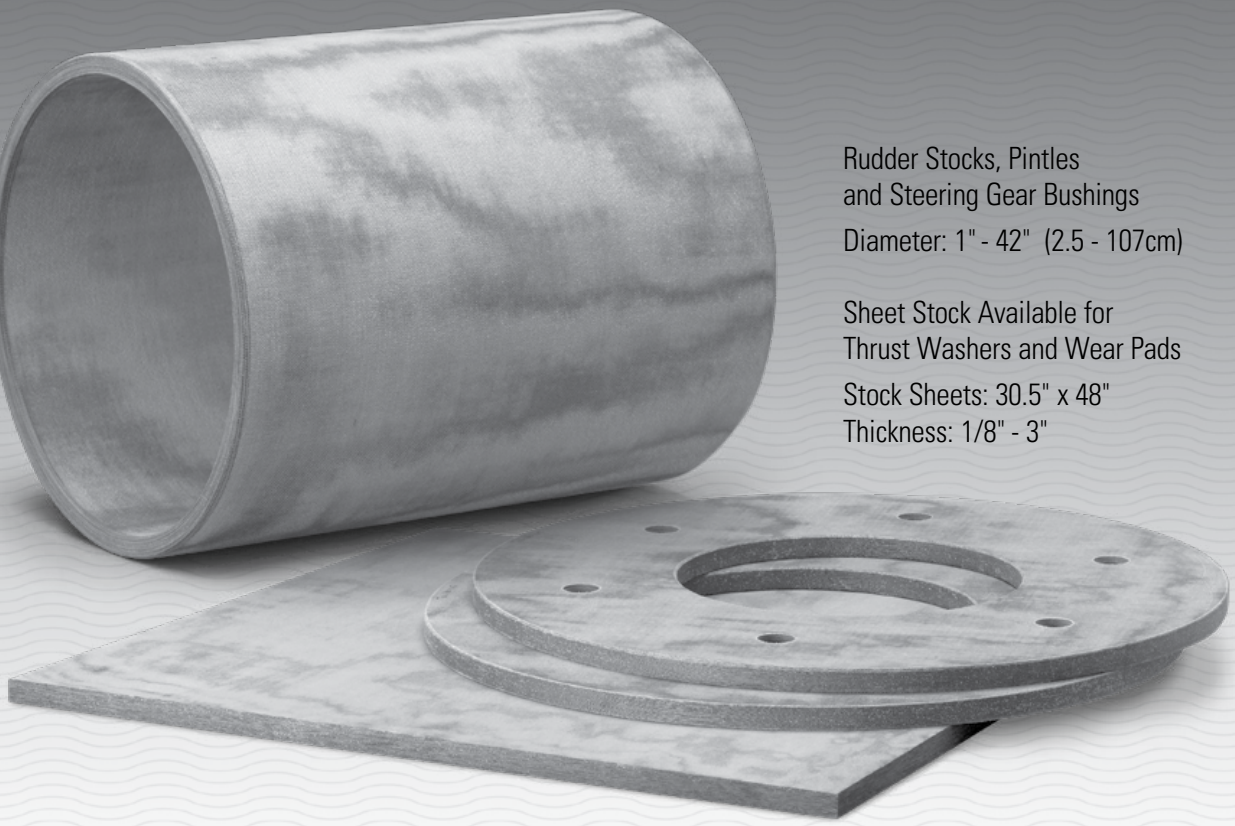
DURAMAX®

DuraBlue® Composite Rudder Bushing

- ► Greaseless, Self-Lubricating, Pollution Free
- ► Extremely Long Life
- ► High Load Capability & Ultra Low Friction



Rudder Stocks, Pintles
and Steering Gear Bushings

Diameter: 1" - 42" (2.5 - 107cm)

Sheet Stock Available for
Thrust Washers and Wear Pads

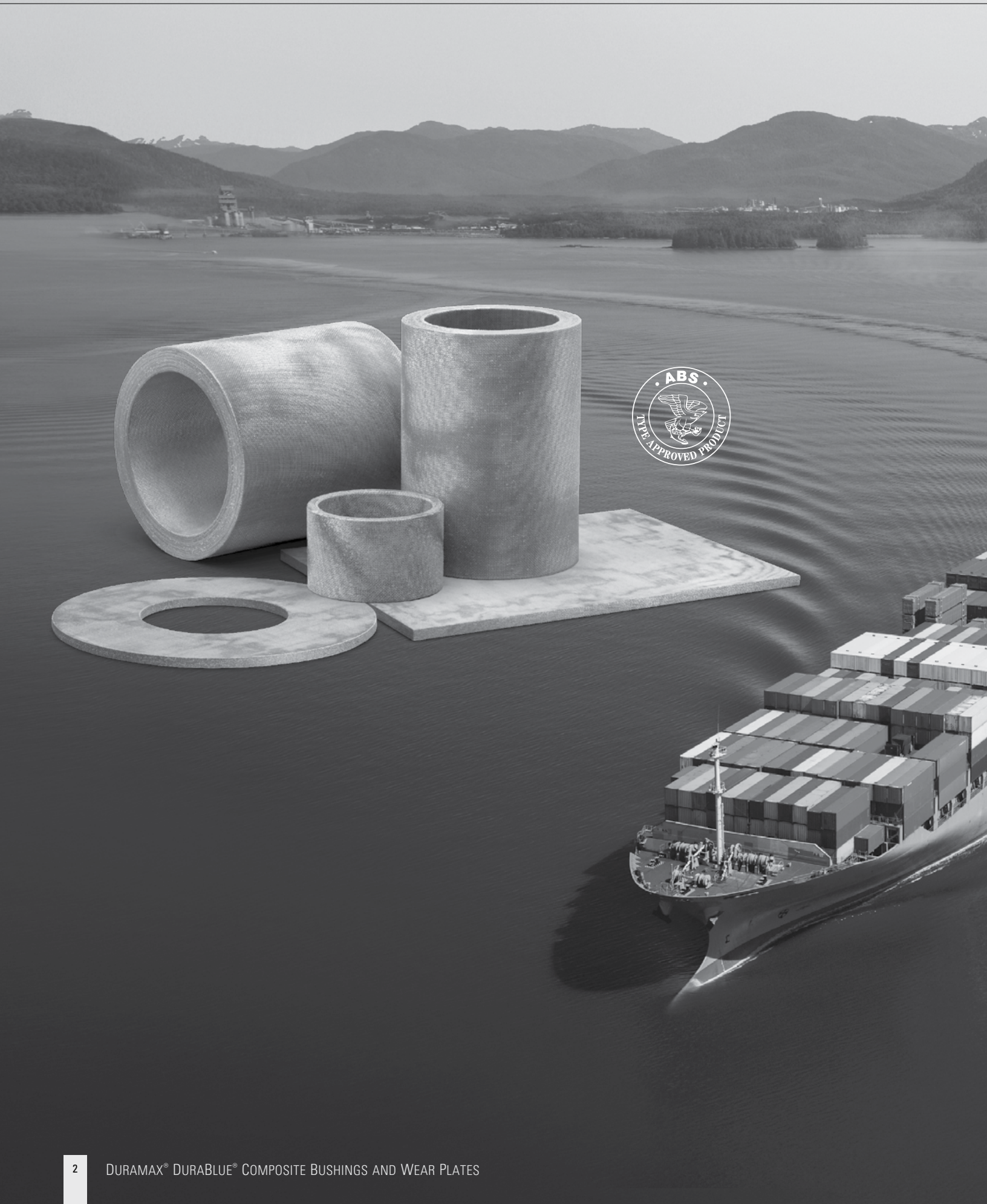
Stock Sheets: 30.5" x 48"
Thickness: 1/8" - 3"

