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A Guide to

Packing and Gaskets

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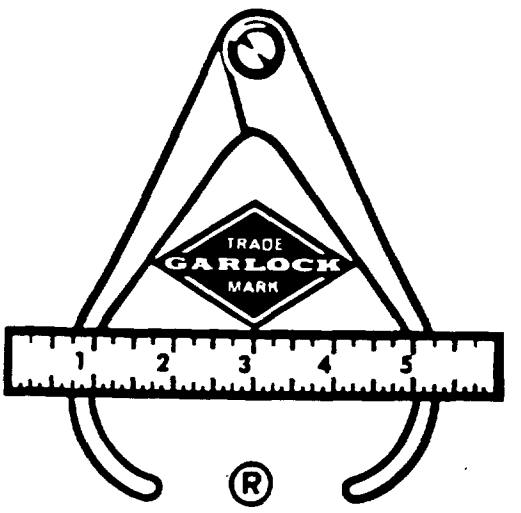


A Guide to Packing and Gaskets

A knowledge of their design, what materials they are made of, and how they should be istalled and maintained can enable maintenance engineers to extend their use by 50%, forestall emergency shutdowns, and reduce operating and maintenance costs.

ROBERT H. KOCH, *Garlock Inc.*

The chemical process industries handle a diversity of fluids, many of which are highly corrosive, at extremes of temperature and pressure. They therefore demand more from packing and gaskets than do other industries. What follows are the essentials of dynamic sealing (packing) and static sealing (gaskets) as they relate to chemical plants.

Dynamic Packing

Dynamic packings are used to seal moving parts, whether reciprocating, rotary or helical. Under vacuum or high pressure, and over a broad range of temperatures, these packings retain all types of fluids and exclude foreign materials.

Packing is made of five basic materials: fibers, metals, plastics, rubber and leather, which are combined with various impregnants and lubricants, depending on the application.

Packing throttles leakage between a moving and stationary part. It does not stop leaks. If it runs dry, the packing gland will overheat and wear, the packing will be destroyed, and the shaft will become scored. There must be only enough leakage to lubricate and cool the packing without serious loss of the fluid being sealed.

Asbestos is the most widely used fiber material because of its strength, temperature resistance and versatility. White asbestos, which is mixed with an organic fiber to facilitate weaving, is normally used for alkaline, neutral or weak acid solutions. Blue asbestos, usually without any other fiber, is used for strong mineral acids. Graphite fibers also have excellent chemical and temperature resistance.

Vegetable fibers (flax, ramie, jute and cotton) lose their heat resistance above 200 F., and are primarily cold water packings. An advantage of flax and ramie is that their long, strong fibers get stronger as they get wetter.

Synthetic fibers, such as rayon and nylon, are good for water service at temperatures below 250 F. Because of its low friction coefficient and almost total chemical reistance, TFE* fiber, which is good at temperatures up to 500 F., has a life span many times longer than that of other materials against highly corrosive fluids.

Compression metal packings are usually in foil form, although sometimes in braided and shredded forms. Lead, copper and aluminum are common metals for packings that serve as end-rings and as pressure or thermal barriers in high-pressure or high-temperature service.

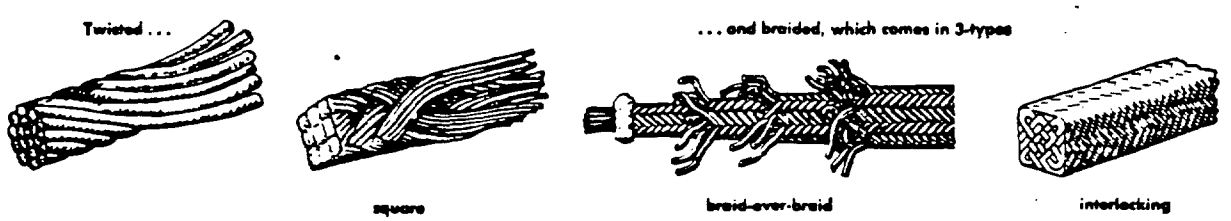
The most common plastics for packings are Kel-F† and TFE, both of which are highly resistant to chemical attack. When unplasticized, Kel-F is good for a temperature range of from −400 to +390 F., and for temperatures up to 300 F. when plasticized. Good within the range of −350 to +500 F., TFE has the additional virtue of being absolutely nonsticking.

