CHESTERTON®
Global Solutions, Local Service.

PACKING

CHESTERTON® PACKING STANDARDIZATION GUIDELINES FOR THE PULP AND PAPER INDUSTRY

Chesterton's packing and gaskets are specifically designed to simplify installation, improve reliability and extend performance of your fluid handling equipment.

This guide provides standardization guidelines for the Pulp and Paper Industry.

THE RELIABILITY-CENTERED ROTATING EQUIPMENT PROGRAM

Chesterton offers extensive experience increasing the reliability and energy efficiency of mission-critical rotating equipment throughout the world's largest pulp and paper plants. With an in-depth understanding of paper mill equipment tough applications, we deliver long-lasting solutions for optimal performance and profitability.

Turn to Chesterton for:

- Maximum Pump Performance: A complete portfolio of innovative mechanical seals and pump packing, high performance lubricants, and industrial coatings—plus the invaluable advice of our on-call regional experts.
- Asset Repairs/Protection: High performance industrial lubricants and coatings that protect new equipment against the forces of corrosion and abrasions and often significantly extend the life of older equipment.
- Energy/Water Reduction: Water and energy reduction programs that can result in dramatic savings and high sustainability ratings for your organization.

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DUALPAC® 2211 PACKING

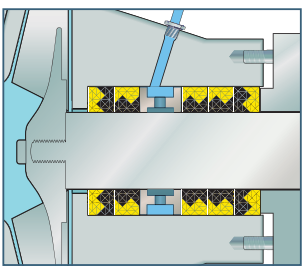
Severe slurry service packing

APPLICATION PARAMETERS

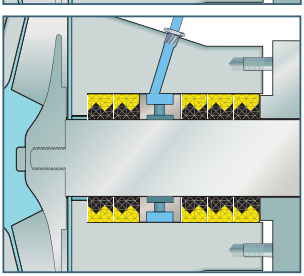
Temperature: 260°C (500°F)
Chemical: pH 3 – 11
Speed: 10 m/s (2000 fpm)

EQUIPMENT TYPE AND SERVICE

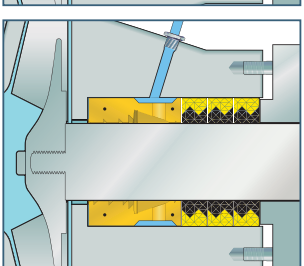
Slurry agitators, pumps, mixers, and tailing water.



Solid resistance and anti-extrusion



All rings oriented for sealing



Chesterton® DualPac® SuperSet™ Packing Set

DualPac® Technology

DUALPAC® 2212 PACKING

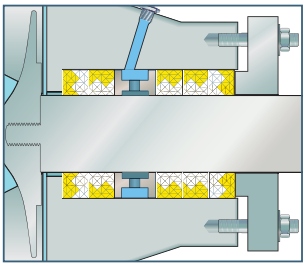
Severe slurry service packing

APPLICATION PARAMETERS

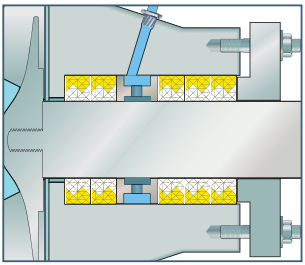
Temperature: 260°C (500°F)
Chemical: pH 3 – 11
Speed: 10 m/s (2000 fpm)

EQUIPMENT TYPE AND SERVICE

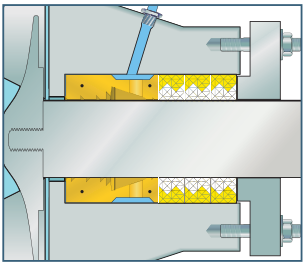
Slurry agitators, pumps, mixers, and tailing water. Can be used where coloration of the product is an issue (non-staining).



Solid resistance and anti-extrusion



All rings oriented for sealing



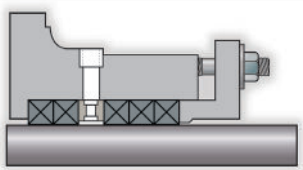
Chesterton® DualPac® SuperSet™ Packing Set

DualPac® Technology

1830 PACKING
Graphite PTFE packing

APPLICATION PARAMETERS
Temperature: 260°C (500°F)
Chemical: pH 0 – 14, except strong oxidizers in 0 – 2 pH range
Speed: 18 m/s (3600 fpm)

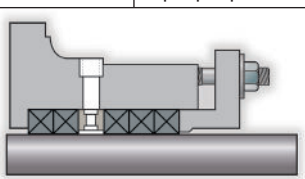
EQUIPMENT TYPE AND SERVICE
Mild chemicals (pH 5 – 9), strong acids (pH 1 – 4), centrifugals (also mech. seals), hydropulpers, hydrofiners, refiners, stock chests, cold water shafts, high density stock pumps, and vacuum pumps.

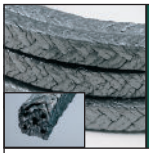


1830 SSP PACKING
Slurry packing

APPLICATION PARAMETERS
Temperature: Max. temp. 260°C (500°F)
Chemical: pH range 0 – 14, except strong oxidizers in the 0 – 2 pH range
Speed: 18 m/s (3600 fpm)

EQUIPMENT TYPE AND SERVICE
Strong acids (pH 1-4), valves and reciprocating, centrifugals, stock pumps, jordans, claflins, hydropulpers, hydrofiners, refiners, stock chests, white water pumps, white liquor pumps, black liquor pumps, green liquor pumps, and evaporators.





1400R PACKING

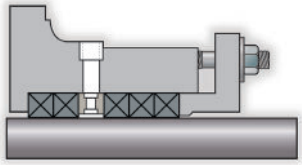
Carbon-reinforced graphite tape

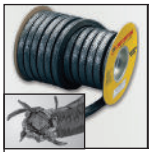
APPLICATION PARAMETERS

Temperature: 650°C (1200°F) steam; 455°C (850°F) oxidizing atmosphere
Chemical: pH 0 – 14 except oleum, fuming nitric acid, and aqua regia
Speed: 20 m/s (4000 fpm)

EQUIPMENT TYPE AND SERVICE

Valves and reciprocating, centrifugals stock pumps, jordans, claflins, hydropulpers, hydrofiners, refiners, stock chests, white water pumps, white liquor pumps, and black liquor pumps.