ABS TYPE APPROVED PRODUCT

Technical Manual

Duramax Marine® is an ISO 9001:2015 Certified Company

DURAMAX MARINE®


ABS
TYPE APPROVED PRODUCT

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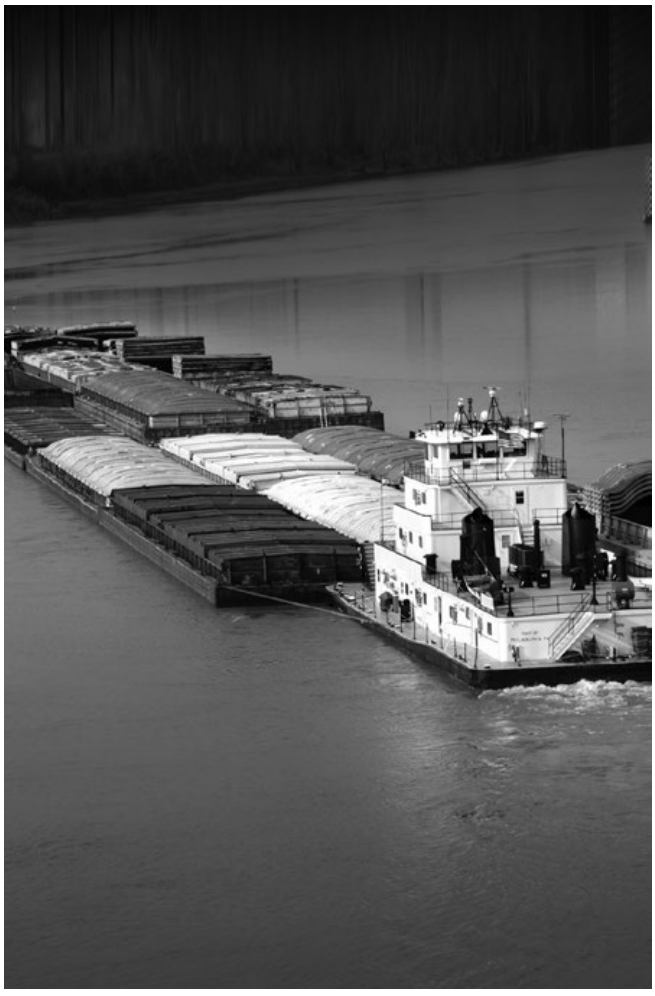
General Information

Duramax Marine®, the world leader in water-lubricated bearing technology has earned the trust of marine professionals worldwide. Our Johnson® Cutless® water-lubricated sleeve and flanged rubber bearings are found in more vessels than any other bearing. We are a company of marine professionals that have advanced water-lubricated propulsion bearings by investing in research and development for decades. As a result, Duramax® bearings have set performance records others are still trying to reach.

Duramax Marine® is committed to providing excellence in every product we manufacture. Our Johnson Cutless®, Advanced Marine bearings and industrial bearings, heat exchangers, impact protection systems, and shaft sealing systems are known worldwide for their engineered quality and dependable performance.



The Duramax® DuraBlue® Composite Bushing is the latest addition to Duramax® bearing line.

DuraBlue® composite bushings are engineered to outperform other rudder bearing materials. It is a pollution-free polymer composite that incorporates an internal lubricant into a proprietary resin system permitting operation, without any need for grease or oil. It delivers a very low coefficient of friction of 0.1 – 0.2. It virtually has no swelling in seawater and has very low coefficient of thermal expansion making it a dimensionally stable material. DuraBlue® has heavy load capacity, corrosion resistant, tolerates edge loading and shaft misalignment.

Duramax Marine® Quality

Quality control has always ensured Duramax Marine® products deliver the performance level expected by marine professionals in the harshest of working environments. Duramax® DuraBlue® composite bushings have been independently tested to the most rigorous standards in the industry.

Duramax DuraBlue® composite rudder bushings exceed the operating and performance standards for all major CLASS Societies. Including:

- ABS - American Bureau of Shipping
- BV - Bureau Veritas
- DNV - Det Norske Veritas
- LR - Lloyds Register
- RINA - Registro Italiano Navale
- GL-Germanischer Lloyds

Duramax Marine is an ISO 9001:2015 Certified company

Duramax Marine® Contact Information:

For information on products, technical support, or for help solving a maintenance problem contact a Duramax Marine® Professional at:

Duramax Marine® LLC
17990 Great Lakes Parkway
Hiram, Ohio 44234 U.S.A.

