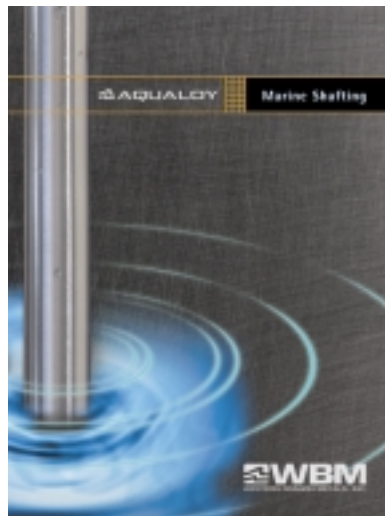


Virtual Brochure

What's Inside



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# Aqualoy® Marine Propeller Shafting

Aqualoy® is the result of many years of experience in supplying boat shafting to the marine industry. Aqualoy marine shafting undergoes more quality controls than any of the competing brands and is used in a wide variety of applications including work boats, pleasure craft, high performance boats, naval craft and other ocean going vessels. From melt to final straightening, the Aqualoy process produces a rounder, straighter shaft. When we ship our product, the Western Branch Metals name and reputation is proudly affixed to each and every bar – Aqualoy marine shafting, there's no substitute for quality!

**Aqualoy 22** provides the best combination of corrosion resistance and strength for marine applications for 2" diameter and under. It is an ideal choice for pleasure craft due to its ability to resist corrosion when sitting idle in seawater for long periods of time. Aqualoy 22 is an austenitic alloy and is non-magnetic.

**Aqualoy 22 High Strength** provides the same corrosion resistance as the Aqualoy 22 but also offers the strength of the Aqualoy 17 in 2-1/4" through 6" diameter. It is ideal for those vessels requiring higher strength shafts while maintaining the highest possible corrosion resistance available. Aqualoy 22 High Strength is an austenitic alloy and is non-magnetic.

**Aqualoy 19** is a nitrogen strengthened Type 304 stainless steel. Corrosion resistance is superior to Type 304 and better than Aqualoy 17. Aqualoy 19 is an austenitic alloy and is non-magnetic. The addition of nitrogen increases strength, toughness and corrosion resistance. Aqualoy 19 shafts have been proven to be successful in several types of boats including sportfishermen and other pleasure crafts as well as workboats where better corrosion resistance is necessary.

**Aqualoy 17** is a precipitation hardening stainless steel, which has the highest strength, and hardness of all stainless steel boat shafting alloys over 2 inches in diameter. Corrosion resistance is comparable to Type 304 but slightly less than Aqualoy 19. Aqualoy 17 is typically used in a workboat environment due to its strength in the larger diameters. Typical vessel applications include crew boats, patrol boats, tugs and trawlers.

All Aqualoy marine shafting is supplied in cardboard tubes (3" diameter and under) or paper wrapped (over 3" diameter) and boxed to ensure the material arrives intact. For special packaging requirements, please inquire.



Aqualoy is a registered trade name of Western Branch Metals, Inc.

# AQUALOY 22

## AQUALOY 22 HIGH STRENGTH

Aqualoy 22 and High Strength 22 offer the best combination of corrosion resistance and strength for any marine shaft application and is superior to Type 316 and Monel 400 in both corrosion resistance and strength. Although highly corrosion resistant, cathodic protection is recommended to avoid galvanic corrosion in salt and brackish water environments. It is an ideal choice for pleasure craft due to its ability

to resist corrosion when sitting idle in seawater for long periods of time. Aqualoy 22 High Strength provides the same corrosion resistance as the Aqualoy 22 but also offers the strength of Aqualoy 17 in 2-1/4" through 6" diameter. It is ideal for those vessels requiring higher strength shafts while maintaining the highest possible corrosion resistance available.

### Chemical Composition

Carbon, Max.	.06
Manganese, Max.	4.00 - 6.00
Phosphorus, Max.	.04
Sulfur, Max.	.03
Silicon, Max.	1.00
Molybdenum	1.50 - 3.00
Chromium	20.50 - 23.50
Nickel	11.50 - 13.50
Nitrogen	0.20 - 0.40
Columbium	0.10 - 0.30
Vanadium	0.10 - 0.30
Iron	Balance

### Physical Properties (AQUALOY 22 is non-magnetic)

Density at 75F (24C)	0.285 lbs/in <sup>3</sup> (7.88 gm/cm <sup>3</sup> )
Modulus of Elasticity	
<i>Tension</i>	28,900,000 psi (199,000 Mpa)
<i>Torsion (Rigidity)</i>	10,800,000 psi (72,900 Mpa)
Poisson's Ratio	.0312

### Minimum Mechanical Properties

	3/4" to 1-1/4"	Over 1-1/4" to 2"	Over 2" to 2-1/2"	Over 2-1/2" to 3"	Over 3" to 12"	High Strength 2-1/4 to 6"
Ultimate Tensile Strength, psi (Mpa)	145,000 (1000)	135,000 (931)	120,000 (827)	115,000 (793)	100,000 (689)	130,000 (896)
0.2% Yield Strength, psi (Mpa)						
<i>Tension</i>	130,000 (896)	105,000 (724)	95,000 (655)	75,000 (517)	55,000 (379)	105,000 (724)
<i>Torsion</i>	86,600 (597)	70,000 (483)	63,300 (434)	50,000 (345)	36,600 (252)	70,000 (483)
Elongation, % in 2" (50.88mm)	18	20	20	25	30	15
Reduction of Area, %	45	50	50	50	50	45
Impact Charpy V-Notch	80	100	100	100+	100+	100
(Typical) ft-lbs (J)	(108)	(136)	(136)	(136+)	(136+)	(136)

AQUALOY 22 meets the following specifications (Analysis Only): ASTM A 276, ASTM A 479 and AMS 5764.

# AQUALOY 19

Nitrogen strengthened, Aqualoy 19 is an austenitic alloy and is non-magnetic. Applications include sportfishermen and other pleasure crafts as well as workboats where better corrosion resistance is neces-

sary. To avoid galvanic corrosion in salt or brackish water, installation of Navy grade zinc anodes is recommended.

### Chemical Composition

Carbon, Max.	.08
Manganese, Max.	2.00
Silicon, Max.	1.00
Chromium	18.00 - 20.00
Nickel	8.00 - 10.50
Phosphorus, Max.	.04
Nitrogen	0.20 - 0.30
Sulfur, Max.	.03
Iron	Balance

### Physical Properties (AQUALOY 19 is non-magnetic)

Density at 75F (24C)	0.286 lbs/in <sup>3</sup> (7.916 gm/cm <sup>3</sup> )
Modulus of Elasticity	
<i>Tension</i>	29,000,000 psi (199,949 Mpa)
<i>Torsion (Rigidity)</i>	11,200,000 psi (76,140 Mpa)
Poisson's Ratio	.0295

## Aqualoy 19 Minimum Mechanical Properties

	Up to 1-1/2"	Over 1-1/2" to 2"	Over 2" to 2-1/2"	Over 2-1/2" to 3"	Over 3" to 12"
Ultimate Tensile Strength, psi (Mpa)	130,000 (896)	115,000 (793)	105,000 (724)	100,000 (690)	95,000 (655)
0.2% Yield Strength, psi (Mpa)					
<i>Tension</i>	105,000 (724)	85,000 (586)	60,000 (414)	55,000 (379)	50,000 (345)
<i>Torsion</i>	70,000 (483)	57,000 (393)	40,000 (276)	36,600 (252)	33,000 (228)
Elongation, % in 2" (50.88mm)	20	25	30	35	35
Reduction of Area, %	55	55	55	55	55
Impact Charpy V-notch	100+	100+	100+	100+	100+
(Typical) ft-lbs (J)	(136+)	(136+)	(136+)	(136+)	(136+)

Note: if higher mechanical properties are required, please inquire.

