Lesson #5

Selection and Replacement of Packing

What is in This Lesson?

Upon completion of this lesson, you should know and/or be able to do the following:

1. The purpose of packing.
2. Common materials used in packing.
3. When to replace packing.
4. A procedure for determining the correct packing size and quantity.
5. Two methods of lubricating packing.
6. Special tools which are required for the replacement of packing.
7. A procedure for packing replacement.
8. A procedure for the installation of Teflon Kevlar packing.
9. Three causes of packing failure.
10. The runout tolerance allowed for packing.

Key Words

- FPM
- Kevlar™
- Teflon
- GFO™
- PTFE
- TFE

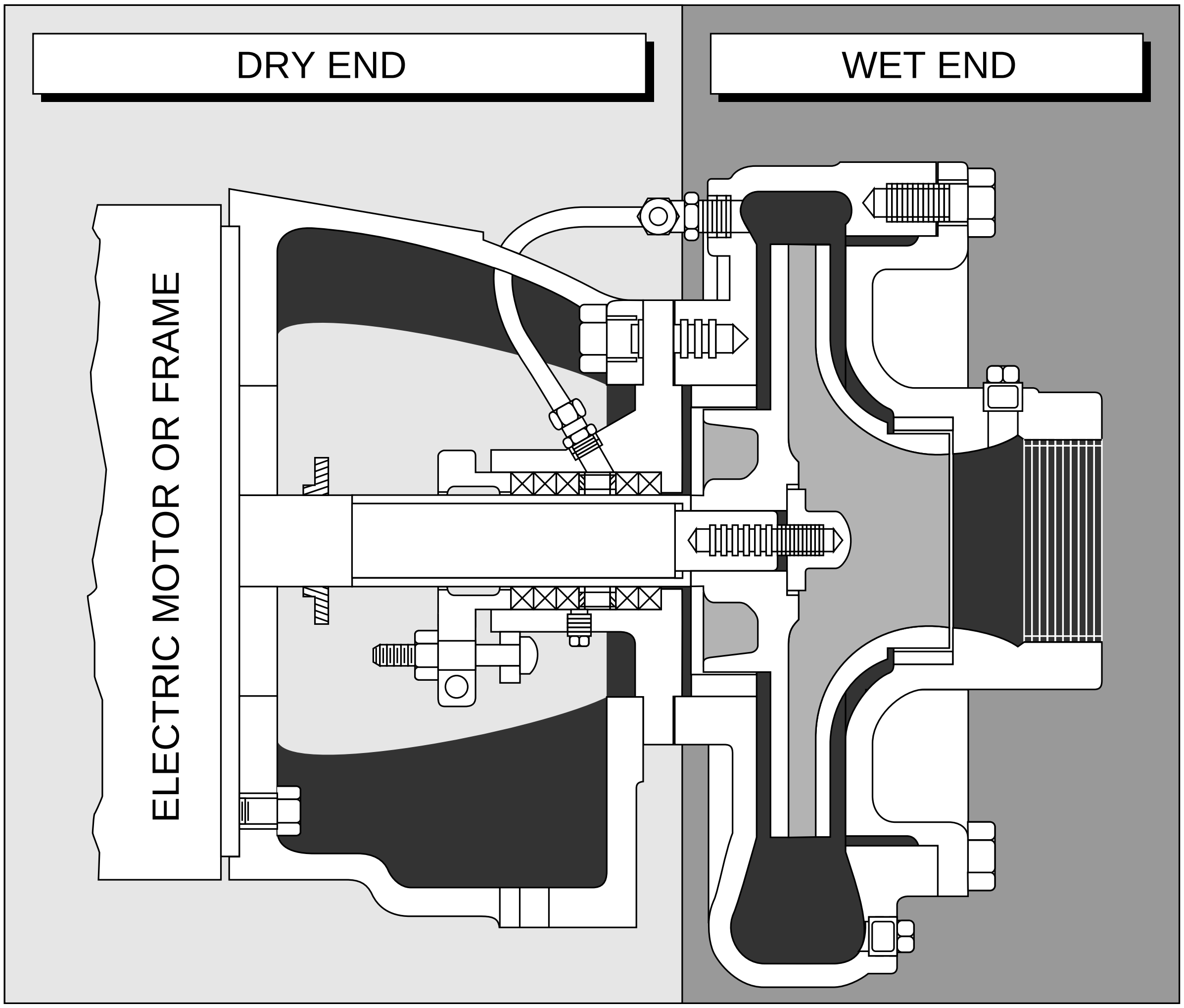
Packing (Also Called Mechanical Packing)

Location

Packing is located in the stuffing box and positioned in the dry end of the pump.