GRAPHMAX™ PACKING

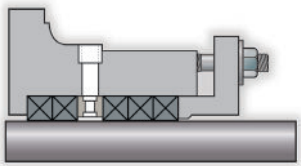
Structurally-reinforced graphite packing

APPLICATION PARAMETERS

Temperature: Max. temp. 650°C (1200°F)
Chemical: pH range 0 – 14, except oleum, fuming nitric acid, and aqua regia
Speed: 17 m/s (3400 fpm)

EQUIPMENT TYPE AND SERVICE

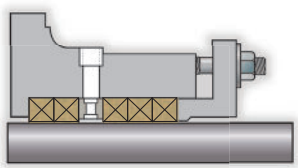
Agitators, boiler feed pumps, condensate pumps, pulpers, stock pumps, refiners, and mixers.



329 PACKING
Stern-Lon™ flax packing

APPLICATION PARAMETERS
Temperature: 135°C (275°F)
Chemical: pH 6 – 8
Speed: 5 m/s (1000 fpm)

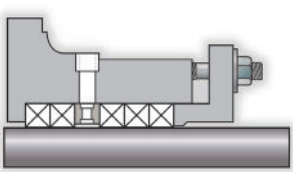
EQUIPMENT TYPE AND SERVICE
Jordans, caflins, and hydro-finers

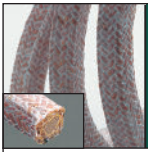


412-W PACKING
Multi-service packing

APPLICATION PARAMETERS
Temperature: Max. temp. 240°C (450°F)
Chemical: pH range 4 – 10
Speed: 10 m/s (2000 fpm)

EQUIPMENT TYPE AND SERVICE
Mild chemicals (pH 5 – 9), cold water shafts, pocket grinder, and vacuum pumps.





1727 MULTI-LON™ PACKING

Pump packing

APPLICATION PARAMETERS

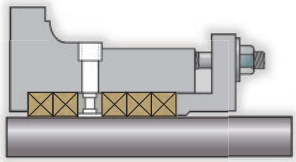
Temperature: Max. temp. 255°C (488°F) non-oxidizing

Chemical: pH range 1 – 13 unaffected by non-oxidizing acids, dilute bases, organic solvents. Should not be used in concentrated or hot sulfuric (>60%), or nitric acids (>10%), or strong bases.

Speed: 10 m/s (2000 fpm)

EQUIPMENT TYPE AND SERVICE

Mild chemicals (pH 5 – 9), centrifugals (also mech. seals), stock pumps, jordans, claflins, hydropulpers, hydrofiners, white liquor pumps, pocket grinder, and drying cylinder box.



1730 MILL PACK™ PACKING

High performance thermoset fiber packing

APPLICATION PARAMETERS

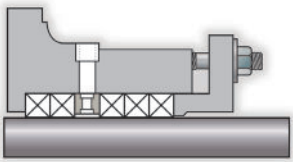
Temperature: 290°C (550°F)

Chemical: pH 1 – 13

Speed: 10 m/s (2000 fpm)

EQUIPMENT TYPE AND SERVICE

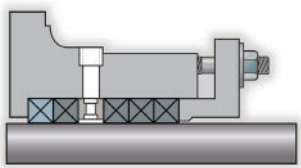
Stock agitators, stock pumps, service water, and white water.



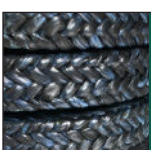
1760 PTFE/GRAPHITE PACKING
with optional 477-1T bottom ring
Excessive heat and pressure; anti-extrusion

APPLICATION PARAMETERS
Temperature: 260°C (500°F)
Chemical: pH 0 – 14
Speed: 18 m/s (3600 fpm)

EQUIPMENT TYPE AND SERVICE
Pre-steaming vessels, high and low pressure feeders, grinding stones, hydropulpers, agitators and mixers; LP/HP feeders, outlet devices, liquor pumps, and green liquor agitators.



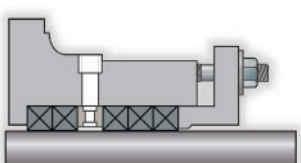
477-1T bottom ring optional



377 CARBMAX™ PACKING

APPLICATION PARAMETERS
Temperature: 288˚C (550˚F)
Chemical: pH 1 – 14 (except strong oxidizers) *
Speed: 15 m/s (3000 fpm)

EQUIPMENT TYPE AND SERVICE
Valves and reciprocating, centrifugals, stock pumps, Jordans, claflins, hydropulpers, hydrofiners, refiners, stock chests, green liquor pumps, and lime slurry.

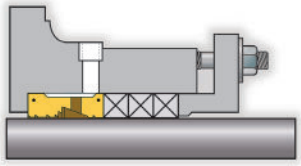


*Consult Chesterton MP Application Engineering for concerns on compatibility.

SPIRALTRAC® VERSION P ENVIRONMENTAL CONTROLLER

- Split or solid for ease of installation.
- Available in a wide variety of materials.
- No modifications required to the stuffing box.
- Replaces bottom rings of packing plus lantern ring.

EQUIPMENT TYPE AND SERVICE
Typically used in any packed application.

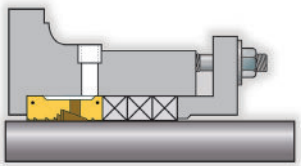


SPIRALTRAC® SUPERSET™ PACKING SET

Complete set including SpiralTrac® Version P packing set and packing rings

Applicable to all packing styles.

EQUIPMENT TYPE AND SERVICE
Black liquor, white and green liquor, TMP/CTMP refiners, thick stock pumps, hydropulpers, chemical and liquor pumps, agitators and stock pumps.



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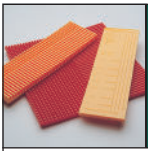


TAMPING TOOLS

- Available in common cross sections.
- Adaptable to cut to:
  - Specific height to ensure that each ring is tamped to the bottom of the stuffing box.
  - Specific length to fit around shaft and fit into the stuffing box.

COMPRESSION PACKING INSTALLATION INSTRUCTIONS

CAUTION: Observe all depressurizing and cooling requirements, maintenance, and safety procedures before installation. Installer must follow all plant procedures and safety practices. Read all safety instructions before proceeding.

