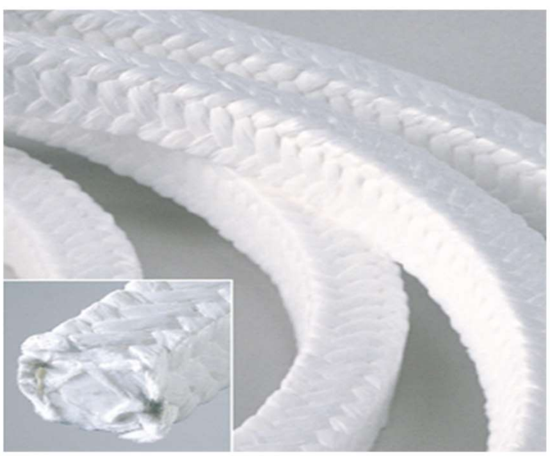
Compression Packing

Technical Manual

4th Edition




COMPRESSION PACKING
Technical Manual
4th Edition

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PREFACE

This manual, sponsored by the members of the Compression Packing Divisions of the FLUID SEALING ASSOCIATION and the EUROPEAN SEALING ASSOCIATION, provides information on compression packings and their components and the selection and proper methods of application. The guidelines in this manual represent the combined efforts of member and associate member companies of these Divisions, who have provided the material and technical personnel needed to complete this work. They are established, reputable packing manufacturers, producing quality packings in accordance with modern manufacturing practices.

This manual is arranged and detailed to provide a useful reference for all involved in the handling and operation of compression packings, from the manufacture of fibers, to particular construction, and eventually to the end use in very specific applications. The information details not only the usage of compression packings, but also its constituent parts and various methods of manufacture.

The suggested procedures are based on substantial and generally proven experience. In using any type of compression packing, the condition and maintenance of the equipment will affect and cause variations in the results from their installation and use. Thus, these Associations and their members cannot accept responsibility for failures or damage resulting from recommendations or suggestions within this manual.

There will also be variability in the quality of the materials and the construction of compression packing. Members of these Associations do adhere to high levels of quality, but they cannot speak for other suppliers. Appearance alone is not sufficient to determine the level of performance to be expected from a packing. Adherence to industry standards and focus on life cycle costs must be emphasized.

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Founded in 1933, the FLUID SEALING ASSOCIATION® (FSA) is an international trade association. Member companies are involved in the production and marketing of a wide range of fluid sealing devices primarily targeted to the industrial market. FSA membership includes a number of companies in Europe and Central and South America but is most heavily concentrated in North America. FSA members account for a majority of the manufacturing capacity for fluid sealing and containment devices in the Americas market.

The ***EUROPEAN SEALING ASSOCIATION (ESA)***, established in 1992, is a pan-European organization, established in 1992, representing a strong majority of the sealing industry in Europe. Member companies are involved in the manufacture, supply, and use of sealing materials, which are employed extensively across all sectors of industry for the safe containment of fluids during processing and use.

For a current list of FSA and ESA members or to contact the associations for technical answers or to provide feedback on this manual, refer to the following websites:

Fluid Sealing Association
www.fluidsealing.com

European Sealing Association
www.europeansealing.com

DEFINITION AND USES OF COMPRESSION PACKINGS

Control of fluid loss is essential to the successful operation of mechanical equipment used in fluid handling. Various methods are utilized to control leakage at shafts, rods, or valve stems and other functional parts of equipment requiring containment of liquids or gases.

The oldest and still most common of these sealing devices is compression packing, so called because of the manner in which it performs the sealing function. Made from relatively soft, pliant materials, compression or mechanical packings consist of a number of rings, which are inserted into the annular space (stuffing box) between the rotating or reciprocating member and the body of the pump or valve (see Figure 1).

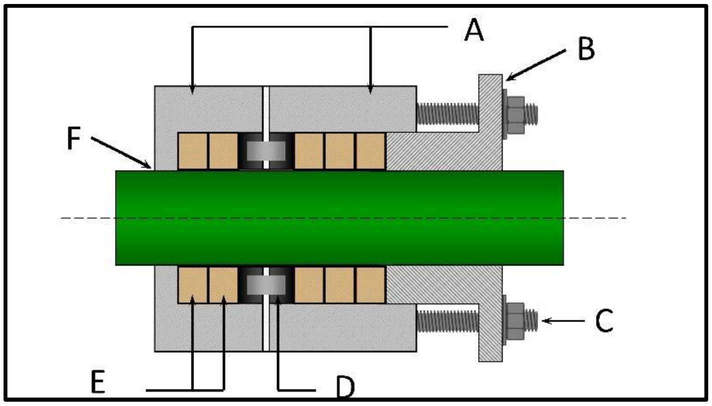


Figure 1. General Stuffing Box Arrangement
A: Stuffing Box Area
B: Gland
C: Gland Stud Bolts and Nuts
D: Lantern ring
E: Packing
F: Throat

By tightening a follower or packing gland against the top or outboard ring, pressure is transmitted to the packing set, which expands the rings radially against the side of the stuffing box and the reciprocating or rotating member and effects a seal.

Compression packings are the most common sealing device for controlling fluid loss in mechanical equipment.

Compression packings find their major use in the process industries (e.g., petrochemical, pharmaceutical, chemical, pulp & paper, steel mills) and the service industries (e.g., utilities, marine, water, sewage, fossil / nuclear power plants).

They seal all types of fluids including water, steam, acids, caustics, solvents, gases, oil, gasoline, and other chemicals over a broad range of temperature and pressure conditions. Packing can also be used to seal solids flow streams such as powders.

Compression packings are used in mixers, agitators, dryers, valves, expansion joints, soot blowers, rotary pumps, centrifugal pumps, reciprocating pumps, and many other types of mechanical equipment.

Compression packings seal all types of fluids in valves, pumps, and other equipment in the process and service industries.

HOW COMPRESSION PACKINGS WORK

Proper function of compression packings used in rotating or reciprocating pump service normally depends on a fluid film between the surface of the moving component of the equipment and the packing for lubrication. Sources of this fluid film are either the self-lubricating properties of an advanced packing material, the leakage of the fluid pumped, the built-in lubricants in liquid, solid, or combination form, or an external lubricant supply.

On equipment start-up, built-in lubricants may be released from the packings by gland pressure to provide initial lubrication and sealing. During service, continuous fluid film lubrication is provided by ongoing adjustment of the gland pressure and any combination of these sources: the built-in lubricants, the packing material, the pumped service fluid, or the external lubricant. If the pumped fluid must not flow through the packing rings, the advanced packing material or built-in lubricants must block its passage. When pump suction is under vacuum, an external means of lubrication such as a lantern ring (seal cage) may be used (see Figure 2). For a positive pressure configuration, (see Figure 3).

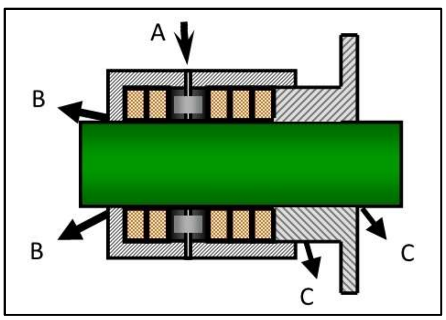


Figure 2. Lantern Ring Arrangement
A: Fluid Inlet connected to Pump Discharge or External Fluid Source
B: Leakage into pump
C: External Leakage

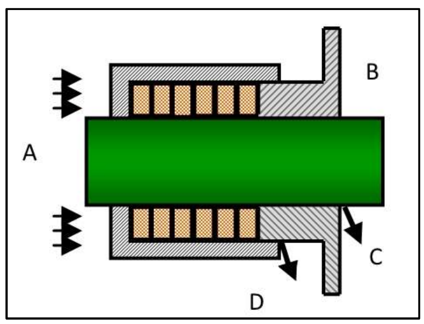


Figure 3. Positive Fluid Pressure
A: Positive Fluid Pressure
B: Atmospheric Pressure
C: Shaft Leakage
D: Stuffing Box Bore Leakage

Gland pressure is regulated to provide optimum lubrication to seal and prevent overheating and consequent damage to the shaft or rod. The built-in lubricants that are lost gradually during the operation of the equipment are compensated by further gland adjustment. In a live loaded packing system, the gland follower will continue to push against the packing even when packing volume is lost by friction, extrusion, consolidation, etc. The effective service life of the packing is reached when adjustments to the stuffing box gland do not result in consistent control of the leakage from the packing seal. When the packing density increases due to consolidation and/or extrusion of the packing, this process often results in volume loss that can no longer be compensated by gland adjustments, either because the gland bottoms out against the stuffing box, or leakage level does not respond to the adjustments.

Compression packings used in valves with slow or infrequent motion or static operations are required to seal without leakage. Various impregnants may be used to assist in this function. Some packings are designed with non-migrating stable lubricants for operation under extreme pressure and temperature. Refer to *Types of Packing Materials and Lubricants* for descriptions of lubricants and impregnants.

LUBRICANTS BUILT INTO THE COMPRESSION PACKINGS, LEAKAGE OF THE PUMPED FLUID, AND/OR EXTERNAL LUBRICANTS SUPPLY THE FLUID FILM LUBRICATION BETWEEN THE PACKING AND MOVING COMPONENT.

ADVANCES IN COMPRESSION PACKINGS

With advances in material technology, including that for fibers and lubricants, compression packings continue to be a viable solution for a wide range of modern sealing applications. These advances give packings the following notable properties:

- High pressure and vacuum capability
- High and low (cryogenic) temperature capability
- Broader range of chemical resistance
- Less abrasive effect on mating surfaces
- Improved dimensional stability in ring or rope form
- Improved sealing capability
- Better abrasion resistance

No longer perceived as antiquated technology, packings consist of some of the most advanced modern materials, which can seal fugitive emissions in valves and abrasive or viscous liquids in pumps when used with barrier fluids and flush techniques. Injectable packings provide sealing when equipment operations must continue with no downtime.

Modern high-performance packings are developed for applications involving extreme operating conditions. For example, many packing materials with properties that dissipate heat are used in high speed rotating applications with no to low lubrication. When preferred, advanced lubricants are also available. Refer to the section, *Types of Packing Materials and Lubricants* for descriptions of lubricants.

Advancements in fiber and lubricant technology have enabled high-performance of packings in a wide range of modern applications.

Developed with performance features comparable with mechanical seals, the modern high-performance packings can bring competitive cost savings when materials are correctly applied to each specific sealing environment. Note just a few:

- Time savings with ease of installation
- Equipment savings with continued performance in the case of axial shaft movement
- Sealing equipment savings with continued performance in the case of gritty or viscous media and of pressure changes in fluid and/or flush
- Operation savings with reduction in friction and thus power consumption

Because compression packings are specifically engineered to solve each application in the broad range of fluid sealing, they are provided in a wide array of configurations, materials, and dimensions.

No, to low, lubrication is needed with advanced packing materials used in high speed rotating applications.

TYPES OF PACKING CONSTRUCTION

Compression packings are made from a wide range of materials in a variety of shapes, sizes, and constructions. The following is a description of the most common constructions and their advantages:

Variability in the quality of the materials and the construction of compression packing will exist; thus, adherence to industry standards and focus on life cycle costs must be emphasized.

The square braid is formed when yarns, rovings, ribbons, and other various materials, either alone or in combination, are processed on equipment where strands pass over and under strands running in the same direction. Resulting packings are usually supplied in a square cross-section, but rectangular sizes can also be braided by this method. The square braid packings, which are usually soft and pliable and can carry a large percentage of lubricant, are generally used for high-speed rotary service at relatively low pressure. The packing softness makes it usable on old or worn equipment.

This construction is more commonly used to manufacture smaller square packings up to a nominal size of 6 mm (¼ inch). This 2-track square braid forms rougher packings in larger dimensions. Eight braiding yarns are plaited around 4 corner strands into a 2-track plait (see Figure 4). The braiding yarns crisscross diagonally through the packing; thus, even if one strand is damaged, the braid will not unravel. The corner yarns provide stability to the packing. The square braid is flexible and easy to produce.

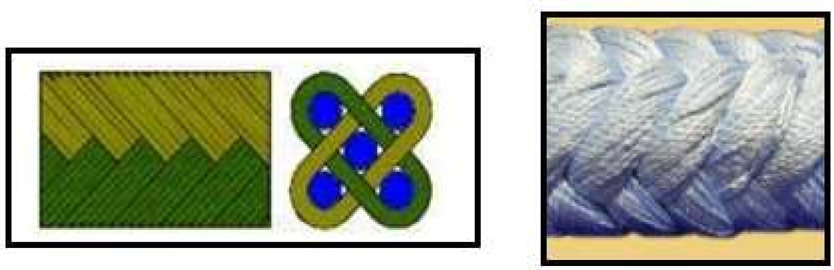


Figure 4. Square Braid - 2 Track Structure.

The interbraid is also known as diagonal braid, cross-braid, and lattice® braid. It is formed when yarns, rovings, ribbons, and other forms of various materials, either alone or in combination, are processed on equipment where the strands crisscross from the surface diagonally through the body of the packing. Each strand is strongly locked by other strands to form a solid integral structure that cannot easily unravel or come apart in service. There are no jackets to wear through and no plaits to come loose. Interbraid packing has an even distribution of yarn density throughout and has the potential for improved lubricant retention. The finished packing is relatively dense but flexible. Interbraid packings are suitable for applications on agitators, valves, expansion joints, both reciprocating and centrifugal pumps, and for oven door or static sealing. For larger packing cross-sections, 3-track (see Figure 5) or 4-track (see Figure 6) diagonal braids are used. The name, diagonal braid, comes from the diagonal tracks made by the additional yarn strands. For a 3-track braid, braiding machines with 12 to 18 carriers are commonly used to manufacture nominal packing dimensions between 5 and 12 mm (3/16 and ½ inch). Usually packings in dimensions from 10 to 80 mm (3/8 to 3 inches) are produced on 4-track braiding machines with 24, 32, or more carriers.

The Interbraid is also referred to as a diagonal braid.

By using a higher number of yarn carriers, finer surface structures can be maintained with larger packing dimensions, which ensures a better contact between packing, shaft, and housing. By using thinner yarns, a much denser braid can be created, which guarantees a better impregnation retention and minimizes the leakage paths.

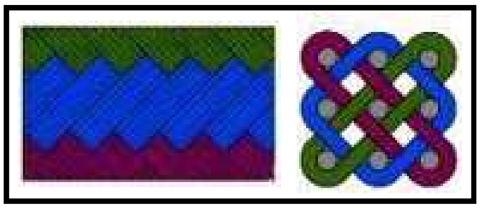
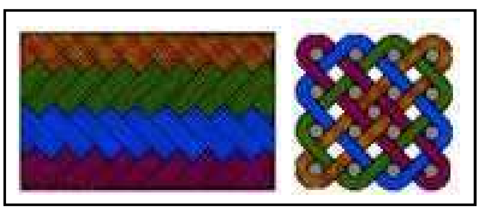


Figure 5. Interbraid - 3 Track Structure



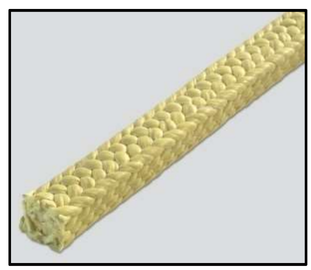


Figure 6. Interbraid 4 Track structure

Corner reinforcement, another type of interbraid but with reinforcing fibers in the corners, can refer to two separate constructions. In the first one, a fiber is inserted in each corner of the packing running longitudinally. The jacket is braided around these corner posts that add tensile strength in each corner. The second method, see figure 7., also referred to as a cross over track, uses a stronger fiber to be woven only in the corners of the packing. This corner fiber provides strength and extrusion resistance. In between the corners of the packing, a fiber with more lubricity or heat dissipation is used to lessen friction. Corner reinforced packings can be suitable for applications with increased abrasiveness, combined with high speed rotating pumps.

Figure 7. Corner Reinforced

BRAID-OVER-BRAID

Braid-over-braid packings are concentric or round braids manufactured by braiding a thin tubular jacket around a core material. Round braiding machines braid tubular jackets using yarns, rovings, ribbons, and other forms of various materials, either alone or in combination. Braid-over-braid packings can be formed into round, square, or rectangular cross sections.

The braid has a fine and dense surface structure, which is not as abrasion resistant as a diagonal braid. To increase the density or the size, the core can be braided over with several yarn layers of braid-over-braid. Depending on the size of the packing machines, 16, 48, or more carriers are used (see Figure 8). Parallel orientated or twisted yarns can be used as core materials, providing good elasticity and flexibility.

Alternatively, other cores can be used, such as extruded rubber or elastomers. Not only square shapes but also rectangular or round cross-sections can be produced, depending on the shape of the packing. Large endless concentric packing rings can be produced with special braiding machines where the top of the machine can be split.

Braid-over-braid packings are relatively dense and are recommended for high-pressure, slow-speed applications such as valve stems, expansion joints, and groove gasketing. These packings are mainly used in static applications due to their ability to sustain a high degree of elastic deformation.

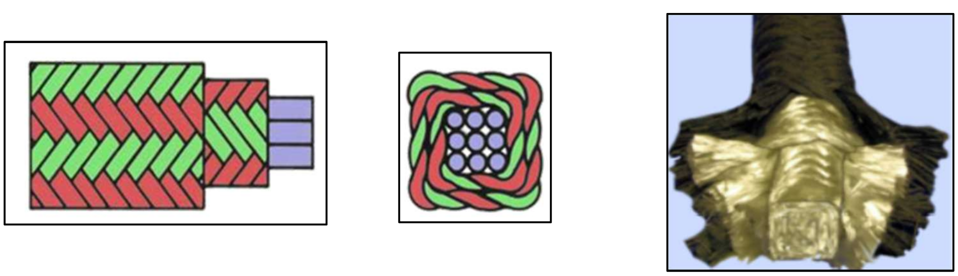


Figure 8. Braid Over Braid Track Structure

The Braid-Over-Braid is also known as round braid or multiple braid.

BRAID-OVER-CORE

The finished construction of braid-over-core packings is produced by braiding one or more jackets of yarns, rovings, ribbons, or other forms of various materials over a core, which may be extruded, twisted, wrapped, or knitted. See Figure 9. This construction allows for a wide range of densities and different cross-sectional shapes.

Figure 9. Braid Over Core

COMBINATION SETS

As the name implies, combination packing sets are combinations of different packing ring types, as illustrated in Figure 10. There are various reasons to combine 2 or more packing types. The most common reason is to prevent extrusion with rings that are installed at both ends of the packing set, on the gland and media sides in the stuffing box.

These anti-extrusion rings have a higher-pressure resistance than the packing material between them and prevent extrusion of the packing through the clearances in the stuffing box. In addition to the extrusion protection, the anti-extrusion rings can function as wipers to hold loose packing particles in the stuffing box, and prevent contaminants from atmosphere to enter inside the packing set and damage the softer mid-rings. A typical combination is carbon filament end rings with flexible graphite rings. Also, very soft packings like extruded or injectable compounds need end rings because they will readily migrate through clearances at low pressures.

Other materials like metal discs or machined plastics are also used as end rings, such as on the media side to prevent abrasive materials from entering the stuffing box.

Figure 10. Combination Set

BULK

A bulk packing is a homogeneous material, which is supplied in powdered, shredded, or fibrous form used alone or blended with each other. This is a highly conformable product, which can be used to pack a variety of stuffing box sizes, (Figure 11.).

Injectable packings, a form of bulk packings, are injected at high pressures to replenish a seal on operating equipment to prevent unnecessary downtime until scheduled maintenance is to occur.

Figure 11. Bulk

TWISTED

Twisted packing is formed when yarns, rovings, ribbons, and other forms of various materials are twisted together or around a core to obtain the desired size, Figure 12. In the case of yarn or roving, one size of packing can be used for several stuffing box sizes; because of its twisted construction, strands from a larger size can be untwisted and removed so that the remaining packing will fit a smaller annular size stuffing box. When metallic materials are used in the packing, they can be made to resist high temperatures and pressures, to resist the penetration of fluids, and to conform to the irregularities of worn equipment.

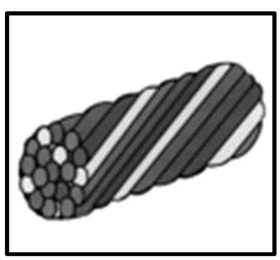


Figure 12. Twisted

WRAPPED, ROLLED, AND FOLDED

Wrapped, rolled, and folded packings are formed when strips of various materials (e.g., lead, copper, aluminum, rubberized woven fabrics) are either spirally wrapped, rolled, or folded upon themselves or around a resilient or compressible core (see Figure 13). The rubberized fabric types are strong, dense, resilient, and are resistant to the penetration of fluids. The metallic types can also be made to resist the penetration of fluids and can conform to the irregularities of worn equipment.

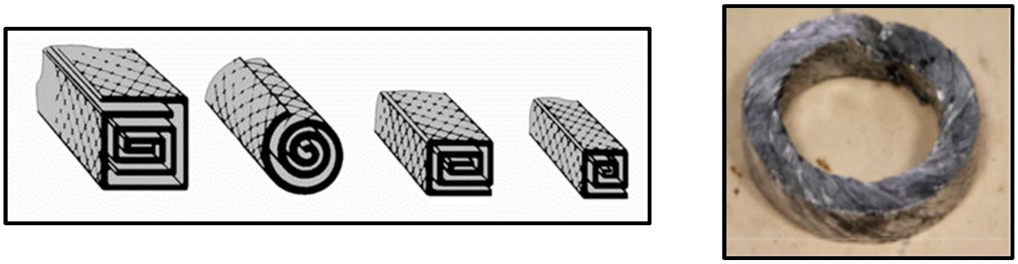


Figure 13. Wrapped, Rolled, and Folded Geometric Structures

EXTRUDED

Extruded packing is a homogeneous mixture of various materials that are extruded to produce the desired cross-section, see Figure 14. Extruded packings can be made into a wide range of densities and compressibility and are sometimes supplied with a skeletal jacket. These packings are designed to retain lubricants, contributing to long packing life. They are conformable to irregularities in the stuffing box. Extruded packings are used in centrifugal and reciprocating pump applications and cover a broad range of service requirements. Extruded rings are used in combination with anti-extrusion rings to minimize the risk of packing extruding through equipment clearances.

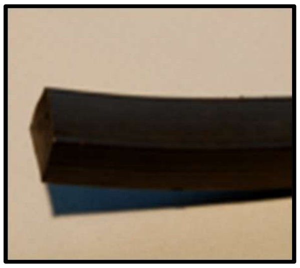


Figure 14. Extruded

LAMINATED

Laminated packing is formed when fabric laminated plies, cured in slab form, are cut into strips or rings of the desired size, Figure 15. Details of construction can be varied to meet end use requirements. This type of packing is highly resilient.

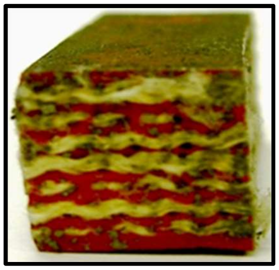


Figure 15. Laminated

MOLDED

Molded packing is a mixture of various materials, not necessarily homogeneous, molded to produce the desired cross-section, Figure 16. Molded packings can be made into a wide range of densities and compressibility. Molded packing materials are not necessarily hydraulically compressed and may require temperature treatments to form the part, depending upon the materials used. Wave packing sets are a type of molded packing used primarily as the hydraulic seal assembly inside marine fin stabilizers.

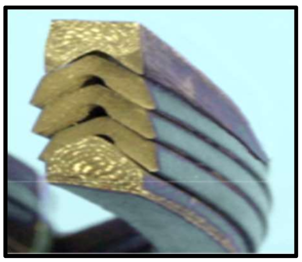


Figure 16. Molded

DIE FORMED

Die-formed packing comes in a pre-compressed ring form. Many compression packing materials, which are usually compressed hydraulically within a tooling die of a specified size, can be supplied in controlled density and size. See Figure 17.

Figure 17. Die Formed

MACHINED

Machined packing rings, typically produced in Polytetrafluoroethylene (PTFE) in ‘V’ or ‘U’ shaped sections, are usually supplied in sets consisting of top and bottom adapter rings and sufficient ‘V’ or ‘U’ section rings to make up the depth required, Figure 18. Activation is by lip sealing and is in part energized by the pressure forces acting against the seal set.

The chemical resistance, very low coefficient of friction, and high wear resistance of PTFE is of particular advantage in reciprocating valve and pump application.

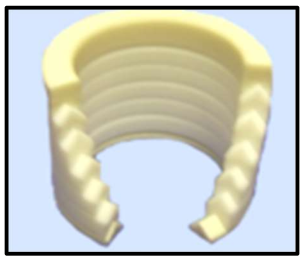


Figure 18. Machined

FLEXIBLE GRAPHITE TAPE

Flexible graphite tape is formed when sheet produced by exfoliating and calendering natural flake graphite is slit into various tape widths, Figure 19. When used as compression packing, the slit tape is normally corrugated or embossed to improve its handling characteristics and, thus, its ability to be formed into rings. It can be die-formed or compressed in the stuffing box to form endless rings.

Figure 19. Graphite Tape

MANUFACTURING METHODS

Methods for manufacturing compression packings include braiding, die-forming, molding, laminating, and extruding. These are the technologies that are in common use. A brief description of each method follows.

TECHNOLOGY OF BRAIDING

To produce the variety of shapes, sizes, and construction in compression packings, braiding machines of different design are used. The fibers are wound around bobbins and mounted on a platen. Each bobbin travels along a specified path, guided in a track that criss-crosses the tracks of other bobbins (see Figures 20 and 21). The interlaced paths will then determine the construction of the packing. Often, a core of fibers or other material is fed at the center of the packing while the bobbins feed the outer part of the packing and create the general shape of the packing. The most common shape is square but can also be rectangular or cylindrical.

The interlaced paths traveled by the bobbins of wound fibers will determine the construction of the packing.

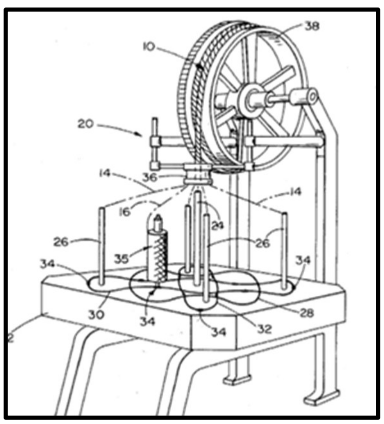


Figure 20. Braider Paths

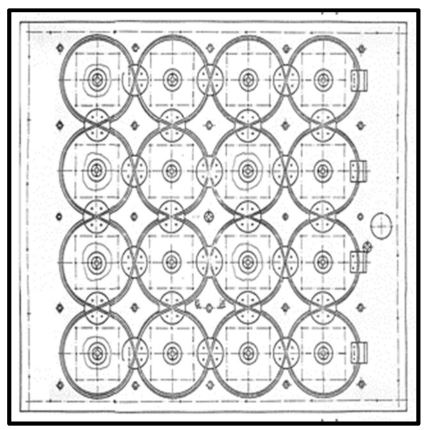


Figure 21. Interlaced Paths

Braiders are sometimes classified by the direction in which the packing is formed. Traditionally, braiders (see Figure 22) formed the packing on top of the bobbins. These are considered upright braiders. An inverted braider forms the packing below the bobbins (see Figures 23 through 25). The packing can also be formed to the side (see Figure 26.)

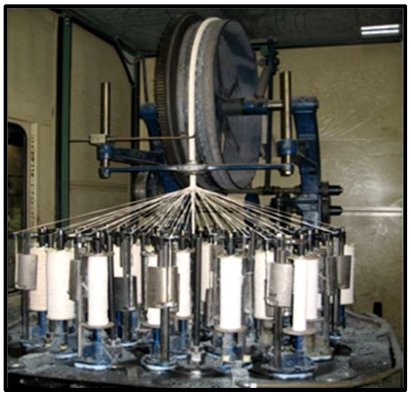


Figure 22. Upright Packing Braider

An inverted braider is superior in many respects to one that braids upright. Inverted braiders have the capability to braid through dispersions and lubes, providing higher quality at lower cost and saving production time. Inverted braiders allow the addition of impregnates during the braiding process which improves packing lubrication in contrast to impregnating the dry packing after braiding, as done with traditional upright braiders.

Particles which fall off the yarn during the braiding process do not dirty the packing and do not fall into the gears and on the tracks causing excessive wear and defects in the braiding process. Less wear on the carrier shoes and horn gears decreases the possibility of defects in the packing caused by broken fibers. Inverted braiders have more carriers, which allows for quicker production of large volumes of packing.