Function

Packing serves to control the leakage of water along the pump shaft and prevent air from entering along the shaft when the pump is in a suction lift condition.



How it Works

The material that is used to control this leakage must be flexible so that it can be properly tightened around the shaft. The packing must be kept under enough pressure so as to control leakage, which means that it must run tight against the rotating shaft. The result of two objects rubbing against one another is friction, which causes abrasion and heat. The packing material selected must be able to withstand the friction without failure or undue damage to the shaft or shaft sleeve. It must also be able to transfer the heat that is generated to the walls of the stuffing box. And it must be able to handle this heat without being damaged.

Reducing Heat from Friction

The heat that is generated by the friction can be reduced by increasing the amount of leakage past the packing. It can also be controlled by the use of an external lubricant. Grease, oil and water are all used as external lubricants. They are applied through the lantern ring. Water is the most common external form of lubrication. When water is used, it is referred to as seal water.

Function Summary

In conclusion, packing must control leakage. It must be able to do this without undue damage to itself or the shaft and it must be able to carry away the heat that is generated from friction between the shaft and the packing.

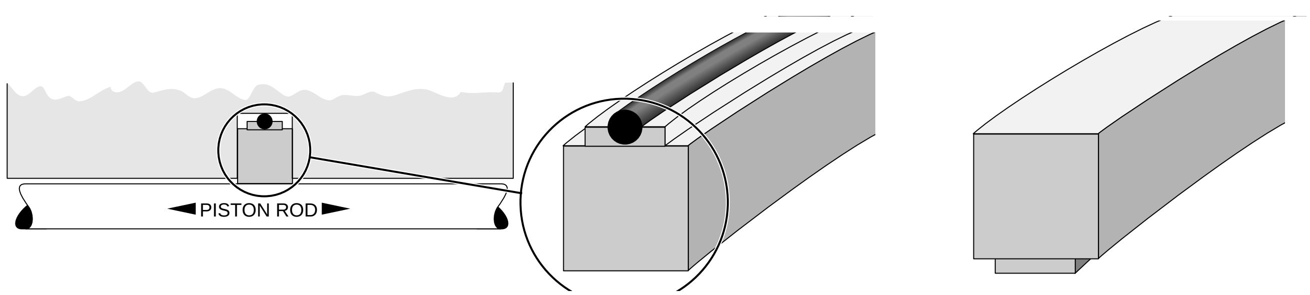
Packing Types

Three Categories

There are three categories of packing: compression packing, automatic packing and floating packing.

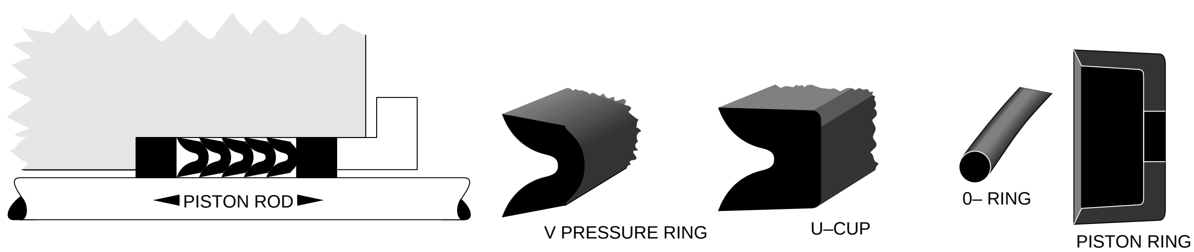
Floating Packing

Floating packing includes piston rings and will not be discussed in this lesson.