Packing Selection

Select packing and packing arrangement. Before cutting the packing rings, the correct cross-section of the packing must be determined. The shaft/sleeve diameter, stuffing box bore, and depth must be measured. The use of a vernier caliper is recommended and is the most accurate way to measure while a scale is typically used to measure the depth. Packing cross section is calculated by:

$$\text{Cross Section} = \frac{\text{Stuffing Box Diameter} - \text{Shaft/Sleeve Diameter}}{2}$$

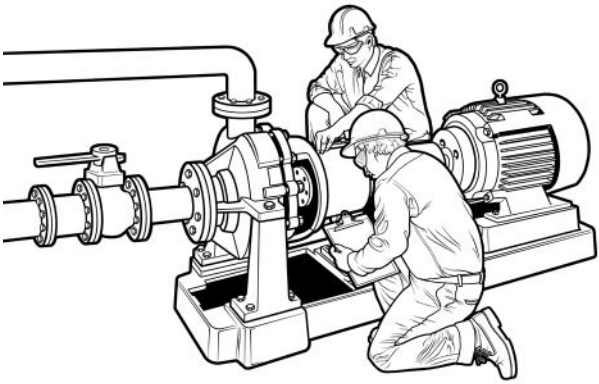
The number of rings of braided packing required is calculated by:

$$\text{Number of Rings} = \frac{\text{Stuffing Box Depth}}{\text{Cross Section}}$$

COMPRESSION PACKING INSTALLATION INSTRUCTIONS

Clean and Inspect

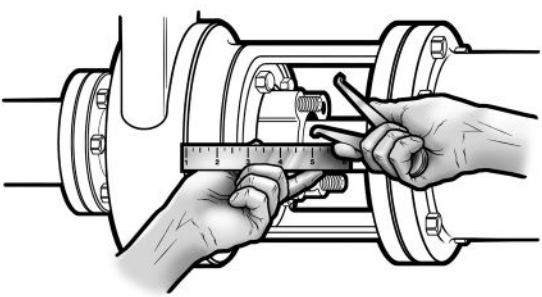
1. Unpack stuffing box using standard methods, being cautious not to nick or scratch the shaft/sleeve. Ensure that the stuffing box is completely free from used packing and any additional solids or corrosion left from the process.
2. Inspect pump shaft/sleeve to insure that it is in good condition, free from corrosion, nicks, scoring, or excessive wear. Sleeve conditions have a direct impact on the service life of packing in pumps. Replace if found defective.
3. Clean packing gland and gland follower to insure the gland can move freely into the pump stuffing box.
4. Verify that packing gland follower contacts top of stuffing box when fully inserted to insure packing will be loaded. Clean and retest if necessary.



COMPRESSION PACKING INSTALLATION INSTRUCTIONS

Measure and Document

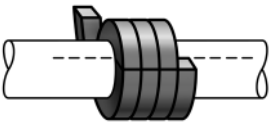
1. Measure and document the shaft/sleeve OD, stuffing box bore, and depth. When using a lantern ring, measure from the top of the inlet port to the end of the stuffing box.



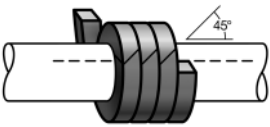
COMPRESSION PACKING INSTALLATION INSTRUCTIONS

Cut Rings

1. Wrap the packing around a mandrel of the same diameter as the pump shaft/sleeve. Mark one ring.
2. Remove from mandrel and either butt or skive cut the rings, according to detailed installation instructions for the braided packing.
3. Cut one ring at a time and check their fit on the mandrel or pump shaft/sleeve before proceeding to the equipment.



Butt cut packing

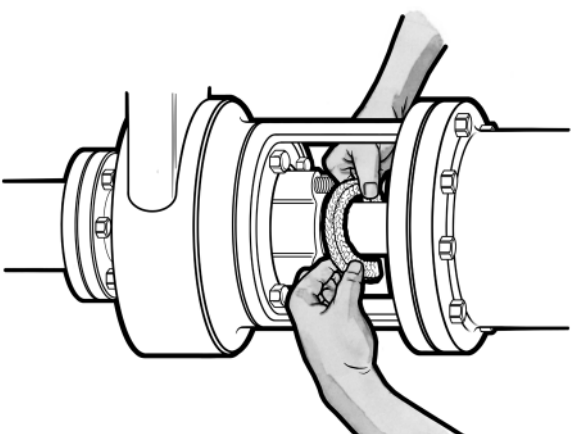


Skive cut packing

COMPRESSION PACKING INSTALLATION INSTRUCTIONS

Install

1. Install each packing ring by inserting it into the stuffing box and tamp into position with a suitable tool.
2. Ensure each ring is seated fully in the stuffing box before installing the next ring.
3. Stagger joints of subsequent rings at 90 degrees.
4. After installing the last ring, install packing gland and follower and tighten gland bolts to finger tight. Packing gland nose should slightly enter box approximately 1/8" to 3/16".
5. Start pump and tighten gland nuts.
6. Reduce leakage gradually by tightening gland nuts slowly until leakage is controlled.
7. If leakage stops completely, back off the gland and readjust to prevent packing from overheating.

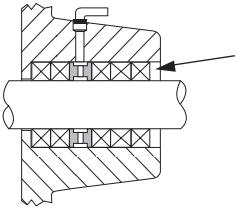


SPIRALTRAC® VERSION P ENVIRONMENTAL CONTROLLER

Installation Instructions

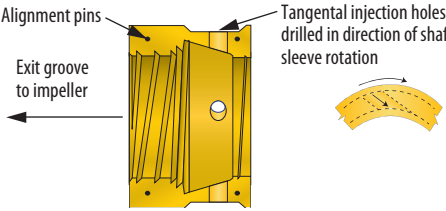
Important: *In some process equipment, a flush in/flush out piping arrangement is utilized. In all cases, when using SpiralTrac Environmental Controller use flush in only and plug the flush out port. Chesterton recommends that a flowmeter and check valve be utilized on the flush line.*

Fig. 1
Typical Stuffing Box Arrangement



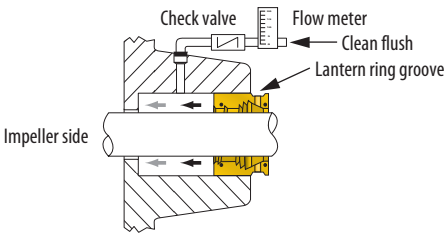
1. Disassemble Version P Type "S" split bushing. Components (Fig. 2) will be two halves of bushing with alignment pins in place.

Fig. 2



2. Separate halves of SpiralTrac Version P and position on the shaft/sleeve as shown in Fig. 3. When installed, lantern ring groove will correspond with the injection port as shown in Fig. 4.