Figure 23. Inverted Braider

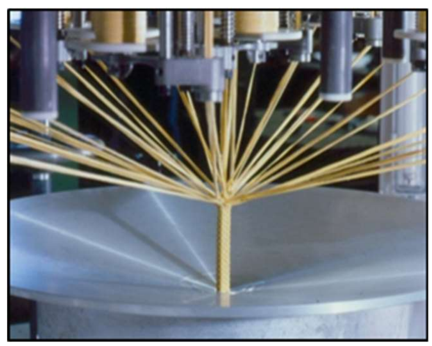


Figure 24. Inverted Braiding

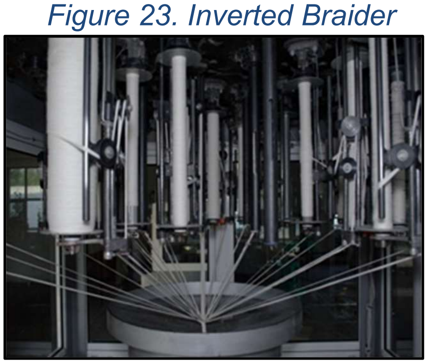


Figure 25. Inverted Bobbins

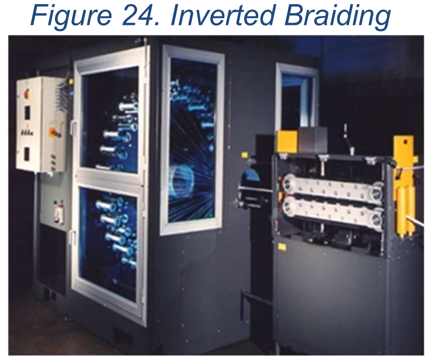


Figure 26. Horizontal Braider

Three-Track machines are faster, but 4- track machines produce a braid which is squarer along the cross section. Braiders with fewer carriers produce more packing at a faster rate; but for the same cross section, packings manufactured on braiders with more carriers tend to maintain their shape and resist leakage more consistently.

Many considerations in the design of the braiding machine affect quality and performance. While it may be difficult to observe the differences, the trained eye notices the variations in the operation of the machine and the product it manufactures.

Evaluation of Output

Machine manufacturers offer specification sheets from which the machine's output capability is determined. Use the following equation to determine the braider output rate (BOR):

BOR (m/hr or ft/hr) = $[60 * RPM * P_{hg}] / P_{fp}$ {1}

where

RPM is the rotational speed (revolutions per minute)
P_{hg} is the number of picks per horn gear and
P_{fp} is the number of picks per meter or foot of product being made.

Carrier Design

The carrier is to release smoothly without hanging up or sticking. The rollers, which are to roll easily, contain bearings. The rollers are to be deep and wide enough to contain multiple ends of yarn without allowing the yarns to jump off the rollers.

Bobbin Capacity

The more meters (yards) a bobbin holds, the longer the machine runs before it needs setting up again. Larger bobbins will allow for longer runs preventing need for tying ends when adding material that could create defects. Unfortunately, larger bobbin sizes usually bring larger, slower horn gears with more expense in building the machine. This needs to be evaluated, for the advantages of fewer setups can be offset by machine size.

Tension Spring

Each fiber has different characteristics. Some fray or stretch easily, while others do not. By adjusting the spring tension in the braider, an operator can accommodate the characteristics of many different fiber types.

Pulling Mechanism

The mechanism of the machine for pulling out the packing from the braider must be synchronized with the packing formation to avoid breaking and damaging the packing. Some secondary processes, such as squaring, can be done while the packing exits the braiding machine.

TECHNOLOGY OF DIE-FORMING

The fabrication of die-formed or die-molded rings begins with the machining of a tooling die to the size and geometry of the desired ring. The tooling die (see Figure 27) consists of a core, pusher, shell, and base, each usually of a strong tool steel. The core, shell, and base restrain the sealing material to the desired ring geometry and size. This is usually a cylindrical geometry with dimensions of the inner diameter and outer diameter of the ring.

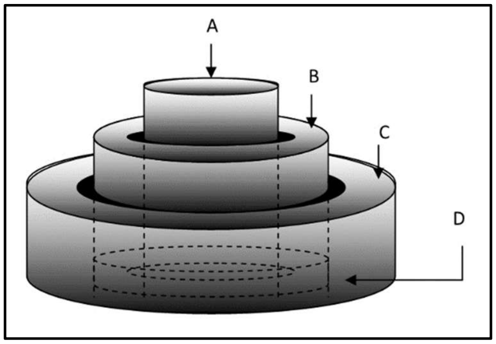


Figure 27. Tolling Die
A: Core
B: Pusher
C: Shell
D: Base

The amount of sealing material used and of compression applied renders the ring density and height.

The pusher compresses the sealing material against the core, shell, and base and into the density and height needed. The amount of sealing material used and of compression applied renders the ring density and height (see Figure 28). The die is most often hydraulically compressed to ensure the application of an equal load and uniform density across the entire ring.

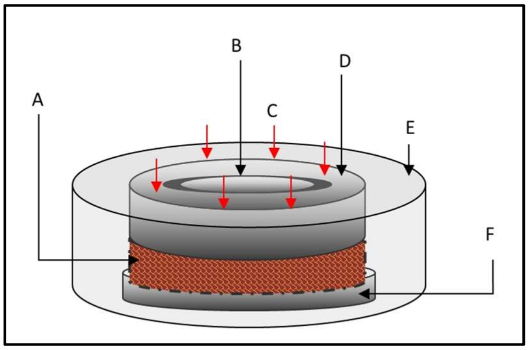


Figure 28. Tooling Die During Compression
A: Sealing Material
B: Core
C: Load
D: Pusher
E: Shell
F: Base

TECHNOLOGY OF MOLDING

Materials, such as fibers and adhesives, are mixed and set into a mold or hollowed solid. High temperatures and pressures may be applied to the mold so as to set the materials within it to the shape of the mold. The mold is itself made of a material that will withstand any temperatures or pressures applied. Similar to die forming, the molding technology restrains and forms the materials within to the geometry of the mold; but unlike die forming, compression may not be necessary, and heat or drying may be used to set the material.

Unlike die forming, compression may not be necessary in molding.

TECHNOLOGY OF LAMINATING

Layers of fabric, typically 300 to 400 mm (11.8 to 15.7 inches) wide, which have been impregnated and proofed with non-vulcanized natural or synthetic rubber, are plied together to form a slab of the required thickness. This can either be carried out on a horizontal table or more usually by winding the material around a large diameter rotating drum and then slitting it to form the slab. For some products, the fabric layers may be separated by thin layers of rubber sheet.

The slab is then pressed between heated platens on a press to vulcanize the rubber and produce a composite material with excellent resiliency. The slab can then be slit along its length to produce either square or rectangular cross-section strips which can then be cut to the required length to produce rings of the required size or preformed into rings in dies. The strips are often impregnated with liquid lubricants such as mineral oils and surface dressed with graphite or other dry lubricants.

The construction within the body of the slab can be varied to give different properties. For example, narrower strips of fabric can be wound onto the drum at 45º to the surface and wider layers of rubber placed top and bottom. When slit after pressing the slab, the resulting cross-section has fabric layers running at 45º. This makes a finished packing that is softer and more sensitive to gland adjustment, which is suggested for sealing worn or damaged shafts.

The construction within the body of the laminated slab can be varied to give different properties.

TECHNOLOGY OF EXTRUDING

Extruded packings are usually made from PTFE powder, graphite powder, grease, fillers, binders, and fiber materials. These raw materials are mixed in a mixer or agitator to form a granulate or resin.

This granulate is fed through a hopper into an extrusion machine. The cylinder of the extrusion machine is heated to temperatures up to around 200 °C (392°F). The material melts into a liquid and is transported and pressurized by a plunger or rotating screw.

At the end of the pressure cylinder, the packing material is forced through a die. The die determines the shape and size of the resulting packing. Round, square, or rectangular shapes are most commonly made.

A continuous length is formed, which is solidified by being either air or water cooled after leaving the die. Once the product has cooled, it can be spooled or cut into lengths. In this way, very dense and plastically pliable packing compound lengths are formed. This packing can be gas tight and capable of absorbing abrasive media particles.

Very dense and plastically pliable packing compound lengths are formed by extrusion.

TYPES OF PACKING MATERIALS AND LUBRICANTS

CAUTION: Many packing manufacturers offer blends of the materials listed below. As a result of blending, the limitations listed for speed, temperature, pH range, or other properties will change. Please consult the packing manufacturer for specific application information

Contact the packing manufacturer when nuclear grade, FDA grade, or other specialty grade materials are needed. Application limitations of packings of the same fibers will vary due to the differences in additives, such as coatings and lubricants, from each manufacturer. Variability in the quality of the materials and the construction of compression packing will exist; thus, adherence to industry standards and focus on life cycle costs must be emphasized. This manual does not claim to address all the health and safety concerns, if any, associated with handling and use of the various packing materials described in this manual. It is the responsibility of the user to ensure that a particular material is compatible with the process in which it is intended to be used in terms of performance but also in terms of health, safety, and regulatory requirements.

CELLULOSIC OR VEGETABLE FIBERS

Cellulosics, such as flax, jute, ramie, and cotton are the natural fibers used in packings. Since they are natural, they have been used in packings longer than the man-made fibers. Their chief advantage is their low price in comparison to the synthetic fibers. Their chief disadvantages are their poor chemical and heat resistance. They have very poor resistance to acids but are generally resistant to alkalis.

BAST FIBERS

Flax
Flax is obtained from a plant stalk. It is the oldest textile fiber known in the vegetable group, and it can reach a length up to forty inches.

Jute
Jute is also obtained from the plant stalk. The stalk produces two to five times as much fiber as the flax plant. Raw jute fibers range from 1.2 meters to 2.1 meters (4 feet to 7 feet) in length. The greatest disadvantage of the fiber is that water causes it to degrade.

Ramie
Ramie, when properly degummed, is white, soft, highly lustrous, and has high resistance to the effects of bacteria and fungi. Wet and dry strength are very high. Ramie is among the strongest of all natural fibers. Knotting and flexing qualities are also high. Ramie fiber must be degummed prior to yarn manufacturing because the gum, which binds the fibers, is water and caustic soluble and could cause yarn to disintegrate.

Cotton
Cotton is the most commonly known and used vegetable fiber. Cotton fibers, less than 50 mm (2 inches), are shorter than the other cellulosic fibers. As in the case of the other cellulosics, cotton has poor resistance to acids.

MAN-MADE FIBERS

Acrylic Fibers
Acrylic fibers are manufactured by numerous companies and marketed under several trade names. The properties of the various acrylic fibers used in compression packing are similar. Acrylic fibers soften at temperatures approaching 204°C (400°F). In most environments above 177°C (351°F), shrinkage can reduce the fiber by as much as 10%.

Better performance may be achieved with the use of a special heat treated, pre-oxidized acrylic fiber. Fibers of this type are capable of temperatures to 260°C (500°F) with minimal shrinkage. The chemical structure makes these special fibers more thermally conductive than the base acrylic fiber and slightly more chemically resistant.

Aramid Fibers
Aramid fibers can be divided into two basic classes: para-aramid and meta-aramid. The classes are differentiated by the type of building blocks (monomers) that determine the molecular structure of polymer chains. The fibers are easily distinguished by color but differ also significantly in certain chemical and physical properties. The para-aramid fibers are bright yellow while meta-aramid fibers are white.

Para-aramid fibers, well known for their high strength, are five times the strength of steel wire for equal weight and possess a modulus similar to glass without the brittleness. The high strength and linear rigidity of these fibers make them appropriate for high pressure sealing applications and highly abrasive media. Para-aramid fibers, distinguished by a very low rate of thermal expansion, are suitable for high-temperature applications. The chemical resistance of para-aramid fibers covers a broad variety of organic solvents and acids and bases within a pH range of 3-11. Para-aramid fibers are either continuous filament or staple fibers. Continuous filament fibers will have higher tensile strength to withstand higher traction and superior performance in abrasive service. These fibers are better for sealing high static pressure or plunger pumps. Staple para-aramid yarns consist of shorter, twisted fibers. Staple yarns absorb more lubricants and are better for sealing abrasive fluids containing many small sharp-edged particles. Staple fiber yarn will also be more flexible and more conformable than continuous multi-filament.

Meta-aramid fibers are well known for their chemical and hydrolytic resistance, fiber toughness, and high temperature resistance. The pH range for meta-aramids is 1-13. Their resistance to hydrolytic degradation makes them a suitable choice for hot-wet conditions. The thermal stability for both fibers is excellent. Meta-aramid fibers will not melt nor start to decompose until 426°C (800°F) is reached, and para-aramid fibers are stable to 555°C (1031°F). However, the glass transition temperature of meta-aramid fibers is 270°C (518°F), which limits its use compared to para-aramids. Many packing manufacturers recommend para-aramid fibers for continuous service up to 260°C (500°F) under harsh conditions. Both fibers form durable packings which qualify them for applications with slurries and abrasive fluids.

Polyphenylene Sulfide (PPS) Fiber

Polyphenylene sulfide fiber (PPS), white in color, contains a long-chain synthetic polysulfide with at least 85% of the sulfide linkages attached directly to two aromatic rings. This fiber offers a good combination of physical, thermal, and chemical properties. The fiber retains 40% of its tensile strength up to 227°C (440°F). This fiber offers excellent resistance to acids and alkalis; however, strong oxidizing agents cause degradation. This fiber is not susceptible to hydrolysis.

Polyimide (PI) Fibers

Polyimide fibers (PI) are a natural gold-yellow color, also available in mass-dyed blue or orange. They are dry-spun from an aromatic polyimide. They possess excellent thermostability up to 260°C (500° F) and good resistance to chemicals. As with other textiles, PI fibers offer superior dimensional stability and extrusion resistance combined with minimal shaft-wear. They are often blended with PTFE fibers in compression packings to enhance performance.

Polybenzimidazole Fiber (PBI)

Polybenzimidazole fiber (PBI) is made from high-performance organic compounds. This fiber is inherently flame resistant and does not melt, drip, nor burn in air. This fiber offers an excellent resistance to a variety of chemicals, solvents, fuels, and steam. Retaining significant strength after thermal exposures, it can withstand high temperatures up to 298°C (570°F) short term.

Melamine Fiber

Melamine fiber is made from melamine resin. This fiber is available in staple form only. The staple fiber is thermally stable and offers excellent flame resistance. The recommended sustainable usage temperature is up to 204°C (400°F). Melamine fiber is very resistant to aromatics and alkalis, is stable to hydrolysis, but does not have permanent resistance to acids.

Carbonaceous Fibers

All fiber-based carbon and graphite yarns used in compression packings are made by a series of heat-treatments (heat stabilizations) of some type of organic or synthetic precursor. After the final heat-treatment process, the fiber retains much of its original shape and form; however, there is significant volume loss.

Generally, after the base carbonaceous fiber is created, it is usually subjected to additional heat-treatments which increase the carbon content, the purity level, and the degree of crystallinity. Under proper manufacturing conditions, the mechanical properties are also improved.

Carbon and graphite yarns for compression packings are available with carbon contents ranging from roughly 63% to 99%+, depending on the precursor, the method of heat-treatment, and the time-at-temperature used in the manufacturing. Descriptions of carbon content follow.

0 - 63%: These yarns are not suitable for use in braided packings.

63-65% "PRE-OX": The precursor has been subjected to a preliminary heat-treat process, but the purity level is still low. The fibers have little heat stabilization and should be used only up to 300°C (572°F). These yarns are mainly used in braided packings for pump applications.

73-85%"INTERMEDIATE": The precursor has been subjected to higher temperature heat stabilization than pre-ox materials, but carbon content and purity levels are still relatively low. These are typically low cost packing materials used in temperature applications up to 350 °C (662°F).

95-99% "CARBON": The precursor has been heat-treated to approximately 1800°C (3272°F), substantially increasing the carbon content and purity of the fibers. Carbon packings are universally used for higher temperature valve applications up to 400 °C (752°F) where purity level is not normally a concern.

99%+ "GRAPHITE": The precursor has been heat-treated to 2000°C (3632°F) and higher, again increasing the carbon content and purity level over carbon yarns. These yarns are used at temperatures up to 450 °C (842°F) and in applications where packing purity is a concern.

Descriptions of the three different precursor materials used to produce carbonized or graphitized fibers follow.

Rayon-based: "Continuous filament" plies of white viscose rayon are twisted, cleaned, and then subjected to two heat-treatment processes to achieve the desired carbon or graphite (purity) level. Carbonized and graphitized rayon have sufficient tensile strength and a low modulus. These fibers are excellent for high speed pump applications. The yarns have a smooth surface area and are normally used when minimal coating is desired. Graphite rayon yarn is standard material for nuclear and military applications.

Pitch-based: By-products of the petroleum distillation process are extruded into pitch-based fibers. These fiber bundles are twisted into "staple filament" plies, spun into yarns, and then heat-treated to the desired carbon or graphite level. These yarns typically have a less-smooth surface and are therefore suited for the consistent containment of coatings and lubricants. Pitch-based carbon fibers are widely used in valve packing applications, but are more and more replaced by PAN fibers. Graphitized, isotropic pitch fibers are best for thermal dissipation while carbonized isotropic treated fibers produce a material with excellent mechanical properties.

PAN-based: Polyacrylonitrile (PAN) is a thermally stabilized synthetic fiber which is further heat-treated to produce a material with excellent mechanical properties. A polymer is used to produce fibers and yarns; it is first thermally oxidized at 200 – 300 °C to form an oxidized (pre-ox) PAN fiber. At over 1000 °C in inert atmosphere it is then carbonized to produce carbon fibers. PAN carbon fibers dominate the carbon fiber market. Advantages are their high strength and good crystalline structure when graphitized, which leads to superior oxidation and chemical resistance.

Carbon and graphite yarns are inert to most chemicals and have low frictional coefficients. Carbon and graphite packing yarns are commonly coated with PTFE, colloidal graphite, or other coatings to aid in material handling, braiding, and to meet the sealing requirements of specific packing applications. For mechanical properties of carbonized and graphitized fibers, see Figure 29.

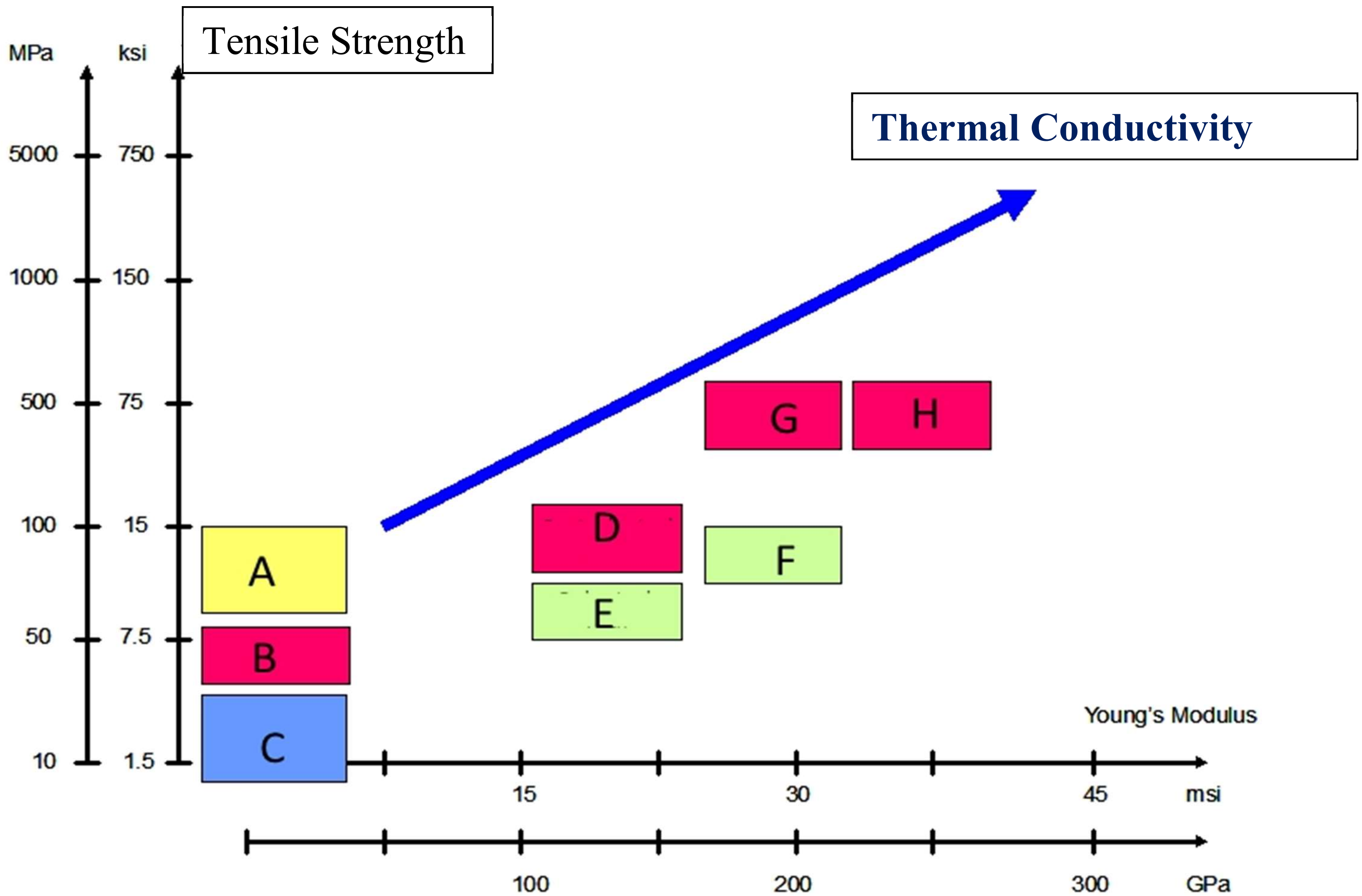


Figure 29. Mechanical Properties of Carbonized and Graphitized Fibers

A: Carbonized Graphitized Rayon
B: Oxidized PAN
C: Flexible Graphite
D: Semi carbonized PAN
E: Carbonized Pitch
F: Graphitized Pitch
G: Carbonized PAN
H: Graphitized PAN

Ceramic Yarns

Ceramic yarns are made from silicate fibers with a base core usually of glass fibers. Ceramic yarns have extreme temperature resistance up to 900°C (1652°F). They are used in static applications in oven doors and furnaces and have been used as an insulating material in conjunction with valve packing.

Glass Fibers

Glass fibers have superior thermal resistance properties, dimensional stability, and tensile strength. They resist most chemicals and can be formulated to resist strong acids. Glass fibers are available in continuous filament yarn, staple fiber yarn, textured yarn, chopped strand, and mats. The fibers are produced in two basic forms: staple fiber and continuous filament. The bulk density and tensile strength of staple yarn is considerably less than continuous filament yarn.

Several glass formulations are used to form fibers. E (electrical) glass is the most common. C (chemical) glass and S (strength) glass are also important. Each type is formulated for particular characteristics to meet the requirements demanded by end use.
Glass is recommended for static applications only.

Glass is treated with chemical sizing to protect the fibers. Treatments, such as the addition of PTFE to compression packings, have been developed to meet particular end uses.

Glass will not burn. Temperatures normally encountered do not affect glass; “E” glass retains 75% tensile strength at 343°C (650°F), and 50% at 583°C (1081°F). “E” glass softens at 732°C-877°C (1350°F-1611°F), and “S” glass softens at 849°C-970°C (1560°F-1778°F). Common solvents, oils, petroleum distillates, bleaches, and most organic chemicals do not affect glass fibers; however, strong acids, pH less than 4, will corrode “E” glass at elevated pressures. “C” glass and “S” glass resist all strong acids except hydrofluoric and are more rigid than “E” glass. Strong alkali will corrode all commercially available glass fibers.

Novoloid Fibers

Novoloid fibers are thermoset (non-melting) phenolic fibers with good resistance to chemicals including acids, bases, bleaches, solvents, oils, hot water, and steam. The pH range for Novoloid fibers is 1-13. The fibers do not soften or shrink when heated and withstand temperatures up to and above 250°C (480°F). Packing manufacturers may recommend lower practical limits depending on formulation.

Novoloid fibers are gold to purplish brown. With a low fiber density of 1.27g/cm^3 (80 lb/ft^3), they fill more volume per unit weight than other packing fibers. They are highly compatible with PTFE and other packing lubricants and are available as spun yarns. Novoloid fibers are flexible and non-aggressive, with low modulus and good elongation; therefore, Novoloid packings are pliable and conform well to shaft surfaces with low abrasion. They are easy to cut and install. As a result of their resilience, they are well suited for use with slurries and suspensions.

Polytetrafluoroethylene Fibers (PTFE)

PTFE fibers have an unusually high resistance to chemicals and heat as well as exceptionally low levels of friction and adhesion. PTFE fibers have a higher degree of molecular orientation than their resin counterparts, and thus, significantly greater resistance to cold flow.

Packings braided from PTFE fibers offer outstanding performance in highly corrosive environments as well as under less severe operating conditions. They have a low coefficient of friction, high compressive strength, good dimensional stability, and are self-lubricating. They have a pH range of 0-14 and, depending on speed and pressure, can give continuous service up to 260 °C (500°F). Some manufacturers can supply PTFE packings that are suitable for oxygen service as well as FDA related applications.

Expanded PTFE

The expansion process for PTFE creates a micro-structure of interconnected PTFE nodules and fibrils, creating an extremely strong micro-structure that is considerably higher in tensile strength. This strength results in far more resistance to cold flow, which then decreases creep relaxation when compared to traditional non-expanded fiber. The resulting fiber is still 100% PTFE and, therefore, maintains all the inert properties of PTFE with a pH range of 0-14 with few exceptions. It has low surface free energy (18.5 dynes/cm^2 or .00027 psi) with excellent self-lubricating values and can withstand continuous service in temperatures from -200º C to 260º C (-328º F to 500º F). The expanded PTFE structure also makes this fiber more accepting to additives such as viscous lubricants (silicone oils are most common) or additives such as PTFE dispersions. This fiber meets the requirements of FDA related applications (FDA 21 CFR 177.1550) and can be provided for oxygen service, but verify with the manufacturer prior to application. Expanded PTFE yarns are provided in either single or multiple ply form and range in denier from approximately 10,000 to 23,000. These yarns generally are used in applications where the surface speed is under 10 m/s (2000 FPM).

Expanded Polytetrafluoroethylene/ Graphite Composite Fiber (ePTFE/Graphite)

ePTFE / Graphite creates a compression packing fiber that combines the properties of each material. The graphite content creates a fiber that is thermally stable and has a high thermal conductivity. The ePTFE fiber provides strength and high conformability and enhances the ability of the packing to be easily installed and removed. The combination of the two materials creates a packing with a low coefficient of friction, good dimensional stability, and high resistance to chemicals with a pH range of 0-14. ePTFE / Graphite fibers are only limited by temperature and can give continuous service up to 288°C (550°F). These yarns are generally used in applications where surface speed is under 20 m/s (4000 FPM).

METALS

Foils

Metals are divided into two categories: foils and wires. Lead, copper, and aluminum are readily moldable, heat conductive metals used in packings.

Lead foil

Lubricated lead foil packings can be used by themselves or in combination with other materials to break down pressure or equalize load deformation on installed packing. Lead foil packing can handle temperatures to 233°C (450°F).

Aluminum foil

Lubricated aluminum foil packings are used in high temperature pumps or valves handling crude oil and petroleum distillates. Functional temperatures of aluminum foil are to 538°C (1000°F).

Copper foil

Lubricated copper foil packings are used primarily as end rings (bull rings) on slow reciprocating, worn, and/or non-concentric shafts and are functional in temperatures to 538°C (1000°F).

Wires

Copper Wire

Copper wire can be braided into a packing by itself or within a yarn to improve tensile strength of the yarn. It is functional, as a braided packing, to temperatures of 538°C (1000°F). In combination with yarns, the temperature will be determined by the specific yarn involved.

Brass Wire

Brass wire is normally inserted in a packing to give the packing added tensile strength. Temperature limits depend on the specific yarn being used.

Lead Wire

Lead composition wire is braided to form a square braided packing and can be furnished either in coil or ring form. Generally, it is used as an anti-extrusion ring in combination with other packings in temperatures to 233°C (450°F).

Nickel-Chromium Alloy Wire

Inconel® wire is generally used as an insert in higher temperature yarns to give the yarns increased tensile strength. This wire may also be furnished as a mesh for core material. It is used in temperatures to 538°C (1000°F) or higher, depending on the yarn involved or the application.

Stainless Steel Wire

Stainless steel wire, normally used as an insert in a variety of yarns for increasing the tensile strength of a packing, is functional in temperatures to 454°C (850°F).

Nickel-Copper Wire

Monel® wire is used as an insert in high temperature yarns and, in most cases, has been replaced by Inconel® wire. It is functional in temperature to 454°C (850°F).