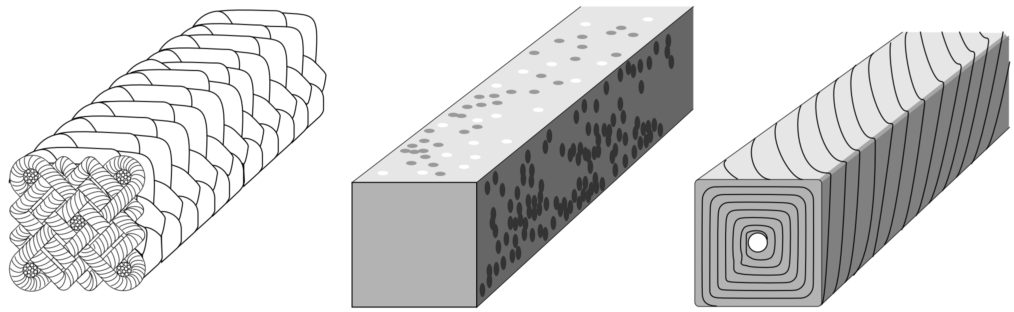
Automatic Packing

Automatic packing includes pre-formed materials, such as cups, and O-rings. Pre-formed cups are commonly used in piston and reciprocating pumps. This material will be lightly discussed in the lesson on positive displacement pumps.



Compression Packing

This lesson will concentrate on compression packing. This material is also referred to by some manufacturers as mechanical packing. Compression packing is manufactured by a variety of weaving, twisting and braiding processes. Some material is actually molded. We are not going to weigh the merits of the individual methods of manufacturing. Instead, we will focus on the characteristics of the various materials and how to correctly install them.



Basic Components

Compression packing is composed of two items: a bulk material and a lubricant.

Bulk Material

The bulk material is formed into a rope-like shape with a square cross section (the cross section can be any shape. However, the packing used in most pumps has a square cross section) by braiding together strands of plant, animal, mineral, metal or synthetic fibers.

Common Bulk Materials

The common materials used to form the packing bulk are:

Plant fibers: such as flax, cotton or jute

Animal fibers: such as wool and leather

Mineral fibers: blue or white asbestos and graphite

Synthetics: Teflon™[1], Kevlar™[2], GFO™[3], TFE™[4], rayon and carbon

Metallic–such as lead, aluminum or copper, in strands or foils

Common Lubricants

The lubricants include various greases, graphite, inert oils, mica and various synthetics such as silicone, Teflon™, TFE™ and PTFE™[5].

Manufacturing Process

In order to make a packing, the manufacturer will take a fiber such as graphite and impregnate a second material such as TFE. They may also mix a high quality oil lubricant which will help the packing during start up. Or they may take a plant fiber such as flax or cotton and soak it in a high quality oil. The fiber is rolled in a lubricant, such as flake graphite, and then woven or braided into a packing material. The combinations of

1 **Teflon** - A synthetic material produced by DuPont.
2 **Kevlar™** - A synthetic fiber produced by DuPont.
3 **GFO™** - A fiber produced by Gortex that is a composite of graphite, PTFE and a high temperature lubricant.
4 **TFE** - Tetrafluroethylene polymer fiber. Commonly called Teflon™.
5 **PTFE** - Polytetrafluorethylene; a compound used in the manufacture of various packing materials. May be a fiber or part of the lubrication system.

fibers and lubricants are almost unlimited and gives the operator a tremendous number of choices. Because of the cost of these materials and the cost of replacement, the selection should be made with care.

Packing Selection

Manufacturer's Information

This section is intended to give the operator an overview of the packing selection process. It is not a substitute for the information that is given by the pump and packing manufacturers. Proper packing selection is best accomplished with the help of the pump manufacturer or with the aid of one of the major packing manufacturers. Catalogs developed by the packing manufacturers usually give adequate details for proper selection.

Selection Criteria

Packing is selected for the pump operating pressure, shaft speed, pumped fluid temperature and type of fluid being pumped.

About Asbestos Packing

Until the mid 1980's, the most commonly used packing in the water and wastewater industry was the asbestos base with graphite lubrication. Unfortunately, safety considerations in the manufacture of asbestos have caused all US manufacturers of asbestos-based packing to stop production. The result has been a large insurgence of synthetic packing materials. As of the date of this publication, no real winner has yet emerged.