Besides natural rubber, synthetics such as the following are among the more popular packing materials: synthesized natural and substitute natural elastomers, which have good rubberlike properties; buna-N and neoprene, which have excellent heat- and oil-resistant

* A tetrafluoroethylene resin, such as Teflon.

† The trademark for a line of fluorocarbon products that includes polymers of trifluorochloroethylene and certain copolymers which are available as resins, dispersions, gums, oils, waxes and greases and are characterized by high thermal stability and resistance to chemical corrosion.

Types of Packing



When choosing packing, first consider what material will contain the fluid, then what type suits the service—Fig. 1

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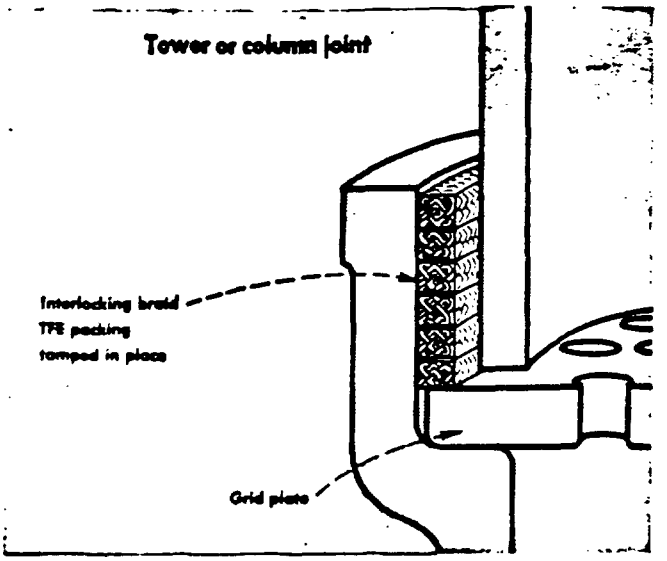
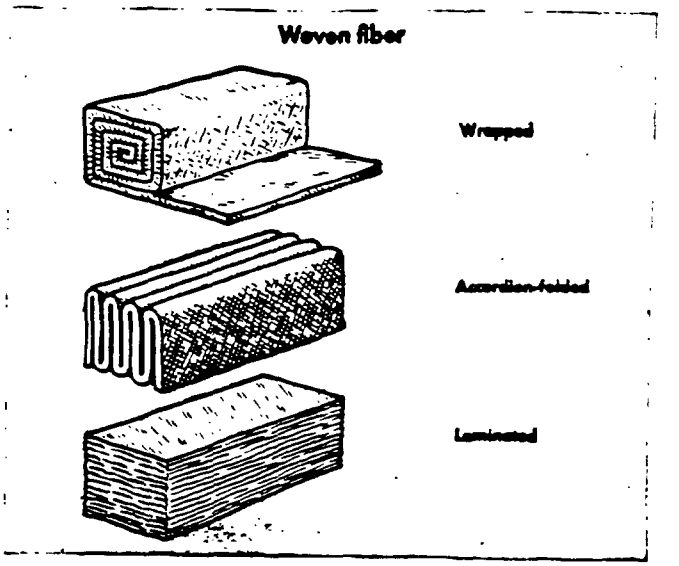


This packing need not be jammed to keep a seal—Fig. 2



Cloth may be reinforced with brass or Monel wire—Fig. 3

qualities; butyl, which is impermeable to gases; and silicone, which withstands temperatures from −100 to +500 F.

Leather packings have high tensile strength and can handle pressures up to 100,000 psi.

All of these packing materials—plastics, rubber, leather—are most commonly found in molded or machined V, U and O-rings.

Impregnants and lubricants are vital to packing, and constitute a good percentage by weight of some types of braided packing. Impregnants include tallow, lard oil, fish oil, soap, castor oil, paraffin, lubricating oil, silicones, fluorocarbons, graphite and mica. Which is selected depends on the packing application.

Packing constructed of fibrous materials is conventionally in twisted or braided form (Fig. 1). Twisted packing does not have the strength of braided packing, and is primarily suitable for valve stems; if sizes smaller than the standard are needed, it can be easily untwisted so that strands can be removed.

The three most common types of braided packing are square braid, braid-over-braid and interlocking braid (Fig. 1).