FLEXIBLE GRAPHITE TAPES AND YARNS

Flexible graphite tape (ribbon) is manufactured by exfoliating, expanding, and then compressing natural graphite flakes to a specific density (e.g., 0.7 g/cm^3 (44 lb/ft^3)). Flexible graphite tape may be layered with adhesive and reinforcing fibers, such as cotton, glass, stainless steel, or carbon. It can be converted into a yarn, which can be braided into packing.

Flexible graphite tape can be die molded or compressed on site to form endless labyrinth rings (see die-formed ring illustration on page17). The final density of the die molded or compressed graphite varies between 1.2 g/cm^3(75 lb/ft^3) and 1.8 g/cm^3(113 lb/ft^3). Graphite tape packings have a low coefficient of friction, a pH range of 0-14, and are noted for their excellent thermal properties, enabling them to be used in applications to 2500°C (4532°F) in non-oxidizing atmospheres. Due to their temperature resistance and density, they make ideal steam valve packings. The tape has almost universal chemical inertness and is naturally lubricious, compactable, and resilient. However, the material is fragile and susceptible to wear in abrasive condition or media.

HYBRID OR COMPOSITE FIBER & YARN

Hybrid or composite yarn may be defined as a linear assemblage of high-performance fibers and/or filaments formed into a continuous strand. A variety of yarns are used in packings and gasketing products. Braided packings and twisted ropes are constructed by combining various strands of yarns using the standard forming techniques.

Using the state-of-the-art, high-performance staple fibers and filaments, virtually hundreds of hybrid yarn structures can be developed using the standard yarn processing techniques, such as fiber blending, core spinning, and twisting. Such engineered hybrid yarns offer a unique combination of properties generally unattainable in individual filament yarns.

Hybrid yarn structures, containing filament fiberglass and/or metal wire cores and wrapper fiber blends of high heat resistant fibers, such as acrylics, aramids, Novoloid, and PBI, provide optimal combination of mechanical, chemical, and thermal properties, Figure 30. These yarns, treated with a variety of lubricants such as PTFE and graphite, provide excellent qualities in braided packings.

Hybrid yarn structures can be made from a number of manufacturing methods. For example, a core can be used with an outer knitted jacket. The use of a knitted jacket of higher strength material around a softer material will give strength to the fiber as a whole. The individual yarns are over knitted before braiding. Jacket materials can be metal wire, fibers such as glass fiber and carbon fiber to increase strength, or PTFE to increase lubricity.

Since different types of hybrid yarns offer different sets of properties, for details on their technical performance, it is advisable to check with the fiber or yarn manufacturer.

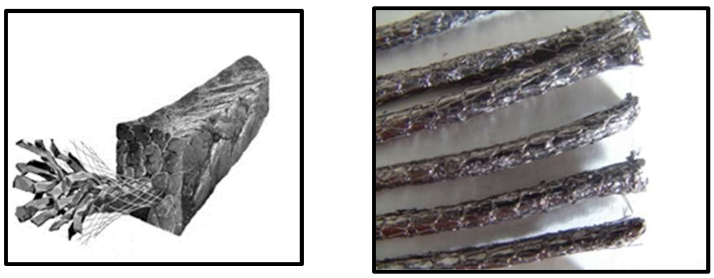


Figure 30. Hybrid Yarn Structures

Hybrid yarn structures can provide an optimal combination of mechanical, chemical, and thermal properties.

LUBRICANTS

Compression packings generally contain lubricants when they are used on high-speed equipment where frictional heat is generated. The lubricants provide resiliency that allows the packing to deform and recover under slight mechanical deficiencies, such as shaft movement. They may also provide inter-fiber lubricity that reduces frictional heat and acts as a fluid barrier by closing the voids in braided structures to prevent leakage through the cross-section of the packing. Packing lubricants can be lost by being squeezed out mechanically, melted at high temperatures, or dissolved or precipitated by reacting chemically with the media being pumped. The loss of the volume occupied by the lubricant, which, in some cases, may be as high as 40%, forces continual retightening of the packing. This can produce a lifeless mass of abrasive fibers and can result in drastic shaft or sleeve wear.

Excessive gland follower pressure under such conditions may be compared to a brake band on which greater pressure is applied for faster braking action. Under those conditions, extreme frictional heat is developed, and excessive wear occurs. In spite of the fact that the same mechanical principle is applied for packing, it should be remembered that unlike the brake band, the packing is merely expected to seal and create a fluid barrier and not a braking action as a brake band. Accordingly, jam packing will be successful only if the packing is tightened to that minimum that creates a seal without acting as a brake and creating excessive friction and wear. This can be achieved only if the packing selected possesses the ability to retain its dimension under the operating conditions. When this can be accomplished, tightening of the gland follower will be reduced to a minimum. Regardless of the material used, the choice of the lubricant, or the shaft finish, the packing will wear since it is in contact with the shaft. Nevertheless, proper combination and selection of materials will greatly assist in reducing wear to a minimum and prolonging the life of the packing.

Since preservation of the full volume of lubricants under severe thermal and chemical conditions is difficult, lubricants must be selected carefully to achieve these goals. The subject of lubricants is a broad one, and the relationship in frictional processes and lubricants and their environments is very complex. The following is a basic introduction. Lubricants are available in liquids, solids, and semi-liquids (e.g., greases, emulsions, dispersions). They may also be classified according to their mode of performance and may be classified as hydrodynamic lubricants, boundary, extreme pressure, and solid lubricants.

Historically, lubricants fulfilled only a minor role until the industrial revolution. Most needs were then supplied by various oils and greases derived from animal, vegetable, and fish oils. In the latter part of the nineteenth century, however, the merit of mineral oil-based lubricants, with respect to superior temperature and oxidation resistance, was recognized and their use became widespread.

Lubricants provide resiliency that allows the packing to deform and recover under slight mechanical deficiencies such as flexing.

Colloidal Polytetrafluoroethylene (PTFE)

Colloidal Polytetrafluoroethylene (Colloidal PTFE) in a water carrier has been the most valuable asset to the packing industry. The fine particles of suspended PTFE are forced into the yarn under pressure and, as the water carrier is evaporated and dried, the solid PTFE particles, which have deposited themselves throughout the packing, become a blocking agent that reduces porosity of the fibers while providing all of the features and lubrication properties of solid PTFE. Such features of colloidal PTFE are high-temperature resistance, excellent chemical inertness, an extremely low coefficient of friction, and self-lubricating properties.

In addition, the PTFE will greatly reduce the harshness and abrasive nature of fibers that are used in the packing industry.

PTFE has the disadvantage of high heat retention properties.
Consequently, a "break-in" lubricant can be added to the PTFE to prevent excessive frictional heat buildup caused by high shaft speeds. The break-in lubricant used must be selected carefully and distributed throughout the fiber in such a way as to allow the packing to perform under high-speed conditions without burning. There are instances where PTFE impregnated packings

cannot be used even if a break-in lubricant is present due to their relative heat sensitivity at high speeds. Under such conditions, other lubricants or packings should be selected.

Animal & Vegetable Lubricants

Lubricants are derived from animal and vegetable life in the form of fatty substances that vary in consistency from very fluid oils at low temperatures to hard solids that melt at about 50°C (125°F). It is customary to regard as an oil any fatty substance that is fluid below 20°C (68°F), and as a fat any substance that is solid above this temperature. Among the very large number of these oils and fats, products, such as castor oil, rapeseed oil, and cotton seed oil, represent typical products derived from vegetable life. Tallow (oil and fat) and beeswax are representative of the products derived from animals. These products are often referred to as fixed oils and fats because they cannot be distilled without decomposition, are partially insoluble in water, and, with the exception of castor oil, are also insoluble in alcohol at room temperature.

They are, on the other hand, with the exclusion of castor oil, completely soluble in ether, carbon disulfide, chloroform, carbon tetrachloride, petroleum, benzene, and mineral lubricating oils. (Note that some of these solvents are toxic and must be handled with proper precaution. None of these chemicals should be present in the final product.) The fixed oils and fats are considered to possess greater greasiness than mineral oils. A lubricant of a greater oiliness will cause less heat, thus reducing wear. Although fixed oils and fat were probably man's first lubricants, and in spite of the fact that they possess some very excellent lubricating properties, the following objectionable features have practically eliminated them from this purpose:

- They are more expensive than mineral oils.
- They oxidize much more readily than mineral oils and, as a result, harmful deposits of gum resins and acids are formed in use and storage.
- They are not obtainable in a wide range of viscosities.

Biodegradable Lubricants

The first lubricants were environmentally friendly and biodegradable; materials such as vegetable oils and animal tallow. As the petrochemical industry emerged, products with improved functionality were developed and they gradually displaced the natural lubricants. The wide-spread use of petroleum-based lubricants with various additives has led to the conclusion that accidental release to the environment is potentially harmful. Biodegradable lubricants are further described by the following terms:

Biodegradability: This term refers to the ability of a substance to be decomposed by a microorganism. Although typical mineral and synthetic based oils are ultimately biodegradable, the rate at which this will occur makes them undesirable in the environment. There are a number of standards used to determine biodegradability such s the EPA Shake Flask test method.

Biodegradable Compounds: Most current mineral oil substitutes consist of vegetable oils, such as soybean or high-oleic soybean, natural esters, synthetic esters and polyglycols. They are generally more prone to oxidation and less thermally stable than mineral oils.

Rapeseed and canola oil were the most common base stocks initially employed for vegetable-based lubricants. Synthetic esters are made by reacting alcohols with fatty acids. This produces improved low temperature flow properties as well as mitigates the chemical attack on some elastomeric seals at high temperature. Canola based greases also have been developed and are beginning to be applied in rotating equipment applications.

Since the release of lubricants contained in a set of packing rings would be extremely small, the potential of contaminating the environment is not a significant concern. In some applications, such as food or pharmaceutical, the concern could be based on contamination of the product being processed.

Biolubricants applies to all lubricants which are both rapidly biodegradable and nontoxic to humans and aquatic environment.

Petroleum (Mineral) Lubricants

Most lubricants are made from petroleum that consists of the elements carbon and hydrogen chemically combined to form compounds called hydrocarbons.

Synthetic Lubricants

The industrial revolution created a demand for new lubricants to meet high-performance specifications. These synthetic lubricants are in many ways comparable to mineral lubricant oils and possess excellent viscosity-temperature characteristics. They find extensive use as high temperature lubricants because they decompose and oxidize to volatile products, leaving no carbon residue. Accordingly, they are especially suitable where non-staining is desirable.

Silicones

Silicones range in type from low boiling fluids to viscous fluids and gums. As lubricants, they will withstand extreme weights of stress. They are chemically inert and thermally stable to 360°C (680°F). Because of these favorable physical and chemical properties, the high temperature silicones fulfill most of the requirements for an ideal lubricant. Some silicone lubricants are suitable in sealing applications for food processing. NOTE: Avoid the use of silicone when sealing paint media.

Chlorofluorocarbons

These lubricants possess outstanding oxidation resistance and thermal stability. They can be heated to 300° C (572°F) without decomposition.

Solid Lubricants

The most widely used solid lubricants are graphite, mica, and molybdenum disulfide.

Graphite

The classification of natural graphite is quite varied, but three physically distinct common varieties are customarily distinguished: flake, amorphous, and lump. Graphite can be used in different forms as well as in combination with other impregnations. Graphite impregnations have good heat dissipation and because of their low friction they are smooth to the spindle. Especially at high temperatures graphite impregnations are working well. In inert atmosphere, they can be used up to 1500 °C (2732 °F).

Molybdenum Disulfide

Molybdenum disulfide has been used as a lubricant for some time and has often been mistaken for graphite because of similar appearance and behavior. The two materials, however, are quite different in performance as solid lubricants, especially with respect to environmental conditions. In sophisticated lubricants, both graphite and molybdenum disulfide may be mixed with fine articles of fluorocarbon resins and occasionally with inorganic solids in soap-thickened mineral oils. This can result in highly efficient and extremely chemically and thermally stable lubricants at very high temperatures.

Greases

A grease is a solid or semi-solid lubricant consisting of a thickening or gelling agent in a liquid lubricant. This includes not only soap types but also non-soap types. The fluids used in compounding greases are comparable with those used for lubrication. In most cases, compounded greases contain oil in the SAE 20 to 30 range. The majority of all industrial greases are composed of a soap or soaps and a petroleum oil. They may contain filler materials and additives as well.

Other Solid Lubricants

Other solids, such as boron nitride and chromium chloride, that, like graphite, exhibit low friction characteristics at high temperatures, are to a limited extent being used as lubricants.

Tungsten Disulfide

Tungsten disulfide is a nontoxic, non-corrosive, inorganic, high-temperature lubricant. Some sources also claim it is an effective corrosion inhibitor.

Mica

Mica is a high-temperature lubricant that will not pit or damage stainless steel valve stems. It is thermally resistant to 600°C (1112°F).

CORROSION INHIBITORS

Galvanic corrosion is an electro-chemical reaction that may occur between two dissimilar metals or between a metal and a carbon and/or graphite material. In order for a reaction to occur, the two dissimilar metals or materials must be in contact with an electrically conductive fluid. When these conditions are present, the material that is closer to the anodic end of the galvanic scale may be corroded. The degree of separation between the two materials in the galvanic scale determines how fast the corrosion reaction will occur - the larger the difference, the faster the potential corrosion rate.

In the compression packing industry, galvanic corrosion is most commonly encountered when a valve, having a different stem metallurgy than the valve body, is packed with a carbon and/or graphite packing set and is exposed to liquid-state water for a period of time. Since steel is more anodic than the carbon-atom-based carbon or graphite materials, the 410-SS stem will be corroded.

The corrosion can be controlled or eliminated by several methods:

1) Change the stem material over to an austenitic (commonly 300 series) stainless steel, rather than martensitic (400 series) stainless steels that are very susceptible to galvanic corrosion.

2) Eliminate the liquid water exposure. The galvanic corrosion reaction can proceed only if an electrically conductive fluid is present.

3) Use compression packing materials that have a galvanic corrosion inhibitor system incorporated as part of their basic make up. Galvanic corrosion inhibitor systems can be broken down into two basic types: active inhibitors and passive inhibitors. Both types function to either modify or to interfere with the reaction, and either type can be used effectively to eliminate or drastically reduce the amount of corrosion that can occur. Active and passive inhibitor systems are described below:

    a) Active (Sacrificial) Inhibitor Systems: When dissimilar materials are present in an electrically conductive fluid, the material that is the more anodic will be the one to suffer corrosive attack. All of the various steels are more anodic than carbon/graphite materials, so the steels would normally be the target material to suffer corrosion. However, zinc is more anodic than any of the steel variations. If zinc powder is incorporated into a packing system, the electrolytic cell will redirect its corrosive attack on the zinc instead of the steel, affording corrosive protection to the steel stem.

       The active systems are sacrificial in nature, since the zinc is gradually consumed over a period of time. The steel of the stem and box will continue to remain protected as long as an adequate amount of zinc remains available to function as the sacrificial anode. Laboratory testing on surface zinc powder coated rings, subjected to continuous corrosion exposures, has shown that this protection period can extend in excess of 77 weeks.

While other metal choices are occasionally considered, such as aluminum, zinc is the only active inhibitor choice that is routinely used and popularly approved. Most compression packing materials can be supplied with a zinc powder protection system. The reacting zinc may be present as a surface dusting over the product, and/or it may be incorporated into the product as part of an employed coating system.

b) Passive (Protective Coating) Inhibitor Systems:
Passive inhibitor systems provide corrosion protection by building a film-type protective coating over the surface of one of the two dissimilar materials. In the case of valves, this coating forms over the surface of the stem. Once this film is formed, the electrical contact between the two dissimilar materials is broken and the corrosion reaction stops.

While there are many passive inhibitor compounds that are available on the market, the two most prominent choices are phosphate and barium molybdate. Testing conducted by a wide variety of sources has validated the reliability and service life longevity of both of these choices described below:

1) Phosphate: This system is widely used in combination with flexible graphite tape rings and braids. The technology does not exist, as yet, to apply it as a separate solution coating to conventional braided stock. As a secondary feature, phosphate also has the capability to enhance the oxidation temperature resistance of flexible graphite rings.

2) Barium Molybdate: This system is applied to materials by way of a separate solution coating process. As a result, it can be used with most types of compression packing material. Unlike the phosphate choice, barium molybdate does not afford any additional oxidation resistance to materials to which it is applied. It is not at all uncommon for the two passive choices to be used together in the same combination packing set. For example, phosphate inhibited flexible graphite rings may be used in combination with barium molybdate inhibited braided end-rings. It is also not uncommon for zinc-coated braided end rings to be combined with passive inhibited flexible graphite tape rings. The three inhibitors are compatible in use together.

HANDLING OF PACKINGS

Packings are composed of a wide range of non-metallic and metallic materials in various forms and designs. The section *Types of Packing Materials and Lubricants* overviews the principal materials and forms currently employed in a majority of packings. It does not attempt to address all materials and forms employed. Many of the materials described, particularly those used for braided fiber packings, are often augmented with various organic and inorganic lubricants or corrosion inhibitors to enhance performance. Advances in material technology and designs have led to packings with superior sealing capability over a wide range of ever more stringent application conditions. These advances also have enabled reduced emissions and a cleaner environment with reduced process fluid losses. Handling of these advanced packings materials also has generally provided the user with a greater margin of safety.

Packings range in complexity from single homogeneous materials, such as PTFE and flexible graphite, to braided combinations of various fibers, wires, or foils with lubricant additives. Specific statements about the health and safety aspects of handling these packing materials are beyond the scope of this publication. This manual does not claim to address all the health and safety concerns, if any, associated with handling and use of the various packing materials described in this manual. It is the responsibility of the user of any of the packings to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. To aid with these determinations it is best to contact a preferred FSA or ESA manufacturer for an updated Safety Data Sheet (SDS) before the specific packing is to be employed.

Instructions on packing storage and shelf life must also be requested from the manufacturer.

It is the responsibility of the user of any of the packings to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

PROTOCOL FOR PROPER PACKING SELECTION

With proper attention to selection, installation, and maintenance of compression packing, a high degree of successful operation can be anticipated. Successful sealing with compression packings is a function of several important related factors:

1) Careful selection of packing materials to meet the specific application requirements
2) Complete consideration of surface speeds, pressures, temperatures, and media being sealed
3) Proper attention to good installation and break-in procedures
4) High standards of equipment maintenance
5) Correct design of the stuffing box

These factors are discussed below and are covered in detail in most of the product bulletins of the major packing manufacturers.

For packings to work successfully, factors related to the packing material, packing installation, application environment, and equipment must be considered.

It is the responsibility of the maintenance personnel to select the proper compression packing for a given application. To determine which packings should be used, there are certain basic questions that must be answered. The acronym "STAMPS" can be used to identify these key questions [2]:

S – Size – What are the stuffing box dimensions?
T – Temperature – What is the temperature of the medium?
A – Application – What type of equipment is it?
M – Media – What medium is being sealed?
P – Pressure – What is the internal pressure being sealed?
S – Shaft Speed – What is the surface speed of the shaft?

The acronym "STAMPS" can be used to select the proper packing for a given application.

The size of the packing depends upon the size of the stuffing box. Use the following equation to determine the packing size:

Packing size = (OD – ID) / 2 {2}
OD = bore diameter
ID = stem/shaft diameter

The temperature of the medium to be sealed will affect the medium's reactions within the system, thus requiring corresponding properties in the packing. This limits the packing choice. Temperature limits are assigned to each packing style by the packing manufacturer.

Compression packing seals many types of equipment. The equipment of each application will operate with varying frequency, speed of motion, and leakage criterion. These characteristics, specific to each application, will affect the choice in packing. For example, is the equipment a control valve or a block valve; is the valve manually or actuator operated? Is the equipment a pump; is the pump centrifugal or reciprocating?

All *media* in the application must be compatible with the packing style. Is the packing material chemically compatible with all media that will be present (e.g., sealed media, cleaning media) to prevent degradation and chemical attack of the packing material? Is the medium to be sealed slurry or abrasive? What is the percentage of solids, if any? Is the medium toxic or flammable? Is it monitored by government agencies?

The pressure of the sealed medium and of outer fluids of the system, such as flush, must be considered. Similar to temperature, pressure affects a medium's reactions within the system, thus requiring corresponding properties in the packing. The pressure limits are assigned to each packing style by the packing manufacturer.

The shaft speed is a key variable in the level of friction within the stuffing box. Shaft speed when considered along with the shaft size can indicate conditions in the stuffing box due to rigidity or flexibility in the shaft. Such conditions may be increased friction upon the packing due to the deflection caused after a shaft reaches critical speed [3].

The following tables may be considered as a guide or starting point for the selection of the proper packing.

pH Factor: The pH factor is a numerical measure of the intensity or severity of an acid or caustic. In Table 1, pH values are given for a wide range of acid and caustic services. For example, distilled water is neutral at 7 (see Table 2).

Using the pH factors, select from Tables 1, 2, and 3 the best packing for the particular application, following this procedure:

1) Determine the pH factor.
2) Select from Table 1 the material or materials best suited for the pH factor.
3) After this selection, using the pH factor, turn to Table 2 to find within what range the pH factor falls.
4) Knowing the temperature and pH, use Table 3 (Sections 1 and 2) to determine the correct packing for the application.
5) Use Tables 4, 5, and 6 for information on tolerances, shaft speed, and strong oxidizers (a general listing).

For technical requests, complete the Application Form on page 40 or download it from the FSA or ESA website.

Fluid Sealing Association	European Sealing Association
www.fluidsealing.com	www.europeansealing.com

TABLE 1.

pH Factor for Determination of Correct Packing Material.

Range	Packing Material
0-1	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber*, Flexible Graphite*, Novoloid
2-3	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite, Aramid-PTFE Dispersions, Acrylic-PTFE Dispersion, Glass, Novoloid
4-5	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite; Aramid-PTFE Dispersions, Lube and Graphite; Acrylic-PTFE Dispersion, Lube and Graphite; Glass; Novoloid
6-7	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite; Aramid-PTFE Dispersions, Lube and Graphite; Acrylic-PTFE Dispersion, Lube and Graphite; Glass, Metal, Novoloid, Flax
8-9	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite; Aramid-PTFE Dispersions, Lube and Graphite; Acrylic-PTFE Dispersion, Lube and Graphite; Glass, Novoloid, Flax
10-11	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite; Aramid-PTFE Dispersion, Acrylic-PTFE Dispersion, Glass-PTFE Dispersion, Novoloid
12-13	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite, Novoloid
14	PTFE Fiber, ePTFE/Graphite, Carbonaceous Fiber, Flexible Graphite, Novoloid

Note: Many braids incorporate the use of various metal wires or strips in their designs. Typical choices are Inconel® **, lead, copper, and aluminum. These metals cannot be graded over all general pH classifications due to their susceptibility to chemical attack by various concentrations of assorted chemicals. When a planned service involves the use of a braid-metal combination type packing, consult your local packing manufacturer to determine its suitability for the intended service.

*Not rated for oxidizing service

**International Nickel Company Trademark

TABLE 2. pH Values.

pH	Description
14	Maximum Caustic
13	Severe Caustic
12	Severe Caustic
11	Severe Caustic
10	Mild Caustic
9	Mild Caustic
8	Mild Caustic
7	Neutral (Distilled Water)
6	Mild Acid
5	Mild Acid
4	Mild Acid
3	Severe Acid
2	Severe Acid
1	Severe Acid
0	Maximum Acid

Compression Packing
Application Data Sheet

Name:____
Company:____
Address:____
Phone:_(_____)____
Fax:____(_____)____
E-Mail:____

EQUIPMENT ID:____

Application Data

Size

Shaft / Stem / Sleeve Diameter____________ Lantern Ring Length___________________
Bore Diameter_________________________ Distance to flush Port ___________________
Stuffing Box Depth______________________ Packing Arrangement__________________
Stem and Bore condition (note presence of scratches or pitting)
____

Temperature

Max Temp______________________________ (Specify degrees F or C)
Normal Operating Temp__________________
Does temperature cycle frequently ?__________

Application (What type of equipment is being sealed?)______________________________
____
Is the packing sealing a moving or static surface?___________________________________
If moving, is it rotary, reciprocating, or helical?____________________________________

Media (What is the fluid being sealed ?)____
Is the media toxic ? _______________ Explosive ? ___________
Is leakage monitored ? _____________
Is the stuffing box fitted with a flush arrangement ? __________
What is the flushing fluid?_______________________________

Pressure

Max Pressure:___________________________
Normal Operating Pressure:________________

Speed ________________________________
(Specify RPM or FPM for rotary applications, Strokes per minute and stroke length for reciprocating applications)

TABLE 3.

	Service Conditions							Motion			Acid		Alkali		Gases				Water			Oils		Solvent	
	Temperature		Pressure	(Stuffing Box)	Shaft Speed		pH Range	Rotary	Reciprocating	Valve Stem	Corrosive	Mild	Corrosive	Mild	Air & Dry Industrial	Br/Cl	Ammonia	Oxygen	Steam	Water	Salt Water	Petroleum	Synthetic	Aliphatic	Aromatic
	°F	°C	PSI	BAR	FPM	m/s																			
Vegetable Fiber																									
Lubricated	210	98	150	10	1000	5	5-9	X	X	X										X	X				
PTFE Coated	250	120	300	20	1200	6	5-9	X	X	X										X	X	X	X		
Acrylic																									
Lubricated	250	120	300	20	1500	7.5	4-10	X	X	X		X		X	X		X			X	X	X	X		
PTFE Coated	500	260	500	34	2250	11	2-12	X	X	X		X		X	X		X		X	X	X	X	X	X	X
Aramid																									
Lubricated	250	120	300	20	1500	7.5	4-11	X	X			X		X	X		X			X	X	X	X		
PTFE Coated	500	260	500	34	2250	11	2-12	X	X	X		X		X	X		X		X	X	X	X	X	X	X
Carbon/Graphite																									
Carbon-Pumps (3)	500	260	500	34	4000	20	(2)	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X
Graphite-Pumps (3)	500	260	500	34	4000	20	(2)	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X
Valve Application (3)	1250	675	4000	272			(2)			X	X	X	X	X	X		X	(1)	X	X	X	X	X	X	X
Graphite Tape-Die Form	1250	675	4000	272	4000	20	(2)	X	X	X	X	X	X	X	X		X	(1)	X	X	X	X	X	X	X
Braided Flex/Graphite	1250	675	3000	204	4000	20	(2)	X	X	X	X	X	X	X	X		X	(1)	X	X	X	X	X	X	X
Copolyimide																									
Lubricated	250	120	300	20	500	7.5	4-11	X	X			X		X	X		X			X	X	X	X		
PTFE Coated	500	260	500	34	2250	11	1-12	X	X	X		X		X	X		X		X	X	X	X	X	X	X
Glass																									
Dry	1200	648					2-12				X	X	X	X	X				X	X	X	X	X	X	X
PTFE Coated	500	260	300	20	1800	9	2-12	X		X	X	X	X	X	X				X	X	X	X	X	X	X
Melamine																									
Lubricated	250	120	300	20	1500	7.5	4-11	X	X	X		X		X	X					X	X	X	X		
PTFE Coated	400	200	500	34	2000	10	3-14	X	X	X		X	X	X	X				X	X	X	X	X	X	X
Metals (4)																									
Aluminum	1000	538	1000	70	1000	5	4-10	X	X	X		X		X	X				X	X	X	X	X	X	X
Copper	1900	1038	1000	70	1000	5	4-10	X	X	X		X		X	X				X	X	X	X	X	X	X
Novoloid																									
PTFE Coated	400	200	500	34	2000	10	1-13	X	X	X		X		X	X		X		X	X	X	X	X	X	X
Polypheneylene																									
PTFE Coated	400	200	500	34	2000	10	1-14	X	X	X		X	X	X	X				X	X	X	X	X	X	X
PTFE																									
Lubricated	500	260	300	20	1800	9	0-14	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Dry	500	260	300	20	1000	5	0-14	X	X	X	X	X	X	X	X	X	X	(1)	X	X	X	X	X	X	X
ePTFE Graphite Lubed	500	260	300	20	3600	20	0-14	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
PTFE Graphite Unlubed	500	260	300	20	2300	20	0-14	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X

***CAUTION: Many packing manufacturers offer blends of the above defined materials. As a result of blending, the limitations listed for speed, temperature, pH range, etc. will change. Please consult packing manufacturer for specific application information. The above listed recommendations are for reference only. Consult manufacturer for style suitability to the intended service.**

Notes:

(1) Consult manufacturer for proper oxygen certifiable style.
(2) 0-14 except in strong oxidizers, refer to Table 6 for a list of strong oxidizers.
(3) Temperature, pressure, and shaft speed performance are heavily dependent upon employed *coating system. Consult manufacturer for* proper style selection.

TABLE 4.