## AQUALLOY 17

Aqualoy 17 has the highest strength and hardness of all stainless steel boat shafting alloys over 2 inches in diameter. Corrosion resistance is comparable to Type 304. Vessel applications include tugs, trawlers, crew boats, patrol boats and other workboats due to its high strength in the larger diameters. To avoid galvanic corro-

sion, cathodic protection is recommended for salt or brackish water environments. Navy grade zinc anodes, properly installed, should provide satisfactory protection against galvanic corrosion. For sizes over 8" in diameter, please inquire.

### Chemical Composition

Carbon, Max.	.07
Manganese, Max.	1.00
Phosphorus, Max.	.04
Sulfur, Max.	.03
Silicon, Max.	1.00
Chromium	15.00 - 17.00
Nickel	3.50 - 5.00
Copper	3.00 - 5.00
Columbium + Tantalum	0.15 - 0.45
Iron	Balance

### Physical Properties (Aqualoy 17 is magnetic)

Density at 75F (24C)	0.284 lbs/in <sup>3</sup> (7.87 gm/cm <sup>3</sup> )
Modulus of Elasticity	
<i>Tension</i>	29,100,000 psi (200,600 Mpa)
<i>Torsion (Rigidity)</i>	11,270,000 psi (77,700 Mpa)
Poisson's Ratio	.0291

### Minimum Mechanical Properties

For 3/4" through 8"	
Ultimate Tensile Strength, psi (Mpa)	135,000 (931)
0.2% Yield Strength, psi (Mpa)	
<i>Tension</i>	105,000 (724)
<i>Torsion</i>	70,000 (483)
Elongation, % in 2" (50.88mm)	16
Reduction of Area, %	50
Impact Charpy V-notch	50
(Typical) ft-lbs (J)	(68)
Hardness Typical	
<i>Rockwell</i>	C28/37
<i>Brinell</i>	277/352

AQUALLOY 17 meets the following specifications (Analysis and Mechanical Properties for H1150 only): AMS-5643 and ASTM-A-564.

## The Aqualoy Process

The Aqualoy Process is the transformation of stainless steel bars into marine shafting. Beyond the chemical and mechanical properties of the stainless steel, the key components of boat shafting lie in the finishing of each shaft to exacting marine tolerances – diameter, straightness and finish.

The finishing of Aqualoy Marine Shafting involves several steps. The initial step is checking the diameter. Each shaft is inspected to ensure the diameter is within the applicable plus or minus tolerance as well as the out-of-round tolerance.

The next step, straightening, is considered to be the most crucial aspect of the finishing process. Each shaft is straightened to tolerances well within the industry standard as shown on the following Straightness Tolerance Table. Precision straightening not only prolongs the life of the shaft but reduces the amount of time spent during the machining process as well.

The final step, polishing, is performed using state of the art equipment designed specifically for marine propeller shafting. From 3/4" through 8" diameter, each shaft is polished and inspected resulting in an excellent RMS finish, unequalled in the industry.

The Aqualoy Process has proven to be the difference as Aqualoy Marine Shafting has become the brand of choice by boat builders and shipyards around the world.



### Diameter Tolerances

Diameter limits, inches	Permissible Variation, inches		
	Plus	Minus	Out-of-Round
3/4" to 15/16" incl (centerless ground and polished)	0.001	0.001	0.001
1 to 1-1/2 excl (centerless ground and polished)	0.002	0.001	0.0015
1-1/2 to 2 incl (centerless ground and polished)	0.003	0.001	0.002
Over 2 to 4 incl (centerless ground)	0.005	0.001	0.003
Over 4 to 4-1/2 incl (centerless ground)	0.005	0.005	0.005
Over 4-1/2 to 5-1/2 incl (centerless ground)	0.008	0.008	0.008
Over 5-1/2 to 7 incl (centerless ground)	0.008	0.012	0.008
Over 7 to 8 incl (centerless ground)	0.008	0.014	0.008
Over 8 to 12 incl (centerless ground)	0.010	0.016	0.010
Over 12 (centerless ground)	0.015	0.020	0.015

\* Diameter tolerances up to 4" in diameter, per the ABYC P-6 standards

## Straightness Tolerance Table

### Specified Diameters of Shafting – Over 15/16" (23.8mm) to 8" (203.2mm)

Specified Length of Bar Feet (meter)	(Throw in One Revolution from Straightness) inches (millimeters)	(Throw in One Revolution from Straightness) inches (millimeters)
up to 3' (.9144) incl.	0.005 (.1270)	0.0025 (.0635)
over 3' (.9144) to 4' (1.2192) incl.	0.0065 (.1651)	0.0025 (.0635)
over 4' (1.2192) to 5' (1.524) incl.	0.0080 (.2032)	0.003 (.0762)
over 5' (1.524) to 6' (1.8288) incl.	0.0095 (.2413)	0.003 (.0762)
over 6' (1.8288) to 7' (2.1136) incl.	0.0110 (.2794)	0.003 (.0762)
over 7' (2.1136) to 8' (2.4384) incl.	0.0125 (.3175)	0.003 (.0762)
over 8' (2.4384) to 9' (2.7432) incl.	0.0140 (.3556)	0.004 (.1016)
over 9' (2.7432) to 10' (3.0480) incl.	0.0155 (.3937)	0.005 (.1270)
over 10' (3.0480) to 11' (3.3528) incl.	0.0170 (.4318)	0.006 (.1524)
over 11' (3.3528) to 12' (3.6576) incl.	0.0185 (.4699)	0.007 (.1778)
over 12' (3.6576) to 13' (3.9624) incl.	0.0200 (.5080)	0.008 (.2032)
over 13' (3.9624) to 14' (4.2672) incl.	0.0215 (.5461)	0.008 (.2032)
over 14' (4.2672) to 15' (4.5720) incl.	0.0230 (.5842)	0.008 (.2032)
over 15' (4.5720) to 16' (4.8768) incl.	0.0245 (.6223)	0.008 (.2032)
over 16' (4.8768) to 17' (5.1816) incl.	0.0260 (.6604)	0.010 (.2540)
over 17' (5.1816) to 18' (5.4864) incl.	0.0275 (.6985)	0.010 (.2540)
over 18' (5.4864) to 19' (5.7912) incl.	0.0290 (.7366)	0.010 (.2540)
over 19' (5.7912) to 20' (6.0960) incl.	0.0305 (.7747)	0.010 (.2540)
over 20' (6.0960) to 21' (6.4004) incl.	0.0320 (.8128)	0.012 (.3048)
over 21' (6.4004) to 22' (6.7052) incl.	0.0335 (.8509)	0.012 (.3048)
over 22' (6.7052) to 23' (7.0100) incl.	0.0350 (.8890)	0.012 (.3048)
over 23' (7.0100) to 24' (7.3148) incl.	0.0365 (.9271)	0.012 (.3048)
over 24' (7.3148) to 25' (7.6196) incl.	0.0380 (.9652)	0.014 (.3556)
over 25' (7.6196) to 26' (7.9244) incl.	0.0490 (1.2446)	0.014 (.3556)
over 26' (7.9244) to 27' (8.2291) incl.	0.0505 (1.2827)	0.014 (.3556)
over 27' (8.2291) to 28' (8.5339) incl.	0.0520 (1.3208)	0.014 (.3556)
over 28' (8.5339) to 29' (8.8387) incl.	0.0535 (1.3589)	0.016 (.4064)
over 29' (8.8387) to 30' (9.1435) incl.	0.0550 (1.3970)	0.016 (.4064)

For diameters supplied in random lengths from which multiple finished shafts will be cut, please refer to the Industry Standard straightness above. Also, random lengths cut to length may go out of Industry Standard straightness due to relief of stresses.