Fig. 3



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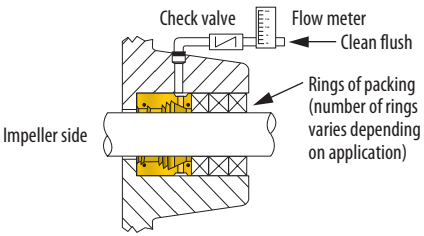
SPIRALTRAC® VERSION P ENVIRONMENTAL CONTROLLER

Installation Instructions

Fig. 4



Note: *On double ended pumps make sure the rotation is correct for each end. Rotation is determined by shaft/sleeve rotation as viewed from drive end of the pump.*

3. Push the device evenly into the stuffing box.
4. Install packing rings and gland follower loosely.
5. Tighten packing to attain a drip rate leakage as per instructions of manufacturer.

Note: *Self locking nut on gland studs may be required.*

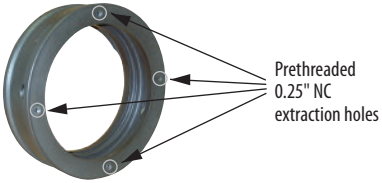
CAUTION: Do not over tighten packing.

SPIRALTRAC® VERSION P ENVIRONMENTAL CONTROLLER

Removal Instructions

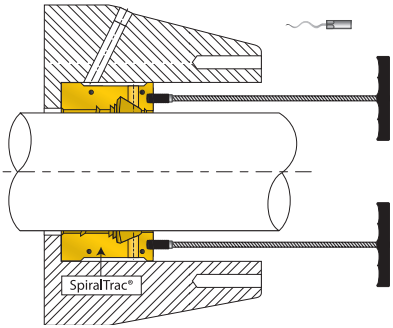
These instructions are meant as a general guide for the removal of SpiralTrac Version P devices with prethreaded extraction holes. For PTFE devices which do not have the prethreaded holes, use Option #3.

If you should encounter problems removing the SpiralTrac from the stuffing box please contact your Chesterton® representative.



Option #1

Remove worm end from two packing tools and screw the shafts/sleeves into the prethreaded 0.25" NC holes in the face of the SpiralTrac packing device and pull evenly.



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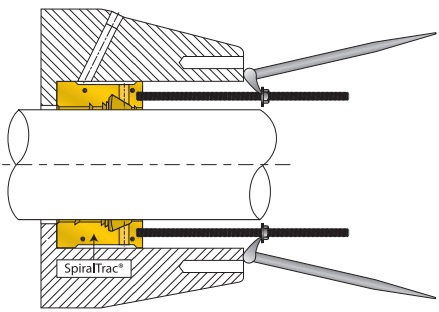
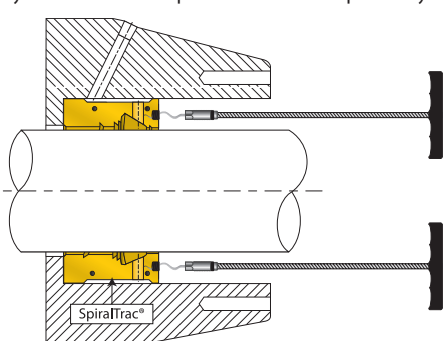
SPIRALTRAC® VERSION P ENVIRONMENTAL CONTROLLER

Removal Instructions

Option #2
Screw 1/4" NC (M6 x 1.0) threaded rods into the prethreaded holes in the face of the SpiralTrac® Version P. Thread nuts and washers evenly down the rods until pressure can be applied with pry bars. Then pull the SpiralTrac packing device out evenly.



Option #3—For PTFE Devices Only
Using the predrilled holes as guides, screw the worm end of the packing removal tools directly into the face of the SpiralTrac version P and pull evenly.

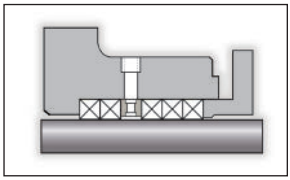


TECHNICAL REFERENCE

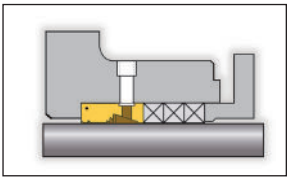
Compression Packing—Flow Rates

When flushing is required, flushwater must be connected to the lantern ring connection of the stuffing box. Flushwater supply lines should be fitted with a check valve. A flowmeter can be used to set and monitor flush rates. Flowmeters and check valves should be located as close to the stuffing box as possible. Flush pressure shall be a minimum of 15 psi or 1 bar over normal stuffing box pressure. Flow rates guidelines for flushed packing arrangements are shown as follows.

Note: *SuperSet™ Packing Set flow rates shown are guidelines. In most cases flow rates can be lowered even further.*



Standard 5 ring set with lantern ring



SuperSet Packing Set

Shaft Size	Standard 5 ring set with lantern ring		SuperSet™ Packing Set	
	Pumps	Agitators/ Refiners*	Pumps	Agitators/ Refiners*
inch	gpm		gpm	
<1.5	0.5		0.3	
1.5 – 2.5	0.5 – 1.0		0.3 – 0.5	
2.5 – 3.5	1.0 – 1.5	1.0 – 1.5	0.5 – 0.8	0.5 – 0.8
3.5 – 4.5	1.5 – 2.0	1.5 – 2.0	0.8 – 1.0	0.8 – 1
4.5 – 5.5	2.0 – 2.5	2.0 – 2.5	1.0 –1.3	0.8 – 1
5.5 – 6.5	2.5 – 3.0	2.5 – 3.0	1.3 – 1.5	1.0 – 1.5
6.5 – 7.0	3.0 – 3.5	3.0 – 3.5	1.5 – 1.8	1.0 – 1.5
7.0 – 7.5	3.5 – 4.0	3.5 – 4.0	1.8 – 2.0	1.5 – 2.0
7.5 – 8.0		4.0 – 4.5		1.5 – 2.0
8.0 – 8.5		4.5 – 5.0		2.0 – 2.5

** Applicable for refiner speeds <1750 rpm*

TECHNICAL REFERENCE

Compression Packing—Flow Rates

Shaft Size	Standard 5 ring set with lantern ring		SuperSet™ Packing Set	
	Pumps	Agitators/ Refiners*	Pumps	Agitators/ Refiners*
mm	l/min		l/min	
<40	2		1	
40 – 60	3 – 4		1 – 2	
60 – 80	4– 5	4– 5	2 – 3	2 – 3
80 – 100	5 – 6	5 – 6	3 – 4	3 – 4
100 – 120	5 – 6	5 – 6	3 – 4	3 – 4
120 – 140	6 – 7	6 – 7	4 – 5	4 – 5
140 –160	7 – 8	7 – 8	4 – 5	4 – 5
160 – 180	8 – 10	8 – 10	5 – 6	5 – 6
180 – 200		10 – 12		6 – 7
200 – 220		12 – 14		7 – 8

** Applicable for refiner speeds <1750 rpm*

Where flushing is specified, there shall be an uninterrupted source of gland sealing water that meets the following minimum criteria:

pH : 6.5 – 8
Dissolved solids : < 1000 ppm
Suspended solids
>60 microns : None
<60 microns : <100 ppm
Hardness (Ca+, Mg+) : <200 ppm as $CaCO_3$
Temperature : <40°C (130°F)

TECHNICAL REFERENCE

Seal Chamber Pressure Estimation

Seal chamber pressure must be known before the proper seal and flush plan can be selected. Seal chamber pressure can vary from pump design, flow rate, and fluid being pumped. Suction and discharge pressures are required to perform these calculations. Often, pump specification sheets can be old and outdated, i.e., design, operating points may have changed due to a change in process demands.