PHONE: 440-834-5400
FAX: 800-497-9283 USA & Canada
info@DuramaxMarine.com

www.DuramaxMarine.com

Duramax® DuraBlue® Physical and Mechanical Properties

PROPERTY	UNIT		VALUE	
Compressive Strength (ASTM D695)	MPa	Psi	> 207	> 35,000
Shear Strength (ASTM D2344)	MPa	Psi	> 13.8	> 2,000
Modulus of Elasticity (ASTM D638)	MPa	Psi	> 3,102	> 450,000
Hardness (ASTM D785)	Rockwell "R"		> 110	
Density (ASTM D792)	10^3 kg/m^3	lb/in^3	1.25	0.045
Water Absorption (ASTM D570)	%		< 0.5	
Coefficient of Thermal Expansion (ASTM D696)	10^{-6}/°C	10^{-6}/°F	43	24
Chemical Resistance	NA		Good	
Color	NA		Blue	
Maximum Temperature (ASTM D648)	°C	°F	100	212
Minimum Temperature	°C	°F	< -200	< -328
Advised Maximum Working Temperature	°C	°F	80	176
Typical Friction Value	NA		0.1 – 0.2	
General Wear Resistance	NA		Very Good	
Resistance Against Abrasive Wear	NA		Good	
Deflection*	in		< 0.010	

**after 24 hour at 15 N/mm^2*

Professional Technical Support Team

Duramax Marine® products are backed by a team of marine experts to solve maintenance problems to keep your vessel operating at peak performance at all times.

- 24 hour turn around on quick-ship orders
- Offer technical assistance during installation
- Engineering assistance for specific application and environment
- Offer sizing instructions and on site machining tips

Worldwide Distribution Network

Our global distribution network can supply the highest quality bushings and bearings to meet your needs. Our distributor network is staffed with marine experts that can help you with your problems and probably has your part in stock. If the part you need isn't in stock we can manufacture it to the specific size you need and ship it to you within 24 hours.

DuraBlue® Is an Environment-Friendly Rudder Bearing

Duramax® DuraBlue® is engineered with a proprietary polymer composite formulation that contains a solid lubricant that allows for dry running above and below the draft line as in upper and lower pintle bearing applications. It has an outstanding wear life.

DuraBlue® is a versatile material

DuraBlue® composite material is available in both tube and sheet configurations. It can be used in many different applications including: plain bearings, flanged bearings, thrust washers, carrier plates, spherical bearings, wear rings, pads and strips.

DuraBlue® can be custom ordered from our factory machined to size. Thrust washers and rudder carrier plates are often ordered pre-machined ready for installation.

We can also produce custom DuraBlue® bushings with an attached flange. Contact Duramax Marine® for more information.

Maximum Bearing Design Pressure

DuraBlue® has been tested and approved for continuous operation without lubrication at pressures up to 25N/mm^2 (3625 psi).

Shaft Material and Surface Finish

DuraBlue® runs well with extended wear life when running against 316 Stainless Steel, Inconel, Monel, Stellite, Bronze, Hardened Nickel Chrome Boron shaft sleeves and Gunmetal.

Shaft or shaft liner should be smooth and free from defects. A 4 to 32 micro inch surface finish is recommended for long bearing life. DuraBlue® should always run against a suitable alloy as its mating surface and should never be used as a composite surface running against a composite surface.

Calculating Rudder Bearing Design

Duramax® DuraBlue® Rudder Bearings are easy to size, machine and install using the instructions provided in this technical manual. If you have technical questions you can contact Duramax® Engineering for support.

What you need to know:

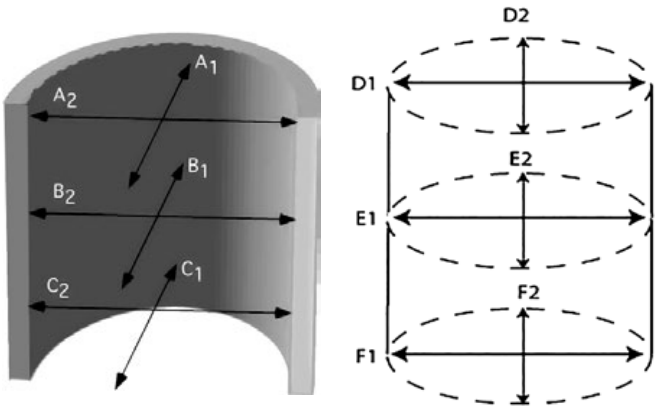
- Housing and shaft sizes with tolerances
- How will bushing be installed?
  -Interference fit using freeze method or hydraulic press
  -Bonding in place with adhesive

Housing and Shaft Requirements

When fitting bearings, measure at three points along internal diameter of bushing housing and OD of the corresponding shaft. Also take two measurements at 90° to each other in the radial plane to obtain the average diameters of each position.

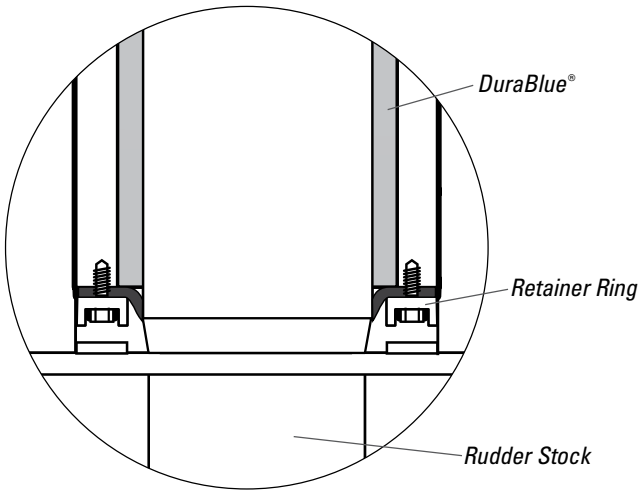
Measuring of Housing ID

Measure Corresponding Shaft or Liner OD



Note: the bushing will take the shape of the housing when fitted with an interference. An interference fit can still be attained if the housing is oval or wearing is not excessive (0.1mm per 100mm or 0.004" per 4"). DuraBlue® will not compensate for extreme wear. In situations where the housing is not round it is advisable to use the adhesive bonding method of installation. A combination of interference fit and adhesive bonding can also be used for improved shear strength.