### Finish Tolerance Table

Diameter, Inches	Typical Surface Finish
3/4 to 2	30 RMS Max.
Over 2 to 14-1/2	70 RMS Max.

**Length Tolerance** All Aqualoy shafting is typically supplied in random lengths with a length tolerance of plus 12 inches minus zero inches. For exact length bars, please inquire.

**Weight Per Foot Table**

Diameter		Weight	
Inches	(Millimeters)	lbs / ft	kg / m
3/4	(19.0)	1.502	(2.24)
7/8	(22.2)	2.044	(3.04)
1	(25.4)	2.670	(3.98)
1-1/8	(28.6)	3.379	(5.03)
1-1/4	(31.7)	4.172	(6.21)
1-3/8	(34.9)	5.048	(7.52)
1-1/2	(38.1)	6.008	(8.95)
1-3/4	(44.4)	8.177	(12.18)
2	(50.8)	10.680	(15.91)
2-1/4	(57.1)	13.517	(20.13)
2-1/2	(63.5)	16.688	(24.86)
2-3/4	(69.8)	20.192	(30.08)
3	(76.2)	24.030	(35.79)
3-1/4	(82.5)	28.202	(42.01)
3-1/2	(88.9)	32.708	(48.72)
3-3/4	(95.2)	37.547	(55.93)
4	(101.6)	42.720	(63.63)
4-1/2	(114.3)	54.068	(80.53)
5	(127.0)	66.750	(99.42)
5-1/2	(139.7)	80.768	(120.30)
6	(152.4)	96.120	(143.17)
6-1/2	(165.1)	112.808	(168.03)
7	(177.8)	130.830	(194.87)
7-1/2	(190.5)	150.188	(223.70)
8	(203.2)	170.880	(254.52)
9	(228.6)	216.270	(322.13)
10	(254.0)	267.000	(397.70)
11	(279.4)	323.070	(481.21)
12	(304.8)	384.480	(572.68)

**Metric Conversion Information**

**LENGTH**

1 millimeter = 0.03937 inches      1 centimeter = 0.3937 inches      1 meter = 3.281 feet  
 1 inch = 25.4 millimeters      1 inch = 2.54 centimeters      1 foot = 0.305 meters

**WEIGHT**

1 kilogram (1000 grams) = 2.2 pounds  
 1 pound = 0.454 kilograms

**FORCE**

1,000 pounds per square inch (psi) = 6.8948 megapascals (MPa)  
 1 kilowatt = 1.34 horsepower

# Boat Shafting Comparison

## Physical and Typical Mechanical Properties

	A Q U A L O Y			Type	Duplex	Monel	Steel	Steel
	17	19 <sup>1</sup>	22 <sup>2</sup>	316	2205	500 <sup>3</sup>	C1018 <sup>4</sup>	C1045 <sup>5</sup>
Density lbs/in <sup>3</sup> (gm/cm <sup>3</sup> )	.284 (7.838)	.281 (7.775)	.286 (7.916)	.288 (7.971)	.282 (7.812)	.306 (8.476)	.284 (7.838)	.284 (7.838)
Ultimate Tensile Strength 1000 psi (Mpa)	145 (1000)	145 (1000)	150 (1034)	85 (586)	120 (828)	156 (1076)	58 (400)	82 (570)
0.2% Yield Strength Tension 1000 psi (Mpa)	125 (862)	125 (862)	125 (862)	35 (242)	82 (566)	115 (793)	32 (221)	45 (310)
0.2% Yield* Strength Torsion 1000 psi min. (Mpa)	70 (483)	70 (483)	70 (483)	23 (159)	43 (297)	67 (462)	20 (138)	30 (207)
Elongation, % in 2 in. (50.8mm)	19	22	25	60	30	22	25	16
Reduction of Area, %	60	65	58	70	-	30	50	40
Impact Charpy V-Notch, ft-lb (N•m)	55 (74)	150 (202)	100 (135)	95-120 (129-162)	-	44 (59)	-	-
Hardness, Brinell	311	300	302	150	226	300	116	163
Modulus of Elasticity in Tension, 1,000,000 psi (Mpa)	28.5 (196.5)	28 (193.1)	28 (193.1)	28 (193.1)	27.5 (189.7)	26 (179.3)	30 (206.8)	30 (206.8)

\* All values for 0.2% Yield Strength (in Torsion) are minimums

<sup>1</sup> All values for 0.2% Yield Strength (in Torsion) are minimums

<sup>2</sup> Up to 1-1/2" (38.1mm)

<sup>3</sup> Over 1-1/4"(31.75mm) to 2" (50.8mm) incl and Aqualoy 22 High Strength from 2-1/4" (57.15mm) to 6" (152.4mm)

<sup>4</sup> Trademark of The International Nickel Company

<sup>5</sup> Estimated Minimum Values

<sup>6</sup> Over 1" (25.4mm) to 3" (76.2mm)

## Shaft and Bearing Selection

### Shaft Diameters

The following formulas determine the appropriate shaft diameter and safety factors based on the variables listed along with the ABYC guidelines for minimum safety.

$$D = \sqrt[3]{\frac{321,000 \times P \times S.F.}{S_t \times N}}$$

$$S.F. = \frac{D^3 \times S_t \times N}{321,000 \times P}$$

D = Shaft Diameter, inches (mm)

P = Shaft Horsepower

S.F. = Safety Factor\*

S<sub>t</sub> = Yield Strength, torsional shear, lbs./in.<sup>2</sup> (MPa)

N = Shaft Speed, RPM

\* According to ABYC, safety factors of 2 are considered adequate for boats intended for light pleasure service.

Pleasure boats intended for heavy service and all diesel and gas turbine pleasure boats should consider safety factors approaching 5.

Commercial and high performance craft should consider safety factors approaching 10.

### Bearing Spacing

The formula below is for computing maximum shaft-bearing space:

$$L = \sqrt{2 \times \frac{3.21 D}{N}} \times \sqrt{4 \times \frac{E}{W_1}}$$

L = Maximum unsupported length, feet (m)

D = Shaft Diameter, inches (mm)