Tolerance and Measurement Standards.

Cross Section	Tolerance
to 1/4"	+/- 1/64"
to 6 mm	+/-. 0.4 mm
1/4" to 1"	+/- 1/32"
6 mm to 25 mm	+/- 0.8 mm
greater than 1"	+/- 1/16"
greater than 25 mm	+/- 1.6 mm

Note: Compression packings are manufactured from a wide range of materials and combinations of materials. Therefore, the dimensional tolerances of the finished products will vary according to the material and methods of manufacture.

The generally accepted method of measurements in the packing manufacturing environment is a hand-held, direct reading, vernier caliper. To ensure concentricity, the inside diameter is measured using a ground dimensional plug gauge and the outside diameter is measured by the above method (caliper) while plug is inserted.

TABLE 5.

Shaft Speed Conversion.

Feet per minute
FPM = (π/12)(Ds)(RPM)
where Ds = Shaft Diameter (inches)
RPM = Revolutions per minute

Meters per second
m/s = (Π)(Ds)(RPM)/ 60,000
= (RPM)(Ds) / 19,100

where Ds = Shaft Diameter (mm)
RPM = Revolutions per minute

Conversion Factor
1 m/s = 196.8 FPM
1 FPM = 0.005 m/s
At shaft velocities exceeding 20 m/s (4000 FPM), consult manufacturer.

TABLE 6.

Strong Oxidizers.

Bleach	Bromates	Bromine
Butadiene	Chlorates	Chloric Acid
Chlorine	Chlorites	Chromates
Chromic Acid	Dichromates	Fluorine
Haloates	Halogens	Hydrogen Peroxide
Hypochlorites	Iodates	Nitrates
Nitric Acid	Nitrites	Nitrous Oxide
Peracetic Acid	Perborates	Perhaloate
Percarbonates	Perchlorates	Perchloric Acid
Perhydrates	Peroxides	Persulfates
Permanganates	Sodium Borate	Sulfuric Acid

VALVE PACKINGS

Valve stem packings are generally available in three basic constructions:

1) Diagonal-interlock braided yarn packings
2) Flexible graphite products
3) Plastallic cored, round braided general service packings

TYPES OF VALVE PACKING

DIAGONAL-INTERLOCK BRAIDED YARN PACKINGS

This braid is designed for use in general service applications or as braided end rings on the top and bottom of graphite die-formed tape rings for critical or control valve applications. When used alone (i.e., straight-sets), required compression rates generally fall within a range from 25% to 30%. When used as braided end rings on the top and bottom of a set of die-formed graphite tape rings, the required compression rates are reduced to approximately 20%. These rings act as anti-extrusion and wiper rings, and they compensate for any surface irregularities in the bottom of the stuffing box as well as add resiliency to the set. For packings of 5 mm (3/16") and under, square or plait braid is normally used.

FLEXIBLE GRAPHITE PRODUCTS

Flexible Graphite Die-Formed Rings

Flexible graphite die-formed rings are valve stem packing rings die-formed from flexible graphite ribbon. A predetermined length of flexible graphite tape is compressed in a properly dimensional mold to the desired density resulting in a solid ring. For ease of installation when the valve bonnet cannot be removed, split rings should be specified. Die-formed flexible graphite rings are available in commercial grade (95-98% purity) and nuclear grade (99%+ carbon purity).

The commercial grade material makes up the vast majority of usage for industrial applications. Nuclear grades are almost exclusively specified by the nuclear power industry due to the stringent quality control procedures required during manufacturing. Both industrial and nuclear grade rings are manufactured in density ranges from 1.2 g/cm^3 - 1.8 g/cm^3 (75 lbs/ft^3 to 110 lbs/ft^3), depending on the finish of the valve stem and the stuffing box.

Active or passive inhibitors may be applied during or after fabrication of each ring to insure against corrosion and pitting of the valve stem. Rings of a compatible braided material are recommended as anti-extrusion and wiper rings. Also, metal discs can be used on the bottom of the set as anti-extrusion rings which has the additional advantage of preventing adhesion of graphite to the bottom of the stuffing box. The metal also enables easier removal of the die-formed rings.

Flexible Graphite Tape

Flexible graphite tape can be die formed into packing rings in the stuffing box itself when flexible graphite die-formed tape rings are not available. Using this method, a length of tape is wrapped around the valve stem or pump shaft until the buildup of the material is sufficient to completely fill the packing space.

The wrapped tape ring is then eased down into the box and individually compressed to approximately 50% of the original tape width until the stuffing box is completely filled. A top and bottom end ring of carbon or graphite yarn should be used to eliminate tape extrusion when compressed.

Other Graphite Packing Forms

In addition to die-formed graphite ring packings and expanded graphite tape packings, flexible graphite packings are available in several other forms, including braided packings, laminated rings, and injection molded rings. The disadvantage during big valve revisions and for storage purposes is that die-formed rings made from expanded graphite foil are only available in specific ID and OD dimensions. It is impossible to carry a stock which can cover all the possible ID/ OD combinations in the field.

Here, braided expanded graphite packings made from graphite tape with a carrier yarn have become popular. These packings are available in length form from a spool in all standard dimensions. They offer the advantage to be used for a quick repair service. In addition, they have a lower density compared to die-formed rings and can adapt easier to the stuffing box, especially in reworked valves where the shaft or housing size can differ from standard dimensions.

Braided expanded graphite packings are available in a wide range of varieties, such as Inconel® wire reinforced or containing different impregnations. In high pressure service, they should also be used in combination with end rings made of carbon or graphite filament packings. Only when the expanded graphite is over-knitted on the outside with a fine wire mesh can this type of packing can be used without end rings.

PLASTALLIC CORED, ROUND BRAIDED GENERAL SERVICE PACKINGS

These braids consist of a yarn jacket that is round-braided around a central extruded plastallic core. Inconel® wire is usually, but not always, twisted with or inserted into the yarns before braiding.

This packing type is normally recommended for general service applications. Required compression rates will typically fall within a range from 28% to 35%.

COMBINATION SETS

As the name already implies, combination packing sets are combinations of different packing ring types. There are various reasons to combine two or more packing types. The most common reason is the use of anti-extrusion rings, which are installed at both ends of the packing set on the gland and media sides.

These rings have a higher-pressure resistance than the packing material between them and prevent extrusion of the packing through the clearances in the stuffing box. Besides the extrusion protection, the anti-extrusion rings can also function as wipers to hold loose packing particles in the stuffing box and prevent abrasive solids from the atmosphere or media from entering the packing set and damaging the mid-rings. Typical combinations are carbon filament end rings with expanded graphite rings.

Also, very soft packings, like extruded or injectable compounds, need end rings because they will readily migrate through clearances at low pressures. Other materials, such as metal discs or machined plastics, are also used as end rings on the media side to prevent abrasive materials from entering the stuffing box.

APPLICATION RECOMMENDATIONS FOR PACKINGS

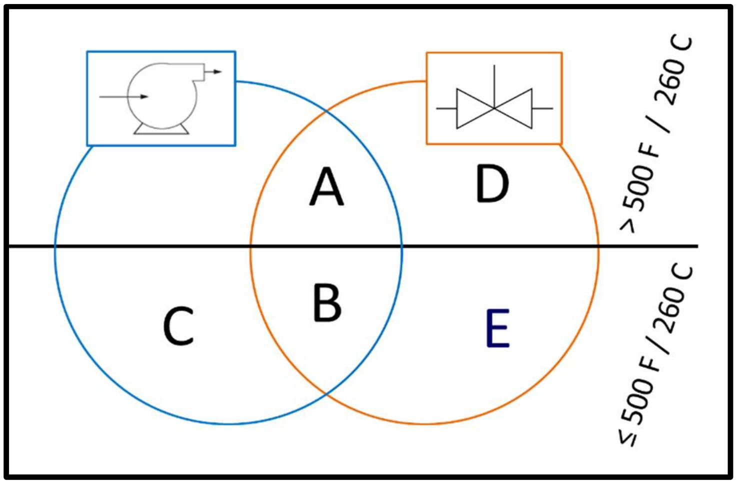


Figure 31. Packing Recommendations for Pumps and Valves

A: Carbon and graphite fiber braids – Fiber reinforced graphite foil braids
B: PTFE Coated, ePTFE/Graphite, Synthetic fiber braids
C: Vegetable fibers, Flax Ramie, Jute – Synthetic fibers, Lubricated PTFE Lubricated PTFE with graphite, Acrylic, Para-Aramid, Novoloid, Polyimide, PBI, Rayon
D: Die formed Graphite Foil Rings, Wire reinforced graphite foil braids, Wire reinforced plastallic cored packings
E: Dry PTFE braids

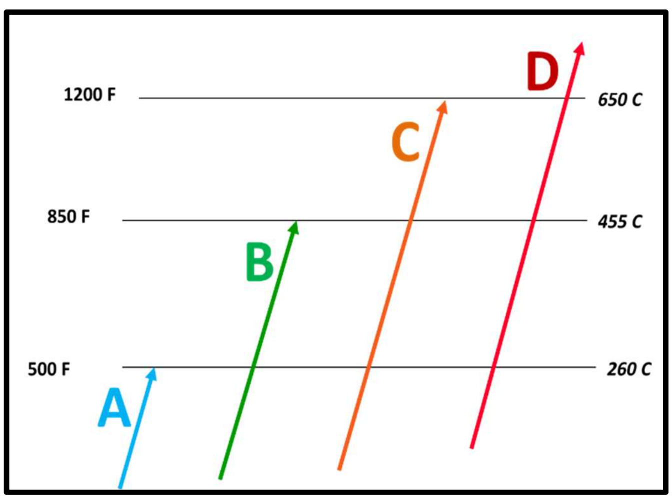


Figure 32. Temperature Limits of Packing Materials

A: Many Synthetics
B: Carbons and Graphite in air
C: Carbon and Graphite in steam or non-oxidizing
D: Ceramic fibers

APPLICATION RECOMMENDATIONS FOR PACKINGS IN VALVES

Valve packing materials and configurations are influenced by the operating conditions of the valve. Most importantly, the packing material selected for a valve is to have the characteristics of low coefficient of friction and conformability for forming into the valve stuffing box or sealing compartments (see Figures 31 and 32 for general packing applications). Packing selection criteria for a valve depends on the following operating conditions:

- Media (fluid being sealed)
- Temperature range
- Pressure
- Motion (reciprocating, rotary, oscillating, etc.)
- Speed (static or dynamic)
- Chemical concentration (pH Limit)
- Equipment conditions (shaft run out, mating surface condition)
- Stuffing Box Dimension (shaft/stem, bore and depth)

PACKING MATERIAL RECOMMENDATION

In packing valves, a wide range of compression packings can be used in general low-to-mild operating conditions.

For high temperature applications, die-formed flexible graphite middle rings and braided carbon graphite or braided flexible graphite packing are the ideal suitable packing material and configuration. High temperature and high pressure will require similar die formed flexible graphite middle rings and braided wire reinforced flexible graphite end rings. Otherwise, metallic packing, made from metal foils such as lead, aluminum, brass, copper, and nickel, is highly recommended as packing rings or as end rings. Metal end cap rings are not recommended in control valves; however, depending on the construction and service, wire reinforced packing may be used as end rings. A special section on control valves is discussed on page 51.

The packing material selected for a valve is to have the characteristics of low coefficient of friction and conformability for forming into the valve stuffing box

In steam applications, a packing style with extruded plastallic core will work very well in sealing steam or gas. For high temperature and high chemical applications, braided carbon and graphite packing, braided flexible graphite, and die formed flexible graphite are used. For low temperature and severe chemical service, all PTFE braided packing and carbon and graphite braided packing are recommended.

For valve applications in ambient conditions, about all listed compression-packing materials will be suitable. The most common valve packings are PTFE fiber, PTFE filament, Novoloid, Aramid, Acrylic, polyimide and any combination of listed packing materials. For emission control valve packing, live loading of the combination set of die-formed flexible graphite middle ring packing with braided end rings will work well to reduce emissions.

For highly actuated valves where packing friction is a concern, a trapezoidal or triangular die-formed shape of packing ring is recommended. In this design, the packing contact area is significantly reduced, which, in turn, reduces the amount of friction force exerted by the packing.

The following are typical valve packing application conditions and recommendations *only*:

Contact a packing manufacturer for specific application recommendations.

Valve Application: General Services

Conditions: Valve Stuffing box pressure ------up to 20 bar/300 PSI
Process fluid temperature ---------up to 260ºC/500ºF
Process fluid pH level -------------3-11
Application Media -----------------Water, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, and power utilities.

Packing Recommendation: Interbraided Synthetic Packing (Acrylics and Polyimide Yarns).

Valve Application: Chemical Service

Conditions: Valve Stuffing box pressure -----up to 20 bar/300 PSI
Process fluid temperature --------up to 260ºC /500ºF
Process fluid pH level -------------0-14
Application Media -----------------Chemicals, corrosive, ammonia, liquor, mild acids & caustics, gases, oil, steam, and solvents.

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, and wastewater.

Packing Recommendation: PTFE based packing (dry or lubricated filament/yarns), Novoloid, carbon or graphite based packings.

Special Considerations: Chemical compatibility, the material's resistance to aggressive media, is of high concern with chemical service. PTFE is often selected because of its excellent chemical resistance properties. Graphite is suitable for many chemical services but may be attacked by oxidizing processes including some acids.

Valve Application: High Temperature Chemical Service

Conditions: Valve Stuffing box pressure ------up to 20 bar/300 PSI
Process fluid temperature ---------up to 650ºC/1200ºF
Process fluid pH level -------------0-14
Application Media -----------------Caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, and power utilities.

Packing Recommendation: Braided carbon and graphite packing (Carbon Filament, graphite filament/yarns) or die formed flexible graphite rings with braided carbon or graphite packing rings.

Special Considerations: It should be verified with the packing manufacturer that the high temperature packing material will also provide the needed chemical resistance. Corrosion rates increase at high temperature.

Valve Application: High Temperature & Pressure Service

Conditions: Valve Stuffing box pressure ----up to 69 bar/1000 PSI
Process fluid temperature -------up to 538ºC/1000ºF
Process fluid pH level ----------- 4-10
Application Media ---------------Water, mild acids & caustics, gases, oil, steam, solvents, and HF Gas

Industries: Petrochemical, power generation, steel & metal, mining & minerals, oil & gas, pulp and paper, agriculture, wastewater, marine, and pharmaceuticals.

Packing Recommendation: Die-formed flexible graphite rings with braided carbon or graphite packing rings.

Special Considerations: Contact the packing manufacturer for oxidizing services.

Valve Application: Super high Pressure and Temperature

Conditions: Valve Stuffing box pressure -----over 69 bar 1000 PSI
Process fluid temperature --------over 650ºC/1200ºF
Process fluid pH level ------------0-14
Application Media ----------------Air, gases, oil, steam

Industries: General industries, oil & gas, pulp and paper, agriculture, power generation, pharmaceutical, municipal, marine, power utilities, steel & metal, and mining & mineral.

Packing Recommendation: Wire reinforced braided extruded core packing (e.g., fiberglass, Inconel® wire and colloidal graphite) or die formed flexible graphite rings with braided wire re-enforced flexible graphite packing ring (made from flexible graphite tape and fiberglass yarns and special extruded core material).

Special Considerations: Oxidation rates of some materials increase with higher temperatures. Contact the packing manufacturers for oxidizing services.

Valve Application: Rising or Reciprocating

Conditions: Valve Stuffing box pressure --up to 34 bar/500 PSI
Process fluid temperature -----up to 260ºC/500ºF
Process fluid pH level ---------0-14
Application Media ---------------Water, mild acids & caustics, gases, oil, steam, and solvents.

Industries: General industries, oil & gas, pulp and paper, agriculture, power generation, pharmaceutical, municipal, marine, power utilities, steel & metal, and mining & mineral.

Packing Recommendation: Low-friction designed die-formed flexible graphite rings with Braided Carbon or Graphite Packing rings (concave convex design).

Valve Application: Control Valves

Conditions: Valve Stuffing box pressure -----up to 34 bar/600 PSI
Process fluid temperature ------- up to 650ºC/1200ºF
Process fluid pH level ----------- 0-14
Application Media -------------- Water, acids & caustics, gases, oil, steam, and solvents.

Industries: General industries, oil & gas, chemical, pulp and paper, power generation, pharmaceutical, municipal, marine, power utilities, steel & metal, and mining & mineral.

Packing Recommendation: For temperatures below 260ºC/500 ºF, PTFE based packings, either braided or in the shape of V-rings. For higher temperatures, low friction designed die-formed flexible graphite rings with braided carbon or graphite packing end rings.

Special Considerations: The number of rings used is typically no more than five. If the stuffing box was designed to accommodate more rings of packing, bushings are used to take up the space. The major consideration is the reduction of friction while maintaining low emission sealing levels. High friction levels can make the valve “hunt” for the right position and this will lead to increased wear and decreased system efficiency. Because of high cycling, live loading is often used to maintain proper loading on the packing rings.

INSTALLATION AND ADJUSTMENT INSTRUCTIONS FOR VALVE PACKINGS

The importance of packing the valve correctly cannot be overemphasized. Many packing failures are due to incorrect installation of the packing. Refer to the instructions below to ensure effective installation of packings on valves. For “handling” of packing materials, refer to page 36.

1) **FOLLOW PLANT SAFETY REGULATIONS** in preparation for and during installation.

2) **REMOVE ALL OLD PACKING FROM THE STUFFING BOX (**see Figure33). Packing extractors and water jets are suitable tools for removing packing without damaging the stuffing box. Clean the box and stem thoroughly and examine the stem for wear and scoring. Replace the stem if wear is excessive. Make certain that the stem is concentric to the bore of the stuffing box. Refer to TABLES 9 and 10 on pages 101 and 102 for information on equipment conditions and their effects on the sealing system.

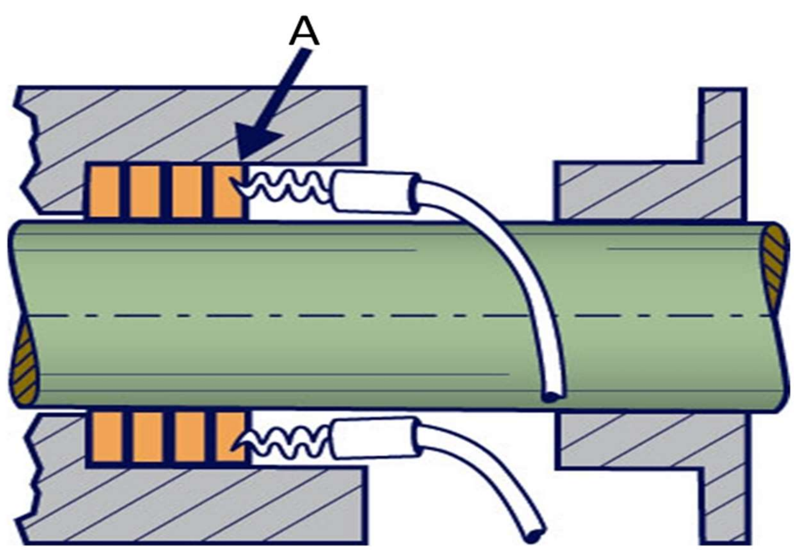


Figure 33. Packing Removal

A: Point away from shaft at 90^0

3) **USE THE CORRECT CROSS-SECTION OF PACKING OR DIE-FORMED RINGS.** To determine the correct packing size, measure the diameter of the stem inside the stuffing box area, if possible, to determine the inner diameter (ID) of the ring. Then, measure the diameter of the stuffing box or bore to give the outer diameter (OD) of the ring. Subtract the ID measurement from the OD measurement and divide by two. The result is the cross-section size.

4) **WHEN USING COIL OR SPIRAL BRAIDED PACKING, ALWAYS CUT THE PACKING INTO SEPARATE RINGS.**

Never wind a coil of braided packing into a stuffing box. The one exception to this general rule applies to PTFE and ePTFE cord packing (see step 5). Rings can be cut with butt (square) or skive (diagonal) joints, depending on the method used for cutting (see Figures 34 and 35). Typically butt joints are used in dynamic services (i.e. rotary pumps, mixers, agitators etc.) where controllable leakage is expected, and skive joints are used in 'stationary' services such as valves where minimal to zero leakage is required.

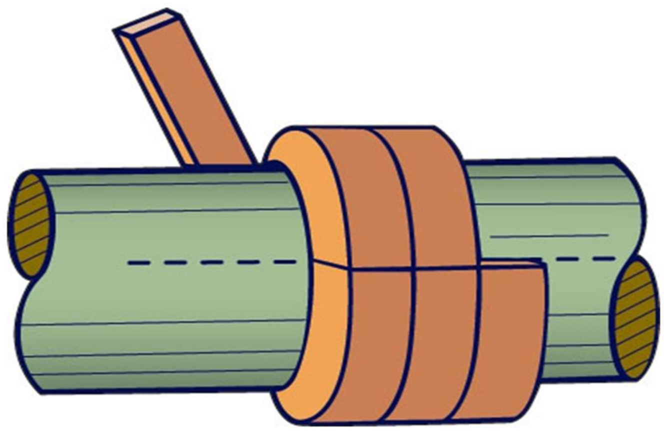


Figure 34 Butt Cut

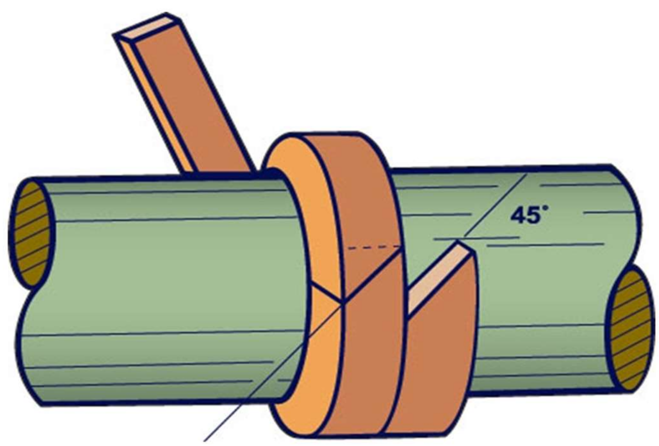


Figure 35 Skive Cut

The best way to cut packing rings is to do it on a mandrel with the same diameter as the stem or shaft to be sealed in the application in the stuffing box area. Be sure the first ring of each packing type is cut carefully and tested on the stem for proper fit.

Note that packings made of different materials and braid methods behave differently when bent around a shaft. Rings cut to a calculated length may not fit properly when installed (See figure 36).

Figure 36 Length of ring is dependent on construction

Hold the packing tightly on the mandrel, but do not stretch. Although *not recommended*, rings can be cut on the stem outside the stuffing box; however, make sure that the stem is not damaged. Be sure the first ring is cut carefully and tested on the stem for proper fit. The ring can also be inserted into the stuffing box (if available), making certain it fits properly within the packing recess, prior to cutting additional rings. Each additional ring can be cut in the same manner, or the first ring can be used as a master from template for the remainder of the rings are to be cut. If the butt cut rings are cut on a flat surface, be certain that the side of the master rings, not the OD or ID surface, is laid on the rings to be cut. This is necessary so that the end of the rings can be reproduced.

When cutting diagonal joints, use a miter board (see figure 37) so that each successive ring can be cut at the correct angle. It is necessary that the rings be cut to the correct size. Otherwise, service life is reduced. This is where die-molded rings are of great advantage. They give you the exact size ring for the ID of the stem and the OD of the stuffing box with no waste due to incorrectly cut rings.

When cutting diagonal joints, use a miter board so that each successive ring can be cut at the correct angle. It is necessary that the rings be cut to the correct size. Otherwise, service life is reduced.

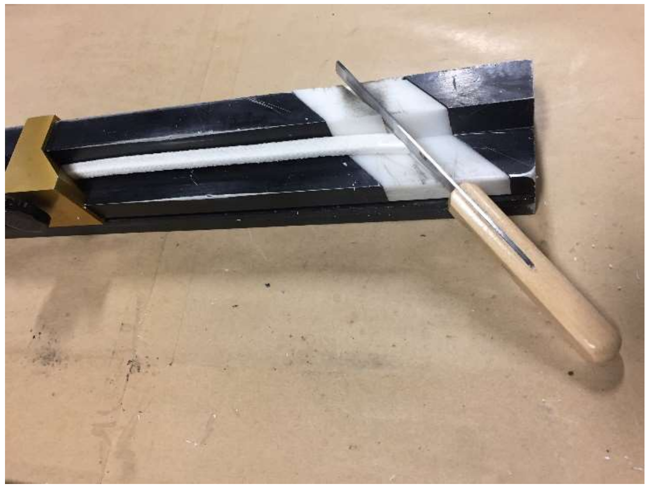


Figure 37 Measuring and Cutting Tool for Compression Packing

5) **INSTALL ONE RING AT A TIME.** See Figure 38 for installation of *cut rings*. For installation of *die formed rings of flexible graphite*, in order to prevent cracking and

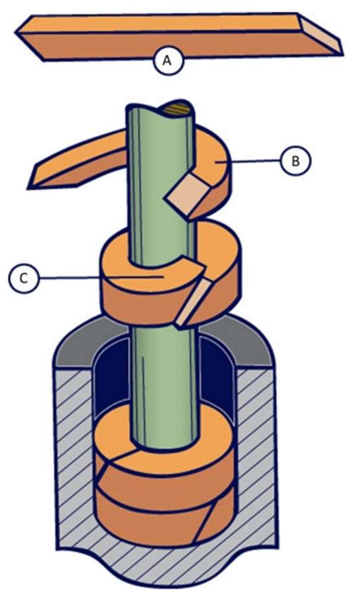


Figure 38 Spreading of Cut Sealing Rings

breaking of the material, do not spread apart the ring as shown in Figure 38. Form a helix with the die formed ring (see Figures 39 and 40). In small valves with 3-5 mm (1/8-3/16 inch) cross sections, soft packing materials, (e.g., ePTFE, PTFE) do not need to be cut into individual rings but may be wrapped around the stem in a consistent spiral to fill the stuffing box. Contact the manufacturer for instructions.

Make sure the ring is clean and has not picked up dirt in handling. Joints of successive rings should be staggered and kept at least 90 degrees apart. Each individual ring should be firmly seated with a tamping tool or suitable split bushing fitted to the stuffing box bore. When enough rings have been individually seated so that the nose of the gland will reach them, individual tamping should be done by the gland.

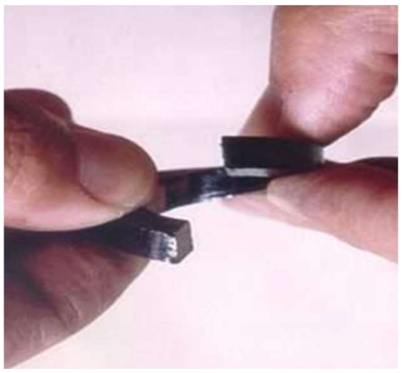


Figure 39 Helix spreading of ring

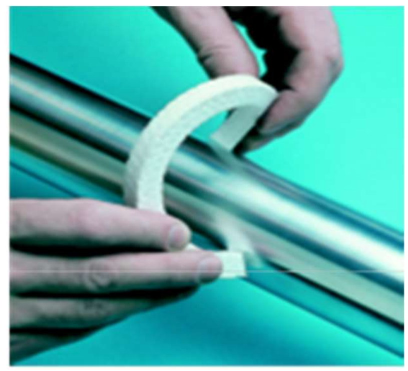


Figure 40 Installation of ring

1) **SLIDE GLAND FORWARD UNTIL IT CONTACTS THE PACKING. TIGHTEN THE GLAND BOLTS TO THE TORQUE VALUE SUGGESTED BY THE MANUFACTURER.** During this time, turn the valve stem back and forth to determine the ease of turning. Do not torque down to the point where the stem will not turn.

2) **INSPECT THE VALVE IN A BENCH TEST OR AFTER IT HAS BEEN IN SERVICE.** If leakage is observed, adjust the gland in accordance with safe maintenance procedures and manufacturer's recommendations.

3) **LIVE LOADING A VALVE STEM PACKING GLAND.** In its simplest form, live loading is the application of a spring load to the gland follower of a packed valve. A disc spring between the gland follower and its fastening studs and nuts provides an effective way to establish and maintain a controlled amount of stress in the packing set. The amount of the packing stress in a live loaded system can be controlled by the size of the disc spring used and how far it is compressed or deflected.

   In a live loaded packing system, the follower will continue to push against the packing even when packing volume is lost by friction, extrusion, consolidation, etc. The spring load will be slightly reduced as the springs expand, but this reduction in load will be much less than the load that is lost if the packing set was not live loaded. This remaining load allows the packing stress to remain at a level above the minimum sealing stress and may enable the packing to remain leak free (see Figure 44 on page 64). For live loading theory, refer to the section, *Liveloading*, in the *Technical Reference* of this manual.