It is, for this reason, that suction and discharge pressures should be physically measured with pressure gages.

Single Stage, Single Suction, Overhung Process Pumps

Overhung centrifugal pumps are the most common process pumps in the industry. The seal chamber is located behind the pump impeller.

Seal chamber pressure can vary based on pump design. The following equations are based on closed throat design seal chambers. Pump designs include wear rings and balance holes in the impeller to reduce thrust load on the bearings. The seal chamber pressure is a function of wear ring clearance as well as size and location of the balance holes.

Quick estimate	$Psb = Ps + .25\ (Pd - Ps)$
Enclosed or semi-enclosed impellers with wear ring design and balance holes	$Psb = Ps + .05\ (Pd - Ps)$
Open impeller design with centrifugal pump-out vanes or repeller (no balance holes)	$Psb = Ps + *D\ (Pd - Ps)$

**D = .3 if the impeller is at minimum diameter and.1 if the impeller is at maximum diameter.*

TECHNICAL REFERENCE

Seal Chamber Pressure Estimation

Single Stage, Double Suction Pumps

The single stage, double suction impeller is placed between bearings while the seal chambers are located adjacent to the suction eyes of the impeller. The stuffing box pressure is equal to the suction pressure.

$Psb = Ps$

Multi-Stage Pumps

Multi-stage pumps inherently have higher discharge pressures, but low-to-medium stuffing box pressures due to impeller arrangement, casing design, balance drums and the use of balance lines. These multi-stage pumps can be mounted horizontally or vertically.

Two Stage Horizontal Pumps

Impeller arrangement can have two configurations:

1. Back to Back

In this arrangement, the seal chambers are located adjacent to the suction eye of the impeller. One chamber will see suction pressure and the other will see first stage discharge pressure.

$Psb_1 = Ps$

$Psb_2 = Ps + .5\ (Pd - Ps)$

2. Eye to Eye

In this arrangement the seal chambers are located adjacent to the backside of the impeller. One chamber will see the discharge of the first stage and the other will see pump discharge pressure (second stage discharge).

$Psb_1 = Ps + .5\ (Pd - Ps)$

$Psb_2 = Pd$

TECHNICAL REFERENCE

Seal Chamber Pressure Estimation

Multi-Stage Horizontal Pumps

Multi-stage boiler feed pumps are used to develop high pressures, but the seal chamber is not necessarily at a high pressure. These pumps have a low-pressure chamber (suction pressure) and a higher-pressure chamber (pressure between suction and discharge).

$Psb_1 = Ps$

Typically, a balance line is used to reduce pressure in the higher pressure seal chamber. Provided pump tolerances are in check, the higher-pressure seal chamber is as follows:

$Psb_2 = Ps + 5$ bar g (75 psig)

Note: If pump tolerances are not in check and, in the absence of a balance line, the higher-pressure chamber will be a pressure between suction and discharge pressure.

$Psb_2 = Ps + 0.5\ (Pd - Ps)$

Multi-Stage Vertical Pumps

(Can or Turbine)
In these pumps the seal chamber is located at the discharge elbow. Therefore the seal chamber pressure would see discharge pressure.

$Psb = Pd$

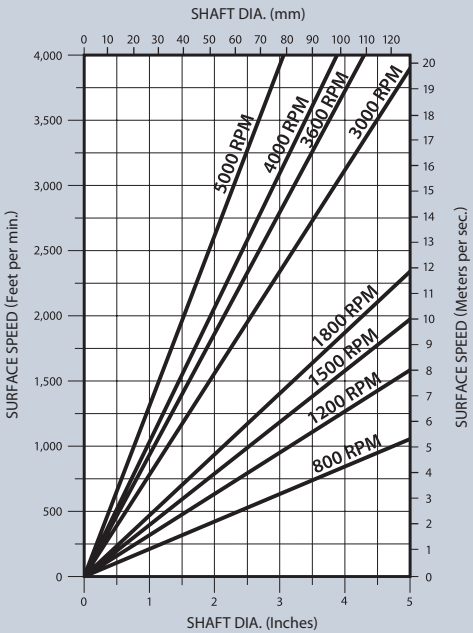
Note: The installation of a bleed-off line can reduce seal chamber pressure, provided pump tolerances are in check.

$Psb_2 = Ps + 5$ bar g (75 psig)

TECHNICAL REFERENCE

Seal Chamber Pressure Estimation

Shaft Speed Conversion Chart



Use formulas below to determine approximate shaft speeds if not shown in chart above.

$$FPM = \frac{\text{Dia. inches x R.P.M.}}{4} \qquad M/S = \frac{\text{Dia. millimeters x R.P.M.}}{18750}$$

TECHNICAL REFERENCE

Seal Chamber Pressure Estimation

Metric Formulas

$$\text{Head (m)} \quad \frac{\text{Pressure (bar)} \times 9.8}{\text{SG}} = \frac{\text{mm Hg.} \times 0.0014}{\text{SG}}$$

$$\text{Pressure (bar)} = \frac{\text{Head (m)} \times \text{SG}}{9.8}$$

$$\text{Mm of Mercury} = \frac{\text{Head (m)} \times \text{SG}}{0.0014}$$

$$\frac{\text{Q (l/min)} \times \text{Head (m)} \times \text{SG}}{\text{Efficiency} \times 6128}$$