Selection Guide

When attempting to determine the type of packing material that you wish to use, you can consider the following guidelines (This table is based on the assumption that cold water, 34 - 70°F, is being pumped.):

Condition	Packing Material
Low pressure (less than 100 psi) Low speed (1,000 FPM[6] and below)	Plant fibers with Teflon, silicon, TFE, or PTFE lubrication. Flax and jute are more abrasive than asbestos and can cause shaft damage. Cotton is soft, but is difficult to hold at high pressures.
Medium pressure (100 to 150 psi) Medium speed (1,000 - to 2,000 FPM)	Graphite, acrylics, TFE, Kevlar, PTFE and carbon's. Most of these packings will not operate well when the temp. at contact with the shaft exceeds 500°F. As the shaft speed approaches 2000 FPM, the amount of leakage required will need to be increased.
High pressure (above 150 psi) High speed (above 2,000 FPM)	Metal packing, or packing with metal cores or combinations of synthetics and metals. Because high gland pressures will be required to control leakage, there will be high temperature where the packing meets the shaft. Therefore, packing that will work above 500° F should be used.

[6] FPM - The speed of the shaft in feet per minute.

Conclusion

In conclusion, the greater the pressure and the greater the shaft speed, the more solid the packing needs to be. At the same time, the high pressures and high RPM will normally require greater pressure on the gland to control the leakage. This will result in a higher temperature where the packing contacts the shaft. Therefore, packing that will operate at the higher temperatures should be used.

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Shaft speed comparisons

Shaft size in inches	RPM	Speed in FPM
1	1800	450
1	3200	850
1	3600	1050
2	1800	900
2	3200	1700
2	3600	1800
3	1800	1400
3	3200	2500
3	3600	2800

Individual Rings or by the Pound

Compression packing may be purchased by the pound or in individually cut rings. Usually, it is less expensive to purchase packing by the pound. The exception is if you need only enough packing for one or two pumps and the packing is changed only annually. In this case, it may be the most cost-effective to purchase the packing in individual cut rings.

Non-traditional Packing

One recent major change in packing materials has been the introduction of a paste-like material that replaces compression packing and is placed between two rings of regular braided packing. One manufacturer, in fact, recommends a GFO fiber packing be used. One ring is placed in the bottom of the stuffing box. The box is then filled with this paste-like material. A second ring is placed between the material and the gland. The seal water is disconnected and the gland tightened so that no leakage occurs. As of the date of this publication, the author was unable to determine the composition of the paste-like material.

Effectiveness

The material appears to be extremely effective, especially in making temporary repairs to pumps whose shaft is too worn to hold regular packing. Several utilities have made a nearly complete switch to the material. While it may not be the total answer to the problems associated with packing, the fact that it can be placed in a worn stuffing box is of great benefit to those who are trying to make it through the season.

Packing Size Selection

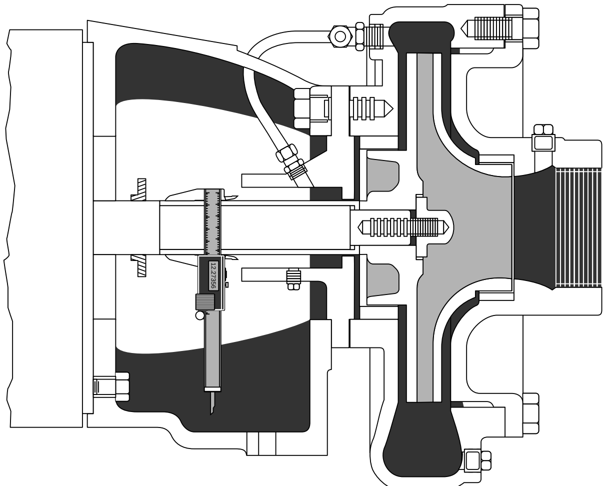
Determining Size

One of the major problems encountered in packing installation is determining the proper size. The size may be determined by the manufacturers. If the manufacturer's information is not available, size may be determined by actual measurement of the stuffing box. There are at least two methods of making this measurement: 1) using a snap gauge and 2) using a dial caliper.