PUMP PACKINGS

Quality pump packings are generally available in the following constructions:

1) Interbraid
2) Square braid
3) Braid-over-braid

TYPES OF PUMP PACKING

The interbraided pump packings, generally recommended for most pump applications including severe services, consist of a variety of materials that are compatible with a wide range of applications. The materials common to interbraided packings are the following:

1) Carbon yarn impregnated with PTFE or graphite dispersion
2) PTFE yarns impregnated with PTFE dispersion or other lubricants
3) PTFE or ePTFE/graphite yarns with lubricants or anti-extrusion corner fibers
4) Flexible graphite yarns with lubricants or anti-extrusion corner fibers
5) Blends of the above fibers or other synthetic fibers impregnated with dispersions or lubricants

The square braided pump packings are used in general services and in special applications requiring a square or rectangular geometry for custom gasketing. The densely formed braid-over-braid pump packings can be used in reciprocating applications. Both square braid and braid-over-braid packings are available in the materials discussed above.

Other yarns, such as Novoloid and staple Para-aramid, both impregnated with PTFE and lubricants, can be used in pump service. These and others are discussed under *Types of Packing Materials and Lubricants*. The many construction types are discussed in detail under *Types of Packing Construction*. In the next section, general guidelines are provided on materials and construction for pump services.

Contact a packing manufacturer for specific application recommendations.

APPLICATION RECOMMENDATIONS FOR PACKINGS IN CENTRIFUGAL PUMPS

The following recommendations are a general reference *only* of compression packing material for pump packing applications.

Refer to Figures 31 and 32 on page 47 for general application recommendations. Contact a packing manufacturer for specific application recommendations.

Braided PTFE Packing

PTFE packing is suitable for general centrifugal pump applications. At low pressure, high-speed applications, PTFE yarn with carbon graphite coating and PTFE dispersion along with a suitable lubricant is recommended. If the media has a pH level 0 to 14, expanded PTFE filament yarn with suitable lubricant is recommended. Pure lubricated PTFE or ePTFE packing materials are generally used in applications where the surface speeds are less than 10 m/s (2000 FPM).

For food and beverage applications, use bleached PTFE filament yarn with food grade lubricants such as mineral oil or vegetable oil. If lubricant is not allowed, use the dry version of this packing. PTFE handles all chemicals, except ethylene gas, has high tensile strength, and excellent corrosive service for pH 0-14.

Braided ePTFE / Graphite Packing
Expanded PTFE yarn with graphite is suitable for general centrifugal pump applications. If the media has a pH level 0 to 14, this yarn with suitable lubricant is recommended. This material is generally used in applications where surface speeds are less than 20 m/s (4000 FPM) and is easy to install and remove from stuffing boxes.

Braided Flexible Graphite and Carbon/Graphite Packing
Boiler feed pump applications: Braided flexible graphite with carbon filament and colloidal graphite has proven to work effectively. This packing material has the ability to run dry due to the heat dissipation property of the various graphite materials in this packing. It is excellent in corrosive service pH 0-14 except in strong oxidizers and has excellent dry running and high-speed capabilities.

Braided Aramid Packing
For highly abrasive media, use aramid packing with PTFE dispersion and suitable lubricant. Aramid filament or spun aramid will handle all sorts of abrasive particles suspended in the pumping fluid because it has a very high tensile strength compared to all the other packing materials. This packing is excellent in abrasive applications. It is used in all types of pumping equipments found in the petrochemical industries, chemical processing, pulp and paper, marine, steel/metal, mining wastewater, and power utilities.

Flexible Metallic Packing
For high-pressure reciprocation plunger pump applications, a combination of braided flexible graphite with metal foil end rings is recommended. This packing is excellent in high-speed applications. It is excellent in charge pumps, crude oil slurry pumps, and boiler feed pumps.

Braided Synthetic Packing (Acrylics and polyimide yarn)
This packing is a general industry and commercial grade packing used in all mild pump applications. This packing is non-abrasive to the mating surface. This packing is excellent for low speed, low temperature and moderate speed applications.

The following are typical pump packing application conditions:

Pump Application: General Services

Conditions: Pump speed ------------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------ up to 20 bar/300 PSI
Process fluid temperature - up to 260ºC/500ºF
Process fluid pH level ------ 3-12

Application Media ------------Water, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, and power utilities.

Packing Recommendation: Interbraided Synthetic Packing (Acrylics and Polyimide Yarns).

Pump Application: Chemical Service

Conditions: Pump speed ------------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------ up to 20 bar/300 PSI
Process fluid temperature - up to 260ºC/500ºF
Process fluid pH level ------ 0-14
Application Media ----------- Chemicals, corrosive, ammonia, liquor, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, and power utilities.

Packing Recommendation: PTFE Based Packing (dry or lubricated filament/Yarns)/expanded PTFE, ePTFE/Graphite, or Graphite based.

Special Considerations: Chemical compatibility, the material's resistance to aggressive media, is of high concern with chemical service. PTFE is often selected because of its excellent chemical resistance properties. Graphite is compatible with many chemicals but should not be used with strong oxidizers.

Pump Application: High Temperature Chemical Service

Conditions: Pump speed ------------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------ up to 20 bar/300 PSI
Process fluid temperature -- up to 650ºC/1200ºF
Process fluid pH level ------ 0-14
Application Media ---------- Water, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, and power utilities.

Packing Recommendation: Braided Carbon, Graphite Packing, Braided flexible graphite packing (Carbon Filament, graphite filament/Yarns).

Special Considerations: It should be verified with the packing manufacturer that the high temperature packing material will also provide the needed chemical resistance. Corrosion rates increase at high temperature.

Pump Application: High Temperature & Pressure Service

Conditions: Pump speed ------------------ up to 18 m/s (3600 FPM)
Stuffing box pressure ------- up to 68 bar/1000 PSI
Process fluid temperature -- up to 538ºC/1000ºF
Process fluid pH level ------ 4-10
Application Media ----------- Water, mild acids & caustics, gases, oil, steam, solvents, and HF Gas

Industries: Power generation, steel & metal, mining & minerals, oil & gas, pulp and paper, agriculture, wastewater, marine, and pharmaceuticals.

Packing Recommendation: Metal foil packing (Babbitt, aluminum, stainless steel, copper foil) anti-extrusion end rings for throat/bearing.

Special Considerations: The use of mechanical seals should be considered for many high pressure applications. Contact the manufacturer for packing pressure limitations.

Pump Application: Abrasive Services

Conditions: Pump speed ------------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------- up to 20 bar/ 300 PSI
Process fluid temperature -- up to 260ºC/ 500ºF
Process fluid pH level ------ 2-12
Application Media ---------- Water, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, mining, commercial, municipal, marine, and power utilities.

Packing Recommendation: Interbraided Aramid, Polyimide, PTFE Packing (Aramid Filament or spun PTFE, spun aramid, PTFE and Polyimide Yarns), ePTFE/Graphite, Novoloid.

Special Considerations: In some cases, special abrasion-resistance end rings in the stuffing box bottom may be needed as a barrier to abrasive contaminants. Aramid yarn can itself be abrasive to some sleeve material, so consult manufacturer for recommendation.

Pump Application: General Food Services

Conditions: Pump speed ------------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------- up to 20 bar/300 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------ 0-14
Application Media ----------- Food products, portable water, chemicals, corrosive, gases, oil, steam, and solvents

Industries: Food & beverage, chemical and pharmaceuticals.

Packing Recommendation: Interbraided FDA compliant packing (Acrylics and Polyimide Yarns), FDA compliant PTFE packing.

Special Considerations: Contact the packing manufacturer for packing materials that are compliant to FDA or other applicable food service requirements.

Pump Application: High Speed Services

Conditions: Pump speed ------------------ up to 23 m/s (4500 FPM)
Stuffing box pressure ------- up to 34 bar/500 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------- 0-14
Application Media ----------- Boiler feed water, condensate, paper stock, liquor, ammonia, air, gases, oil, steam, and solvents

Industries: Pharmaceuticals, chemical, petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, and power utilities.

Packing Recommendation: Interbraided flexible graphite, Expanded PTFE (Flexible graphite/carbon yarn & colloidal graphite, Expanded PTFE w/graphite coating).

Special Considerations: In some cases, the addition of lubricants will assist in the reduction of friction in high speed applications.

INSTALLATION AND ADJUSTMENT INSTRUCTIONS FOR PUMP PACKINGS

The importance of packing the pump correctly cannot be overemphasized. Many packing failures are due to incorrect installation of the packing. Refer to the instructions below to ensure effective installation of packings in pumps. For “handling” of packing materials, refer to page 36.

1) **FOLLOW PLANT SAFETY REGULATIONS** in preparation for and during installation.

2) **REMOVE ALL OLD PACKING FROM THE STUFFING BOX (**see Figure 41). Packing extractors and water jets are suitable tools for removing packing without damaging the stuffing box. Clean the box and shaft or sleeve thoroughly and examine the shaft for wear and scoring. Replace the shaft or sleeve if wear is excessive. Make certain that the shaft is concentric to the bore of the stuffing box. Refer to TABLES 9 and 10 on pages 101 and 102 for information on equipment conditions and their effects on the sealing system.

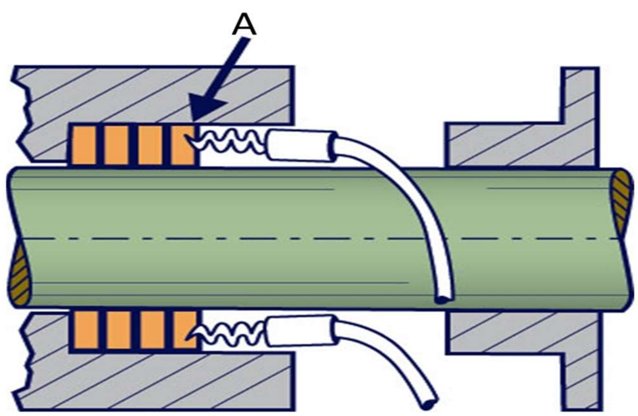


Figure 41. Packing Removal

A: Point away from shaft at 90^0

3) **USE THE CORRECT CROSS-SECTION OF PACKING OR DIE-FORMED RINGS.** To determine the correct packing size, measure the diameter of the shaft or sleeve inside the stuffing box area, if possible, to determine the inner diameter (ID) of the ring. Then, measure the diameter of the stuffing box or bore to give the outer diameter (OD) of the ring. Subtract the ID measurement from the OD measurement and divide by two. The result is the cross-section size.

4) **WHEN USING COIL OR SPIRAL PACKING, ALWAYS CUT THE PACKING INTO SEPARATE RINGS.** Never wind a coil of packing into a stuffing box. Rings can be cut with butt (square) or skive (or diagonal) joints, depending on the method used for cutting (see Figures 42 and 43). Be sure the first ring is cut carefully and tested on the shaft for proper fit. The best way to cut packing rings is to cut them on a mandrel with the same diameter as the shaft in the stuffing box area.

Hold the packing tightly on the mandrel, but do not stretch. Although *not recommended*, rings can be cut on the shaft or sleeve outside the stuffing box; however, make sure that the shaft is not damaged. Cut the ring and insert it into the stuffing box, making certain it fits properly within the packing recess.

Each additional ring can be cut in the same manner, or the first ring can be used as a master from which the remainder of the rings are cut. If the butt cut rings are cut on a flat surface, be certain that the side of the master rings, not the OD or ID surface, is laid on the rings to be cut. This is necessary so that the end of the rings can be reproduced.

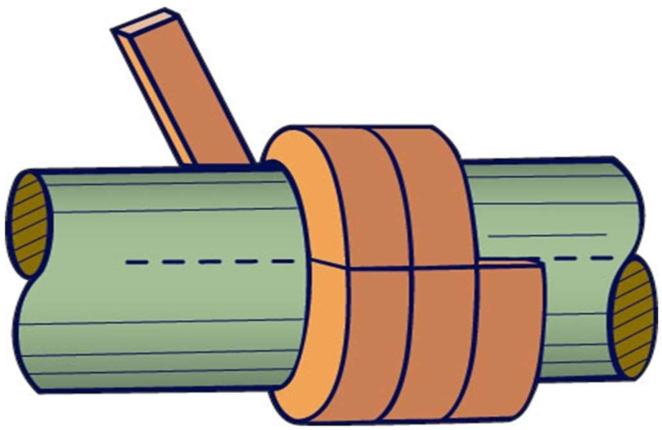


Figure 42. Butt Cut

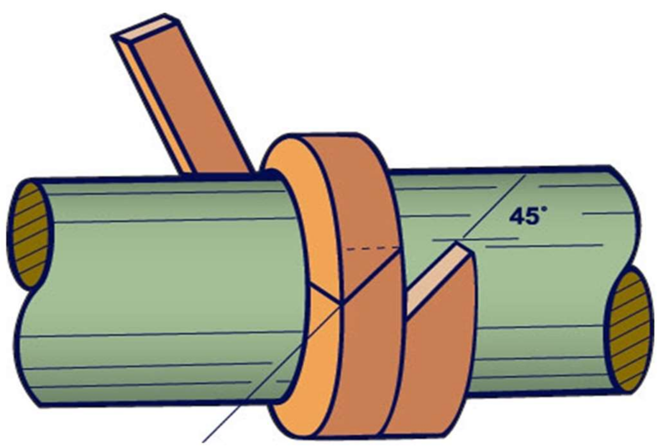


Figure 43. Skive Cut

When cutting diagonal joints, use a miter board so that each successive ring can be cut at the correct angle (Figure 44). It is necessary that the rings be cut to the correct size.

Otherwise, service life is reduced. This is where die-cut rings are of great advantage. They give you the exact size ring for the ID of the stem and the OD of the stuffing box with no waste due to incorrectly cut rings.

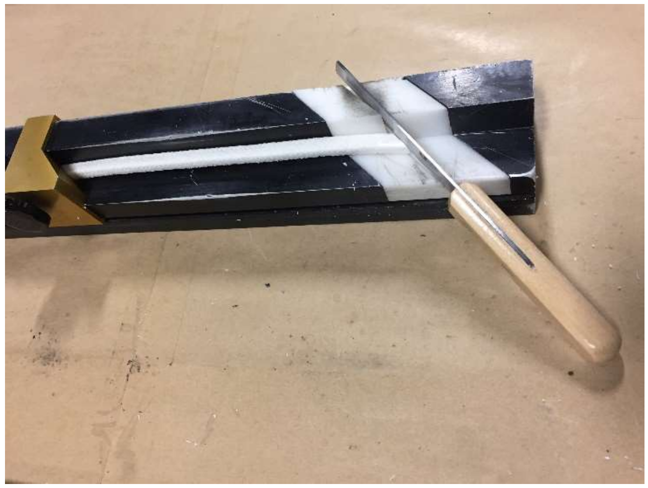


Figure 44. Measuring and Cutting Tool for Compression Packing

5) **INSTALL ONE RING AT A TIME.** See Figures 45 and 46 for installation of *cut rings*. For installation of *die formed rings of flexible graphite*, in order to prevent cracking and breaking of the material, do not spread apart the ring as shown in Figure 45. Form a helix with the die formed ring (see Figures 46). Make sure it is clean and has not picked up any dirt in handling. Seat rings firmly, except PTFE filament and graphite yarn packings which should be snugged up very gently and then tightened gradually after the pump is operating. Joints of successive rings should be staggered and kept at least 90 degrees apart. Each individual ring should be firmly seated with a tamping tool or, a suitable split bushing fitted to the stuffing box bore. When enough rings have been individually seated so that the nose of the gland will reach them, individual tamping should be done by the gland.

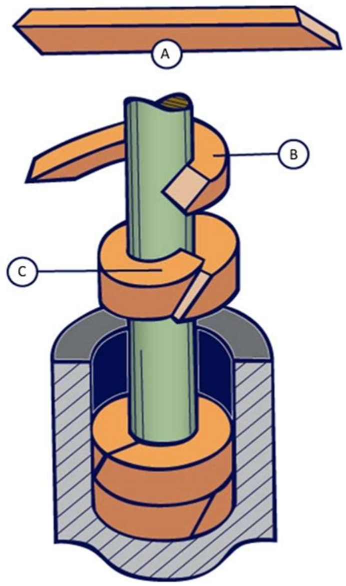


Figure 45. Spreading of Cut Sealing Rings

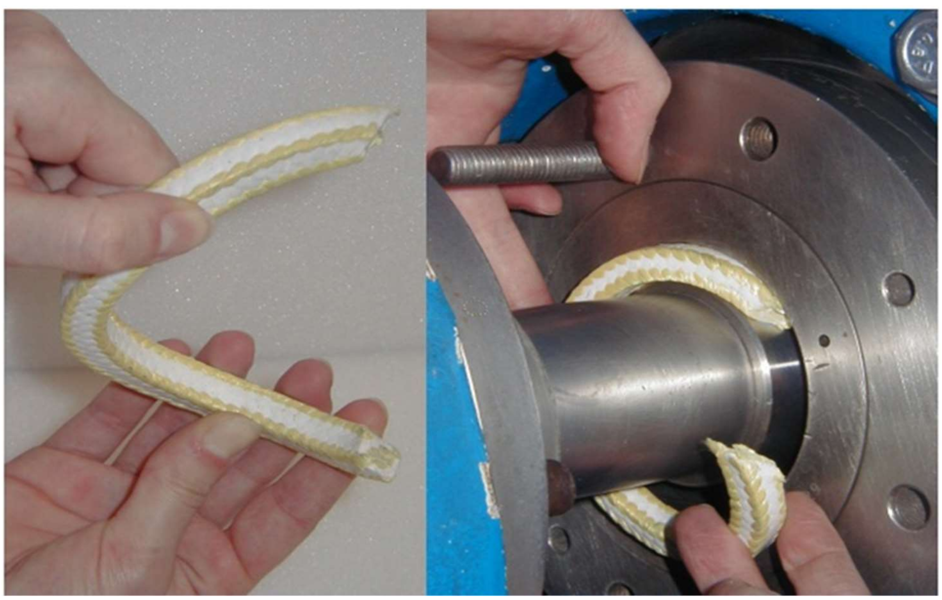


Figure 46 Spreading of ring and installation

6) **IF THE STUFFING BOX HAS A LANTERN RING (**see Figure 47, p. 66, and 54, p. 81), make sure that the lantern ring is installed properly so it will remain under the inlet as gland pressure is applied.

7) **TAKE UP GLAND BOLTS AFTER THE LAST RING IS INSTALLED** finger tight or very slightly snugged up (see Figure 47). Do not jam the packing into place by excessive gland loading.

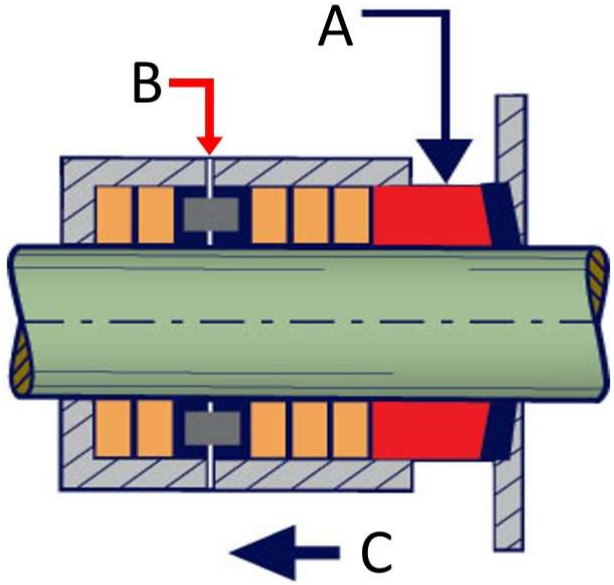


Figure 47 Compression Packing

A: Gland Follower
B: Lantern Ring
C: Direction of Gland Compression

8) **WHEN SPECIFIED BY THE PUMP MANUFACTURER, PROVIDE MEANS OF LUBRICATING THE SHAFT AND PACKING THROUGH THE LANTERN RING BY SUPPLYING WATER, OIL, GREASE, OR LIQUID HANDLED IN THE PUMP.** Fittings for this purpose are standard on many pumps. Flush pressure should be a minimum of 1 bar (14.5 psi) above stuffing box pressure. Refer to the section *Stuffing Box Design and Pressure Distribution* for a stuffing box pressure formula and to *Flush Water* in the *Technical Reference* of this manual.

9) **START PUMP AND TAKE UP GLAND BOLTS GRADUALLY.** Make sure gland bolts are taken up evenly.

10) **DO NOT STOP LEAKAGE ENTIRELY AT THIS POINT. THIS CAN CAUSE THE PACKING TO BURN, HARDEN, AND DAMAGE EQUIPMENT.**

11) **ALLOW PACKING TO LEAK FREELY WHEN STARTING UP A NEWLY PACKED PUMP.** Excessive leakage during the first hour of operation can result in a better packing job over a longer period of time. Contact the packing manufacturer for specific application recommendations.

12) **CONTINUE TO TAKE UP GRADUALLY ON THE GLAND TO SEAT THE PACKING** until leakage is decreased to a tolerable level, preferably 8-10 drops per minute, per inch of shaft diameter. Some packing can run virtually leak free. Contact your packing manufacturer for specific recommendations.

13) **REPLACE PACKING WHEN FREQUENCY OF ADJUSTMENT INCREASES OR LEAKAGE CANNOT BE CONTROLLED BY FURTHER TAKE-UP ON THE GLAND. DO NOT ADD MORE PACKING RINGS.**

NOTE: ON BOTH CENTRIFUGAL AND RECIPROCATING PUMPS, about 70% of wear is on the outer two packings nearest the gland; however, each additional ring does throttle some fluid pressure. On most pumps, there must be enough rings so if one fails, another does the sealing, and the pump need not be shut down.

The mechanical pressure curve in Figure 48 shows seven packing rings. The first four rings do the majority of the sealing. The bottom three do little sealing but are needed to fill the available space or recess. With high temperatures, high pressures, corrosive chemicals, or abrasive particles in the fluid, more rings may be the only solution for some services. In such cases, the bottom ring controlling the fluid may have the most wear from these severe service conditions.

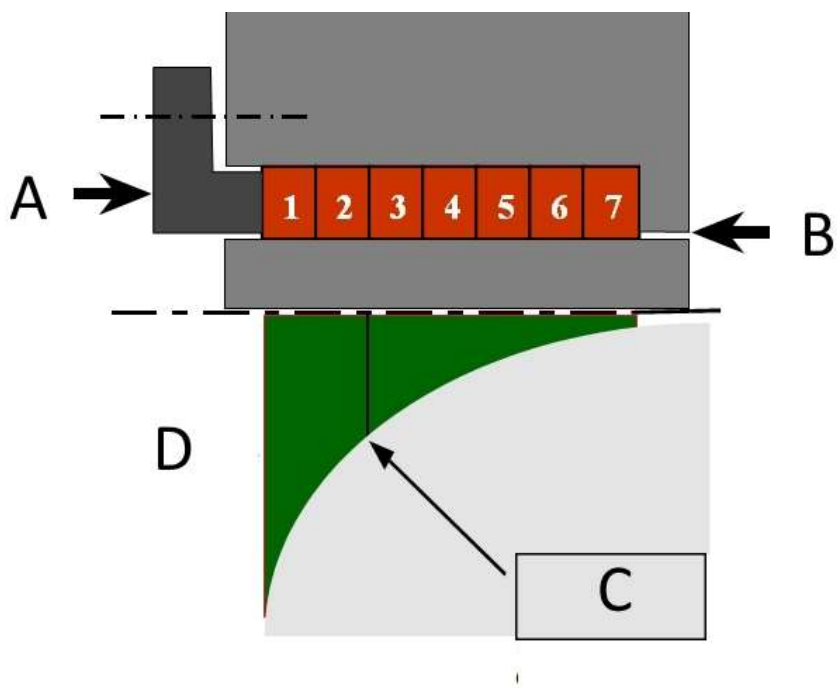


Figure 48. Stuffing Box and Radial Pressure Distribution

A: Gland Pressure
B: Media Pressure
C: 70% of total sealing force comes from the first two rings of packing
D: Radial Pressure

With deep stuffing boxes that would require large numbers of rings to fill the available space, metal bushings are sometimes recommended as spacers. The advantage of using fewer packing rings is less shaft or sleeve wear, less friction, lower power consumption and lower operating temperatures. Also, the stuffing box design is simpler and takes less material. The radial pressure distribution is also more uniform as is shown in Figure 49.

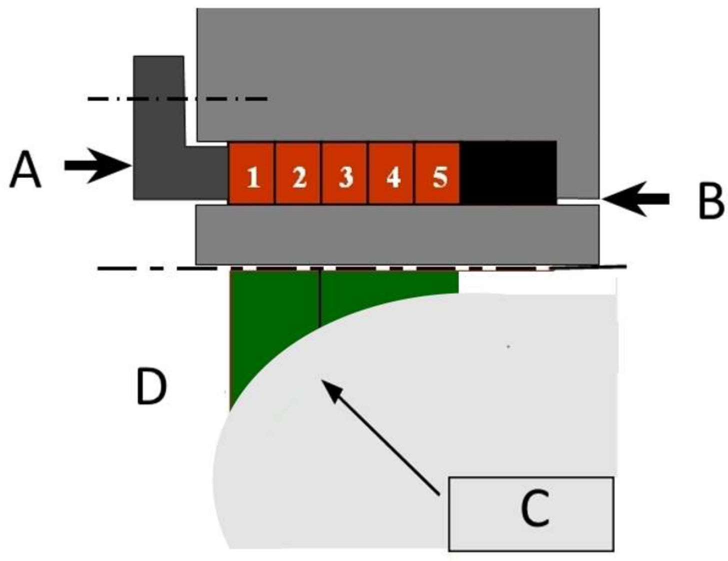


Figure 49 Optimizing the Number of Packing Rings

A: Gland Pressure
B: Media Pressure
C: More uniform Radial pressure force
D: Radial Pressure

Refer to the section *Technical Reference* for certain issues that apply to packing wear.

CAUTION: ALL PACKINGS MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.

Note: Depending on the installation method, such as tamping or compressing each ring separately, the radial contact pressure of each ring will vary. Also, in the case of reciprocating applications, the shear forces of the axially sliding shaft on the packing rings can lead to a more uniform radial pressure distribution. See the illustration in Figure 50

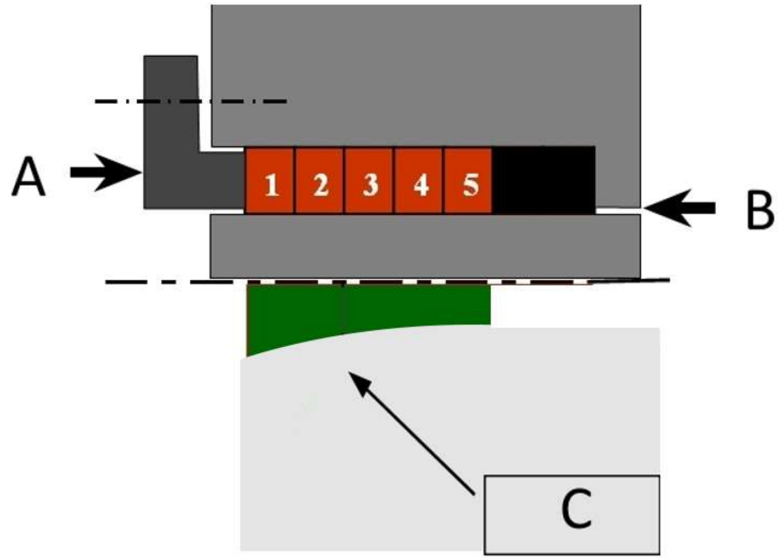


Figure 50 Optimizing Radial Contact Pressure

A: Gland Pressure
B: Media Pressure
C: More uniform Radial pressure force
D: Radial Pressure

SPECIALTY EQUIPMENT PACKINGS

TYPES OF SPECIALTY EQUIPMENT PACKING

Some examples of specialty equipment that utilize compression packing are soot blowers, mixers, compressors, heat exchangers, expansion joints, clinker grinders, agitators, digesters, etc.

Various types of compression packings are required for the various operating conditions of specialty equipment. While most specialty equipment can be modeled as a pump or valve and can be sealed with pump packing sets or valve packing sets, complex specialty equipment applications may require combinations of the various ranges of packing styles.

The following recommendations are given as a general reference.
Contact packing manufacturers for recommendations on specific specialty equipment.

Complex specialty equipment applications may require combinations of the various ranges of packing styles.

APPLICATION RECOMMENDATIONS FOR SPECIFIC SPECIALTY EQUIPMENT

Similar to pump and valve packing, specialty equipment packing materials and configurations are most likely influenced by the operating conditions of the equipment.

The following recommendations are a general reference only. Contact packing manufacturers for specific recommendations.

