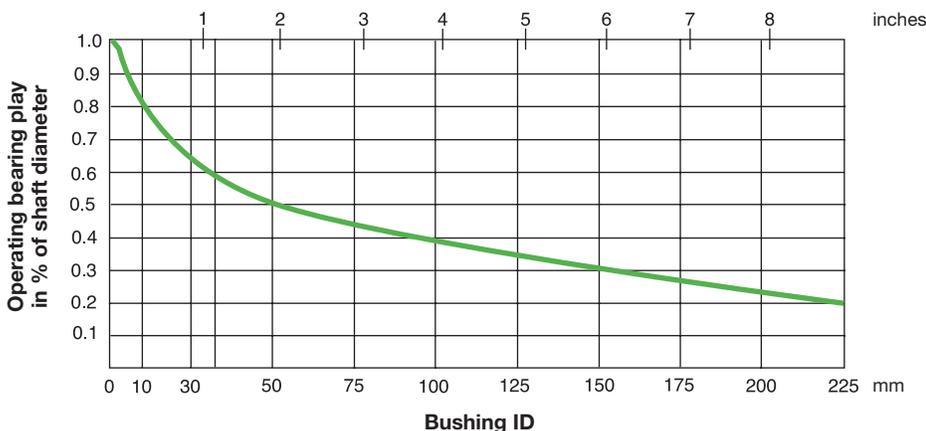
The calculated area pressure on the bearing outer race must be less than the values given in *Figure 7*. If the values are greater, a steel sleeve should be used in the bore. The bearings could then be pressed into the steel sleeve. A decision to use a cast nylon sheave in a specific application can only be made once both the area pressure in the groove and on the bearing outer race have been calculated.

## Sheaves Without Bearings

The calculation for surface area pressure for bushings (running the sheave on the shaft) is the same as for anti-friction bearings. However, for a bushing, the area pressure must be multiplied by the speed of the sheave in order to obtain the PV-value. The PV-value decides whether the sheave can run directly on the shaft

$$\text{PV-value} = \text{Pressure} \times \text{Velocity in (N/mm}^2 \times \text{m/s)}$$

Sheaves made of Oilamid® (cast nylon + oil) have a maximum PV-value of about 0.1 N/mm<sup>2</sup> x m/s when running dry or 0.6 N/mm<sup>2</sup> x m/s when running with lubrication. Anti-friction bearings should be used where these PV-values are exceeded.



Minimum recommended operating bearing play for sheaves running directly on the shaft.

**Figure 8**

## Load Calculation Example

### Conditions:

Sheave tread diameter:	23"
Wire Rope:	1" diameter open stranded (1/4" strand diameter, 8 strands)
Load:	20,000 lbs line pull with 120° wrap angle
Bearing:	Tapered roller (2) OD 4.375" x 1.5" long (cup length 1.1875")

### Groove pressure:

$$F_{res} = 2 \cdot 20000 \cdot \sin \left[ \frac{120}{2} \right] = 34,641 \text{ psi}$$

$$p'_e = 650 \cdot \sqrt{\frac{(2 \cdot 0.525) \cdot 34641}{2 \cdot 0.525 \cdot 0.25 \cdot 23}} = 44,038$$

$$p' = 44038 \cdot \sqrt{\frac{3}{8}} = 26,967 \text{ psi}$$

### Result:

The sheave groove can withstand the line pull at line speeds up to about 600 ft/min. in ambient temperatures of 70°F or line speeds up to about 300 ft/min. at ambient temperatures up to about 100°F (see *Figure 3*). These figures are for continuous service. Load capacity for intermittent operation is higher.

### Bore pressure:

$$p = \frac{34641}{4.375 \cdot 1.1875 \cdot 2} = 3334 \text{ psi}$$

### Result:

The sheave bore can hold the load at ambient temperatures up to about 120°F in continuous service (see *Figure 7*).