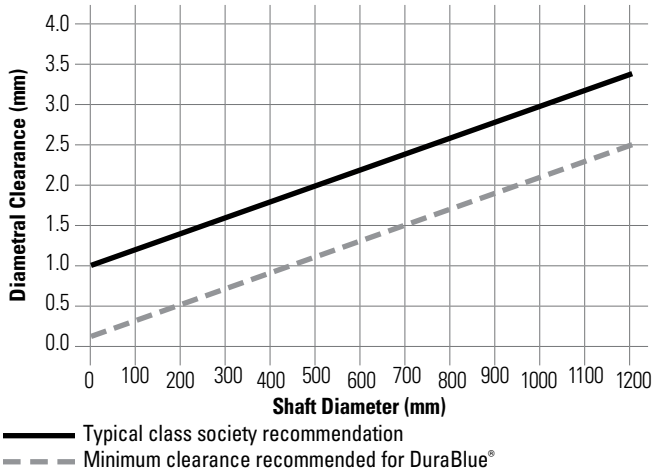
If using the press fit method for installation, the housing should have a chamfered edge to prevent shaving of bushing during installation. When bushing is fitted in position one end should be retained with a shoulder or with an additional retainer ring at the other end to limit axial movement.



Axial movement of fitted bearing limited by shoulder or retainer ring at opposite end.

Calculating Running Clearance

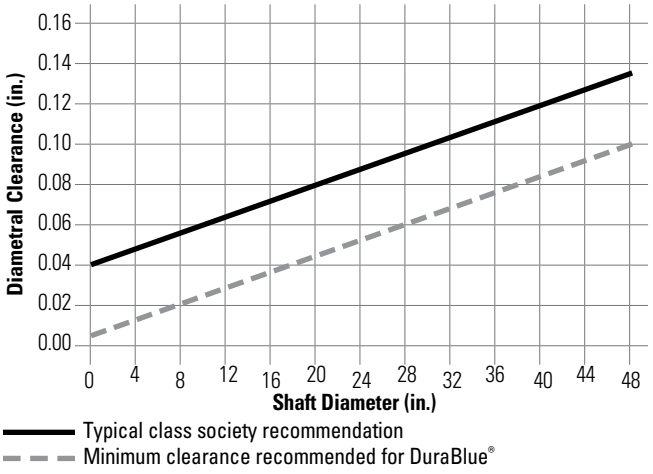
These charts illustrate the recommended running clearance for DuraBlue® Rudder Bushings. The dotted line indicates the minimum and optimal clearances we recommend for bushings that are in good alignment and with minimum housing distortion. The solid line indicates typical minimum classification clearances. For example, Lloyds Register specify 0.002d + 1.0mm (0.040") but not less than 1.5mm (0.06") for synthetic bearings. If Classification Society rules don't apply, select a clearance between the two lines.



Upper slope (Typical class minimum):
Clearance = (0.002) x Shaft Diameter) + 1.0mm

Lower slope (DuraBlue® optimal / minimum):
Clearance = (0.002 x Shaft Diameter) + 0.1mm

Mean between the two slopes
Clearance = (0.002 x Shaft Diameter) + 0.55mm



Upper slope (Typical class minimum):
Clearance = (0.002) x Shaft Diameter) + 0.040"

Lower slope (DuraBlue® optimal / minimum):
Clearance = (0.002 x Shaft Diameter) + 0.004"

Mean between the two slopes
Clearance = (0.002 x Shaft Diameter) + 0.022"

Calculating Bushing Interference Amount

The following calculation can be used to determine the optimal interference to ensure the DuraBlue® bushing is securely fastened within the housing.

Optimal Interference Calculation:
0.0025" x housing ID (smallest dimension)

Please consult Duramax Engineering if bushings will be used or installed in sub-zero temperature conditions.

Compensating for Taper or Out-of-Round housing.

If an interference fit method is used the DuraBlue® composite will, to some degree, take the shape of the housing. If the housing is out of round, the minimum measured housing diameter should be used to calculate the interference fit. If out of round exceeds 0.004" per 4" the interference fit method is not recommended. In this case it is best to bond into place using a 2 part epoxy adhesive. Refer to section on Bonding Bushing on page 11.

If you have a difficult installation contact our engineering team for support.

Minimum Bushing Wall Thickness

DuraBlue® wall thickness is typically determined by the application requirement. Generally there is no limit for the maximum wall thickness.

Optimal wall thickness can be defined by using the following formula:
0.0345 x shaft outside diameter plus 2 mm (0.08")

The optimal wall thickness is calculated so the bushing has sufficient residual hoop strength to permit an acceptable level of shear strength in an interference fit installation. In some applications reduced wall thicknesses may be acceptable.

If you have an application where wall thickness falls below the optimal recommended thickness contact Duramax Marine® Engineering for a review of the application.

Note: When fitting a bushing with an optimum thickness wall into a housing, the interference is considered as an equal reduction of the internal diameter of the bearing after fitting.

General Information

Duramax® DuraBlue® can be easily machined using conventional methods used for brass, aluminum, or lignum vitae. Tungsten carbide turning tools are preferred with cutting speeds of 5.5 meters (19 feet) per second. DuraBlue® bushings should always be machined DRY without the use of coolant. This is particularly important if the bushing will be bonded with epoxy adhesive.