Most importantly, the packing material selected for this equipment is to have the characteristics of low coefficient of friction and have high resilience for forming into the stuffing box or the equipment's sealing compartments. Packing selection and design criteria depend on the following conditions:

- Media (fluid being sealed)
- Temperature range
- Pressure
- Motion (reciprocating, rotary, oscillating)
- Speed (static or dynamic)
- Chemical concentration (PH Limit)
- Equipment conditions (shaft run out, mating surface condition)
- Stuffing Box Dimension (Shaft/rotor, bore, depth, clearances)

PACKING MATERIAL RECOMMENDATION

Many types of specialty equipment exist that utilize packing, such as soot blowers, mixers, compressors, heat exchangers, mining equipment, etc. Contact packing manufacturers for recommendations on specific specialty equipment.

In specialty equipment packing, about every type of compression packing can be applied for low to mild operating conditions. In many cases, a combination of the various ranges of packing styles may perform better, depending on the complexity of the equipment. Most specialty equipment can be modeled as a pump or valve, in order to apply pump packing sets or valve packing sets. Some of the specialty equipment that use compression packing as the sealing component are the following:

Soot Blower Application: General Service

Conditions: Equipment speed ------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------- up to 20 bar/300 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------ 0-14
Application Media ---------- Chemicals, corrosive, ammonia, liquor, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, power utilities, and power generation.

Packing Recommendation: Soot blower set comprised of combination chevron design of concave and convex rings (die molded design of flexible graphite beveled middle rings with beveled male and female end rings).

Special Considerations: Retractable soot blowers can be prone to radial motion when extending and retracting during operation. The addition of bronze bushings can provide additional radial support and stabilize the parts in relative motion, thereby increasing the effectiveness of the packing.

Mixer/Agitator (Vertical/Horizontal) Application: General Service

Conditions: Equipment speed ------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------- up to 20 bar/300 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------ 0-14
Application Media ---------- Chemicals, corrosive,
ammonia, liquor, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, power utilities, food processing, and pharmaceutical.

Packing Recommendation: All general service pump packing, braided combination set of flexible graphite middle ring and braided graphite packing, Aramid fiber packing, Polyimide packing, metallic packing, Novoloid.

Special Considerations: Mixers and agitators tend to run at low shaft rotational speed but can experience a significant amount of radial run-out. Packing with a flexible core either fibrous or elastomeric can be used to provide resiliency against shaft movement and achieve an effective seal. Many mixers are top entering, and the packing is not lubricated by the product. In this situation, provision to cool the packing with a flush must be made if the speed and pressure are too high to have the packing in a dry running condition.

Reciprocating Pump Application: General Service

Conditions: Equipment speed ------------ up to 10 m/s (2000 FPM)
Stuffing box pressure ------- up to 135 bar/2000 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------ 0-14
Application Media ---------- Chemicals, corrosive, ammonia, liquor, mild acids & caustics, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, power utilities, pharmaceutical, and food & beverages.

Packing Recommendation: All general service pump packing, braided combination set of flexible graphite middle ring and braided graphite packing, Aramid fiber packing, PTFE “V” Ring packing, Energized core packing, Polyimide packing, and die formed metallic packing.

Special Considerations: Reciprocating pumps are positive displacement pumps that can generate high pressure levels. For the high-pressure cases, the use of anti-extrusion rings is beneficial at each end of a packing set. Die formed rings will minimize consolidation of the packing under the reciprocating motion.

Compressor Application: General Service (reciprocating/centrifugal)

Conditions: Equipment speed ------------ up to 23 m/s (4500 FPM)
Stuffing box pressure ------- up to 20 bar/300 PSI (reciprocating) --- up to 135 bar/2000 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------- 0-14
Application Media ------------ Chemicals, corrosive, ammonia, air, gases, and oil

Industries: Petrochemical industries, oil & gas, pulp and paper, commercial, municipal, marine, power utilities, and power generation.

Packing Recommendation: All general service pump packing, braided combination set of flexible graphite middle ring and braided graphite packing, Aramid fiber packing, Polyimide packing, and metallic packing.

Special Considerations: Centrifugal compressors tend to operate at high speeds. The build-up of heat from the high-speed operation might need to be addressed. As in the case of reciprocating pumps, reciprocating compressors can generate high pressure levels. The use of anti-extrusion rings is beneficial at each end of a packing set. Die formed rings will minimize consolidation of the packing under the reciprocating motion.

Boiler Feed Pump Application: General Service

Conditions: Equipment speed ------------ up to 20 m/s (4000 FPM)
Stuffing box pressure ------- up to 20 bar/300 PSI
Process fluid temperature -- up to 260ºC/500ºF
Process fluid pH level ------ 5 - 9
Application Media ----------- Condensate Water

Industries: Power Generation, commercial, municipal, marine, power utilities, and pharmaceutical

Packing Recommendation: Braided flexible graphite packing, general service pump packing, braided combination set of flexible graphite middle ring and braided graphite end rings packing, Polyimide packing and combination of flexible graphite and metallic packing.

Special Considerations: Boiler feed pumps operate under significant pressure, high speed, and elevated temperature levels. The main consideration is to maintain liquid lubrication to the packing and prevent flashing of the water into steam. Cooling can be accomplished with a jacketed stuffing box and/or a flush. Most boiler feed pumps are of a multi-stage double ended construction, but do not necessarily have the same pressure at each stuffing box. Some pumps have pressure equalizing lines while others will have one stuffing box at or near suction pressure with the other at the discharge pressure of the stage feeding the cross over line. This must be taken into consideration for determination of the proper environmental controls.

Condenser sheet/heat exchanger Application: General Service

Conditions: Stuffing box pressure ---------- up to 20 bar/300 PSI
Process fluid temperature ----- up to 260ºC/500ºF
Process fluid pH level --------- 0-14
Application Media ------------- Chemicals, water, corrosives, ammonia, gases, oil, steam, and solvents

Industries: Power Generation, petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, power utilities, pharmaceutical, and food & beverages

Packing Recommendation: Combination set of high density machined fiber rings and metallic foil rings.

Oven Door Application: General Service

Conditions: Oven pressure ---------------- up to 20 bar/300 PSI
Process fluid temperature -- up to 537.8ºC/1000ºF
Process fluid pH level ------ 0-14
Application Media ---------- Chemicals, corrosive, ammonia, air, gases, oil, steam, and solvents

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, and power utilities.

Packing Recommendation: Braided woven glass fiber strip, braided flexible graphite, and ceramic.

Special Considerations: The sealing application is primarily static. The one factor to be most concerned about is that the packing is capable of resisting the high temperature conditions and corrosion from the medium being sealed as corrosion rates increase with temperature.

Piping Expansion Joint Application: General Service

Conditions: Stuffing box pressure -------- up to 20 bar/300 PSI
Process fluid temperature --- up to 260ºC/500ºF
Process fluid pH level ------- 0-14
Application Media ----------- Chemicals, corrosive,
ammonia, mild acids & caustics, air, gases, oil, steam, solvents, and water

Industries: Petrochemical industries, oil & gas, pulp and paper, agriculture, wastewater, commercial, municipal, marine, power utilities, and power generation.

Packing Recommendation: Braided Flexible graphite packing, braided wire re-enforced extruded core fiberglass packing, braided-carbon fiber.

Special Considerations: Expansion joints allow for thermal expansion of pipes. While the motion to be accounted for is primarily axial, there can be some significant radial loads involved. Proper alignment is critical. The best packing for this application will be a dense packing with low levels of lubricants. This insures effective sealing while requiring minimal adjustments.

INSTALLATION AND ADJUSTMENT INSTRUCTIONS FOR SPECIALTY PACKINGS

Most specialty equipment can be modeled as a pump or valve in application of installation procedures. Refer to the valve or pump installation instructions in this manual and contact the packing manufacturer for specific instructions of packing installation for your specialty equipment. For “handling” of packing materials, refer to page 36.

TECHNICAL REFERENCE

STUFFING BOX DESIGN AND PRESSURE DISTRIBUTION

The stuffing box is a cylindrical recess that surrounds a reciprocating or rotating shaft. It is designed to prevent leakage of processing media from valves, pumps, and specialty equipment or to prevent contamination of processed media/fluids due to leakage of air or other environmental fluids into the valves, pumps, and specialty equipment.

It generally consists of a stem or shaft or sleeve (G); a bore (H); a stuffing box area (A); a throat (F); a recess for the packing (A); a packing compressor or gland follower (C); a gland (B); compression packing (E); and/or a lantern ring (D) (see Figure 51).

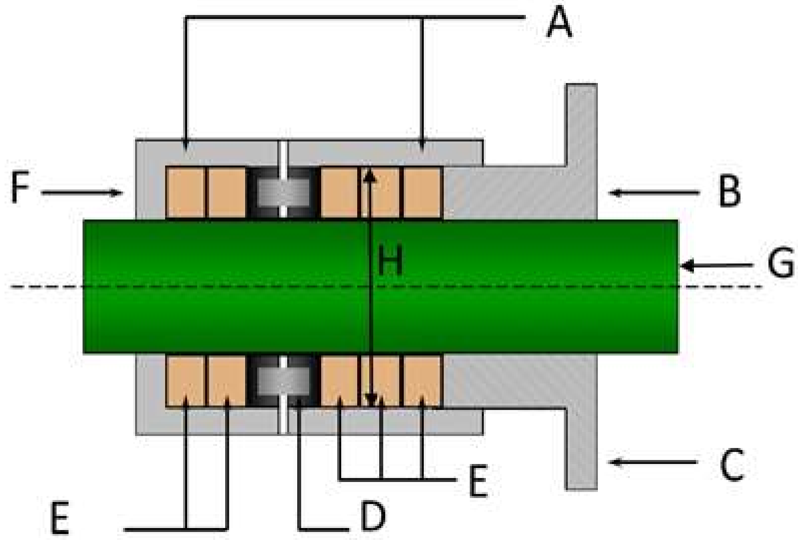


Figure 51. General Stuffing Box Arrangement

A: Stuffing Box Area
B: Gland
C: Gland Stud Bolts and Nuts
D: Lantern ring
E: Packing
F: Throat
G: Shaft or Sleeve
H: Bore

The pressure distribution upon the packing within the stuffing box is affected by both mechanical and fluid/medium pressures. The mechanical pressures consist of the gland follower pressure applied axially to the packing rings, which, in reaction, expands the cross-section radially and generates pressure against the bore and the shaft. The internal pressure from the processed medium is sealed ideally due to the radial reaction pressure (see Figures 48, 49, 50 and 52).

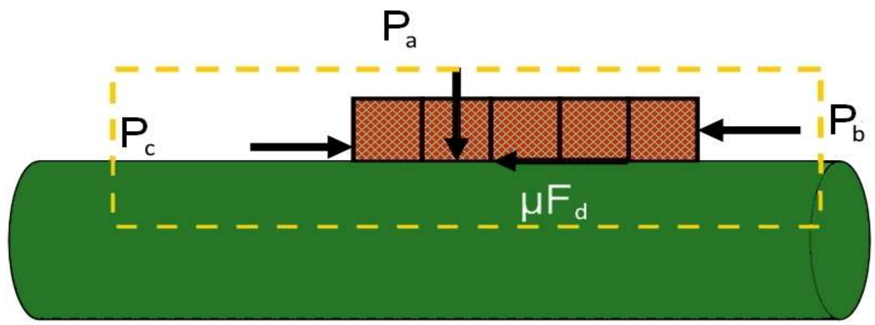


Figure 52. Stuffing Box Design and Pressure Distribution

P_a: Radial/Normal Pressure
P_b: Gland Pressure
P_c: Fluid Pressure
μF_d: Axial Pressure

However, the applied mechanical pressure does not evenly distribute pressure radially among each packing ring due to axial friction. The highest mechanical compression and strongest seal is in the outer two packing rings nearest the gland (see Figure 48 on page 67). The compression and sealing strength decreases in the rings nearest the throat; however, these packing rings at the throat do protect the outer sealing rings from the effect of other system conditions and mechanical deficiencies.

The stuffing box pressure (SBP) for end suction centrifugal pumps can be determined indirectly by an approximation formula: SBP = PS + 25%(TDH) where PS is the Pump Suction and TDH is the Total Dynamic Head.

Some of these system conditions that effect the seal are the processed fluid/medium pressures of the system, fluctuation in flush pressure (see *Flush Water* in the *Technical Reference*), or chemical degradation and/or abrasive wear from the processed fluid. Some of the mechanical deficiencies that effect the seal are shaft run-out, gland misalignment, or lack of concentricity between the shaft and bore. System conditions and mechanical deficiencies must be considered in determining the most successful sealing method. For example, fluid pressures of the system are used to calculate the pressure within the stuffing box. On end suction pumps, the stuffing box pressure (SBP) can be determined indirectly by an approximation formula:

$$SBP = PS + [25\% \, (TDH)] \qquad \{3\}$$

(PS is the Pump Suction Pressure, and TDH is the Total Dynamic Head).

Other types of pumps, where this formula may not be valid, are the following:

- On end suction pumps, where there are balance holes in the impeller, the stuffing box pressure is close to the suction pressure.
- On split case pumps with double suction, the stuffing box pressure is suction pressure.

- On multi-stage split case pumps, one stuffing box will likely be at suction pressure while the other might be at discharge pressure of the first stage.
- On other multi-stage pumps, there can be balance lines to equalize the pressure of both stuffing boxes. Quite often there are pressure break-down devices (e.g. balancing drums, close clearance bushings) with lines going back to suction pressure. In these cases, the stuffing box pressure will remain close to the suction pressure.
- On vertical pumps, the stuffing box pressure will typically be at discharge pressure, unless a pressure breakdown system is in place. It must be noted that with use and eventually wear, the pressure break-down devices effectiveness can decrease, and let the pressure in the stuffing box increase. What may be considered a packing problem could turn out to be a pump problem.

Refer to the next technical sections for a discussion of other variables used in determining the best sealing method.

GUIDELINES FOR PUMP STUFFING BOX DIMENSIONS

Refer to the following dimensions for typical stuffing box design. The following standards provide recommendations for pump stuffing box design: ANSI B73, and ISO 3069. Refer to the section *Standards, Regulations, and Environmental Legislation* for descriptions and sources

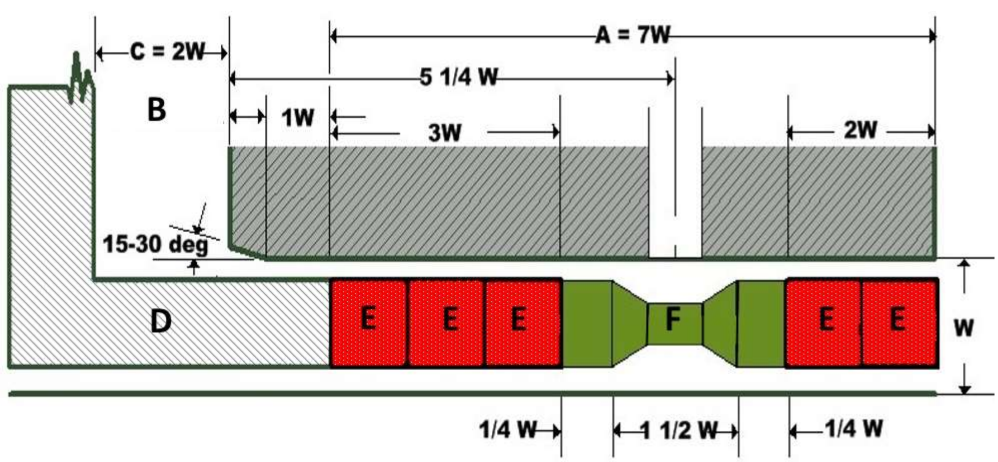


Figure 53 Stuffing Box Dimensions

B: Chamfer
D: Gland Follower
E: Packing
F: Lantern Ring
W: See tables 7 and 8

TABLE 7.
Range for Outer Dimension of Shaft (Metric).*

Range for Outer Dimension (OD) of Shaft	W
16 mm < Shaft OD ≤ 29 mm	8 mm
29 mm < Shaft OD ≤ 48 mm	10 mm
48 mm < Shaft OD ≤ 75 mm	13 mm
75 mm < Shaft OD ≤ 120 mm	16 mm
120 mm < Shaft OD ≤ 300 mm	19 mm

TABLE 8.
Range for Outer Dimension of Shaft (Imperial).*

Range for Outer Dimension (OD) of Shaft	W
5/8" < Shaft OD ≤ 1-1/8"	5/16"
1-1/8" < Shaft OD ≤ 1-7/8"	3/8"
1-7/8" < Shaft OD ≤ 3"	½"
3" < Shaft OD ≤ 4-3/4"	5/8"
4-3/4" < Shaft OD ≤ 12"	3/4"

*These dimensions are guidelines. Contact the packing manufacturer for packing space requirements.

Refer to the figure 53 for the following dimensions:

ROTATING SHAFTS

Dimension A, shown above, is the total depth of packing including lantern ring. A standard depth of 7W or 7 times the packing cross section has been established when a lantern ring is used. A depth dimension of 5W is used where lantern ring is omitted.

LANTERN RING POSITION

It should be noted that the Figure 53 shows the dimensions of 2W on the pressure side of the lantern ring and 3W on the gland end of the stuffing box. While this is a common practice, it should be noted that 3W on the pressure side and 2W on the gland end of the stuffing box can also be used. Consult the packing manufacturer of your choice for the proper setup to best service your application. Figures 54 through 57 show typical methods for the use of compression packings in pumps and the use of lantern rings when external means of lubrication are needed.

GLAND TAKE-UP

The gland take-up or gland follower length (Dimension C) should be limited to 2W or 2 cross sections of packing. This is to compensate for those packings which will have the largest volume loss. Additional gland take-up is not recommended in order to prevent galling of the shafts. This means that complete take-up will take place before equipment is damaged; therefore, packing replacement would be indicated. This is based on the theory that most damage is done during the late running of packing life.

LANTERN RING

The suggested depth or length of lantern ring, also known as the seal cage, is set at 2W.

CHAMFER DEPTH

To contribute to easy entrance of packing into the stuffing box, the chamfer depth should be a standard machined dimension for the given chamfer angle.

CHAMFER ANGLE

Wedging or guiding action is best between 15 and 30 degrees.

GLAND ENTRANCE

It is recommended that a minimum of 1W be maintained to minimize the probability of gland cocking and allow for general variations of packings, such as molded or soft packings.

SIZE LIMITATION

In designing equipment with shaft diameters below 16 mm (5/8”), consult with the individual packing manufacturer regarding packing space required (W).

CLEARANCE

Clearances should be accepted machining practices, taking into consideration thermal expansion and contraction of metals.

FINISHES

Finishes of rotating elements in contact with packing should be the best economically possible, bearing in mind that the finer or smoother the finish, the longer the packing life expectancy. For valves, check to ensure that all dimensional and surface smoothness measurements for the stem and stuffing box are within specification. These include: maximum total stem dimensional tolerances (bilateral or unilateral) and stem O.D. circularity, taper, and straightness requirements. The stem surfaces that contact the packing should be free of scratches, pits, or voids deeper than 0.05 mm (0.002 inches). Generally, the stem finishes should be 0.80 Ra micrometers (32 Ra microinches) or smoother. The stuffing box surface finish should be 3.2 Ra micrometers (125

Ra microinches) or smoother. The bore should meet squareness to the bonnet gasket surface perpendicularity tolerance. The bore also should meet circularity, taper, and straightness requirements and the bore and bonnet stem hole shall be concentric within an acceptable positional tolerance. The packing chamber bore also must be free of scratches, pits, or voids deeper than 0.015 mm (0.006 inches). The packing gland also should meet dimensional tolerances. Contact a packing manufacturer for specific application recommendations.

PRESSURES

The standard dimensions given in this section are intended for use up to approximately 103 bars (1500 psi).

PERFORMANCE

Performance at various high speeds (m/sec or FPM) is a function of the material used rather than the stuffing box dimensions. These high-speed recommendations are not considered here. Consideration of high-speed problems should be referred to individual packing manufacturers.

ENVIRONMENTAL CONTROLS

FLUSH WATER

Proper use of flush water in a pump packing installation is vital to the sealing success. Refer to the FSA website for topics on pump packing installation techniques. Following are techniques for successful use of flush systems [7]. See Figure 54 for one example of a lantern ring flush arrangement. Flush water is used to prevent or minimize packing deterioration caused by the pumping medium, such as solids from slurries, and to cool the packing and sleeve from heat caused by medium and/or friction.

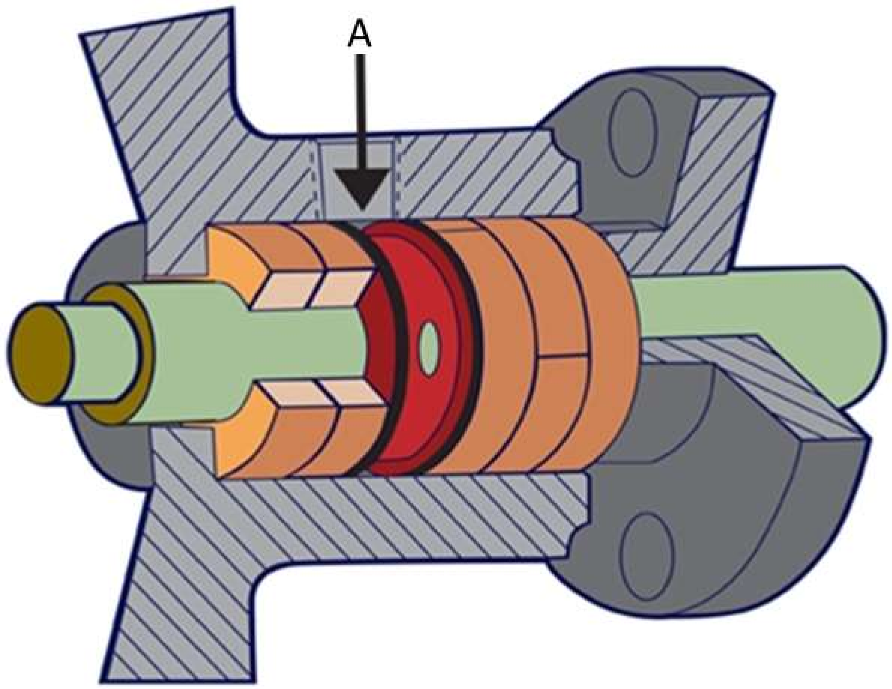


Figure 54 Option for Placement of a Lantern Ring for Flush

A: Lantern Ring

Flush pressure is generally 1 bar (14.5 psi) over the stuffing box pressure.

Excessive flush pressure may cause greater friction wear on packing or unwanted dilution of pumping medium.

The flush pressure is generally 1 bar (14.5 psi) over the stuffing box pressure, thus keeping the pumping medium out of the stuffing box and away from the packing. When head pressure varies, a higher flush pressure than 1 bar (14.5 psi) may be used to compensate for any maximum head pressure; however, the higher the flush port is pressurized, the greater the packing is compressed. This causes greater friction wear between the packing, shaft, and stuffing box, lessening the packing life.

Excessive flush pressure may also cause unwanted dilution of the pumping medium, which is costly to remove.

The following problems can arise with flush systems: (1) Bottom packing rings in the stuffing box must leak to allow flow of the flush, but if the bottom rings are incorrectly installed to seal, the flow of flush into the system will be hindered; (2) The lantern ring can move, allowing a packing ring to block the flush port and causing the flush to flow along the outside diameter of the stuffing box; (3) The flush water is contaminated and causes deterioration in the packing.

To avoid these problems, follow installation procedures from the packing manufacturer, perform regular maintenance of pumps with flush, and, in cases of contaminated flush, consider not using a flush system. The regular maintenance program can consist of the following inspection:

(a) Is the flush clean?
(b) Is the flush pressure monitored?
(c) Is the flush pressure constant or fluctuating?
(d) What is the flush pressure relative to the stuffing box pressure?
(e) Does the sealed medium contain solids?
(f) Does the pump need a flushing system?

Lantern Rings

A lantern ring is used to supply or extract different media to or from the stuffing box, Figure 55. It has a number of holes and is located under a bore in the stuffing box housing for external injection or extraction of media. It can be made from metals like stainless steel, carbon steel or bronze or from plastic materials like PTFE, PTFE/Carbon, PE and others.

Figure 55 Lantern Ring

Often the lantern ring is used to supply a water flush for cooling the stuffing box or to apply grease for additional lubrication. But depending on the application and type of media the location of the lantern ring and its function in the stuffing box can vary. In Figure 56 different examples are shown.

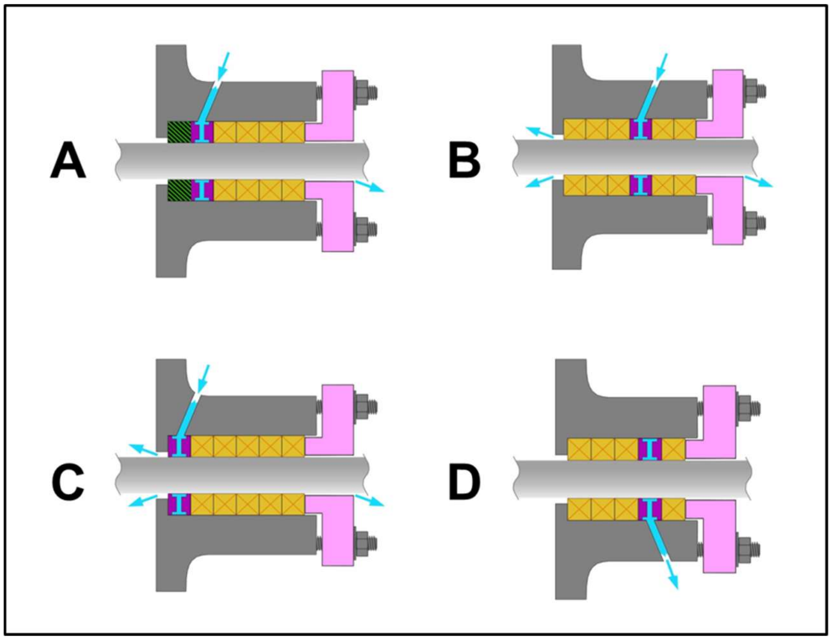


Figure 56. Lantern Ring Arrangements

In the case of hard and abrasive media like slurry or river water in example A, a spacer ring can be installed at the bottom of the housing to reduce the clearances and to prevent larger solids from entering the stuffing box. Then the lantern ring is placed directly behind the spacer and flush water can be applied as a barrier fluid.

Example B shows the configuration for crystallizing media such as sugar, paints or plastics. Here the first three packing rings seal against the media and the flushing medium provides a barrier against the crystallizing fluid. The two packing rings on the gland side act as a secondary seal to minimize leakage from the flushing medium.

In the arrangement in example C the lantern ring is placed directly at the bottom of the stuffing box to flush with an inert gas which acts as a barrier against potentially explosive or toxic media. The following packing rings act as a safety seal.

In example D the lantern ring is used for leakage extraction in case of special or expensive media which can be re-directed into the production process.

There are also arrangements with two lantern rings in the stuffing box. For example, in high speed rotary pumps one lantern ring can be used for the supply of cooling water and the other one to extract the flush water again, Figure 57. But in this case the stuffing box length has to be fairly long.

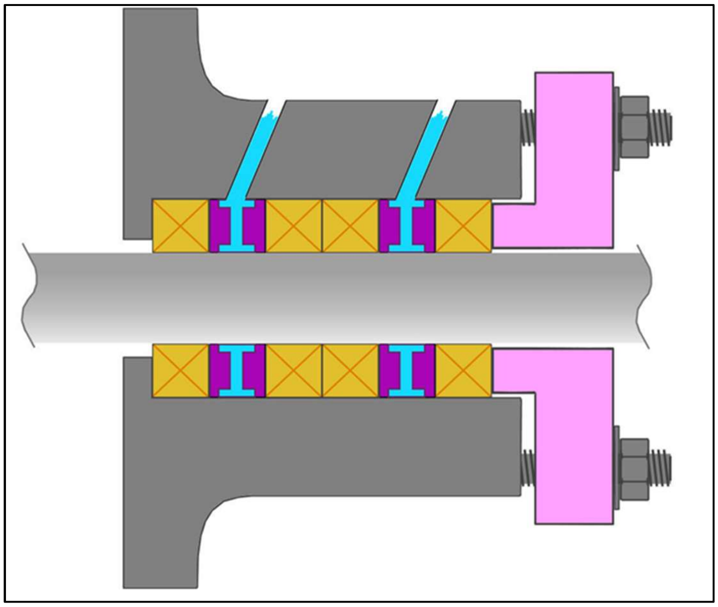


Figure 57 Stuffing Box with Two Lantern Rings

Sealing Rotating Shafts Mechanical Seals or Compression Packing?