The loosely locked braids of the square braid are produced by one pass through the braiding machine. Its advantage—assuming thorough internal lubrication—is that its strands can adjust to uneven rod motion.

Braid-over-braid consists of a series of braided tubes, which are placed one over the other. It is a dense packing that serves well in stems under high pressure, if the stem or rod is in good condition, or where motion is relatively slow. Because it resists extrusion, it is useful in reciprocating service.

In interlocking braid, every braiding strand passes diagonally through the body of the packing. This type of braid combines flexibility and firmness in a completely unified structure, with each strand contributing to the packing's over-all strength. Unlike other types of braid, wear will not loosen its strand.

A new soft-yarn TFE interlocking braid packing, for example, has proved highly successful in the bell and spigot joints of high-silicon cast iron towers. It has been common practice to pack these joints with blue asbestos rope, which is covered with putty or porcelain to keep it from blowing out. This method has two disadvantages: (a) if the packing is jammed too tightly to obtain a seal, this brittle material is likely to be broken by thermal changes; (b) the asbestos rope loses its physical properties after extended exposure to the process materials, which results in leaks.

This specially impregnated interlocking-braid TFE packing (Fig. 2) is compressible enough to be tamped into place and to maintain a seal without being jammed in too tightly. It is sufficiently resilient to compensate readily for dimensional changes in equipment caused by temperature variations. And its resistance to corrosive chemicals ensures longer packing life.

Cloth woven from basic asbestos fibers may be reinforced with various kinds of wire, such as brass or Monel, or impregnated with rubber or other compounds, which act as a binder and reduce porosity. The cloth is either wrapped around itself, or accordion-folded, or laminated with rubber and cemented with a binder (Fig. 3). These types of construction make such packings highly suitable for reciprocating motions that are involved with higher pressures, slow speeds, or heavy-duty service. They are used infrequently as end-rings, together with another type of packing that seals, for very slow rotary service.

Metal packings are of spiral-wrapped, folded, crumpled or braided construction. They are lubricated between layers to form lubrication reservoirs, which simulate a lubricated metallic bearing while serving as a seal. Although generally used for higher speeds, they often prove to be the only possible packing for high-temperature applications. They may also serve as bull rings to prevent extrusion of other types of packing.

Shredded fibers (asbestos), plastics (TFE) and metals are combined with graphite and a binder to

make shredded packing, which is also called "plastic" packing, because of its softness and the ease with which it compresses. Shredded packing can be obtained in bulk, coils or die-formed rings. While it is excellent for sealing gases (because it permits little leakage), end-rings are necessary to prevent its extrusion.

There are four broad functional classes of dynamic seals: compression, automatic, floating and mechanical.

Compression Packing

Compression or jam-type packings are "soft packings" that are installed in the stuffing box and adjusted periodically by taking up a gland. Compression types include twisted, braided, laminated cloth, shredded and metal foils.

In a typical compression packing installation, the fluid is throttled to an average leakage rate of 10 or 12 drops per minute, which flow through the slight clearance between the moving shaft and the packing to act as a lubricant (Fig. 4A). The lubricant in the packing itself takes over during periods of dry operation, and acts as a safety valve if the packing is overtightened and the fluid flow is cut off.

The hazards of successive over-tightening of the gland are shown in Fig. 4. When over-tightening eliminates leakage, the packing runs dry on the shaft, which builds up friction heat. This heat will melt the lubricant in the packing and temporarily prevent the packing from burning up and the shaft or rod from scoring (Fig. 4B).

This lubricant loss reduces the packing's volume, and as leakage from the casing again resumes (Fig. 4C) further tightening may be necessary. If the gland is again tightened to eliminate all fluid leakage, the cycle is repeated until (Fig. 4D) there is no saturant left in the packing and its volume cannot be further reduced. The ultimate result is burned up packing and a scored shaft.

If packing were adjusted properly, its life could be more than doubled.

Impregnated packings cannot provide enough lubricant when high operating temperatures are involved or when conditions create high frictional heat. In such cases, external lubrication must be supplied through a lantern ring, which is usually located near the middle of the stuffing box.

Lanterns rings are the means by which a sealing liquid is injected into the packing at a pressure higher than that of the fluid being contained. They are also required for all packings for gases, which leak easily and are poor lubricants because of their low viscosity; for liquids of low viscosity or high volatility when under conditions of high speed or high pressure; for liquids containing large amounts of dissolved or suspended matter; and for fluids of any kind that are poisonous, corrosive, or too valuable to lose.