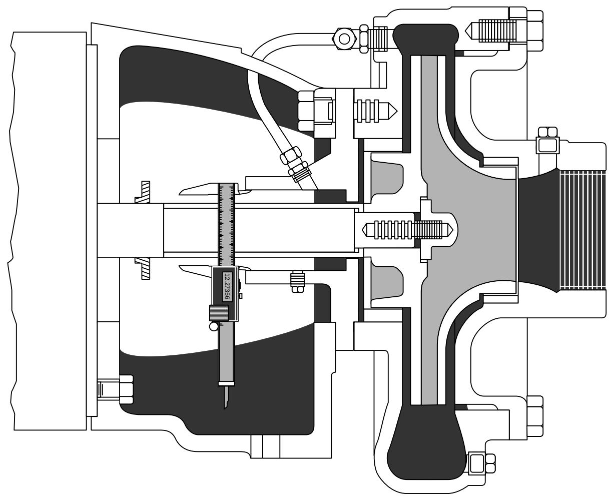
Dial Caliper

With the dial caliper method two measurements are needed: the OD of the shaft and the ID of the stuffing box. Determine the packing cross section by subtracting the shaft OD from the stuffing box ID and divide by two.

$$\frac{ID-OD}{2} = \text{Cross Section}$$



Shaft O.D.



Stuffing Box I.D.

Snap Gauge

A snap gauge may be inserted between the shaft and the stuffing box set and the cross section determined by measuring the length of the snap gauge.

Common Sizes

Packing is available in increments of 1/16" from most manufacturers and in increments of 1/32" from some manufacturers.

Which Size to Select

If the calculated size comes out between two common sizes, you are better off to select the smaller size than to try to force the larger size into the stuffing box. Forcing the larger size into the box can result in excessive pressure between the packing and the shaft, which causes excessive heat and damage to the packing and the shaft.

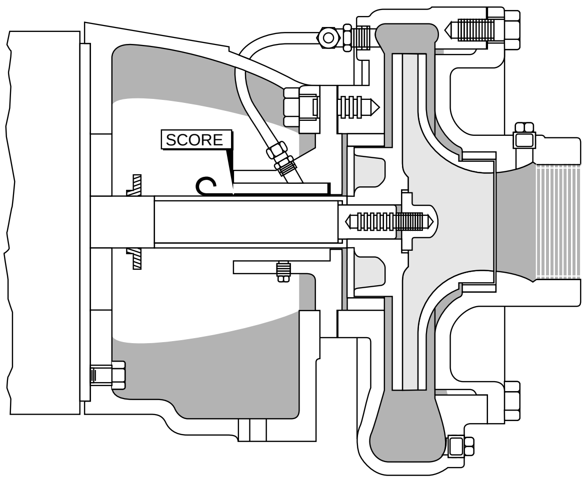
Determining the Number of Rings

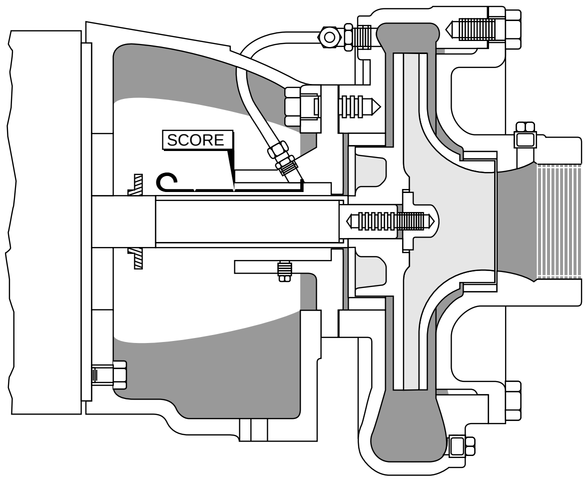
The number of rings can be determined by using a small ruler to measure the depth of the stuffing box and then dividing this by the cross section.