Imperial Formulas

$$\text{Head (ft.)} = \frac{\text{psi} \times 2.31}{\text{sp. gr.}} = \frac{\text{In. Hg.}}{\text{sp. gr.} \times .88}$$

$$\text{BHP (centrifugal)} = \frac{\text{GPM} \times \text{head (ft.)} \times \text{sp. gr.}}{3960 \times \text{pump eff.}}$$

$$\text{PSI} = \frac{\text{head (ft.)} \times \text{sp. gr.}}{2.31} = .49 \times \text{In Hg.}$$

$$\text{BHP (Positive Disp.)} = \frac{\text{GPM} \times \text{psi}}{1715 \times \text{pump eff.}}$$

TECHNICAL REFERENCE

Units of Measure

Mariner's Measure

6 Feet = 1 Fathom
120 Fathoms = 1 Cable Length (U.S.N.)
8.439 Cable Lengths = 1 Nautical Mile
6076.12 Ft. = 1 Nautical Mile
1 Nautical Mile = 1.15 Statute Mile (International)

Inch System Conversion

Inch	X	0.0254	=	Meters
Feet	X	0.305	=	Meters
Yards	X	0.914	=	Meters
Miles	X	1609	=	Meters
Miles	X	1.609	=	Kilometers
Millimeters	X	0.03937	=	Inches
Centimeters	X	0.3937	=	Inches
Meters	X	39.37	=	Inches
Meters	X	3.281	=	Feet
Meters	X	1.094	=	Yards
Kilometers	X	0.621	=	Miles
Sq. Centimeters	X	0.155	=	Square Inches
Sq. Meters	X	10.764	=	Square Feet
Sq. Meters	X	1.186	=	Square Yards
Cubic Centimeters	X	0.061	=	Cubic Inches
Cubic Inches	X	16.2	=	Cubic Centimeters
Liters	X	0.2642	=	Gallons
Gallons	X	3.78	=	Liters
Cubic Meters	X	1.308	=	Cubic Yards
Cubic Yards	X	0.765	=	Cubic Meters

Metric System Prefixes

Mega = 1,000,000	Deci = 0.1	Tera (T) = 10^{12}
Kilo = 1,000	Centi = 0.01	Giga (G) = 10^{9}
Hecto = 100	Milli = 0.001	Nano (N) = 10^{-9}
Deka = 10	Micro = 0.000001	Pico (P) = 10^{-12}

TECHNICAL REFERENCE

Units of Measure

Length

1 centimeter	= 0.3937 inch	= 0.0328 foot
1 meter	= 39.37 inches	= 1.0936 yards
1 kilometer	= 0.62137 mile	= 3280 feet
1 inch	= 2.54 centimeters	
1 foot	= 0.3048 meter	
1 mil	= 0.001 inch	

Square Measure

1 sq. cm.	= 0.1550 sq. in.	
1 sq. meter	= 1.196 sq. yd.	= 10.764 sq. ft.
1 sq. kilometer	= 0.386 sq. mile	
1 sq. inch	= 6.452 sq. cm.	
1 sq. foot	= 929.03 sq. cm.	= 0.092903 sq. meter
1 sq. yard	= 0.8361 sq. meter	
1 sq. mile	= 2.59 sq. kilometers	
1 circular mil	= 0.7854 sq. mil	
1 sq. inch	= 1,000,000 sq. mils	

Cubic Measure

1 cu. centimeter = 0.061 cu. inch 1 cu. in. = 16.39 cu cm.
1 cu. meter = 1.308 cu. yards = 35.316 cu. feet
1 gallon (U.S.) = 231 cubic inches
1 cu. ft. = 7.48 gallons 1 liter = 1,000 cu. centimeters

Time

1 day = 86,400 seconds 1 year = 8,760 hours (approx.)

Velocity

1 ft./sec. = 0.3048 meter/sec. 1 meter/sec. = 3.281 ft./sec.
1 ft./min. = 0.00508 meter/sec. 1 meter/sec. = 196.9 ft./min.
1 mile/hr. = 0.4470 meter/sec. 1 meter/sec. = 2.237 mi./hr.
1 kilometer/hr. = 0.2778 meter/sec. 1 meter/sec. = 3.60 km/hr.

Acceleration

1 ft./sec./sec.	= 0.3048 meter/sec./sec.
1 mile/hr./sec.	= 0.4470 meter/sec./sec.
1 kilometer/hr./sec.	= 0.2778 meter/sec./sec.
Standard gravitatio	= 9.806 meters/sec./sec.
Standard gravitatio	= 980.6 cm./sec./sec.
Standard gravitatio	= 32.2 ft./sec./sec.

TECHNICAL REFERENCE

Units of Measure

Mass

1 slug	= 32.2 pounds mass	= 14.606 kilograms
1 pound mass	= 453.6 grams	

Force

1 pound force	= 1 slug	x 1 foot sec./sec.
1 dyne	= 1 gram	x 1 centimeter/sec./sec.
1 newton	= 1 kilogram	x meter/sec./sec.
1 pound force	= 4.452 newtons	
1 newton	= 100,000 dynes	= 0.224 pound force
1 gram force	= 980.6 dynes	

Pressure

1 atmosphere	= 14.69 pounds/sq. inch	= 29.92 in. of Hg.
	= 76 cm of Hg.	= 33.9 ft. of water

1 in Hg. = 0.491 pounds/sq. inch
Water pressure pounds/sq. inch = head in ft. x 0.434

Torque

Torque is the product of force and perpendicular distance.
1 lb. - ft. = 1.356 newton-meter = 1.356 joule/radian
1 lb. - ft. = 1.356×10^7 dynes-centimeter
1 lb. - ft. = 1.383×10^4 grams-centimeter
1 lb. - ft. = 192 ounce-inches

Power

1 watt = 1 joule/sec.
1 horsepower = 550 ft. lb./sec. = 746 watts
1 watt = 3.413 Btu/hr = 0.239 gram calorie/sec.
P watts = R (ohms) x 1 (amperes)^2

$$\text{P watts} = \frac{\text{E (volts)}^2}{\text{R (ohms)}}$$

Angles

1 circle = 2π radians = 360 degrees
1 radian = 57.3 degrees
1 degree = 0.01745 radians

TECHNICAL REFERENCE

Units of Measure

Work and Energy – Mechanical

1 erg = 1 dyne x 1 centimeter
1 joule = 1 newton x 1 meter = 10^5 dynes x 10^2 cm = 10^7 ergs
1 ft. - lb. = 1 pound force x 1 foot = 1.356 joules

Work and Energy – Heat Equivalent

1 Btu raises 1 pound of water 1°F
1 gram calorie raises 1 gram of water 1°C
1 Btu = 252 gram calories = 778.3 ft.-lb. = 1054.8 joules
1 gram calorie = 0.003964 Btu = 4.184 joules
1 horsepower hour = 2545 Btu