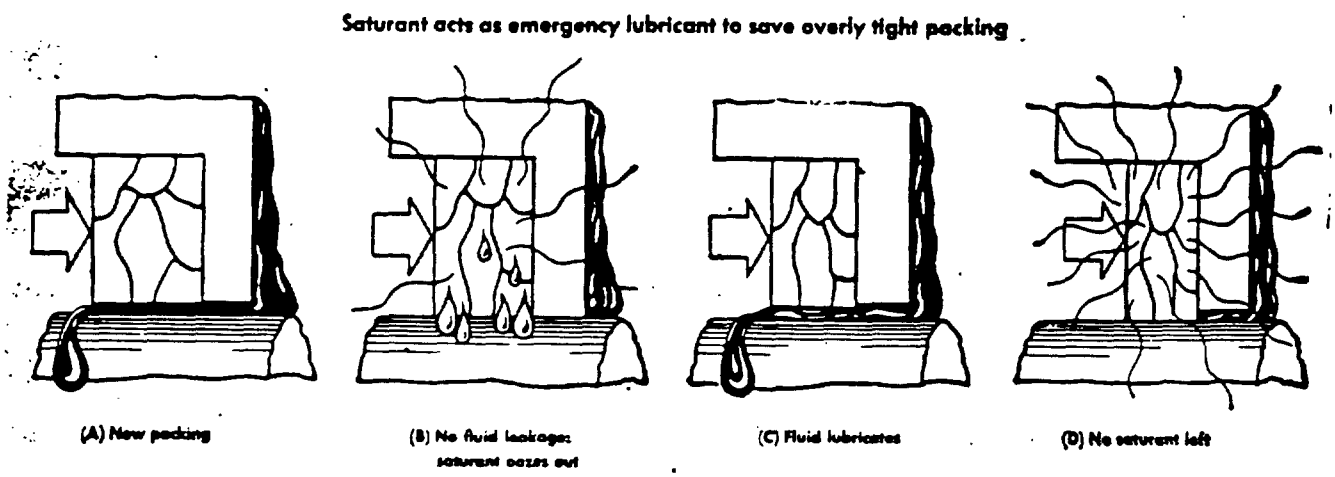
Automatic Packing

Automatic packing is so called because it responds automatically to fluid pressure to establish a seal. The flexible packing lips fluctuate with changing pressures—tightening with increasing pressures, yielding with diminishing pressures. They are ideally suited for reciprocating rods, pistons and rams.

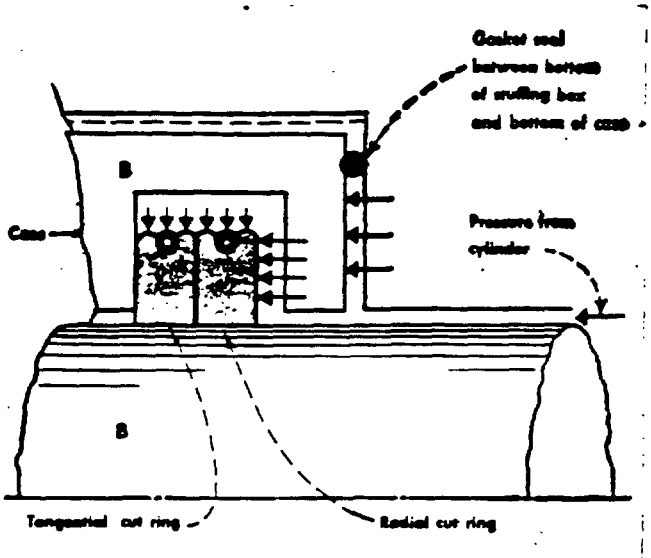
In this classification are V, U and O-rings, and flange and cup packings, which are generally supplied in molded or machined forms.

Because the open side of the V-rings should always face toward the pressure, the male adapter is put into the stuffing box first with its flat surface seated on the bottom of the box. If split, rather than endless, rings are used, the joints should be staggered just as in the case of soft compression packing. Here again, excessive gland pressure will drastically—and uneconomically—shorten the operating life of the packing.