N = Shaft speed, RPM

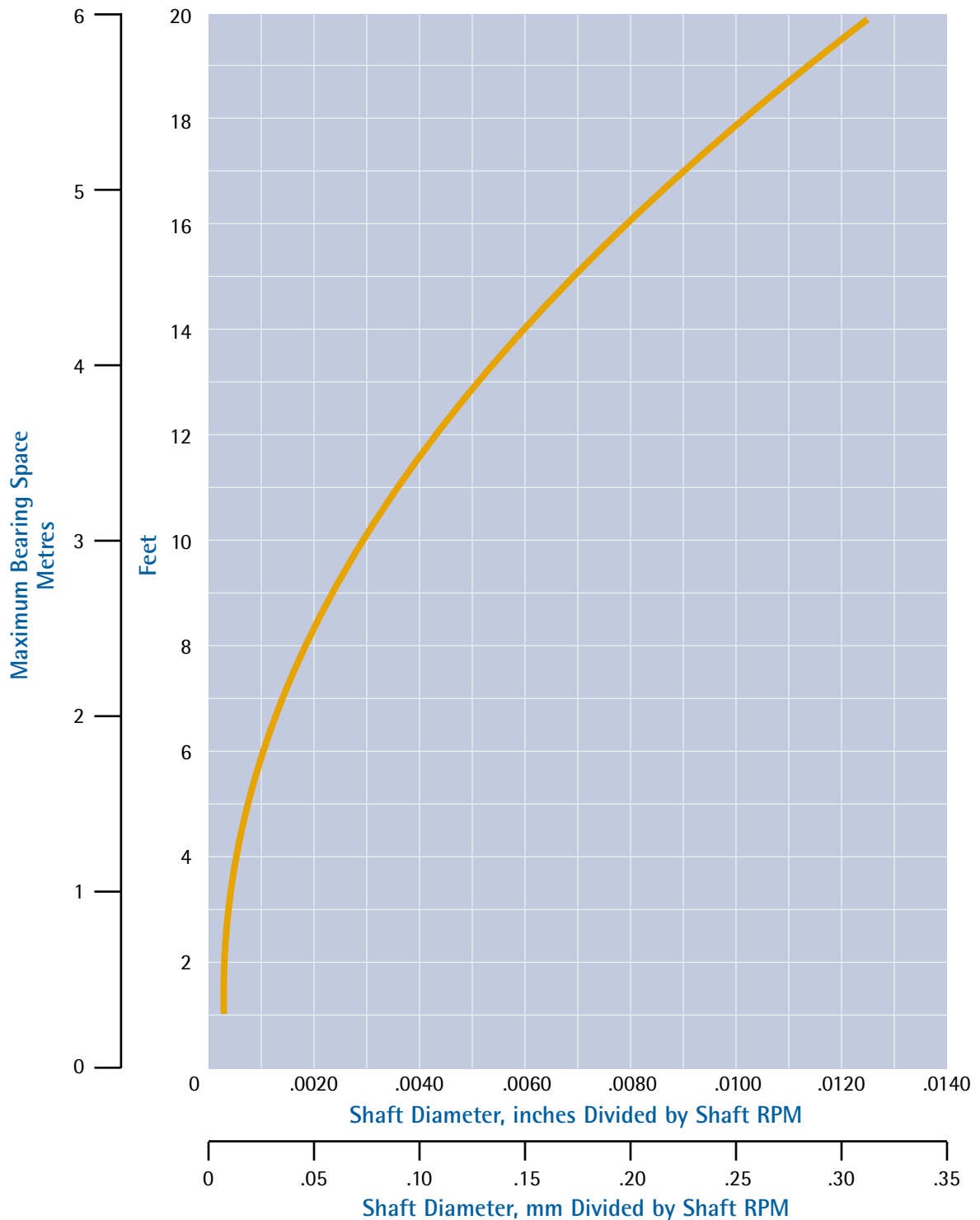
E = Modulus of elasticity in tension, lbs/in.<sup>2</sup> (Mpa)

W<sub>1</sub> = Weight of one cubic inch (cm<sup>3</sup>) of material, pounds (gm)

Note: The minimum required spacing for rigid bearings should exceed 20 shaft diameters when possible to facilitate alignment.

The shaft-bearing spacing formula is based on the formula for critical speed for a shaft having fully flexible bearings at both ends. The most common shaft installation for boats up to about 40 feet (12.192m) in length, consisting of a rigid shaft coupling on a rigid mounting engine at the forward end and a strut bearing at the after end, may be considered to have two rigid bearings. This permits increasing shaft-bearing spacing by 50% over the values shown in the accompanying graph. If the shaft seal is of the rigid type and is located approximately at the midpoint of the shaft, bearing spacing may be twice the values shown in the graphs.

## Bearing Spacing



## Bearing Tolerances

The following are the standards as established by the U.S. Navy, according to BuShips plan number 810-1385664, dated January 14, 1963 "Bearing Stern Tube and Strut". It is essential that bearing to shaft clearance be as shown in the Bearing Tolerance Table. The installer should achieve this clearance by selection of shaft bearings or machining of shaft in way of the bearing or by grinding the bearing as necessary.

## Bearing Tolerance Table

Shaft Size, Inches			Bearing to Shaft Clearance, Inches		
3/4	to	1-3/8	+0.003	to	+0.008
1-7/16	to	1-7/8	.004	to	.010
2	to	2-3/8	.006	to	.012
2-1/2	to	3	.007	to	.014
3-1/8	to	3-3/4	.008	to	.015
3-7/8	to	4-1/4	.010	to	.017
4-3/8	to	4-7/8	.012	to	.019
5	to	5-3/8	.015	to	.023
5-1/2	to	5-7/8	.017	to	.025
6	to	6-3/8	.020	to	.029
6-1/2	to	6-7/8	.022	to	.032
7	to	7-3/8	.024	to	.034
7-1/2	to	7-7/8	.025	to	.035
8	to	8-3/8	.027	to	.037
8-1/2	to	8-7/8	.028	to	.040
9	to	9-7/8	.030	to	.042
10	to	10-7/8	.032	to	.044
11	to	11-3/8	.034	to	.048
11-1/2	to	12-3/4	.035	to	.050
12-7/8	to	13-3/8	.037	to	.052
13-1/2	to	14-1/2	.040	to	.055
14-5/8	to	15	.042	to	.058

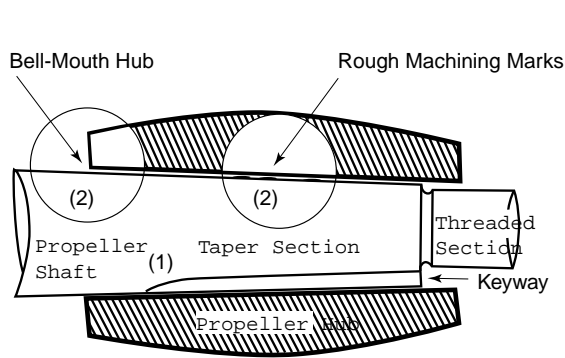
## Recommendations and Procedures for Machining and Installing Aqualoy Marine Shafting

When handling Aqualoy, it is important to avoid the use of wire slings or lifting equipment that may scratch the surface. Careful handling will also preserve the straightness of the shaft, a key element in the machining process. The information below contains important considerations when machining and installing Aqualoy marine propeller shafting.

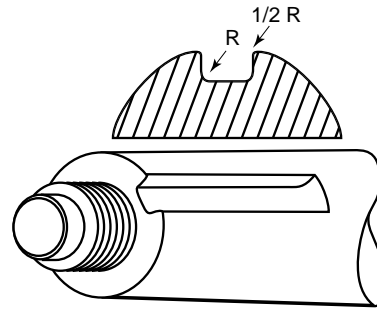
### Machining Procedures

A properly machined keyway and taper is vital to maximizing the service life of your shaft. Improper machining can lead to several problems including crevices, sharp corners and propeller wobble which can result in crevice corrosion problems, stress raisers and added bending stresses, all of which can reduce the service life of your shaft.

Proper size, shape, and alignment of keyways are all essential for maximum shaft life. Keyways with sharp corners and vertical ends produce stress concentrations that can significantly reduce shaft life. This is especially true when the shaft is highly stressed in service. By rounding top corners, filleting interior corners, and using sled-runner type keyway ends, stress concentrations can be prevented. It is highly recommended the top corners of keyways be rounded to one-half the radius of the interior corners. For more specific information related to machining Aqualoy shafting, refer to SAE Standard J-755.



Cross section showing (1) shortening of keyway sometimes minimizes stresses in shaft, and (2) types of corrosion-causing crevices.