Sealing rotating shafts are most often accomplished by selecting one of two methods; Mechanical Seal or Compression Packing. Selection is determined by reviewing the applications technical, environmental, and commercial considerations. Both sealing methods have strengths and weaknesses depending on the application and objectives of the process owner. The summary below is intended as a general overview only as each subject touched can be covered in much greater detail. The reader should consult industry experts on mechanical seals and/or compression packings if specific detailed information is required.

Most often mechanical seals are selected when it is critical to have as close to zero leakage as possible. Examples include but are not limited too; Toxic chemicals, flammable liquids, hazardous substances and other applications where it is critical to eliminate gland leakage. Compression Packings on the other hand are selected when the above is not present and operational reliability, simplicity of installation and maintenance is critical. These include services where mechanical seals frequently have problems such as liquids with solids present (such as Mining processes, Pulp & Paper, Waste Water, Power Generation & Metals processing as a few examples). The reasons for this will be evident with the strengths and weaknesses of each technology listed below.

Strengths of using Mechanical Seals

- Virtually a zero leakage device (i.e. no gland leakage to environment)
- No shaft/sleeve wear
- Capable of higher operational pressures and shaft speeds than compression packings
- No periodic maintenance required if installed properly

Strengths of using Compression Packing

- Low capital costs
- Higher reliability when fluids contain solids
- Better tolerance of shaft deflection and movement conditions which occur when cavitation, vibration or process upsets occur
- Able to handle large axial shaft motion due to differential thermal expansion of shafts and housings
- Failure mode is most often not catastrophic but more gradual resulting in increasing leakage and inability to control gland leakage over time (note: catastrophic failures do occur when/if packing overheats, or gland load is too high)
- Simple to install & operate does not require close tolerances to operate effectively.

Weaknesses of Mechanical Seals

- Requires “clean” flush fluid to lubricate seal faces does not tolerate process fluids with solids present as well as compression packing

- Sensitive to shaft deflection, axial movement & vibration caused by cavitation, process upsets and/or old worn equipment
- Sensitive to flush water pressure fluctuations, sudden drop in flush pressure can cause seal to fail.
- Require tight tolerances of seal faces, surface finish and tolerance of shaft/sleeve (+0 to -.002 inch and <= 32 rms)
- Except for split mechanical seals, the equipment must be disassembled for installation

Weaknesses of Compression Packings

- Some leakage at gland is needed for proper lubrication of packing shaft/sleeve interface removes heat and lubricates
- Wear to shaft/sleeve occurs due to friction
- Requires periodic adjustments to maintain load and lower leakage rate
- Limitations on shaft speed and operating pressures
- Dependent on user technical skills for installation and maintenance

In summary neither Mechanical Seals or Compression Packings are the best option for all services. Each have a place in the Industry depending on specific needs of the respective operating companies and processes. Further when both can meet the technical criteria the selection is often determined by economic, environmental and/or operating companies experience and preferences.

VALVE STEM FRICTION THEORY

Whether rotating or reciprocating, the moving stem in a valve experiences friction due to the normal or reaction pressure of the compression packing against the stem. Although this normal pressure or tightening of the packing radially against the stem is necessary to prevent leakage of the processing fluid, the friction, in turn, may cause wear in the stem, wear in the packing, extrusion of the packing, and/or increased actuator torque, all leading to increased costs.

To prevent costly friction, provided below are two suggestions gathered from the Electric Power Research Institute (EPRI) and Best Available Techniques (BAT) research.

Please refer to these research documents to consider further important details. Contact a packing manufacturer for suggestions on specific applications. It is suggested by one research document that using three to five packing rings along with spacer bushings can be more effective in deep valve stuffing boxes.

1) "Reduce stuffing box depth and replace all unused or unnecessary lantern rings using spacers or bushings. Leave room for only five packing rings (three die formed graphite rings with a top and bottom braided end ring)," as stated in the EPRI Report regarding ineffectiveness of deep stuffing boxes [5].

2) "One alternative consists of sets which are made of rings of different densities, with the density used depending upon the position the ring in the set," as stated in the BAT guidance notes [4].

MECHANICAL PROPERTIES OF PACKINGS

PRESSURE DISTRIBUTION IN THE STUFFING BOX

The principle construction of a stuffing box is seen in Figure 49. By tightening the gland bolts, pressure is induced in the packing set through axial compression. The packing will not transmit the pressure with equal intensity in all directions; however, part of the compressive force acts upon the shaft/ spindle, thus providing sealing pressure while another part is passed on from one ring to the next as so-called axial thrust. Refer to Reference [6] for the theory and equations given below.

Theory is provided for reference only. Contact a packing manufacturer for application recommendations.

The portion of pressure which produces the sealing effect on the shaft depends on certain properties of a packing material and construction and is expressed by the lateral deformation factor K.

$$K = \text{Radial Pressure } P_{rad} / \text{ Axial Pressure } P_{ax} \qquad \{4\}$$

The packing will not transmit the pressure with equal intensity in all directions.

The coefficients of friction between the packing and stuffing box walls ($\mu 1$) as well as packing and shaft ($\mu 2$) are also important influencing factors. To determine the relationship between the load at the top of the stuffing box and at the bottom, Thomson [6] developed the following formula for non-actuated spindles:

$P_{axb} = P_{axg} * e^{-(\mu 1+\mu 2)*K*L/B}$ (N/mm² or lbf/in²) {5}
P_{axb} = Axial pressure (bottom side) (N/mm² or lbf/in²)
P_{axg} = Axial pressure (gland side) (N/mm² or lbf/in²)
K = Lateral deformation factor
$\mu 1$ = Friction coefficient (packing/shaft)
$\mu 2$ = Friction coefficient (packing/housing)
B = Width of packing (mm or inches)
L = Length of packing set (mm or inches)

The actual difference between the two coefficients of friction $\mu 1$ and $\mu 2$ is so slight, however, that in most cases the two values may be safely substituted by 2 * μ.

By combining equations {4} and {5}, the radial pressure P_{radb} exerted by the packing ring at the bottom of the stuffing box can be calculated:

$P_{radb} = P_{axg} * K * e^{-2*\mu*K*L/B}$ (N/mm² or lbf/in²) {6}

A high number of packing rings does not improve performance of the sealing set due to high radial pressure losses in a long stuffing box.

To ensure effective sealing at the bottom of the stuffing box, the radial pressure exerted by the bottom ring must be greater than the media pressure. The most effective distribution of pressure can be assumed if both the specific coefficient of friction and the K-factor are as low as possible. The effects of the friction and the K-factor can be seen in the radial pressure distribution in Figures 48 and 49. This shows also that a high number of packing rings does not improve the performance of the sealing set due to the high radial pressure losses in a long stuffing box.

Strictly speaking, the observations on pressure gradients only hold for semi-static cases. With the movement of the shaft in axial direction, the pressure on the inner diameter of the packing becomes more complex and it is difficult to give a concise statement. The theory above however is based on the assumption that the packing material is homogeneous and absolutely plastic and is thus limited in its accuracy. The other assumption made is that both the lateral deformation factor K and the coefficient of friction μ are not depending on the axial stress. As experiments have shown this is not the case, but for a simple stress estimation, the above formula is sufficient.

STATIC AND SEMI-STATIC APPLICATIONS

Further descriptions of how a stuffing box works require us to differentiate between static and dynamic use of packings. Very small relative movements of the components are characteristic of seals under static or semi-static load. A certain degree of elasticity, low leakage, and low friction, especially in valves, are the principal properties which seals of this category are expected to show.

When a packing ring is compressed, it will be subjected to both plastic and elastic deformation depending on the circumstances. In exclusively static sealing applications, such as housing covers flanges, etc., the seal is required to give an elastic reaction to adapt itself to the dimensional changes of the seal cavity resulting from temperature and stress variations. Reliable seals should neither extrude at elevated temperatures nor release volatile constituents.

So, expanded graphite based materials are especially used at high temperatures in static applications due to their volumetric stability and elasticity. Seals for the use in valves have to meet further requirements such as good resistance to abrasion as a result of spindle movements and low friction which should remain as constant a level as possible.

FRICTION

It is desirable to obtain effective sealing with as little tightening of the gland as possible because friction on the stem will increase in proportion to compression of the packing set by the gland. From the integral of equation {7}, the following formula is derived by which – taking into account the contact surface area – the frictional force F_f can be determined:

$F_f = d * \pi * B/ 2 * P_{axg} * (1-e^{-2\mu*K*L/B})$ (N or lbf) {7}

d = diameter of the contact surface (mm or inches)

By moving the spindle back and forth several times after the packing has been installed, the distribution of axial and radial forces is improved. This improved frictional force is reflected in an adjustment of formula {7}, namely:

$F_r = d * \pi * B * P_{axg} * (1-e^{-\mu*K*L/B})$ (N or lbf) {8}

When lubricants are used, the actual frictional forces occurring during initial run-in are smaller than those for calculated dry friction.

If additional lubricants or packings containing a special lubricant for smooth initial running are used, the actual frictional forces occurring during the running-in period are smaller than those calculated on the basis of the coefficient for dry friction. It is not until these lubricants have been destroyed through thermal impact during pump service that measured friction is approximately equal to calculated friction.

Discrepancies between calculated and measured friction forces are also found if extremely long stuffing boxes are employed. In that case, actual deformation of the lower rings is less than assumed. The effective sealing length is shorter than the length of the packing.

LEAKAGE RATES

Often the permissible leakage rate for static seals is not precisely specified or only a limit is given which is not to be exceeded, irrespective of packing size, pressure difference, and medium. Actual leakage rates can be anticipated only if other specific characteristics of the packing apart from the factors mentioned above are known. By performing numerous experiments and tests, specific seal values could be determined independent of media and gland pressure. A leakage rate at room temperature can be calculated by using the following empirical formula:

$Q = (k_f * A * \Delta p) / (\eta * L)$ (mm³/s or in³/s) {9}

k_f = Specific seal value (mm^2 or in^2)
Δp = Pressure difference (N/mm^2 or lbf/in^2)
A = Surface area of packing ring (mm^2 or in^2)
η = Dynamic viscosity (N*s/mm^2 or lbf*s/in^2)
L = Packing set length (mm or in)

DYNAMIC APPLICATIONS

A packing which is to operate under dynamic conditions resembles in many ways a sliding bearing. In contrast to static or semi-static seals in valves, the most important objective is to prevent frictional heat. The energy converted into frictional heat while adjacent parts move relative to each other depends on:

1. Frictional force generated by gland pressure
2. Coefficients of friction of packing and shaft
3. Shaft speed
4. Viscosity of the medium

Gland pressure is chosen as a function of medium pressure. As a rule, it should amount to between 1.5 and 2 times the pressure of the medium. Higher gland pressures are only tolerated by packings on shafts with a very low rotational speed.

For the user of the packing, gland pressure is the only way of controlling leakage and frictional heat to a certain degree. But as the operation of the stuffing box is affected by a variety of factors occurring simultaneously, the user will often find it difficult to determine the proper relation between leakage and frictional heat.

FRICTION

The states of friction, manifesting themselves between packing and shaft, vary over a wide range. There is, for instance, dry friction, which is associated with non-greased packings, where there is no or only a discontinuous lubricating film between packing and stem surface, as in valve applications.

The second state would be mixed friction where lubricated packings are used with a continuous lubricating film but with incidental point contacts between packing and shaft, like in the running-in phase of pumps or in slow running equipment like agitators with little or no leakage. The third state is fluid friction where a hydrodynamic lubricating film is formed with no contact between packing and shaft, like in pump applications with higher shaft speed.

An outward sign that the initial run-in period is complete is when there is a permanently small amount of leakage at constant temperature.

For pump packings, the process of running-in is particularly important. Upon installation of the packing, the state of friction will be often in the mixed type. However, if a state of fluid friction can be attained, the stuffing box will work better. During the running-in period, friction may lead to an accumulation of heat that causes the expansion of the shaft and packing to such a degree that sealing pressure will increase substantially, causing an even faster generation of frictional heat. The only way to protect the packing from burning and the shaft from getting stuck is to switch off the machine immediately.

Typical pump packings are provided with a running-in aid on the basis of a lubricant. This oil will provide an initial lubricating film, which reduces friction to a minimum. Moreover, the running-in aid will encourage the development of a gap as a result of a slight decrease in the packing volume when the impregnation substance is secreted with rising temperatures.

As soon as the lubricating film, produced by the lubricant, has been entirely substituted by a hydrodynamic lubricating film, developed by the medium, the running-in period is considered to be over. A permanently small amount of leakage at constant temperature is the outward sign that this stage has been reached.

LEAKAGE RATES

When the packing is run-in, the leakage rate is defined as the amount of the medium leaking out through the gap, which is required to allow the formation of a hydrodynamic lubricating film. The following formula will determine the leakage rate:

$Q = (2.5 * \Delta p * \pi * d * h^3 * S) / (12 * \eta * L)$ (mm^3/s or in^3/s) {10}
Δp = Pressure difference (N/mm^2 or lbf/in^2)
d = Shaft diameter (mm or inches)
h = Gap between shaft and packing (µm, µin)
η = Dynamic viscosity ($N*s/mm^2$ or $lbf*s/in^2$)
L = Length of packing set (mm or inches)
S = Surface speed factor with S = RPM/1200

Since the packing is deformed less and less from the top to bottom according to decreasing pressure, it is rather difficult to determine the width of the gap. The width depends on a number of factors other than the gland pressure.
These are the following:

- Stuffing box dimensions

- Shaft revolutions
- Dynamic viscosity of the medium
- Shaft eccentricity
- Elastic modulus of the packing
- Coefficients of expansion and thermal conduction of the packing and shaft

A value of h = 5 – 10 μm (200 - 400 μin) is assumed for the gap. This is dependent on the surface roughness of the shaft sleeve. With a sleeve in good condition the lower value should be used. The least possible width value for the gap is equivalent to the surface roughness of the sleeve. A gap which is almost identical to the surface roughness of the sleeve is produced as a result of attempts to reduce the leakage as much as possible. This can lead to accelerated wear of the packing.

This formula tends to give values of what is to be expected with high performance packing material. A practical guide for aqueous liquids would be to use 10 drops per minute per inch of shaft diameter. (There are approximately 8 to 10 drops in 1 ml). Note that leakage on the outside of the packing can be as much or more than the leakage from the shaft as a result of the condition of the stuffing box bore and depending on how well the rings were cut and meet on their outside diameter.

PUMP PACKING POWER CONSUMPTION

It has generally been assumed that pump packing friction and resulting power consumption is significant. In particular, it has been assumed to be significantly more than the power consumption of mechanical seals under similar pressure, size and speed conditions. An exhaustive study and testing program commissioned by the FSA, the ESA and the CETIM test center were conducted to verify this assumption, and it has proven that this was not accurate.

The traditional theoretical power consumption of compression packings was given as:

$P = Pp \times RPM \times D \times \mu \times Ap \times F$ {11}

Where
P: Power (Horsepower or KW depending on units used)
Pp: is the sealed pressure
RPM: rotational speed
D: Shaft diameter
μ: Coefficient of friction between the packing and the shaft
Ap: Packing contact area
F: Factor depending on units used

This formula gives power consumption estimates that were one to two orders of magnitude higher than what was experimentally measured.
Torque, (and the resulting power consumption at a given speed), is a function of the type of packing used, the leakage rate allowed and the shaft speed and size. Based on extensive testing a new formula for torque is given as:

$T = Pp * K * R * \mu * Ap * S * S_p * F / L$ (Nm/ft.lb) {12}

T: Torque
Pp: Sealed pressure
K: Pressure drop factor
R: Shaft radius
μ: Coefficient of friction between the packing and the shaft
Ap: Packing contact area
S: Size factor
S_p: Speed factor
L: Leakage factor
F: Factor depending on units used

The packing types are divided in three classes based on packing type and leakage rates. The most common are as follows:

Class 1, PTFE, ePTFE/Graphite
Class 2, Aramid, Novoloid, Carbon/Graphite
Class 3, Natural (cellulosic) fibers, acrylic.

The leakage factors L, used in the formula are:

Class 1, L = 2.5

Class 2, L = 10
Class 3, L = 15

The coefficient of friction, μ follows the classes except for class 2.
Class 1, PTFE and ePTFE/Graphite, μ = .03
Class 2, μ = .06, but for carbon/graphite μ = .25
Class 3, μ = .2.

The speed factor, S_p, follows the Stribeck curve with 1 for 3000 or 3600 RPM, .75 for 1500 or 1750 RPM, .6 for 750 or 875 RPM and .8 for 500 to 600 RPM.

A pressure drop factor, K, of .2 applied to the sealed pressure for all classes.

The size factor, S, is a simple ratio of actual shaft size to base testing shaft size of 50 mm or 2”.

As an example, the torque for a 70mm shaft size with five rings of Aramid packing of 13 mm cross section and a process pressure of 5 bar running at 1500RPM is as follows:

5 (pressure) x 100000 (bar to N/m2) x .2 (pressure drop factor) x 70 (Shaft Dia / 2000 moment arm radius and mm to m) x .06 (coef friction) x 70 (packing Shaft Dia) x π/1000 (mm to m) x 13 (cross section) /1000(mm to m) x 5 (#of rings, area in contact with shaft) x 1.4 (ratio of shaft size to base 50mm size) x .75 (speed factor)/ 10 (leakage factor based on leakage class)
Or
5 x 100000 x .2 x 70/2000 x .06 x 70 x π/1000 x 13/1000 x 5 x 1.4 x .75 /10 = .315 Nm

DETERMINATION OF VALVE STUFFING BOX DIMENSIONS

Static and semi-static applications

Valve packings are supposed to compensate for dimensional changes caused by thermal expansion. The movement of the spindle relative to the packing causes additional wear which the packing should also be able to compensate for over a certain number of operating cycles through its natural elasticity.

Packing width

The packing width, (or cross section), B for valves should be as follows in relation to the stem outside diameter d:

For Imperial (inch) dimensions the following relationship can be used:

B = .155 * d + .125 rounded to the nearest 1/16"   {13}

For metric dimensions the following formula can be used:

$B = 1.2 \text{ to } 1.4 * d^{1/2}$ {14}

Notes:

1) *Use the size closest to commercially available cross section*
2) *A simple conversion of the Imperial dimension can also be used to determine the Metric cross section dimension*
3) *Does not necessarily apply to rotary or 1/4 turn valves*
4) *For stem sizes above 4 inch or 100 mm consult packing and valve manufacturer*

Length of packing sets

For valves, it is difficult to determine the appropriate length of the packing set. The maximum allowable length may be calculated using the resistance of the spindle to torsion or bending as a basis. The strength limits of the stem material are normally reached when the length of the stuffing box exceeds 3.7 times the spindle diameter.

If the main objective is to keep friction low, a short packing length is preferable. On the other hand, if long life and very low leakage rates are desired, longer packing sets are required. Experience has shown that the optimum length is between 4 and 7 rings or as in the following formula:

L = 4 to 7 x B   {15}

Dynamic applications

In view of particular processes affecting the stuffing box under dynamic loads, greater packing widths than those used in static applications should be used. Refer to the recommendations for pump packing cross sections given in Tables 7 and 8 on page 78.

LIVE LOADING

The term “Live Loading” refers to the use of a spring mechanism to maintain a load on the gland follower of a packed stuffing box over time and varying conditions. Springs are added between the gland nut and gland to maintain a load/force on the packing during extended operation periods (see Figure 58). The spring’s elastic energy maintains a load on the gland follower to compensate for stress relaxation in the packing.

Live loading is typically used in situations where a conventionally loaded packing set may undergo degradation of gland load due to "packing consolidation". This term is used to describe the gradual filling of internal voids and loss of material that occurs in a packing set over time. There are other mechanisms that result in stress relaxation in the packing such as friction wear, extrusion, loss of lubricant, and differential thermal expansion of materials in the equipment and the packing. Live loading is used to counteract the adverse effects of these processes.

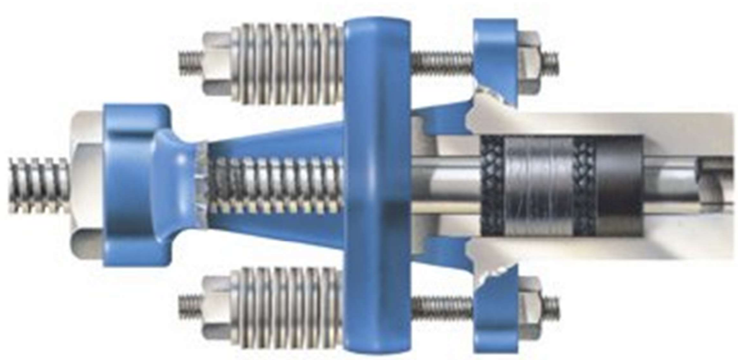


Figure 58 Live Loading of Gland

Live loading is used to counteract the adverse effects of stress relaxation in the packing.

The loss of gland load sometimes results in excessive leakage or frequent need for packing gland adjustments. Spring loading the gland follower is most commonly done with disk springs. Other types of springs, such as wave and coil springs, have also been used. The spring mechanism helps to extend the period of time before re-tightening is required.

Live loading can be advantageous in equipment or services which involve the following criteria:

- Services requiring controlled emission levels
- Need to reduce maintenance or re-torque
- Control valves, air or motor actuated valves
- Frequently stroked or actuated valves
- Valves subject to high degree of thermal cycling
- Valves with difficult access
- In equipment that has been determined to be "critical" to the operation of the facility

Some applications have been particularly well suited to the use of live loading:

- Emission control in chemical processing and refinery services
- Valve leakage control in inaccessible areas of nuclear power plants
- Service in critical system and functional valves, e.g., Main Stream Isolation Valve or control type valve
- Motor operated and air operated valves where response time to stroke is important

After it has been determined that live-loading is a viable option for a given service, a spring set design must be created (see Figure 59). In order for a design to be created, quite a bit of information must be gathered about the valve and the service. Typically, a "live-load data sheet" is provided and should be filled out for each set of equipment dimensions and system parameters. A spring set can then be designed.

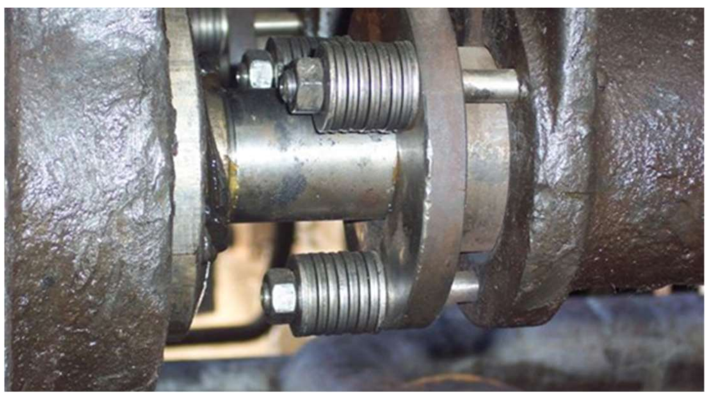


Figure 59. Live Loading a chiller

Along with the live-load hardware, the spring set designer will then provide information identifying the valve to which the spring set is associated. Information such as the gland nut torque, packing type, packing dimensions, and spring set dimensions will be included.
There are common packing/equipment arrangements that are particularly well suited to be used with live loading. The following is typical:

- End rings ensure compression of sealing rings and prevent extrusion
    - Braided and die-formed flexible graphite yarn with high strength, high temperature filament, encapsulated in Inconel® wire
    - Braided carbon/graphite yarn with high temperature lubricant
    - High density high purity die formed graphite
    - Two End or Anti-Extrusion Rings are used, one at each end of the set

- Middle Sealing Rings
    - High purity Flexible Graphite die-formed into rings
    - Passive inhibitor to prevent stem corrosion
    - Low to Medium density
    - Three sealing rings are used

- Carbon Bushing (Split)
    - Allows use of 5 rings in deeper stuffing box.

There are common misconceptions that live-loading will provide a *constant load* on the packing set, and that it will do so *indefinitely*. Neither is true. Live loading can significantly slow the effect of load loss as a result of packing consolidation and operation, but it does not eliminate it completely.

Live loading can be used in a variety of equipment such as mixers, agitators, centrifugal pumps, positive displacement pumps, valves, hydraulic cylinders, compressors, etc. It is applicable to many types of services like chemical processing, food processing, oil and refinery, petrochemical, power generation, pulp & paper, and wastewater treatment.

BEST PRACTICE FOR LIMITING EMISSIONS FOR VALVES, PUMPS, AND SPECIALTY EQUIPMENT

Documents are available for providing guidance in the best practice for sealing technology. These documents do not imply that these guidelines are complete or accurate for individual applications.

Contact the packing manufacturer for specific application recommendations.

Below are excerpts of guidelines on leakage and fugitive emissions that are provided in the Sealing Technology guidance notes.

BEST PRACTICE ON LEAKAGE

Containment of fugitive emissions that are caused by leaks in sealing elements requires consideration of possible causes. The guideline states, "It has been estimated that for every pump in an average plant, there will be 32 valves, 135 flanges, 1 safety valve, and 1.5 open ended lines. Hence, with so many potential sources, leakage losses are often hard to determine. They are also very dependent on the age of the equipment and how well the equipment is maintained. Some of the important causes of the leaking losses are ill-fitting internal or external sealing elements, installation or construction faults, wear and tear, equipment failure, pollution of the sealing element, and incorrect process conditions." [4]

Because compression packings assist pumps, valves, and other sealing equipment in emission control, … proper selection of the packing for each application is stressed.

"Leaking losses are generally higher from dynamic equipment (compared with static equipment) and from older equipment. Valves are considered to account for approximately 50-60% of fugitive emissions," says the guideline.

> **Note:** *Emissions:* In fluid sealing applications, the release of the processing medium into the atmosphere, also known as emissions, is most regulated. Emission levels of a large range of media types from water vapor to volatile organic compounds, naturally occurring or man-made, are continually measured. Due to growing concerns that the man-made emissions contribute to pollution of the environment locally and globally and to environmental concentrations above the level for the healthy functioning of Earth's processes, they are regulated.
>
> Emission regulations for each region are ever changing and are not specifically addressed in this handbook. However, because compression packings assist pumps, valves, and other sealing equipment in emission control, continual awareness of emission regulations is most important and proper selection of the packing for each application is stressed.

BEST PRACTICE FOR VALVES

"Valves with rising stems (gate and globe valves) are likely to leak more frequently than quarter turn type valves such as ball and plug valves," says the guideline. It also suggests for successful sealing with compression packings in valves the following factors:

- Careful selection of packing materials to meet the specific application requirements
- Complete consideration of surface speeds, pressures, temperatures, and medium being sealed
- Proper attention to good installation and break-in procedures

High standards of equipment maintenance

BEST PRACTICE for PUMPS

For reciprocating shafts, gland packings are usually used to minimize emissions. A combination of approaches is given in the guideline to reduce losses from large rotodynamic equipment. Some of these approaches are to use mechanical seals with bearing(s) integrated in their assembly to restrain equipment run-out; to use advanced compression packing designs from reputable manufacturers only; and to use live loading [4].

TROUBLESHOOTING FAILURES

Packings may fail for a variety of reasons. Besides improper installation, packing failures are often due to worn or faulty equipment, shaft misalignment, uneven take-up on the gland bolts, or misapplications of packing material to an application.

If you are having trouble, carefully remove and examine the old packing set. DO NOT THROW THE SET AWAY because it often gives clues as to the condition of the equipment and may be the means of solving the problem. The clues and possible causes in Table 9 were found by examining sets of packing which failed in service.

CAUTION: Follow safe handling procedures as given in Plant Safety Regulations and Material Safety Data Sheets.

TABLE 9.
TROUBLESHOOTING FAILURES.

CLUE	POSSIBLE CAUSE
Excessive reduction in cross-section of packing directly beneath the rod, shaft, or plunger.	Rod or plunger out of alignment, and in the case of the rod or shaft, the bearings may be badly worn, causing whipping of the shaft.
Excessive reduction in the thickness of the packing only in a localized area of the rod or shaft.	Rod or plunger out of alignment, and in the case of the rod or shaft, the bearings may be badly worn, causing whipping of the shaft.
A whole ring or part of a ring is missing from set.	Bottom of stuffing box badly worn, with packing being extruded into the system.
Wear on the outside of one or more rings.	Rings rotating with shaft or loose in the box. Packing cross section is too small.
Axial bulge in one or more rings.	Adjacent rings cut too short or too long, depending on the style of material used, causing packing under pressure to be deformed.
Packings show tendency to extrude between the rod or shaft and gland follower.	Excessive gland bolt pressure and/or too much clearance between rod or shaft and the gland follower.
Rings next to gland follower badly damaged, with bottom rings in fair condition.	Improper installation of packing and excessive gland bolt pressure used.
Wearing surface of rings dried and charred with rest of packings in good condition.	High temperatures and lack of adequate lubrication.
Innermost ring deteriorated.	Packing incompatible with fluid/medium handled.