For automatic valves, the new, combination, cotton duck and nitrile V-ring packing is recommended for



A 10 minute interval between each tightening of the packing gland would give the packing time to adjust itself—Fig. 4



Segmental rings are held about a shaft by springs—Fig. 5

oils, water, mild or dilute aqueous solutions, and water-glycol and emulsion-type fire-resistant hydraulic fluids.

For valves in more-severe chemical service, specially designed V-ring packings of TFE fluorocarbon resin with a hinge or flexible arch at the apex of the "V" provide the necessary flexibility, freedom from friction, excellent wear resistance, and positive sealing under varying pressures. These packings have several advantages over conventional TFE V-rings, including: a greater mass of TFE at the lips, which prevents "toe-in"; parallel sides that provide a tighter seal and longer wear; and a hinge that improves sealing effectiveness through a wider range of pressure changes.

Floating Packing

Like automatic packings, floating metal packings also depend on internal pressure to achieve and maintain a seal. As rod packings for gas or air that is compressed or expanded, they are designated floating types because their segmented rings float freely in their case and can move laterally with a shifting rod.

The segmented rings are held together by garter springs, which cause them to bear on the rod until the fluid pressure of the gas provides the seal. The annular surface of these rings is 10 micro-inches or less, and they are flat within light band readings. They are housed together in the grooves of a metal packing case, which is of either a split-case or an annular solid-cup design.

The sealing theory of floating packings is shown in Fig. 5. On the compression stroke, the gas or air is forced along the rod to the packing groove. This presses the packing rings tightly together and against the sealing face of the groove (BB). The rod packing consists of two single segmented rings: a radially cut ring on the pressure side is dowelled to a tangentially cut sealing ring.

The pressure passes along the radial cut, then envelops the outside of the rings, forcing them tighter to the rod. On the discharge stroke of the compressor, the pressure in the cylinder becomes less than the pressure in the packing case, which allows the air or gas to escape back into the cylinder. The ring segments are constructed so as to automatically close uniformly about the rod to compensate for wear.

Packing for different applications—Table I

Application	Recommended Packing
Dynamic service	
Water, oils, solvents and caustics	
Up to 1,200 ft./min. and to 500 F.	Long-fiber white asbestos yarn with TFE impregnant, interlocking braid.
Above 1,200 ft./min. (except for caustics)	Flexible metallic packing, pleated and spiral-wrapped aluminum foil, braided asbestos core or shredded copper foil
Acids and corrosive chemicals	
General service	African blue asbestos, lubricated and externally graphited, regular square braid.
High speed and to 500 F.	Special TFE fiber yarn, interlocking braid.
Valve stems, all services	
Non stainless steel valves	
Up to 500 F.	Long-fiber white asbestos yarn with TFE impregnant, interlocking braid.
500 to 1,000 F.	Braided wire-reinforced asbestos jacket over a core of asbestos-graphite blend with a corrosion inhibitor.
Stainless steel valves	
Up to 500 F.	TFE as V-rings, cup and cone; diagonal or flat washers.
500 to 1,000 F.	Same as for non stainless steel valves.

Mechanical Seals

Mechanical seals are designed for the precise sealing of rotary shafts at pressures up to 1,200 psi., temperatures of −60 to +500 F., and face velocities up to 5,000 ft./min., depending on their style and application.

Mechanical seals normally consist of a smooth rotating face that seals against a smooth stationary face that is at right angles to the shaft. Because sealing faces are lapped with precision, there is no need for breaking in, or periodic repacking or adjustment. Their spring-loaded and flexibly mounted design continually and automatically compensates for shaft runout, axial end-play, vibration and wear.

They are recommended when leakage must be extremely low, as when fluids are hazardous, corrosive or costly. They are problem solvers for high-speed, high-temperature or high-pressure applications.

Mechanical seals give a virtually leakless seal; con-

sequently, if one drips steadily, maintenance personnel should: (1) check the compression of the gland gasket, (2) look for deflected faces caused by improper gland bolting, (3) check for installation damage to shaft packing, or (4) check for excessive shaft vibration caused by misalignment, impeller imbalance, cavitation, or defective bearings.

The recommendations in Table I are only a general guide because requirements will vary with specific applications.

Static Sealing

Static seals—gaskets—perform a simple function, that of making a pressure-tight joint between two rigid elements, which are usually flanges.