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

Second Method

A second method of determining the correct number of rings is to use a wire bent in the form of a hook. The hook is placed into the stuffing box and scored at the back of the stuffing box with a hack saw blade. The hook is then positioned into the seal water hole and scored again. You are now able to determine the correct number of rings and the correct number on each side of the lantern ring.





Replacing Packing

The Life of the Packing

As was mentioned above, packing contains some type of bulk material and one or more lubricants. Under normal conditions, the packing is placed under pressure. This pressure, along with the heat generated by friction, will cause the lubricant to be squeezed out of the packing. As the lubricant is squeezed out, the packing will be worn down by the shaft. Leakage control is maintained by tightening the packing gland. When the majority of the lubricant has been squeezed from the packing, it is time for the packing to be replaced.

When to Replace

In general, it can be said that packing needs to be replaced when tightening the packing gland with a simple end wrench will no longer control the leakage. Do not remove the packing gland and insert one or two rings of new packing. When the packing is worn out it must be replaced.

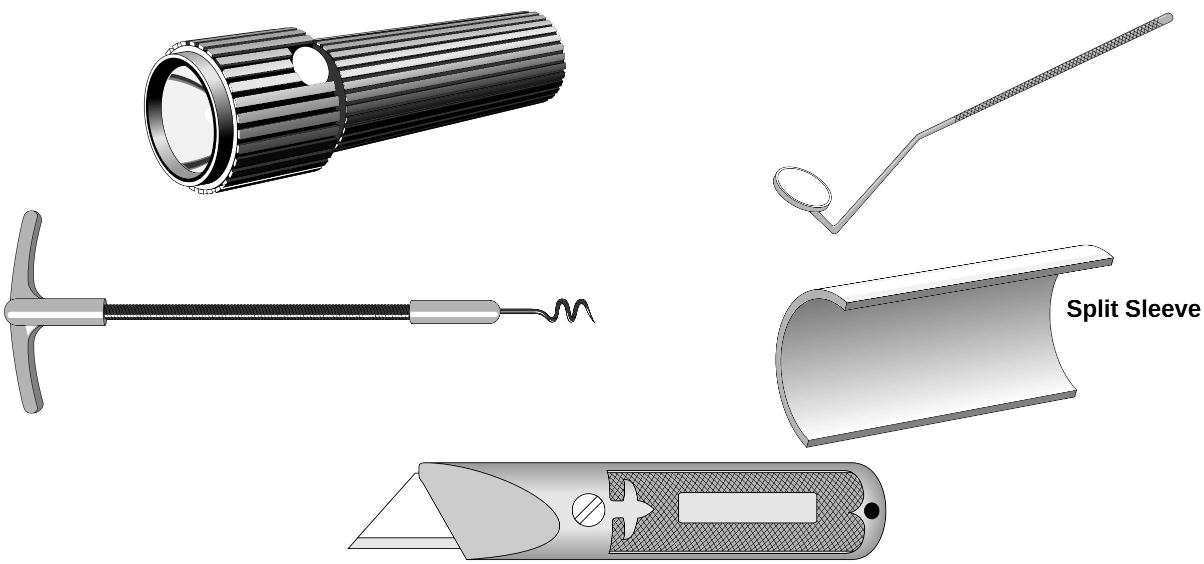
Six Basic Steps

The process of replacing packing involves six steps: selecting the proper tools, shutting down the pump, removing of the old packing, checking the pump condition, installing of the new packing, and start-up.

Selecting the Proper Tools

Many jobs requires special tools. The replacement of packing is no exception. A good packing installation will require the following special tools.

1. Paper knife to cut the packing.
2. Split sleeve or wooden blocks for seating the packing.
3. Packing hooks to remove the old packing.
4. Flashlight to help find the lantern ring and to line up the lantern ring.
5. Mirror to help find the lantern ring.
6. Packing lubricant, such as Teflon or silicone grease to allow you to pre-lube the packing. This will reduce the probability of packing failure during the crucial start-up period.



Pump Shutdown Process

Lock-out

Shut off the power and "lockout" the pump. Use a padlock and accident prevention tag (OSHA 29 CFR1910.147). If the volute case is under pressure, you should shut off the water on both the suction and discharge sides of the pump.