TABLE 10
CAUSES AND SOLUTIONS

OBSERVATION	INSPECTION	CAUSE	SOLUTION
Steam or Smoke	Burned Throat Ring Burned Gland Ring	Overheated Fluid Over-tightening Friction	Cool System Change Packing Style Reinstall Train fitter/installer
Erratic Leakage Grit in Leakage Grit on Gland	Worn Throat Ring All Rings Worn	Abrasion	Check Flush Install Lantern Ring Change Packing Style
Steam or Smoke Poor Adjustment Erratic Leakage	Burned Gland Ring Rings Feathered Toward Lantern	Plugged Flush	Clean, Realign, Reinstall Lantern Ring
Excess Leakage Excess Take-up	Damaged Rings, esp. Throat Rings	Chemical Attack	Change Packing Style Add Lantern Ring
Noise Excess Heat Shaft Movement Difficult Take-up	Eccentric Wear Nibbled Rings	Mechanical Problems	Repair Equipment Change Packing Styles
Excess Take-up Uncontrollable Leakage	Extruded or Feathered Throat Rings	Excess Throat Clearance	Repair Throat Install Anti-Extrusion Rings

STANDARDS, REGULATIONS, AND ENVIRONMENTAL LEGISLATION

Standards and regulations are set by governments, corporations, and institutions to qualify properties, limitations, and performance of fluid sealing products to be used in a range of applications that affect personnel and the environment immediately and ultimately.
A summary of common standards and regulations is provided below. Refer to the FSA and ESA websites for current information. http://www.fluidsealing.com/pump-and-valve-packings/pump-and-valve-packings-publications/

API American Petroleum Institute

API 589 Fire Test for Evaluation of Valve Stem Packing (for Steel Gate Valves)
Evaluates and qualifies packings for fire service. Packing is installed in a gate valve used as the testing jig. This standard has been obsoleted.

API 600 Steel Valves – Flanged & Buttwelding Ends
The Main steel gate valve specification for the API focusing on valve design and construction.

API 602 Compact Steel Gate Valves – Flanged, Threaded and Welded
The standard for smaller forged steel gate valves.

API 603 - Corrosion-resistant, Bolted Bonnet Gate Valves-Flanged and Butt-welding Ends
Valve standard Covering design, material, dimensions, ratings, examination and inspection, and test requirements.

API 607 and ISO 10497 Fire Test for Soft-Seated Quarter-turn Valves
These are valve type tests for fire resistance. Packing and gasket seals are addressed. ISO 10497 was created from API 607.

API 608 Steel Ball Valves – Flanged and Buttwelding ends
The standard used for floating ball valves.

API 609 Butterfly Valves – lug type and wafer type
Specification for butterfly valves between ANSI B16 150-1500 class

API 622 Testing of Process Valve Packing for Fugitive Emissions
A packing test to qualify packing for VOC emissions in high temperature block valves.

API 623 - Steel Globe Valves-Flanged and Butt-welding Ends, Bolted Bonnets
Valve standard covering design, material, dimensions, ratings, examination and inspection, and test requirements.

API 624 - Type Testing of Rising Stem Valves Equipped with Graphite Packing for Fugitive Emissions
A valve type test for VOC emissions qualification based on API-622 qualified packing.

API 641 - Type Testing of Quarter-turn Valves for Fugitive Emissions, First Edition
A valve type test for VOC emissions qualification.

American Society of Mechanical Engineers

ASME B73.1 and ASME B73.2 Pump Dimensional Requirements and Design Features
ASME B73.1 for horizontal end suction pumps and ASME B73.2 for vertical in line centrifugal pumps both for chemical process include dimensional interchangeability requirements and design features to facilitate installation and maintenance.

ASTM Packing Material Standards

ASTM F 1277-02 Standard Test method for Determination of Leachable Chloride in Packing and Gasketing materials by Ion-Selective Electrode Technique
This test method provides the sample preparation and measurement of chloride ion leached from flexible graphite, asbestos, or paper-based packing, and gasketing materials

ASTM F 2087-01 Standard Specification for Packing, Fiberglass, Braided, Rope, and Wick
This specification covers the general requirements and test procedures for braided, rope, and wick fiberglass packing used for boiler, furnace, and other high temperature sealing services up to 538°C (1000°F).

ASTM F 2168-02 Standard Specification for Packing Material, Graphitic, Corrugated Ribbon or Textured Tape, and Die-Formed Ring
This specification covers various types, classes, and grades of flexible graphite material in which valve media temperatures are limited to a maximum of 1050°F (966°C).

ASTM F 2191-02 Standard Specification for Packing Material, Graphitic, or Carbon Braided Yarn
This specification covers staple or continuous filament carbon/graphite yarn valve stem compression packing, suitable for use as end-rings on packing systems for valves. Intended services include steam, hydrocarbons, water, and non-oxidizing chemicals.

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British Standards

BS 4371 Specification for fibrous gland packings – Obsolete
Under ESA PD 002 revision. This standard details gland packings, yarns, lubricants, dimensions and tolerances, and tests to be applied for lubricant content and impurities for use in pumps, valves, and other equipment.

International Society of Automation
(Formerly Instrumentation, Systems, Automation Society)

ISA-SP-93 Standard Method for the Evaluation of External Leakage of Manual and Automated On-Off Valves

The standard specifies a list of requirements for the method of testing fugitive emission from valves and seals.

Fluid Controls Institute

ANSI/FCI 91-1 Standard for Qualification of Control Valve Stem Seals to Meet EPA Emission Guidelines for Volatile Organic Compounds.

This standard classifies control valve stem seals by ability to withstand mechanical and thermal cycles at a specified set of temperature and pressure conditions. Bellows, diaphragms, and tubular seals are not covered by this standard.

International Standards Organization

ISO 15848-1 Classification system and qualification procedures for type testing of valves

This standard gives testing procedures that classify the performance of fully assembled valves in fugitive emissions service.

ISO 15848-2 Production acceptance test of valves

The aim of this standard is to establish standard practice for the evaluation of production valves whose design has been successfully type-tested according to ISO 15848-1.

ISO 3069 Dimensions of cavities

ISO 3069 relates to end suction pumps, including those conforming to ISO 2858; it establishes dimensions of cavities for packing.

Manufacturers Standardization Society of the Valve and Fittings Industry

MSS SP-120 Flexible graphite packing system for rising stem steel valves (design requirements)

This Standard provides packing material and dimensional requirements for valve packing, packing chamber, packing gland, packing washer, bonnet, and stem as they relate to the total packing assembly.

MSS SP-121 Qualification testing methods for stem packing for rising stem steel valves

Withdrawn.

Association of German Engineers (Verein Deutscher Ingenieure)

VDI 2440- VDI 2440 is a German guideline created by experts from industry, universities and public bodies for emission control in mineral oil refineries. The sources of gaseous emissions are stated and the relevant best available technologies (BAT) for emission reduction are described. Also, specific leakage rates for the emissions from valves and flanges are defined as well as the specific testing methods. These leakage rates have been implemented into the German emission directive “TA-Luft”.

FSA/ESA

Test Procedure for Packings for Rotary Applications

The ESA and FSA have combined to develop ESA Publication N°· PD001/2007- Specification for a Test Procedure for Packings for Rotary Applications. This specification gives details of a test procedure for packings to be used to seal the stuffing boxes of rotary equipment such as centrifugal pumps, mixers, agitators etc. The provisions of this standard have been adopted by **DIN EN 16752 - Centrifugal pumps- Test procedure for seal packings**

TA-LUFT

The TA-Luft (Technische Anleitung zur Reinhaltung der Luft) [9] legislation was first introduced in 1984. A new revision was passed in 2002 to meet modern developments and to incorporate the IPPC requirements. This piece of legislation regulates all emissions from industry in Germany. It is valid both for existing and new plants. Existing plants had to be brought to the same standard as new plants by 2007. The latest revision of TA-Luft gives specific emission levels for valves according to the German VDI-guideline 2440 - Emission reduction in oil refineries. Currently for shut-off and control valves, metallic bellows (with a special safety packing) or other equivalent sealing elements have to be used and the following parameters have to be accomplished:

1. The design of the sealing element (e.g. stuffing box with packings) should be lifetime suitable for a proper function under realistic service conditions.
2. The specific leakage rate should be less than 10^{-4} mbar*l/s/m for temperatures below 250 °C (482°F) or smaller than 10^{-2} mbar*l/s/m for temperatures higher than 250 °C (482°F).

Independent testing bodies approve valves, individual packing materials, or specialised sets for the use under specific parameter conditions.

CLEAN AIR ACT

The Clean Air Act is a federal law of the United States. The goal of the law is to:

- reduce outdoor, or ambient, concentrations of air pollutants that cause smog, haze, acid rain, and other problems;

- reduce emissions of toxic air pollutants that are known to, or are suspected of, causing cancer or other serious health effects; and
- phase out production and use of chemicals that destroy stratospheric ozone.

Under the Clean Air Act, the EPA sets limits on certain air pollutants which can be in the air anywhere in the United States. This helps to ensure basic health and environmental protection from air pollution for all citizens. The Clean Air Act also gives the EPA the authority to limit emissions of air pollutants coming from sources like chemical plants, utilities, and steel mills. Individual states, districts, or local authorities may have stronger air pollution laws, but they may not have weaker pollution limits than those set by EPA.

For more comprehensive information on the Clean Air Act visit the EPA's website at: www.epa.gov/air/caa/index.html

INDUSTRIAL EMISSIONS

(Source: European Commission)

To control industrial emissions, the EU has developed a general framework based on integrated permitting. This means the permits must take account of a plant's complete environmental performance to avoid pollution being shifted from one medium - such as air, water and land - to another. Priority should be given to preventing pollution by intervening at source and ensuring prudent use and management of natural resources.

ACT

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

KEY POINTS

- The legislation covers the following industrial activities: energy, metal production and processing, minerals, chemicals, waste management and other sectors such as pulp and paper production, slaughterhouses and the intensive rearing of poultry and pigs.

- All installations covered by the directive must prevent and reduce pollution by applying the best available techniques* (BATs), efficient energy use, waste prevention and management and measures to prevent accidents and limit their consequences.

- The installations can only operate if in possession of a permit and have to comply with the conditions set therein.

- The BAT conclusions adopted by the Commission are the reference for setting the permit conditions. Emission limit values must be set at a level that ensures pollutant emissions do not exceed the levels associated with the use of BATs. However, they may be exceptions, if it is proven that this would lead to disproportionate costs compared to environmental benefits.

- Competent authorities need to conduct regular inspections of the installations.
- The public must be given an early opportunity to participate in the permitting process.

For more information, see the European Commission's webpage on industrial emissions.

KEY TERM

* **Best available techniques (BATs)**: the most effective techniques for preventing or reducing emissions that are technically feasible and economically viable within the sector.

REFERENCES

Act	Entry into force	Deadline for transposition in the Member States	Official Journal
Directive 2010/75/EU	6.1.2011	7.1.2013	OJ L 334, 17.12.2010, pp. 17-119

A correction to Directive 2010/75/EU has been incorporated into the original text. This consolidated version is intended purely as a documentation tool.

Compression Packing
Glossary of Terms

Active Inhibitor A galvanic corrosion inhibitor added to packing that acts as a sacrificial anode, corroding in preference to the surrounding metal. Zinc dust is added to the surface of some packing materials as an active inhibitor. See also “Galvanic Corrosion”. Compare with “Passive Inhibitor”.

Actuate To cause movement of a valve stem either by raising, lowering, or turning it.

Actuator A device attached to a valve, that causes the stem to move. An actuator may use a motor or pneumatics to accomplish this purpose. A valve fitted with an actuator is usually referred to as a control valve.

Ambient Temperature The temperature of the surrounding environment.

AOV An abbreviation for “Air Operated Valve”, a pneumatically actuated valve.

Anti-Extrusion Ring A ring of packing used at one or both ends of a packing set to prevent extrusion of the packing into clearances. (Also called a bull ring) See also “End Ring” and “Junk Ring”

Aramid A family of polymers that are used in a fiberous form as packing materials. Aramid fibers are known for their excellent abrasion resistance, high tensile strength, and characteristic deep yellow color.

Axial In the direction of a shaft or stem axis.

Bevel Cut An angled cut at the seam (or joint) of a packing ring.

Blocking Agent A coating applied to braided packing whose main purpose is to fill the area between the fibers, blocking the passage of media through the body of the braid and improving its sealing characteristics. This may be a grease, an oil, or a PTFE dispersion.

Bolt Torque The moment or turning effort (expressed as Ft-Lb or N-m) required to turn the nuts on a gland follower. The load that a gland follower exerts on a valve packing set can be expressed indirectly in terms of a specific bolt torque.

Body See “Valve Body”

Bonnet See “Valve Bonnet”.

Bore Diameter The dimension of the annular space that packing is inserted into. Also called the stuffing box bore.

Braid Yarns or filaments woven together to form a hollow or solid structure. A braid may have a round (Braid over Braid), square (Simple Crossing Pattern), or Lattice (Interlocking) weave pattern. Braids may have round, square, or rectangular cross-sectional shape.

Braid Over Braid A type of braiding construction in which a series of round braided layers are braided over top of one another.

Braid Over Core A type of braiding construction in which yarns are round braided over a core. Cores may be composed of an elastomer or plastic compound extrusion, a braid, or other materials.

Braider (braiding machine) A mechanical device that interweaves yarns to produce a braid.

Break-In Lubricant A lubricant added to the surface of braided packing. Break-In Lubricants are used to protect the packing from charring during the initial start-up of rotating equipment (such as pumps and mixers).

Bulk Dipping An economical method for applying coating to a packing material by simply dipping a container of braid into a tank containing the coating material.

Bull Ring See "Anti-Extrusion Ring."

Bushing A metallic or carbon ring used to take up excess space in a stuffing box.

Butt Cut A straight cut at the seam (or joint) of a packing ring.

Calender 1) A step in the production of braided packing where a braided material is fed through rollers to compress it to finished size. 2) A machine that is used to calender a braid.

Carbonization The thermal reduction of an organic material to carbon.

Cavitation A term used to describe an undesirable phenomenon which sometimes occurs in pumps. A situation may be created in the area of the impeller, where small vapor bubbles are created. As these vapor bubbles move along the vanes of the impeller to an area of higher pressure, they rapidly collapse. This collapse or "implosion" is so rapid that it may be heard as a rumbling noise or felt as vibration. The forces generated as a result of cavitation may damage the impeller or even the packing set.

Centrifugal Pump A type of pump that relies on the rotation of an impeller to generate pressure and cause flow.

Cold Flow Permanent and continual deformation of a material that occurs as a result of prolonged compression or extension at or near room temperature.

Compressed Height The height of a packing ring or packing set after it has been compressed in the stuffing box.

Compression Packing A deformable material used to prevent or restrict the passage of a pressurized fluid between surfaces that move in relation to each other.

Corrosion Inhibitor An ingredient added to packing that decreases or eliminates the possibility of galvanic corrosion in the stuffing box. Corrosion inhibitors may be classified as either Passive or Active.

Cross-Section 1) The view of a part as if it were cut to show its internal structure. 2) The distance between the shaft or stem surface and the bore of a stuffing box. See also "Packing Space". 3) The shape of a packing ring at a cut. A packing ring might be described as having a square, rectangular, or round cross-section.

Cup and Cone The shape of certain types of die-formed ring sets. In a cup and cone set the rings have conical surfaces that nest into one another.

Cut Ring Set A braided material cut into individual rings for a specific stem/stuffing box size and packaged as a set.

Cycle and Adjust Procedure A procedure used to consolidate a packing set after it has been installed in a stuffing box. This procedure helps to reduce the amount of gland load relaxation that occurs after the valve has been put into service.

Density The ratio of the mass of a body to its volume. (Expressed as gm/cc or lb/ft3) It is common for die-formed flexible graphite rings to be produced to a specific density.

Die Forming A manufacturing process in which braid or flexible graphite is compressed in a mold to form a ring.

Discharge Pressure The fluid pressure measured on the discharge (or outlet) side of the pump where the fluid exits the volute.

Disc Spring See "Spring Washer"

Eccentricity The distance that the central axis of a shaft is offset from the center of the stuffing box through which it passes.

Emissions Release of gaseous or liquid pollutants from leaks in equipment such as flanges, pumps, or valves. This is frequently used in reference to volatile organic compounds monitored by government agencies. It is usually expressed in parts per million volumetric (ppmv, or simply ppm).

End Ring A ring used at the top or bottom of a packing set, usually functioning as a wiper ring and/or an anti-extrusion ring. See also "Anti-Extrusion Ring", "Junk Ring", and "Wiper Ring".

EPA An abbreviation for "Environmental Protection Agency", the US government agency responsible for enforcing the regulations imposed by the Clean Air Act Amendment.

EPA Method 21 A method established by the EPA for performing emissions measurements on equipment such as valves, pumps, and flanges.

ePTFE Expanded Polytetrafluoroethylene A polymer having excellent chemical resistance and more tensile strength than PTFE.

ePTFE/Graphite (Expanded Polytetrafluoroethylene/Graphite) A polymer having excellent chemical resistance and more tensile strength than PTFE. The combination of the ePTFE and graphite creates a packing with a low coefficient of friction, good dimensional stability, and high resistance to chemicals with a pH range of 0-14.

Extrusion The distortion, under pressure, of a portion of a packing into the clearances between mating metal parts.

Finish See "Surface Finish"

Flow Meter A device used to measure the flow rate of a fluid through a pipe. In packing applications, a flow meter may be used to measure the amount of flushing fluid that is entering and/or leaving the stuffing box.

Flush Port A hole in the side of a stuffing box through which a cleansing, cooling, or lubricating fluid is injected.

Flushing Fluid A clean liquid (usually water) which is injected through a flush port to remove solid particles from the stuffing box area to minimize abrasive wear. A flushing fluid might also be used to cool the packing in a high temperature application or to keep air from being drawn into a pump in a suction application.

Follower See "Gland Follower"

FPM An abbreviation for "Feet Per Minute", a measure of the surface speed of a rotating shaft.

Friction Factor An empirically determined factor used to estimate the frictional force generated by the packing on a valve stem. It is important to note that this is not the same as "Coefficient of Friction".

Fugitive Emissions Transient, random, intermittent gaseous or liquid leakage from equipment. See also "Emissions".

Galvanic Corrosion An electro-chemical reaction that may occur between a metal and a more chemically noble material such as another metal, carbon, or graphite. When both materials are immersed in an electrically conductive media called an electrolyte, a galvanic cell is formed and current flows between the two materials. The least noble material (called the anode) will corrode while the more noble material (the cathode) will not.

Gasket Spacer A gasket material cut to fit in a stuffing box between braided packing rings. Gasket spacers may be used to provide protection against abrasive particles, to increase the pressure resistance of some packing sets, or to reduce the flow of fluid through the body of the braid.

Gland See “Packing Gland”.

Gland Follower A part that protrudes into a stuffing box to compress a packing set or packing ring.

Gland Force The amount of force applied to the packing set usually expressed as Lbs or N.

Gland Load The amount of load applied to a packing set that may be expressed in terms of force (N,Lbs.) or pressure (kPa,psi) so the units of measure must be specified.

Gland Pressure The amount of pressure applied to a compression packing set by the gland follower. Usually expressed in kPa or psi.

Gland Stud A threaded rod or eye bolt extending from the equipment housing that the gland follower is tightened against to compress a packing set. See also “Valve Body.”

Hand Wheel A wheel located at the top of a manually operated valve that is used to actuate the valve stem.

Head The pressure at any point in a fluid can be thought of as being caused by a vertical column of the liquid that, due to its weight, exerts pressure at the point in question. The height of this column is called the “static head” (or sometimes simply “head”) and is expressed in terms of feet or meters of liquid.

ID An abbreviation for “Inside Diameter”. Used when denoting the inside dimension of a packing set. (usually equal to the stem or shaft diameter)

Impeller The part of a centrifugal pump that, when rotated, will generate pressure and cause flow.

Interbraid A braided construction in which the yarn is braided in an interlocking weave, making it very difficult to unravel. This construction yields a dense, tightly woven packing material having a square cross-section.

Junk Ring A ring added to the bottom of a packing set as either an anti-extrusion ring or as a bushing. See also “Anti-extrusion Ring”, “Junk Ring”, and “Wiper Ring”.

Lantern Ring A ring added to a packing set to assist in the introduction of a flush fluid to the stuffing box. This ring is usually constructed of plastic or metal.

Leak/Leakage An escape of gases or liquids from equipment.

Leak/Leakage Rate The quantity of fluid passing though (or around) a packing in a given period of time.

Live Loading The use of a spring mechanism on packing gland bolts to maintain load .

Media The fluid that is being sealed.

Method 21 See "EPA Method 21"

MOV An abbreviation for "Motor Operated Valve", a motor actuated control valve.

MRO An abbreviation for "Maintenance and Repair Organization".

MSS An abbreviation for "Manufacturers Standardization Society of the Valves and Fittings Industry"

OD An abbreviation for "Outside Diameter". Used when denoting the outside dimension of a packing set (usually equal to the stuffing box bore).

OEM An abbreviation for "Original Equipment Manufacturer".

OVA An abbreviation for "Organic Vapor Analyzer", a device used to measure the concentration of volatile organic compounds (VOC's) in the vicinity of a stuffing box, flange, or any seal. An OVA is sometimes referred to as a "sniffer".

Oxidizer See "Strong Oxidizer".

Packing Gland The space into which a compression packing is inserted. Also known as a Stuffing Box.

Packing Groove A groove machined into a flange or joint to accommodate a packing ring.

Packing Hook (packing extractor) A tool, similar to a corkscrew, for removing packing from a stuffing box.

Packing Space The distance between the shaft or stem surface and the bore of a stuffing box. Packing space (x) can be calculated by the following equation: $x = (OD-ID) / 2$

Passive Inhibitor A type of galvanic corrosion inhibitor added to packing that acts as a protective coating to block the transfer of electrons and keep a galvanic reaction from occurring. Flexible graphite can be produced with phosphorus added as a passive corrosion inhibitor. See also "Galvanic Corrosion". Compare with "Active Inhibitor".

pH The measure of the strength of an acid or base. On the pH scale, a neutral solution (neither acidic or basic) has a pH of 7. Solutions with a pH below 7 are considered acidic; the smaller the pH value, the more acidic the solution. Solutions with a pH above 7 are considered basic.

Pitting Surface cavities that occur on a metal as a result of galvanic corrosion or mechanical erosion.

Plaited Braided

Plunger A cylindrically shaped part that has a uniform diameter and is used to transmit thrust (as in a hydraulic cylinder) or develop pressure and cause flow (as in a reciprocating pump).

Psi An abbreviation for "Pounds per Square Inch", a unit of pressure.

PTFE An abbreviation for Polytetrafluoroethylene, a polymer having excellent chemical resistance. PTFE dispersion is used as a coating for many styles of packing. Some packing styles are constructed of PTFE fibers.

Pulp In the papermaking industry, pulp is the primary raw material from which paper is made. It is a cellulose fiber product produced by the mechanical and/or chemical processing of wood.

Pump Shaft The metal rod connecting the impeller of a pump to the motor.

Purge Fluid A clean liquid (usually water) that is injected through a flush port to flush solid particles from the stuffing box area to minimize abrasive wear. See also "Flushing Fluid".

Purge Port A hole in the side of a stuffing box through which a flushing fluid is injected. See also "Flush Port".

Quarter Turn Valve A valve that will fully open or close with a 90-degree rotation of the stem.

Radial In the direction perpendicular to a shaft axis.

Radial Expansion The ability for a packing material to move in the radial direction of a stuffing box when it is compressed.

Reciprocating Motion of a shaft back and forth in the direction of its axis.

Reciprocating Pump A type of pump that relies on the reciprocating motion of a plunger, or series of plungers, to generate pressure and cause flow.

Regular Braid A type of braided construction that yields a soft, flexible packing material having a square cross-section. Also referred to as "Square Braid".

Rising Stem Valve A valve in which the movement of the stem is only reciprocating, with no rotation.

Rising / Rotating Stem Valve A valve in which the movement of the stem is both reciprocating and rotating at the same time, usually following a helical path.

Rotary The motion of a body turning on an axis.

Round Braid A braiding method that yields a hollow tube of yarn. See also "Braid Over Braid" and "Braid Over Core"

RPM An abbreviation for "Revolutions Per Minute", a measurement of the rotary speed of a rotating shaft.

Run Out A measurement of how far a shaft moves in the radial direction.

SCC See "Stress Corrosion Cracking".

Scoring Gouges on the surface of a shaft, stem, or bore due to mechanical wear.

Scarf Cut See "Bevel Cut"

Seal Cage See "Lantern Ring".

Shaft The metal rod connecting the impeller of a pump to the motor.

Single End Coating The process of applying a coating to the individual yarns (or "ends") of a packing before they are braided. This process results in a very thorough, uniform coating throughout the braid.

Skive Cut See "Bevel Cut"

Sleeve A metal cylinder that is placed over a pump shaft in the sealing area. In pumping applications, certain media and packing materials can cause abrasive wear on the rotating surface. A sleeve is a relatively inexpensive, replaceable component which protects the pump shaft from experiencing wear.

Slurry A fluid mixed with solid particles. When dealing with a packing application handling slurries, abrasion is a major concern. Steps must be taken to minimize abrasive wear of the packing materials.

Spool Packing Packing material that is braided and sold on a spool. (As opposed to cut ring sets or die-formed ring sets)

Spring Washer A conical disc washer used to live-load a packing gland.

Square Braid A type of braiding construction that yields a soft, flexible packing material having a square cross-section. Also referred to as "Regular Braid".

Stack Height 1) The combined height of all the rings of a packing set. 2) The combined height of all the components in a stack of spring washers used to live-load a packing set.

Stem The metal rod that connects the internal components of a valve to a handwheel, handle, or actuator.

Stock In the papermaking industry, stock is a wet pulp mixture at any point in the papermaking process.

Stress Corrosion Cracking Intergranular attack corrosion of stainless steels that occurs at the grain boundaries under tensile stress. Packing materials with low levels of leachable halides and sulfur compounds are specified to prevent this corrosion.

Strong Oxidizer A highly oxidizing chemical. In packing applications, strong oxidizers such as nitric and sulfuric acids cause the degradation of packing materials such as carbon, graphite and cellulosic fibers. PTFE packing materials are usually used in these applications due to their oxidation resistance.

Stuffing Box The space into which compression packing is inserted. Also known as a Packing Gland.

Suction Pressure The fluid pressure measured on the suction (or inlet) side of the pump where the fluid enters the volute.

Surface Finish A measure of the roughness of a surface. Usually expressed in micro-inches or micro-meters.

Surface Speed The linear speed of a point on the surface of a rotating shaft. Usually expressed in m/sec or FPM.

Texturization The processes of embossing a texture on the surface off flexible graphite. Texturization is applied to affect better adhesion between layers of the flexible graphite and prevent delamination of a die-formed ring.

Thermal Conductivity A measure of the rate at which a substance transfers thermal energy through itself. High thermal conductivity is an advantage in pump packing applications where it is important to transfer frictional heat away from the shaft/packing interface so that the packing does not burn.

Th**ermal Expansion** The increase in volume or length of a material that occurs as a result of a temperature increase.

Tinsel Fine slit widths of metallic foil. Die formed rings are made from tinsel and used as junk rings, bushings, and in some cases even as bearings. Tinsel can be made from aluminum , copper, or other malleable metals .

Torque Informal Definition: A measure of "twisting force". In packing applications, one might be concerned with the torque applied to the gland stud nut, or the torque required to overcome friction between the packing and the valve stem.

Uncompressed Height The height of a packing set or packing ring before being compressed in the stuffing box.

Valve Body A term used to describe the part of a two-piece valve that houses the internal workings of the valve. The flanges that attach the valve to a pipeline are also part of the body.

Valve Bonnet A term used to describe the part of a two-piece valve that attaches to the valve body. It houses the stuffing box and provides support to guide the valve stem.

Valve Stem See "Stem"

VOC An abbreviation for "Volatile Organic Compound"

VHAP An abbreviation for "Volatile Hazardous Air Pollutant".

Volute The internal area (housing) of a centrifugal pump where the fluid comes in contact with the impeller.

Whip Deflection of a shaft (usually on a mixer or a pump) due to a rotating mechanical load. A long shaft length that is not supported by bearings is more susceptible to whip than a short shaft or one that is supported tightly by bearings.

Wiper Ring A ring of braided packing, used in conjunction with flexible graphite rings to wipe a reciprocating valve stem clean of graphite particles and keep the graphite contained in the stuffing box.

Yield The length of a packing material of a specified weight (m/kg or ft/lb). The inverse of this value (kg/m or lb/ft) is also sometimes referred to as yield.

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