Sketches show sled-runner type end and filleted keyway recommended for maximum shaft life. Both top corners as well as bottom corners should be filleted.

## Suggested Starting Rates

Note: Coated carbides can improve machining rates

Operation	Speeds SFM (m/Minute)			Feed
	Aqualoy 17	Aqualoy 19	Aqualoy 22	
<b>Single Point Turning Carbide Tools</b>				
Roughing	130-180 (40-55)	100-160 (30-49)	100-150 (30-46)	.005-.015 (.127-.381mm) In./R
Finishing	150-300 (46-91)	140-210 (43-64)	130-200 (40-61)	.003-.005 (.076-.127mm)In./R
<b>High Speed Steel Tools</b>				
Roughing	60-90 (18-27)	40-60 (12-18)	30-50 (9-15)	.005-.015 (.127-.381mm)In./R
Finishing	100-120 (30-37)	55-75 (17-23)	45-65 (14-20)	.003-.005 (.076-.127mm)In./R
<b>Milling(plain)</b>				
High Speed Steel Tools	40-60 (12-18)	30-35 (9-11)	25-30 (8-9)	.003-.005 (.076-.127mm)In./tooth
<b>Milling(end mill)*</b>				
Super High Speed Steel Tools	40-60 (12-18)	25-30 (8-9)	25-30 (8-9)	.001 (.025mm)In./tooth
<b>Threading—Die Head</b>				
High Speed Steel Tools	10-25 (3-8)	10-25 (3-8)	10-25 (3-8)	-
<b>Threading—Single Point</b>				
High Speed Steel Tools	10-25 (3-8)	10-25 (3-8)	10-25 (3-8)	-
Carbide Tools	60-85 (18-26)	50-75 (15-23)	50-75 (15-23)	-
<b>Drilling</b>				
High Speed Steel Tools	40-60 (12-18)	25-50 (8-15)	25-50 (8-15)	.002-.010 (.051-.254mm)In./R
<b>Saw Cutting</b>				
Reciprocating	Medium Pressure	Heavy Pressure	Heavy Pressure	Up to 2" (50.8mm)
High Speed Steel Blade	60-80 (18-24)	40-60 (12-18)	40-60 (12-18)	6 teeth/inch
				Over 2" (50.8mm)
				4 teeth/inch
<b>Saw Cutting—Band Saw</b>				
	Medium Pressure	Heavy Pressure	Heavy Pressure	Up to 3" (76.2mm)
	60-80 (18-24)	40-60 (12-18)	40-60 (12-18)	6 teeth/inch
				Over 3" (76.2mm)
				3 to 4 teeth/inch

\*Two-fluted end mill shortened 25% gives best results.