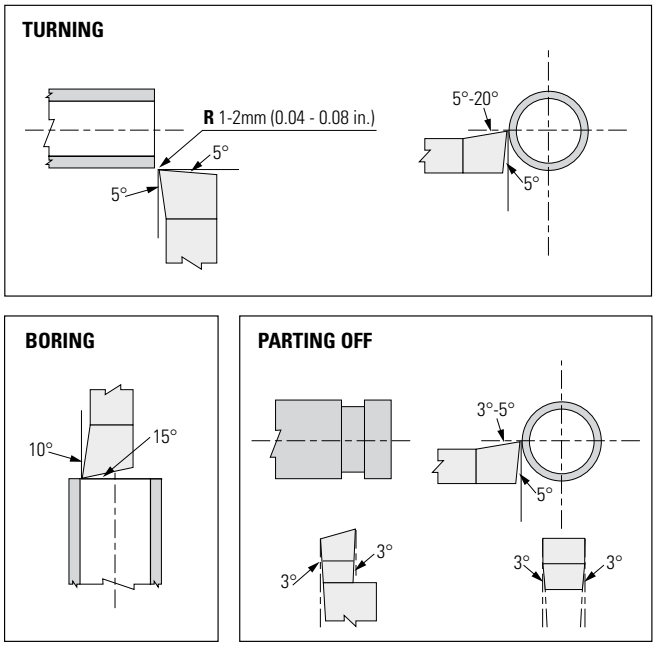
Turning

Butt welded type tungsten carbide tools using K20 grade carbide can be used for most applications. Plansee grade H10T, Sandvik H10A or H13TA, or Mitsubishi HT110 aluminum grades with high positive rates if carbide inserts are used.

Duramax® DuraBlue® contains no asbestos and is completely non toxic. Use of dust extraction equipment is advisable when machining or use of dust particle masks by operators is recommended.

High speed steel tools can be used for machining of chamfers, radii, and other forms with shorter tool life than tungsten carbide.

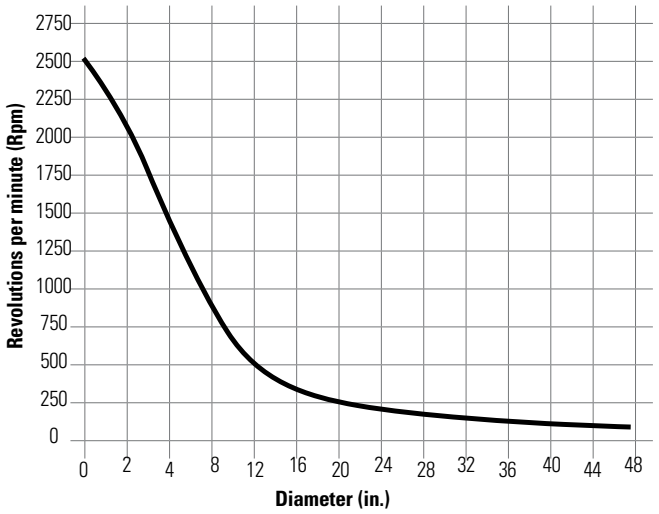
Cutting Angle For Tools



Cutting Speeds

Diameter (mm)	Diameter (in.)	RPM
0 - 50	0 - 2	2100
50 - 100	2 - 4	1000
100 - 150	4 - 6	700
150 - 200	6 - 8	550
200 - 300	8 - 12	350
300 - 400	12 - 16	250
400 - 500	16 - 20	200
500 - 600	20 - 24	175
600 - 700	24 - 28	150
700 - 800	28 - 32	130
800 - 900	32 - 36	120
900 - 1000	36 - 40	100

Feeds



Drilling

DuraBlue® is easily drilled using conventional high speed steel or carbide tipped drills.
The following speed and feeds are suggested:

DRILL DIAMETER		FEED		RPM
mm	in.	mm/min	in./min	
5	0.2	300	12	1600
10	0.4	400	16	800
15	0.6	400	16	600
20	0.8	400	16	400
25	1.0	400	16	350
30	1.2	400	16	300

Depth Of Cut

Roughing 10mm or 0.4 inch
Finishing 3mm or 0.12 inch

Smaller cuts may lead to tool rubbing, causing wear that produces excessive heat build up in the finished part.

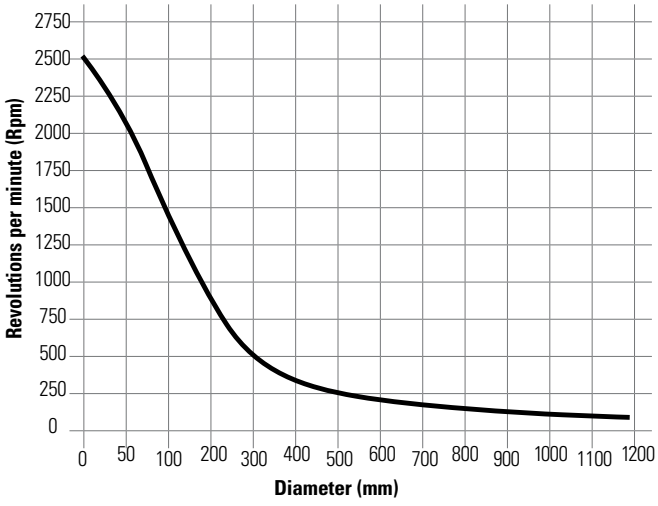
Machining Tolerances

The following tolerance range is provided as a guide for what is normally achievable when machining DuraBlue® Bushings. If your shop's tolerances fall significantly outside this range, contact Duramax® Engineering for support.

MACHINING TOLERANCES			
Bushing OD (Inch)	**Tolerance Band (Inch)**	**Tolerance Band (mm)**	**Bushing OD (mm)**
0-3	0.0022	0.06	1-76
3-6	0.0025	0.06	76-152
6-9	0.0028	0.07	152-229
9-13	0.0030	0.08	229-330
13-16	0.0035	0.09	330-406
16-20	0.0040	0.10	406-508
20-25	0.0045	0.11	508-635
25-30	0.0050	0.13	635-762
30-35	0.0055	0.14	762-889

MACHINING TYPE	ROUGHING		FINISHING	
	mm/rev	**inch/rev**	**mm/rev**	**inch/rev**
Turning	0.7	0.028	0.25	0.010
Boring	0.5	0.020	0.20	0.008
Parting	0.4	0.016	0.20	0.008