There are three principal forces in a joint that affect the functioning of a gasket (Fig. 6):

Compressive Load—This load is the force that initially compresses the gasket; it is usually applied by bolting. It must be sufficient to squeeze the gasket into all the voids in the faces of the flanges—that is, the gasket must "flow" into all the ridges and grooves, and into all the surface imperfections of the joint's faces so that they will mate to achieve a tight seal that will have no paths for leaks. This compressive load must also offset the hydrostatic end-forces encountered so that there will be enough residual stress on the gasket to prevent leakage.

Hydrostatic End-Force—When internal pressure is applied to the assembly, the hydrostatic end-force tends to force the flanges apart and thus reduces the load on the gasket. The difference between the initially applied force and the hydrostatic end-force is the residual load on the gasket.

Internal Pressure—Pressure at the joint tends to bypass or blow out the gasket material. The strength of the gasket material and the residual load on the gasket must be sufficient to contain this pressure.

The ratio of residual load on the gasket area to the internal pressure is referred to as the "m" factor, which is a safety factor. For example, a minimum "m" factor of three is advised for spiral-wound gaskets.

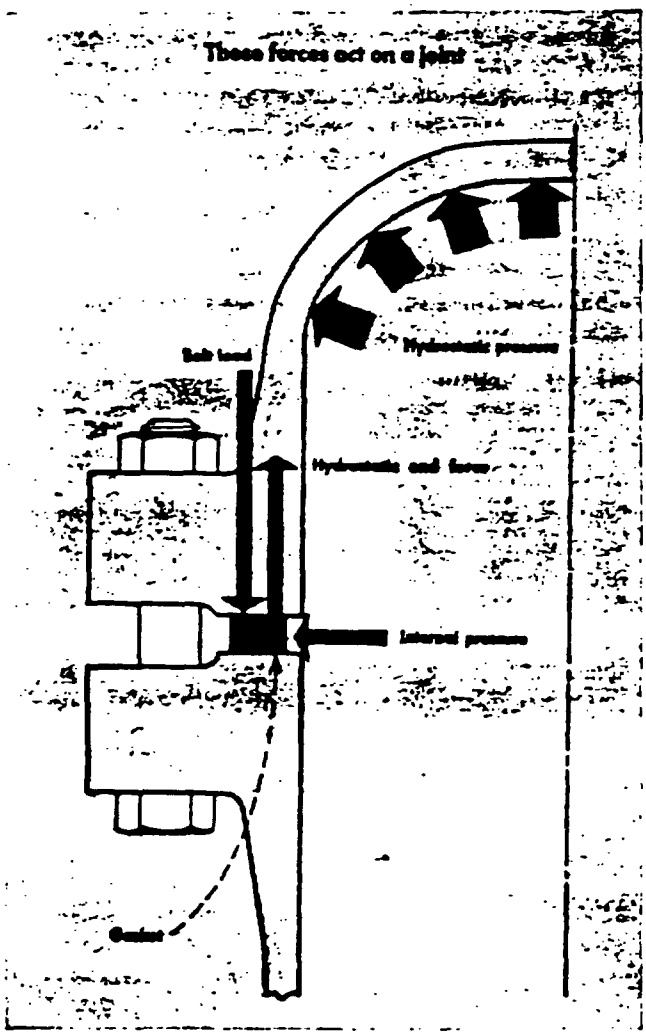
Typical temperature and pressure limitations for various gasket materials are given in Table II.

Rubber, both natural and synthetic, is used most widely against cool aqueous liquids and gases at relatively low pressures. The pressure range of rubber gaskets can be extended if they are reinforced with a fabric or wire insert, the resultant gasketing material being known as cloth-inserted sheet. At extreme temperatures, but at low pressures, such specialized synthetics as Viton or silicone may be used.

Vegetable fiber is a light-service, economical gasket material that is more suitable for fluids such as oils than for water or gases.

Homogeneous TFE offers the ultimate in chemical resistance, yielding only to molten alkali metals and certain fluorine compounds at elevated temperatures. Because it cold-flows readily, however, TFE gaskets should be kept as thin as possible or be confined.