Nominal Shaft Dia., in. (mm)	Dia., Small End, in. (mm)		Taper Length, in. (mm)	Keyway Width, in. (mm)			Keyway Side Depth <sup>a</sup> , in. (mm)			Keyway Fillet Radius <sup>b</sup> , in. (mm)	Thread <sup>c</sup> , in. (mm)		End of Taper to End of Thread, in. (mm)	Extension Beyond Taper, in. (mm)	Undercut, in. (mm)		Dia. of Pin End, in. (mm)	Length of Pin End, in. (mm)	Cotter Pin Hole, in. (mm)		Cotter Pin, in. (mm)		Nuts <sup>d</sup>			Sleeve Dia., in. (mm)		Clearance in. (mm)	Nominal Shaft Dia., in. (mm)			
	Min	Max		Nominal	Min	Max	Nominal	Min	Max		Diameter	Threads per in. (25.4 mm)			J	K			N	P	Nominal Dia., in. (mm)	Length in. (mm)	Size in. (mm)	Plain Thickness in. (mm)	Jam Thickness in. (mm)	Keyway Length in. (mm)	Min			Max		
	A	B																													C	D
3/4 (19.05)	0.624 (15.85)	0.626 (15.90)	2 (50.80)	3/16 (4.76)	0.1865 (4.74)	0.1875 (4.76)	3/32 (2.38)	0.095 (2.41)	0.097 (2.46)	1/32 (0.80)	1/2 (12.70)	13	1-1/16 (26.99)	1-5/16 (33.34)			25/64 (9.92)	1/8 (3.18)	3/8 (9.53)	1/4 (6.35)	1-9/64 (28.97)	9/64 (3.57)	1/8 (3.18)	3/4 (19.05)	1/2-13 (12.7-330.2)	1/2 (12.70)	5/16 (7.94)	1-1/2 (38.10)	—	—	—	3/4 (19.05)
7/8 (22.23)	0.726 (18.44)	0.728 (18.49)	2-3/8 (60.33)	1/4 (6.35)	0.249 (6.32)	0.250 (6.35)	1/8 (3.18)	0.125 (3.18)	0.127 (3.23)	1/32 (0.80)	5/8 (15.88)	11	1-1/4 (31.75)	1-1/2 (38.10)			31/64 (12.30)	1/8 (3.18)	7/16 (11.11)	1/4 (6.35)	1-21/64 (33.73)	9/64 (3.57)	1/8 (3.18)	3/4 (19.05)	5/8-11 (15.88-279.4)	5/8 (15.88)	3/8 (9.53)	1-25/32 (45.24)	—	—	—	7/8 (22.23)
1 (25.40)	0.827 (21.01)	0.829 (21.06)	2-3/4 (69.85)	1/4 (6.35)	0.249 (6.32)	0.250 (6.35)	1/8 (3.18)	0.125 (3.18)	0.127 (3.23)	1/32 (0.80)	3/4 (19.05)	10	1-7/16 (36.51)	1-3/4 (44.45)			19/32 (15.08)	1/8 (3.18)	1/2 (12.70)	5/16 (7.94)	1-33/64 (38.50)	9/64 (3.57)	1/8 (3.18)	1 (25.40)	3/4-10 (19.05-254.0)	3/4 (19.05)	7/16 (11.11)	2-1/8 (53.98)	—	—	—	1 (25.40)
1-1/8 (28.58)	0.929 (23.60)	0.931 (23.65)	3-1/8 (79.38)	1/4 (6.35)	0.249 (6.32)	0.250 (6.35)	1/8 (3.18)	0.125 (3.18)	0.127 (3.23)	1/32 (0.80)	3/4 (19.05)	10	1-7/16 (36.51)	1-3/4 (44.45)			19/32 (15.08)	1/8 (3.18)	1/2 (12.70)	5/16 (7.94)	1-33/64 (38.50)	9/64 (3.57)	1/8 (3.18)	1 (25.40)	3/4-10 (19.05-254.0)	3/4 (19.05)	7/16 (11.11)	2-1/8 (53.98)	—	—	—	1-1/8 (28.58)
1-1/4 (31.75)	1.030 (26.16)	1.032 (26.21)	3-1/2 (88.90)	5/16 (7.94)	0.3115 (7.91)	0.3125 (7.94)	5/32 (3.97)	0.157 (3.99)	0.160 (4.06)	1/16 (1.59)	7/8 (22.23)	9	1-5/8 (41.28)	2 (50.80)			23/32 (18.26)	1/8 (3.18)	5/8 (15.8)	3/8 (9.53)	1-23/32 (43.66)	11/64 (4.37)	5/32 (3.97)	1-1/4 (31.75)	7/8-9 (22.23-228.6)	7/8 (22.23)	1/2 (12.70)	2-13/16 (71.44)	—	—	—	1-1/4 (31.75)
1-3/8 (34.93)	1.132 (28.75)	1.134 (28.80)	3-7/8 (98.43)	5/16 (7.94)	0.3115 (7.91)	0.3125 (7.94)	5/32 (3.97)	0.157 (3.99)	0.160 (4.06)	1/16 (1.59)	1 (25.40)	8	1-13/16 (46.04)	2-1/4 (57.15)			13/16 (20.64)	1/8 (3.18)	3/4 (19.05)	7/16 (11.11)	1-29/32 (48.42)	11/64 (4.37)	5/32 (3.97)	1-1/2 (38.10)	1-8 (25.4-203.2)	1 (25.40)	9/16 (14.29)	3-3/16 (80.96)	—	—	—	1-3/8 (34.93)
1-1/2 (38.10)	1.233 (31.32)	1.235 (31.37)	4-1/4 (107.95)	3/8 (9.53)	0.374 (9.50)	0.375 (9.53)	3/16 (4.76)	0.189 (4.80)	0.192 (4.88)	1/16 (1.59)	1-1/8 (28.58)	7	2 (50.80)	2-7/16 (61.91)			29/32 (23.02)	3/16 (4.76)	7/8 (22.23)	7/16 (11.11)	2-3/32 (53.18)	11/64 (4.37)	5/32 (3.97)	1-1/2 (38.10)	1-1/8-7 (28.58-177.8)	1-1/8 (28.58)	5/8 (15.88)	3-1/2 (88.90)	—	—	—	1-1/2 (38.10)
1-3/4 (44.45)	1.437 (36.50)	1.439 (36.55)	5 (127.0)	7/16 (11.11)	0.4365 (11.09)	0.4375 (11.11)	7/32 (5.56)	0.219 (5.56)	0.222 (5.64)	1/16 (1.59)	1-1/4 (31.75)	7	2-1/4 (57.15)	2-3/4 (69.85)			1-1/32 (26.20)	3/16 (4.76)	1 (25.40)	1/2 (12.70)	2-23/64 (59.93)	13/64 (5.16)	3/16 (4.76)	1-3/4 (44.45)	1-1/4-7 (31.75-177.8)	1-1/4 (31.75)	3/4 (19.05)	4-7/32 (107.16)	—	—	—	1-3/4 (44.45)
2 (50.80)	1.640 (41.66)	1.642 (41.71)	5-3/4 (146.05)	1/2 (12.70)	0.499 (12.67)	0.500 (12.70)	1/4 (6.35)	0.251 (6.38)	0.254 (6.45)	1/16 (1.59)	1-1/2 (38.10)	6	2-5/8 (66.68)	3-1/8 (79.38)			1-1/4 (31.75)	3/16 (4.76)	1-1/4 (31.75)	1/2 (12.70)	2-47/64 (69.45)	13/64 (5.16)	3/16 (4.76)	2 (50.80)	1-1/2-6 (38.10-152.4)	1-1/2 (38.10)	7/8 (22.23)	4-15/16 (125.41)	—	—	—	2 (50.80)
2-1/4 (57.15)	1.843 (46.81)	1.845 (46.86)	6-1/2 (165.10)	9/16 (14.29)	0.561 (14.25)	0.5625 (14.29)	9/32 (7.14)	0.281 (7.14)	0.284 (7.21)	3/32 (2.38)	1-3/4 (44.45)	5	3 (76.20)	3-1/2 (88.90)			1-3/8 (34.92)	3/16 (4.76)	1-3/8 (34.92)	1/2 (12.70)	3-9/64 (79.77)	17/64 (6.75)	1/4 (6.35)	2-1/4 (57.15)	1-3/4-5 (44.45-127.0)	1-3/4 (44.45)	1 (25.40)	5-5/8 (142.88)	—	—	—	2-1/4 (57.15)
2-1/2 (63.50)	2.046 (51.97)	2.048 (52.02)	7-1/4 (184.15)	5/8 (15.88)	0.6235 (15.84)	0.625 (15.88)	5/16 (7.94)	0.315 (8.00)	0.312 (7.92)	3/32 (2.38)	1-3/4 (44.45)	5	3 (76.20)	3-1/2 (88.90)			1-7/16 (36.51)	3/16 (4.76)	1-7/16 (36.51)	1/2 (12.70)	3-9/64 (79.77)	17/64 (6.75)	1/4 (6.35)	2-1/4 (57.15)	1-3/4-5 (44.45-127.0)	1-3/4 (44.45)	1 (25.40)	6-3/32 (154.78)	—	—	—	2-1/2 (63.50)