Surface Speeds



4 METHODS CAN BE USED TO INSTALL DURABLUE® COMPOSITE BUSHINGS:

1. Freeze fit with liquid Nitrogen

2. Freeze fit with dry ice (may require additional press force)

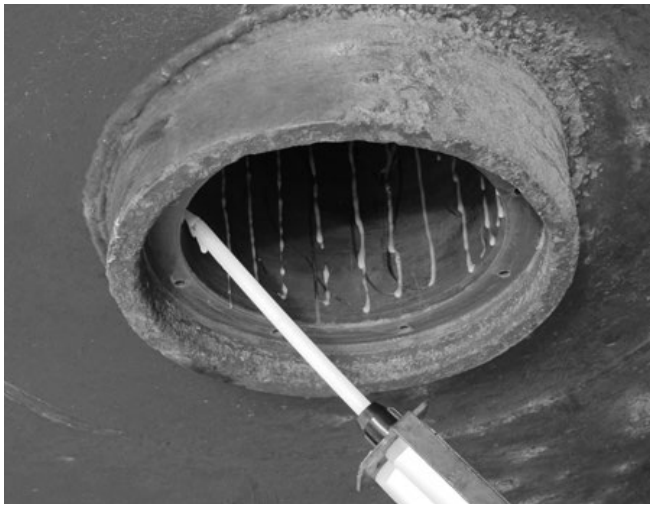
3. Press fit with hydraulic press

4. Bonding in place with 2 part epoxy adhesives.

FREEZE FITTING USING LIQUID NITROGEN IS THE RECOMMENDED METHOD FOR FITTING DURAMAX® DURABLUE® RUDDER BEARINGS.

Warning: Some precautions should be taken when using liquid nitrogen. Read carefully the safety data provided by the manufacturer to avoid severe burns and providing adequate ventilation when gassing occurs in confined spaces.

DuraBlue® thermal properties allow for adequate clearance between the bearing and the housing for easy assembly when frozen. Bearing does not become brittle at cryogenic temperatures.



Fitting Methods: Freeze Fitting, Press Fitting, Bonding

FREEZE FIT USING LIQUID NITROGEN

1. First double check the dimensions of the housing inside diameter (ID). Make a note of the smallest dimension recorded.
2. Locate an insulated container that can withstand a temperature of -197˚C (-320˚F) The container should allow room for adequate clearance while safely inserting and removal of DuraBlue® when freezing.
3. *TIP: In order to reduce the amount of liquid nitrogen required to fill the container, the center of the container can contain another cylinder to displace the volume of liquid nitrogen required. The space on the ID of the bushing may also be displaced by wood timbers or other suitable displacement materials after the bushing is in the container.*
4. Place the bushing in the container and fill with liquid nitrogen to cover the entire bushing. The bushing should remained submerged in liquid nitrogen during the entire freezing process. Typically this freezing process can take 15-30 minutes (size dependent) to shrink the bushing. As the liquid nitrogen is added to the container it will begin to boil rapidly. Once the temperature of the bushing normalizes the boil will slow to a simmer. At this point carefully raise the bushing and check the OD for proper reduction. This can be done using a steel pie tape measure or caliper. An insulated lid can be used to cover the container.
5. When bushing is reduced enough to allow for adequate clearance between bushing OD and housing it can then be removed from container for fitting. Thick leather gloves or cryogenic gloves can be used to handle the frozen bushing. Care must be taken not to touch frozen bushing with exposed skin.
6. *NOTE: The bearing will begin to return to its original size as soon as it comes in contact with any conductive material. NOTE: If the housing was slightly out-of-round it is a good idea to apply a layer of epoxy adhesive to the housing which can offer additional shear strength to the installed bushing. Several beads of adhesive can be applied with a caulk gun and then evenly spread to a thin layer using a protective glove or plastic trowel.*
7. The bushing should be held in place by temporary means after it slides into place. Wait for bushing to return to normal temperature, then the supports can be removed.

USING DRY ICE AND ALCOHOL METHOD

Freeze fitting DuraBlue® using a cooling bath with dry ice and alcohol (methanol or ethanol) is only recommended when liquid nitrogen can not be procured. It may not produce the same amount of interference fit as liquid nitrogen. The use of dry ice and alcohol cooling bath will only produce temperatures of -77°C (-107°F). Additional use of press force or tapping of the bushing using a piece of wood and a mallet may be necessary.

Using this method can take up to 3-4 hours before bushing reaches optimal temperature and size reduction.

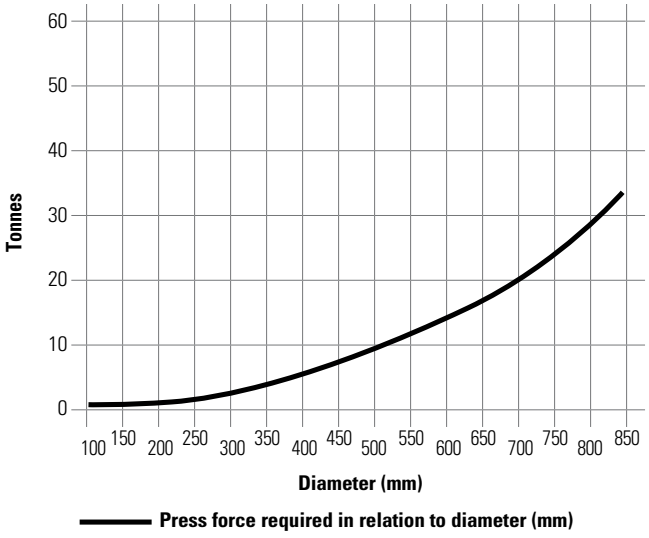
FIRST: You must contact Duramax Marine® Engineering and request appropriate sizing and interference dimensions when using this method. Interference using this method is reduced and must be adjusted accordingly.