Envelope gaskets of TFE provide a thin material with a variable core density and thickness to adjust for flange conditions and pressure requirements. They are ideal for glass or glass-lined piping and other requirements where a high degree of resiliency is re-



Gaskets must fill surface imperfections of flanges—Fig. 6

Typical limitations of gasketing materials—Table II

Gasketing Material	Maximum Temperature × Pressure	Maximum Temperature, F.
Rubber	15,000	225
Vegetable fiber	40,000	225
Cloth-inserted rubber	125,000	225
All TFE	150,000	500
Compressed asbestos	250,000	750
Spiral-wound stainless steel with:		
TFE	>250,000	500
Asbestos	>250,000	850 to 1,200*
Mg-Li ceramic	>250,000	1,200 to 1,900*

* Varies with alloys.



The number of metal plies per radial inch in a spiral-wound gasket largely determines its hardness—Fig. 7

quired because of flange waviness and low bolt loads, and will handle pressures up to 300 psi.

An etched TFE envelope is recommended for larger glass-lined equipment. Because etching increases the friction between the gasket and glass surfaces, this gasket is far less likely to be blown out.

Also, when this type of envelope is subjected to a vacuum, the tendency for it to be sucked into the vessel can be prevented by cementing the etched envelope to the filler.

Of the semimetallic gaskets, the most versatile and widely used is the spiral-wound gasket. Spiral-wound gaskets that are made from a continuous strip of preformed metal are wound spirally from the inside to the outside and have a soft filler, such as asbestos or TFE, between each ply. Variations in the number of metal plies, in the filler material and its thickness, and in the windup tension make spiral-wound gaskets applicable over a broad range of bolting conditions and sealing requirements.

The gasket on the left in Fig. 7, for example, has more metal plies per radial inch, and would be referred to as "hard," compared to the "soft" gasket on the right. Regular gaskets are made to compress a given amount in a standard ASA flange, and it is important that this conforms with the pressure rating of the flange. A 150-lb. gasket in a 900-lb. flange would be crushed by the bolt load or blown out by the line pressure; conversely, a 900-lb. gasket on a 150-lb. flange would lack adequate bolt load, and a satisfactory seal would be highly unlikely. The rating of the gasket is marked on the centering, compression-gage ring.

With ring-joint flanges, large variations in temperature during the process cycle often create difficult leakage problems. The solid ring-type gasket lacks sufficient resiliency to compensate for the changes in contact stress brought about by dimensional changes in flanges and bolts. The spiral-wound gasket with a centering, compression-gage ring covering that area of the flange between the I.D. of the groove and the inside of the bolts has proved a most successful substitute for the regular oval or octagonal solid metal ring.

The spiral-wound gasket reduces costs and eliminates, or considerably reduces, any turbulence in the pipe line. This special gasket was developed for existing ring-joint flanges. In new construction, a raised-face flange is advised, with a spiral-wound gasket.

The success or failure of any gasket depends in large measure on the condition of the flange itself. Seating surfaces should be flat—free from waviness or warpage. A surface finish in the range of 125 root mean square is recommended for hazardous service. For general service, satisfactory performance can be achieved with almost any commercial flange surface, up to the range of 250 root mean square.

Concentric, and even spiral, grooves are acceptable if proper seating loads are provided. A surface made by a planer, however, should never be used because the lines machined into the surface by the planer provide straight-line leakage paths.

Meet the Author



Robert H. Koch is a district sales engineer in Philadelphia for Garlock Inc. Before joining Garlock, he spent 15 years with E. I. du Pont de Nemours & Co.

His experience at Du Pont includes eight years as a packing and gasket consultant to all the company's plants, and as a project engineer and engineering assistant to consultants in lubrication and in packing and gaskets.

Besides a B.S. degree in mechanical engineering from Drexel Institute of Technology, he holds an A.B. degree in social studies from Pennsylvania State University.

Key Concepts for This Article

Active (8)	Passive (9)	Matl. of Constr. (0)
Selection	Gaskets*	Fibers
Maintenance	Packing*	Metals
Installing	Seals*	Plastics
		Rubber
Ind. Variable (6)	Dep. Variable (7)	Leather
Chemicals	Materials of construction*	Impregnators*
Pressure		Lubricants
Temperature		

(Words in bold are role indicators; numbers correspond to EJC-AIChE system except for Role 8 modification. Asterisks mark key concepts suggested for indexing. Others are added to improve reading as an abstract. Indexing is described in *Chem. Eng.*, Oct. 11, 1965, p. 187; or you may order Key Concept reprint, 50¢, using Reader Service Postcard.)