2-3/4 (69.85)	2.257 (57.33)	2.259 (57.38)	7-7/8 (200.03)	5/8 (15.88)	0.6235 (15.84)	0.625 (15.88)	5/16 (7.94)	0.313 (7.95)	0.316 (8.03)	3/32 (2.38)	2 (50.80)	4-1/2	3-1/2 (88.90)	4 (101.60)			1-11/16 (42.86)	1/4 (6.35)	1-11/16 (42.86)	1/2 (12.70)	3-41/64 (92.47)	17/64 (6.75)	1/4 (6.35)	2-1/2 (63.50)	2-4-1/2 (50.8-114.3)	2 (50.80)	1-1/8 (28.58)	6-21/32 (169.09)	—	—	—	2-3/4 (69.85)
3 (76.20)	2.460 (62.48)	2.462 (62.53)	8-5/8 (219.08)	3/4 (19.05)	0.7485 (19.01)	0.750 (19.05)	5/16 (7.94)	0.311 (7.90)	0.314 (7.98)	3/32 (2.38)	2-1/4 (57.15)	4-1/2	3-7/8 (98.43)	4-3/8 (111.13)			1-15/16 (49.21)	1/4 (6.35)	1-15/16 (49.21)	1/2 (12.70)	4-1/64 (102.0)	17/64 (6.75)	1/4 (6.35)	3 (76.20)	2-1/4-4-1/2 (57.15-114.3)	2-1/4 (57.15)	1-1/4 (31.75)	7-11/32 (186.53)	—	—	—	3 (76.20)
3-1/4 (82.55)	2.663 (67.64)	2.665 (67.69)	9-3/8 (238.12)	3/4 (19.05)	0.7485 (19.01)	0.750 (19.05)	5/16 (7.94)	0.311 (7.90)	0.314 (7.98)	1/8 (3.175)	2-1/2 (63.50)	4	4-3/8 (111.12)	5-1/8 (130.17)			2-1/8 (53.97)	3/8 (9.52)	2-1/8 (53.97)	3/4 (19.05)	4-37/64 (116.28)	3/8 (9.52)	3/8 (9.52)	3 (76.20)	2-1/2-4 (63.5-101.6)	2-1/2 (63.50)	1-1/2 (38.10)	8-1/2 (215.90)	3.870 (98.30)	3.872 (98.35)	3/8 (9.52)	3-1/4 (82.55)
3-1/2 (88.90)	2.866 (72.80)	2.868 (72.85)	10-1/8 (257.17)	7/8 (22.23)	0.8735 (22.19)	0.875 (22.23)	5/16 (7.94)	0.310 (7.87)	0.313 (7.95)	1/8 (3.175)	2-1/2 (63.50)	4	4-3/8 (111.12)	5-1/8 (130.17)			2-1/8 (53.97)	3/8 (9.52)	2-1/8 (53.97)	3/4 (19.05)	4-37/64 (116.28)	3/8 (9.52)	3/8 (9.52)	3 (76.20)	2-1/2-4 (63.5-101.6)	2-1/2 (63.50)	1-1/2 (38.10)	9-1/4 (234.95)	4.120 (104.65)	4.122 (104.70)	3/8 (9.52)	3-1/2 (88.90)
3-3/4 (95.25)	3.069 (77.95)	3.071 (78.00)	10-7/8 (276.22)	7/8 (22.23)	0.8735 (22.19)	0.875 (22.23)	5/16 (7.94)	0.310 (7.87)	0.313 (7.95)	1/8 (3.175)	2-3/4 (69.85)	4	4-3/4 (120.65)	5-1/2 (139.70)			2-3/8 (60.32)	3/8 (9.52)	2-3/8 (60.32)	3/4 (19.05)	4-61/64 (125.81)	3/8 (9.52)	3/8 (9.52)	3-1/2 (88.90)	2-3/4-4 (69.8-101.6)	2-3/4 (69.85)	1-5/8 (41.27)	10 (254.00)	4.369 (110.97)	4.371 (111.02)	3/8 (9.52)	3-3/4 (95.25)
4 (101.60)	3.272 (83.11)	3.274 (83.16)	11-5/8 (295.27)	1 (25.40)	0.9985 (25.36)	1.000 (25.40)	5/16 (7.94)	0.309 (7.85)	0.312 (7.92)	1/8 (3.175)	3 (76.20)	4	5-1/8 (130.17)	5-7/8 (149.22)			2-1/2 (63.50)	3/8 (9.52)	2-1/2 (63.50)	3/4 (19.05)	5-21/64 (135.33)	3/8 (9.52)	3/8 (9.52)	3-1/2 (88.90)	3-4 (76.2-101.6)	3 (76.20)	1-3/4 (44.45)	10-1/2 (266.70)	4.619 (117.32)	4.621 (117.45)	3/8 (9.52)	4 (101.60)
4-1/2 (114.30)	3.827 (97.21)	3.829 (97.26)	10-3/4 (273)	1-1/8 (28.58)	1.123 (28.52)	1.125 (28.58)	3/8 (9.52)	0.373 (9.47)	0.376 (9.55)	5/32 (3.97)	3-1/4 (82.55)	4	5-5/8 (142.87)	6-3/8 (161.92)			2-3/4 (69.85)	3/8 (9.52)	2-3/4 (69.85)	3/4 (19.05)	—	—	—	—	3-1/4-4 (82.5-101.6)	3-1/4 (82.55)	1-7/8 (47.62)	9-5/8 (244.47)	5.243 (133.17)	5.245 (133.22)	1/2 (12.70)	4-1/2 (114.30)
5 (127.00)	4.249 (107.92)	4.251 (107.98)	12 (304.80)	1-1/4 (31.75)	1.248 (31.70)	1.250 (31.75)	7/16 (11.11)	0.434 (11.02)	0.437 (11.10)	3/16 (4.76)	3-3/4 (95.25)	4	6-3/8 (161.92)	7-1/8 (180.97)			3-1/4 (82.55)	3/8 (9.52)	3-1/4 (82.55)	3/4 (19.05)	—	—	—	—	3-3/4-4 (95.2-101.6)	3-3/4 (95.25)	2-1/8 (54.00)	10-7/8 (276.22)	5.993 (152.22)	5.995 (152.27)	1/2 (12.70)	5 (127.00)
5-1/2 (139.70)	4.671 (118.64)	4.673 (118.69)	13-1/4 (336.55)	1-1/4 (31.75)	1.248 (31.70)	1.250 (31.75)	7/16 (11.11)	0.435 (11.05)	0.438 (11.13)	3/16 (4.76)	4 (101.6)	4	6-3/4 (171.45)	7-3/4 (196.85)			3-1/2 (88.90)	1/2 (12.70)	3-1/2 (88.90)	1 (25.40)	—	—	—	—	4-4 (101.6-101.6)	4 (101.60)	2-1/4 (57.15)	12-1/8 (307.97)	6.492 (164.90)	6.494 (164.95)	1/2 (12.70)	5-1/2 (139.70)
6 (152.40)	4.791 (121.69)	4.793 (121.74)	14-1/2 (368.30)	1-3/8 (34.93)	1.373 (34.87)	1.375 (34.93)	1/2 (12.70)	0.493 (12.52)	0.496 (12.60)	7/32 (5.56)	4-1/4 (107.9)	4	7-1/2 (190.50)	8-1/2 (215.90)			3-7/8 (98.42)	1/2 (12.70)	3-7/8 (98.42)	1 (25.40)	—	—	—	—	4-1/4-4 (107.9-101.6)	4-1/4 (107.95)	2-1/4 (57.15)	13-1/4 (336.55)	6.992 (177.60)	6.994 (177.65)	1/2 (12.70)	6 (152.40)
6-1/2 (165.10)	5.187 (131.75)	5.189 (131.80)	15-3/4 (400.05)	1-3/8 (34.93)	1.373 (34.87)	1.375 (34.93)	1/2 (12.70)	0.494 (12.55)	0.497 (12.62)	7/32 (5.56)	4-1/2 (114.3)	4	8-1/4 (209.55)	9-1/4 (234.95)			4-3/8 (111.12)	1/2 (12.70)	4-3/8 (111.12)	1 (25.40)	—	—	—	—	4-1/2-4 (114.3-101.6)	4-1/2 (114.30)	2-1/2 (63.50)	14-3/8 (365.12)	7.492 (190.30)	7.494 (190.35)	1/2 (12.70)	6-1/2 (165.10)
7 (177.80)	5.582 (141.78)	5.584 (141.83)	17 (431.80)	1-1/2 (38.10)	1.498 (38.05)	1.500 (38.10)	9/16 (14.29)	0.555 (14.10)	0.558 (14.17)	1/4 (6.35)	5 (127.0)	4	9 (228.60)	10 (254.00)			4-7/8 (123.82)	1/2 (12.70)	4-7/8 (123.82)	1 (25.40)	—	—	—	—	5-4 (127.0-101.6)	5 (127.00)	2-3/4 (69.85)	15-5/8 (396.87)	8.117 (206.17)	8.120 (206.25)	1/2 (12.70)	7 (177.80)
7-1/2 (190.50)	5.978 (151.84)	5.980 (151.89)	18-1/4 (463.55)	1-1/2 (38.10)</																												