1. Find a local supply of dry ice pellets. Pellets are the best shape to fully cover ID and OD of bushing.
2. Locate an insulated container large enough to fully cover bushing on the ID and OD. An insulated cooler with a lid is ideal for this purpose.
3. Place bushing into insulated container and completely cover with dry ice pellets. Next pour in alcohol (methanol or ethanol) until the alcohol fully submerges bushing. Cover the container with an insulated lid.
4. Freezing using this method will only produce a low temperature of -77° C (-107° F). It may take 1-4 hours for the bushing to come down to optimum temperature using this method.
5. After 1 hour check the bushing OD dimension. If longer cooling time is required return bushing to dry ice and alcohol mixture.
6. Once required size has been reached quickly remove bushing from cooling bath and insert into housing. A press or other mechanical means to exert light pressure on the bushing may be required to fully seat the bushing. If necessary, the bushing may be impacted with reasonable force to seat in housing. DO NOT hit the bushing directly with a hammer or mallet. Use a block of wood to evenly distribute impact across the end of the bushing.

PRESS FITTING METHOD

Before press fitting with a Hydraulic Press or Center Pull Jacks make sure the housing has an adequate chamfer to prevent shaving of the bearing. The ease of fitting depends on the finish of the housing. It is something to consider before calculating the force required. When press fitting it is important that the bearing is in line and square with the bore before you begin.

The following diagram illustrates the method to ensure the bearing is square before you start.



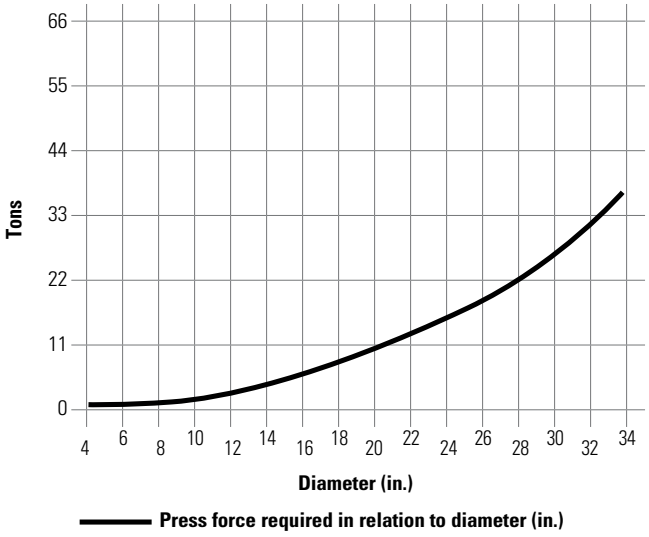


Chart shows fitting force needed for a bushing with a length/diameter ratio 1:1. The actual force needed may be higher than chart calculates. It depends on the actual condition of the housing, the leading chamfers and length/diameter ratio.

BONDING METHOD

Approved adhesives can be used to bond bushing to itself or to metallic substrates. Duramax® tested and approved 2-part epoxy adhesives for bonding DuraBlue® to the housing include:

Araldite® 2014 - Huntsman
DP460 - 3M®
Devcon Plastic Steel® - ITW®

If you don't see an approved adhesive on our list contact Duramax® Engineering for adhesive review. Follow all adhesive manufacturer instructions for proper bonding techniques. Appropriate surface preparation and degreasing of both the bushing and the housing is vital to ensure a good bond.

Adhesive Gap amount

Typically adhesive supplier will provide a recommendation for the thickness required for the adhesive. For the adhesives recommended above, a total diametrical clearance for the adhesive should be 0.015"-0.025". So the adhesive thickness in the gap is .0075"-.0125". Exceeding these limits will begin to reduce the shear strength of the adhesive.

Preparations:

Make sure you're using approved bonding adhesives for use with DuraBlue® and metal substrate.

Preparation is important before bonding operation:

1. Check to make sure there are no oxides or grease present.
2. Degrease both bushing and housing with a solvent such as acetone, MEK or Isopropyl alcohol. It should not be an extended time as to attack DuraBlue. Oxides on housing can be removed with an abrasive paper or wire wool product.
3. Rough housing surface. Shot blast metal surfaces if possible. Remove any remaining particles. DuraBlue® material does not need roughening. If abrasives are used make sure dust particles are removed from surface.
4. Bushings may need to be supported while adhesive sets. Cure time varies depending on adhesives used. Avoid butt joints if possible, Lap is preferred, so load is evenly distributed.

Sizing a DuraBlue® Bushing for Interference Freeze Fit Installation

Following the steps below will provide you with an optimally sized DuraBlue® bushing. The formulas provided are recommended by Duramax Marine®.

Data required for sizing:

Housing ID (smallest dimension): _____

Shaft OD (largest dimension): _____

Machining Tolerance: _____

Interference Amount: _____ *(calculated)*

Running Clearance: _____ *(calculated)*

Follow these steps:

1. Calculate the interference using the following DuraBlue® formula:
   .0025 x Housing ID *(smallest dimension)* = **INTERFERENCE AMOUNT**
   .0025 x _____ = _____

2. Calculate running clearance using following formula:
   (.002 x Shaft OD *[largest dimension]*)+ 0.004" ** = **RUNNING CLEARANCE**
   (.002 x _____) + 0.004" = _____

3. Calculate Bushing ID machining dimension (without tolerance):
   Shaft OD *(largest dimension)* + Interference amount + running clearance = **MACHINED ID**
   _____ + _____ + _____= _____

4. Calculate Bushing OD machining dimension (without tolerance):
   Housing ID *(smallest dimension)* + interference amount = **MACHINED OD**
   _____ + _____= _____

5. Add Machining tolerance band to ID and OD machined dimensions:
   Machining tolerance x 0.500 = ½ tolerance band
   _____ x 0.500 = _____

***Note about RUNNING CLEARANCE*

The added value of 0.004" on running clearance is a reasonable figure for most applications. However larger bushing applications typically have more alignment and housing issues so a larger diametrical clearance should be considered. Likewise smaller shafts can use a smaller adjustment.
Use the following chart to adjust the running clearance added value of 0.004" depending on shaft OD.