### Press Fit Undersize of Center Bore (see *Figure 6*):

$$4.375 \cdot 0.0033 = 0.014" \cdot 1.6 = 0.0231"$$
$$4.375" - 0.0231 = 4.352"$$

Center bore size should be 4.352"  
Tolerance: +0.000" /- 0.004"



## Worksheet for Sheaves Made of Cast Nylon

Company Name \_\_\_\_\_

Contact name \_\_\_\_\_

Address \_\_\_\_\_

Telephone \_\_\_\_\_ Fax \_\_\_\_\_ Date \_\_\_\_\_

### Sheave information

Outer Diameter (OD) \_\_\_\_\_ Inches

Root Diameter (D) \_\_\_\_\_ Inches

Hub Diameter (h) \_\_\_\_\_ Inches

Center Bore Diameter (b) \_\_\_\_\_ Inches

Sheave Thickness (B1) \_\_\_\_\_ Inches

Hub Thickness (B2) \_\_\_\_\_ Inches

Groove Radius (r) \_\_\_\_\_ Inches

Type of Sheave  Fixed  Free Hanging

Color  Natural White  Black

### Bearing/Bushing Information

Bearing/Bushing OD (d<sub>i</sub>) \_\_\_\_\_ inches

Bearing/Bushing Width (L) \_\_\_\_\_ inches

Number of Bearings (Y) \_\_\_\_\_

Shaft Diameter (s) \_\_\_\_\_ inches

Type of Bearing  Bushing  Anti-Friction

Supply with  Bearing  Bushing  Neither

### Wire Rope Information

Rope Diameter (d) \_\_\_\_\_ inches

Strand Diameter (d<sub>s</sub>) \_\_\_\_\_ inches

Number of Strands (Z) \_\_\_\_\_

Type of Rope  Open Wire  Armored Cable

### Quantity Requirements

Qty to be quoted \_\_\_\_\_ Annual Qty Required \_\_\_\_\_

### Application Information

Line Pull (F<sub>s</sub>) \_\_\_\_\_ lbs

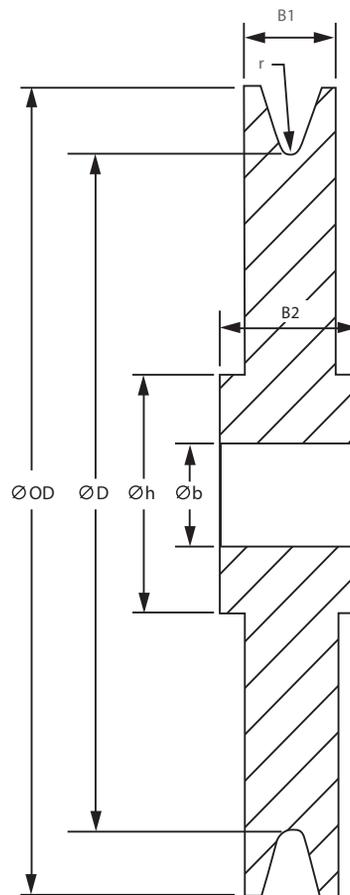
Rope Speed (V) \_\_\_\_\_ fpm

Ambient Temperature (T<sub>a</sub>) min. \_\_\_ max. \_\_\_ °F

Wrap Angle (α) \_\_\_\_\_ °

Fleet Angle \_\_\_\_\_ °

Type of Loading  Circumferential  Point





In addition to being the largest supplier of machined non-metallic sheaves in North America, Timco offers a broad range of other fabricated parts to our customers. Our material options from UHMW-PE and nylon to vulcanized fibre and PEEK means our focus is on choosing the right material for your application. Engineering plastics are machined to our customer's specifications using only the highest quality, heat treated and closely inspected plastic materials. There is no minimum production size. Timco can provide everything from prototypes to full production quantities.

So, if in addition to sheaves you need other fabricated wear or structural components, please contact Timco for a quotation.

# TIMCO

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