## Installation Procedures

**Propeller Fit** In order to properly mate the propeller to the shaft taper, the following is one of the most commonly used methods:

1. The taper should be coated with Prussian Blue
2. The propeller should then be put on the shaft without the key and gently tapped snug onto the taper.
3. If the Prussian Blue is uniformly removed - the fit is good.
4. If the Prussian Blue is not uniformly removed, the fit is not good. An appropriate lapping compound should then be used and the test repeated.

Since a 100% fit is not always possible, an effective seal such as waterproof grease should be used to exclude water. This seal will also protect against dissimilar metal corrosion.

**Alignment** Bearings, shaft and couplings shall be aligned to a tolerance of no more than 0.004" (.10mm) measured between the parallel flange of the coupling with the coupling bolts loose. Smaller shaft sizes should turn freely by hand with the clutch disengaged when the coupling bolts are drawn tight.

Note: The shaft should be aligned after the boat is in the water. Do not force the shaft to accommodate the engine bed, bearings or stuffing box.

**Propeller Overhang** The distance between the forward end of the propeller hub and the aft end of the last strut bearing shall be limited to one shaft diameter. This does not apply where the last bearing is installed aft of the propeller.

**Propeller and Key Installation** The propeller should always be installed on the shaft taper first without the key, and its position marked with a pencil. The propeller is then removed, the key installed and the propeller installed so its position is at the pencil mark. This precaution will indicate if the propeller is riding the key up the keyway end radius, forcing the propeller off center. Every propeller installation should be provided with a system consisting of a straight key, propeller nut, jam nut, and cotter key. Other positive-locking systems may be used if they protect against accidental loss of the propeller. The length of the key shall not be greater than dimension "X" shown in SAE Specification J-755.

**Propeller Diameter vs. Shaft Diameter** The ratio of propeller diameter to shaft diameter should not exceed 15:1. Higher ratios may create excessive stresses and may shorten shaft life. High performance boats, such as racing boats, should consider a ratio of 12:1.

**Shaft Seals and Shaft Logs** Shaft seals shall be readily accessible. Every shaft seal shall be constructed in such a manner that if the sealing element locks or freezes to the shaft, the resulting rotation of the seal will not create a condition wherein more than two gallons of water per minute can enter the hull with the shaft continuing to operate at low speed.

If a shaft seal utilizing replaceable packing material is installed in the boat, it shall have clearance along the shaft line to permit replacement of the packing without uncoupling the shaft or moving the engine. Face-seal and lip-seal types are not considered replaceable within the meaning of this paragraph.

The use of graphite-impregnated packing is prohibited because of the possibility of galvanic corrosion of the shaft material. FEP Fluorocarbon-impregnated asbestos braid, the fibers of which are impregnated with the plastic prior to braiding is considered to be excellent for shaft seals. Wax-impregnated flax packing may be used. A shaft seal of the face-seal, lip-seal, "O"-ring or frictionless types shall be designed in such a manner that it can be operated at low speeds after failure of the seals without permitting more than two gallons of water per minute to enter the hull.

A boat having a stern tube or any other type of construction that tends to trap water next to the shaft shall be provided with a means of water circulation. This recommendation is to avoid the corrosive effects of stagnant water.

## Cathodic Protection

Cathodic protection should be used to prevent localized corrosion in bearing areas or in other crevices (Refer to Galvanic Series Chart). An impressed current system or Navy-grade zinc anodes should be used. If the boat sits idle for extended periods of time, it is strongly recommended the shaft be rotated several turns at regular intervals. For more detailed information, refer to ABYC E-2 "Cathodic Protection".

**Stray Current** The most dangerous cause of corrosion is stray battery current. In cases of rapid and deep pitting, loss of metal, bright discoloration, extensive formation of corrosion products and weakening of batteries, it is likely the result of stray battery current. While the boat is in the water, a multimeter with a current range from 10 amperes to 10 milliamperes can be used to check for possible current leaking.

The first step in checking for current leakage is to turn off all electrical equipment and fixtures aboard, then disconnect the positive connector from the boat's battery terminal and connect the positive lead of the multimeter to the battery post and the negative lead to the connector. Start at the 10 ampere range of the meter (or the highest current range) - check to see that there is no current flow, then switch the meter to low current ranges. With ideal boat wiring and equipment, no current should flow at any setting.

A properly functioning electrical system will have a leakage current of less than 1 milliamperes (0.001 amp). Leakage of a few milliamperes indicates a small amount of corrosion which is rarely dangerous but should be corrected if possible. However, if the meter indicates a sizable fraction of an ampere, separate circuits should be switched off one at a time to find which is at fault, and the wire or equipment be repaired or replaced as soon as possible. If considerable leakage is found to be the case, leave the battery disconnected until the problem is corrected.

### GALVANIC SERIES CHART



# Marine Shafting Repair

## Bearing Area Buildup

Worn bearing areas can be repaired with reasonable success by utilizing one of the two following methods:

### Metalizing (either oxyacetylene arc-spray or plasma flame methods)

This method requires the work temperature to be low, approximately 200 to 400 Fahrenheit (93 to 204 Celsius) to minimize distortion. The bond to the pre-roughened area is mostly mechanical. The plasma flame process gives the densest coating as oxide formation is kept to a minimum. Type 304 stainless is the most readily available coating to be considered for metalizing propeller shafts. The effect on the base metal is regarded to have little or no effect. A problem may arise with regards to the questionable reliability of the shaft coating bond.

### Weld Overlay Fusion Process

A metallurgically intact bond is attainable when matching fillers are used in combination with the appropriate expertise for weld overlay and full welded joints. No pre-heating is necessary. To lessen distortion, a semiautomatic process (gas metal-arc) is utilized by clamping a welding torch to a lathe tool holder for indexing as the shaft rotates in the lathe under the weld head. If this is not possible, longitudinal overlay weld beads may be placed alternately 180 degrees opposite the previous overlay. For Aqualoy shafts, matching weld overlay fillers are preferred. If availability is a problem, there are alternate fillers as shown in the Matching Filler Table. However, the alternate fillers may not possess the hardness, strength and corrosion resistance as that of the base metal.

A note of caution is noted with regards to the weld overlay fusion process for Aqualoy 17. Welding the Aqualoy 17 will create a small area of untempered martensite in the shaft which results in lower ductility. However, this area of the shaft should be adequate for normal seawater service. To restore the mechanical properties of the weld area to almost that of the shaft, perform a post-weld heat treatment at 1150 degrees Fahrenheit (621 degrees Celsius) for four hours. Re-straightening the shaft will most likely be necessary after this process. Aqualoy 19 and 22 in their as-welded conditions have mechanical properties which closely match the base metal in diameters 3" (76mm) and over. Under 3" (76mm) diameter, a decrease in such properties will most likely occur. Additionally, Aqualoy 22 retains basically the same corrosion resistance properties when overlaid using the matching fillers. When welding dissimilar metals, it is recommended the matching filler or alternate filler for the particular Aqualoy grade be used.

## Matching Fillers Table

Aqualoy Grade	Matching Filler	Alternate Fillers
Aqualoy 17	W 17-4PH (AWS E630 and ER630)	Types 308L, 309, 316L
Aqualoy 19	Type 308L (AWS E308L and ER308L)	Types 309, 316L
Aqualoy 22 and HS	Nitronic 50W (AWS E209 and ER209)	Types 308L, 309, 316L

"E" denotes coated electrodes

"ER" denotes bare filler wire

## Straightening

One technique often used to improve straightness is hot straightening. However, special consideration must be given to limiting the temperature to 1000 degrees Fahrenheit (538 degrees Celsius) in order to avoid introducing changes in metallurgical structure. These changes may have a detrimental impact on the mechanical properties and corrosive resistance of the shaft which could result in premature failure. The use of Tempil sticks is recommended to avoid excessive temperatures. If possible, cold straightening is preferred. While this method requires a separate piece of equipment, it will not affect the metallurgical structure of the steel.



The information contained in this product bulletin is accurate to the best of our knowledge and is intended to be used for general information purposes only. Applications specifically suggested for material described herein are made solely for the purpose of illustration to enable the reader to make his own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes. WBM's warranty is limited to the mechanical and physical properties, roundness and accuracy of our published test results concerning the particular shaft grade.

The formulas and tables used in this publication are taken from the ABYC standard, P-6, Propeller Shafting Systems (1992, corrected 1993). The information is printed with the permission of the ABYC. Readers are cautioned that this data does not contain the entire text of the ABYC standard. Readers should purchase a copy of P-6 for reference to ensure that their particular application is in compliance with the ABYC standard.

P-6 can be ordered from: ABYC, Inc., 3069 Solomons Island Road, Edgewater, MD 21037 Phone: 410-956-1050 Fax: 410-956-2737 e-mail: [abycinc.org](mailto:abycinc.org)

Republic Technologies International, Baltimore, Maryland, provided consultation with regards to the marine shafting repair information contained in this data bulletin.