Added Value by Shaft OD (Inches)

1-2 =	+0.002	12-16 =	+0.008
2-5 =	+0.003	16-20 =	+0.010
5-9 =	+0.004	20-25 =	+0.013
9-12 =	+0.005	25-30 =	+0.015

MACHINED ID + ½ tolerance band = **High ID dimension**

_____ + _____ = _____

MACHINED ID - ½ tolerance band = **Low ID dimension**

_____ - _____ = _____

MACHINED OD + ½ tolerance band = **High OD dimension**

_____ + _____ = _____

MACHINED OD - ½ tolerance band = **Low OD dimension**

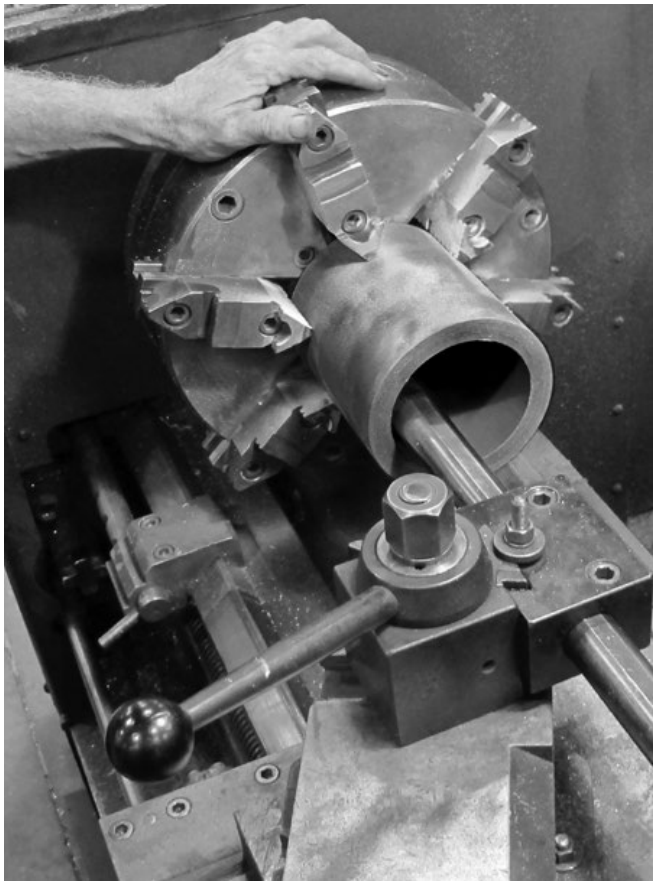
_____ - _____ = _____

6. Use the following formula to calculate the approximate size of the DuraBlue® machined OD after submerged for 30 minutes in liquid nitrogen.
   MACHINED OD x 0.995 = Bushing diameter after 30 minutes in LN^2
   _____ x 0.995 _____ = _____

Machining Tolerances

The following tolerance range is provided as a guide for what is normally achievable when machining DuraBlue® Bushings. If your shop's tolerances fall significantly outside this range, contact Duramax® Engineering for support.

MACHINING TOLERANCES			
Bushing OD (Inch)	**Tolerance Band (Inch)**	**Tolerance Band (mm)**	**Bushing OD (mm)**
0-3	0.0022	0.06	1-76
3-6	0.0025	0.06	76-152
6-9	0.0028	0.07	152-229
9-13	0.0030	0.08	229-330
13-16	0.0035	0.09	330-406
16-20	0.0040	0.10	406-508
20-25	0.0045	0.11	508-635
25-30	0.0050	0.13	635-762
30-35	0.0055	0.14	762-889



Notes:

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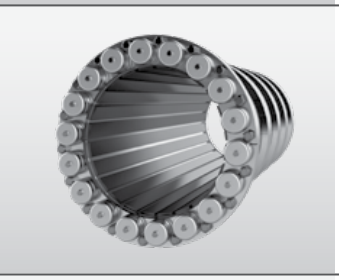
INNOVATION.
EXPERIENCE.
RESULTS.

Duramax Marine® is committed to providing excellence in every product we manufacture. Our Johnson Cutless® marine and industrial bearings, heat exchangers, impact protection systems and sealing systems are known worldwide for their engineered quality and dependable performance. Please contact the factory for information on any of the following Duramax Marine® products:

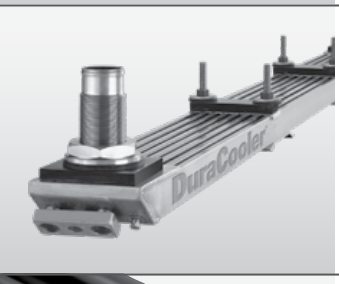
JOHNSON CUTLESS® WATER-LUBRICATED BEARING SYSTEMS

Johnson Cutless® Sleeve and Flanged Bearings



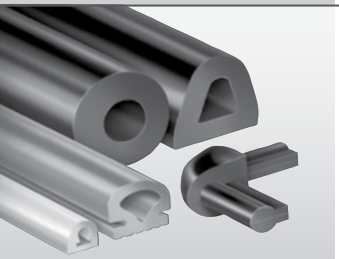
DURAMAX® ADVANCED WATER-LUBRICATED BEARING SYSTEMS

Johnson® Demountable Stave Bearings
ROMOR®I Stave Bearings and Segmental Housings
ROMOR® C- Partial Arc Bearings
DMX® Polymer Alloy Bearings
DuraBlue® Bearings, Rudder & Pintle Bushings, Thrust Washers, and Wear Pads
Industrial Pump Bearing Systems



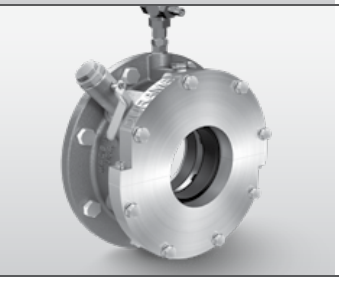
DURAMAX® HEAT EXCHANGE SYSTEMS

DuraCooler® Keel Coolers
Duramax® Demountable Keel Coolers
Duramax® BoxCoolers



DURAMAX® IMPACT PROTECTION SYSTEMS

Johnson® Commercial Dock Bumpers, Fenders & Tow Knees
LINERITE® Composite Batterboard Systems



DURAMAX® SHAFT SEALING SYSTEMS

DryMax® Shaft Seal
Duramax® Mechanical Shaft Seal
Johnson® Heavy-Duty Air Seal Stuffing Boxes
Duramax® Ultra-X® High Performance Compression Packing

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