Work and Energy – Electrical Equivalent

1 joule = 1 watt x 1 second = 1 amp (dc) x 1 volt (dc) x 1 sec.
W (joules) = 1/2 L (henries) x 1 (amperes)^2
W (joules) = 1/2 C (farads) x E (volts)^2
1 kilowatt hour = 3,600,000 joules

Geometric Figures

Circle, area of = $D^2 \times 0.7854 = \pi r^2$ r = radius
Circle, circumference of = πD or $2\pi r$
Sphere, area of = $\pi D^2 = 4\pi r^2$ D = diameter
Sphere, volume of = $D^3 \times 0.5236 = 4/3\ \pi r^3$
Triangle, area of = 1/2 altitude x base
Cone, volume of = area of base x 1/3 altitude
Trapezoid, area of = 1/2 (sum of parallel sides) x altitude
Pyramid, volume of = area of base x 1/3 altitude

Miscellaneous Constants

$\pi = 3.14159$ $e = 2.71828$
$\text{Log}_e X = 2.30259 \log_{10} X$
Electronic charge = 4.5×10^{-10} e.s.u. = 1.60×10^{-20} e.m.u.
Mass units = 1.07×10^{-3} x Mev = 6.71×10^2 ergs
Speed of light = 3×10^8 meters/second
Speed of sound = (in air at sea level) = 1100 ft/second

TECHNICAL REFERENCE

Temperature Conversion Tables

NOTE_The numbers in **BOLD FACE** refer to the temperature either in degrees Centigrade or Fahrenheit which is desired to convert into the other scale.

°C		°F	°C		°F	°C		°F	°C		°F
-17.8	**0**	32.0	5.6	**42**	107.6	28.9	**84**	183.2	171	**340**	644
-17.2	**1**	33.8	6.1	**43**	109.4	29.4	**85**	185.0	177	**350**	662
-16.7	**2**	35.6	6.7	**44**	111.2	30.0	**86**	186.8	182	**360**	680
-16.1	**3**	37.4	7.2	**45**	113.0	30.6	**87**	188.6	188	**370**	698
-15.6	**4**	39.2	7.8	**46**	114.8	31.1	**88**	190.4	193	**380**	716
-15.0	**5**	41.0	8.3	**47**	116.6	31.7	**89**	192.2	199	**390**	734
-14.4	**6**	42.8	8.9	**48**	118.4	32.2	**90**	194.0	204	**400**	752
-13.9	**7**	44.6	9.4	**49**	120.2	32.8	**91**	195.8	210	**410**	770
-13.3	**8**	46.4	10.0	**50**	122.0	33.3	**92**	197.6	216	**420**	788
-12.8	**9**	48.2	10.6	**51**	123.8	33.9	**93**	199.4	221	**430**	806
-12.2	**10**	50.0	11.1	**52**	125.6	34.4	**94**	201.2	227	**440**	824
-11.7	**11**	51.8	11.7	**53**	127.4	35.0	**95**	203.0	232	**450**	842
-11.1	**12**	53.6	12.2	**54**	129.2	35.6	**96**	204.8	238	**460**	860
-10.6	**13**	55.4	12.8	**55**	131.0	36.1	**97**	206.6	243	**470**	878
-10.0	**14**	57.2	13.3	**56**	132.8	36.7	**98**	208.4	249	**480**	896
-9.4	**15**	59.0	13.9	**57**	134.6	37.2	**99**	210.2	254	**480**	914
-8.9	**16**	60.8	14.4	**58**	136.4	37.8	**100**	212.0	260	**500**	932
-8.3	**17**	62.6	15.0	**59**	138.2				266	**510**	950
-7.8	**18**	64.4	15.6	**60**	140.0	43.3	**110**	230	271	**520**	968
-7.2	**19**	66.2	16.1	**61**	141.8	48.9	**120**	248	277	**530**	986
-6.7	**20**	68.0	16.7	**62**	143.6	54.4	**130**	266	282	**540**	1004
-6.1	**21**	69.8	17.2	**63**	145.4	60.0	**140**	284	288	**550**	1022
-5.6	**22**	71.6	17.8	**64**	147.2	65.6	**150**	302	293	**560**	1040
-5.0	**23**	73.4	18.3	**65**	149.9	71.1	**160**	320	299	**570**	1058
-4.4	**24**	75.2	18.9	**66**	150.8	76.7	**170**	338	304	**580**	1076
-3.9	**25**	77.0	19.4	**67**	152.6	82.2	**180**	356	310	**590**	1094
-3.3	**26**	78.8	20.0	**68**	154.4	87.8	**190**	374	316	**600**	1112
-2.8	**27**	80.6	20.6	**69**	156.2	93.3	**200**	392	321	**610**	1130
-2.2	**28**	82.4	21.1	**70**	158.0	98.9	**210**	410	327	**620**	1148
-1.7	**29**	84.2	21.7	**71**	159.8	100	**212**	413	332	**630**	1166
-1.1	**30**	86.0	22.2	**72**	161.6	104	**220**	428	338	**640**	1184
-.6	**31**	87.8	22.8	**73**	163.4	110	**230**	446	343	**650**	1202
0	**32**	89.6	23.3	**74**	165.2	116	**240**	464	349	**660**	1220
.6	**33**	91.4	23.9	**75**	167.0	121	**250**	482	354	**670**	1238
1.1	**34**	93.2	24.4	**76**	168.8	127	**260**	500	360	**680**	1256
1.7	**35**	95.0	25.0	**77**	170.6	132	**270**	518	366	**690**	1274
2.2	**36**	96.8	25.6	**78**	172.4	138	**280**	536	371	**700**	1292
2.8	**37**	98.6	26.1	**79**	174.2	143	**290**	554	377	**710**	1310
3.3	**38**	100.4	26.7	**80**	176.0	149	**300**	572	382	**720**	1328
3.9	**39**	102.2	27.2	**81**	177.8	154	**310**	590	388	**730**	1346
4.4	**40**	104.0	27.8	**82**	179.6	160	**320**	608	393	**740**	1364
5.0	**41**	105.8	28.3	**83**	181.4	166	**330**	626	399	**750**	1382

TECHNICAL REFERENCE

Temperature Conversion Tables

NOTE_The numbers in **BOLD FACE** refer to the temperature either in degrees Centigrade or Fahrenheit which is desired to convert into the other scale.

°C		°F	°C		°F	°C		°F
404	**760**	1400	638	**1180**	2156	871	**1600**	2912
410	**770**	1418	643	**1190**	2174	877	**1610**	2930
416	**780**	1436	649	**1200**	2192	882	**1620**	2948
421	**790**	1454	654	**1210**	2210	888	**1630**	2966
427	**800**	1472	660	**1220**	2228	893	**1640**	2984
432	**810**	1490	666	**1230**	2246	899	**1650**	3002
438	**820**	1508	671	**1240**	2264	904	**1660**	3020
443	**830**	1526	677	**1250**	2282	910	**1670**	3038
449	**840**	1544	682	**1260**	2300	916	**1680**	3056
454	**850**	1562	688	**1270**	2318	921	**1690**	3074
460	**860**	1580	692	**1280**	2336	927	**1700**	3092
466	**870**	1598	699	**1290**	2354	932	**1710**	3110
471	**880**	1616	704	**1300**	2372	938	**1720**	3128
477	**890**	1634	710	**1310**	2390	943	**1730**	3146
482	**900**	1652	716	**1320**	2408	949	**1740**	3164
488	**910**	1670	721	**1330**	2426	954	**1750**	3182
493	**920**	1686	727	**1340**	2444	960	**1760**	3200
499	**930**	1706	732	**1350**	2462	966	**1770**	3218
504	**940**	1724	738	**1360**	2480	971	**1780**	3236
510	**950**	1742	743	**1370**	2498	977	**1790**	3254
516	**960**	1760	749	**1380**	2516	982	**1800**	3272
521	**970**	1778	754	**1390**	2534	988	**1810**	3290
527	**980**	1796	760	**1400**	2552	993	**1820**	3308
532	**990**	1814	765	**1410**	2570	999	**1830**	3326
538	**1000**	1832	771	**1420**	2588	1004	**1840**	3344
543	**1010**	1850	777	**1430**	2606	1010	**1850**	3362
549	**1020**	1868	782	**1440**	2624	1016	**1860**	3380
554	**1030**	1886	788	**1450**	2642	1021	**1870**	3398
560	**1040**	1904	793	**1460**	2660	1027	**1880**	3416
566	**1050**	1922	799	**1470**	2678	1032	**1890**	3434
571	**1060**	1940	804	**1480**	2696	1038	**1900**	3452
577	**1070**	1958	810	**1490**	2714	1043	**1910**	3470
582	**1080**	1976	816	**1500**	2732	1049	**1920**	3488
588	**1090**	1994	821	**1510**	2750	1054	**1930**	3506
593	**1100**	2012	827	**1520**	2768	1060	**1940**	3524
599	**1110**	2030	832	**1530**	2786	1066	**1950**	3542
604	**1120**	2048	838	**1540**	2804	1071	**1960**	3560
610	**1130**	2066	843	**1550**	2822	1077	**1970**	3578
616	**1140**	2084	849	**1560**	2840	1062	**1980**	3596
621	**1150**	2102	854	**1570**	2856	1088	**1990**	3614
627	**1160**	2120	860	**1580**	2876	1093	**2000**	3632
632	**1170**	2138	866	**1590**	2894			

TECHNICAL REFERENCE

Other Handy Formulas

Power Transmission by Shaft

$$HP = [\text{Torque (in lb - ft)} \times \text{rpm}] \div 5250$$

Power to Drive Pump

$$HP = \frac{\text{Gal. per min.} \times \text{total head (inc. friction)}}{3{,}960 \times \text{eff. of pump}}$$

Where: Approx. friction head (ft.) =

$$\frac{\text{pipe length (ft.)} \times [\text{velocity of flow (fps)}]^2 \times 0.02}{5.367 \times \text{diameter (in.)}}$$

Eff. = Approximately 0.50 to 0.85

Formula for Problems Involving Rotating Masses

Time required to change speed of rotating mass from N_1 to N_2 rpm.

$$t = \frac{(Wr^2)(N_2 - N_1)}{(308)(\text{torque lb - ft})} \text{ Sec.}$$

Where (Wr^2) = Flywheel effect.

Kinetic energy of rotating mass.

$$K.E. = \frac{(WK^2)(rpm^2)}{5870} \qquad \text{ft - lbs} = \frac{(WK^2)(rpm^2)}{3.23 \times 10^6} \text{ hp. sec.}$$

Where W = Weight (lbs.)

K = Radius of gyration (ft.)

Induction Motor Acceleration Loss.

$$\text{Loss} \cong \left(1 + \frac{R_1}{R_2}\right) \frac{WK^2 (N_2 - N_1)^2}{3.23 \times 10^6} \text{ hp. sec.}$$

Where R_1 and r_2 = stator and rotor resistances.

Stored energy constant.

$$H = \frac{0.231 (Wr^2)(rpm)^2 \, 10^{-6}}{\text{kva}} \text{ kw. sec. per kva.}$$

Transfer of WK_2 Through a Gear.

$$W_{\frac{2}{1}} = W_{\frac{2}{2}} \left(\frac{N_2}{N_1}\right)^2$$

TECHNICAL REFERENCE

Common Fractions Reduced to Decimals

8ths	16ths	32nds	64ths	Decimal
			1	.015625
		1	2	.03125
			3	.046875
	1	2	4	.0625
			5	.078125
		3	6	.09375
			7	.109375
1	2	4	8	.125
			9	.140625
		5	10	.15625
			11	.171875
	3	6	12	.1875
			13	.203125
		7	14	.21875
			15	.234375
2	4	8	16	.25
			17	.265625
		9	18	.28125
			19	.296875
	5	10	20	.3125
			21	.328125
		11	22	.34375
			23	.359375
3	6	12	24	.375
			25	.390625
		13	26	.40625
			27	.421875
	7	14	28	.4375
			29	.453125
		15	30	.46875
			31	.484375
4	8	16	32	.5

8ths	16ths	32nds	64ths	Decimal
			33	.515625
		17	34	.53125
			35	.546875
	9	18	36	.5625
			37	.578125
		19	38	.59375
			39	.609375
5	10	20	40	.625
			41	.640625
		21	42	.65625
			43	.671875
	11	22	44	.6875
			45	.703125
		23	46	.71875
			47	.734375
6	12	24	48	.75
			49	.765625
		25	50	.78125
			51	.796875
	13	26	52	.8125
			53	.828125
		27	54	.84375
			55	.859385
7	14	28	56	.875
			57	.890625
		29	58	.90625
			59	.921875
	15	30	60	.9375
			61	.953125
		31	62	.96875
			63	.934375
8	16	32	64	1.00000

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