Remove the Old Packing

Packing Gland

Remove the packing gland. If the bolts or nuts are damaged so that once they are loose they cannot be moved by hand, you should either repair or replace them.

Remove Packing

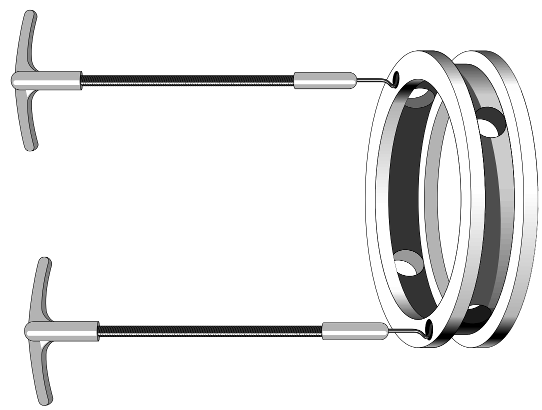
Using a packing hook, remove all of the old packing one ring at a time. If the pump has a lantern ring, it must also be removed. This will allow you to remove the packing below the lantern ring.

Lantern Ring

The lantern ring can sometimes be removed by first locating the holes in its side. (This is what the mirror and flash light are used for.) Insert a packing hook into each of the two holes. The lantern ring can now be pulled out of the stuffing box.

Tapping the Lantern Ring

Another technique requires making alterations to the lantern ring at a time when the pump has been disassembled. First, two packing hooks with removable hooks are purchased. Then the two holes are tapped with the same thread as the ends of the two packing hooks. This is usually a 10/32 thread. Now, when the lantern ring needs to be removed, the packing hooks can be threaded into the two holes and used to pull the ring free of the stuffing box.



Disassemble the Pump

A third alternative is to disassemble the pump.

Using Water Pressure

The process of removing the packing gland and charging the volute case with pressure to blow the lantern ring free is not recommended. This procedure can allow water to enter the motor and cause it to short out.

Plastic Lantern Rings

The development of plastic two-piece and flexible lantern rings has made this process much easier. These lantern rings can be installed as replacements for the originals. If you are unable to easily remove them, they can be broken up with a small chisel and replaced.

Shaft Damage

The shaft sleeve and the shaft shown on the next page were prematurely damaged because the packing below the lantern ring was not replaced each time the packing above the lantern ring was replaced. This old packing becomes hard and abrasive and thus destroys the shaft.

When is Lantern Ring Needed

If there is no external lubricant applied to the lantern ring (this includes piping from the lantern ring to the pump volute), then it should be removed and replaced with a ring of packing. It is serving no purpose unless being used to add lubricant.

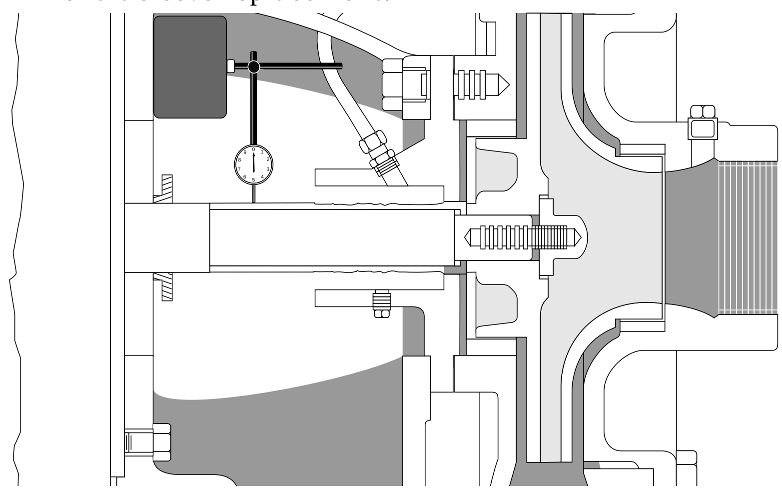
Check the Pump Conditions

Check Runout

Use a dial indicator to check shaft runout. A shaft runout of 0.003” is the maximum allowable. Runout greater than this will cause the packing to leak excessively.

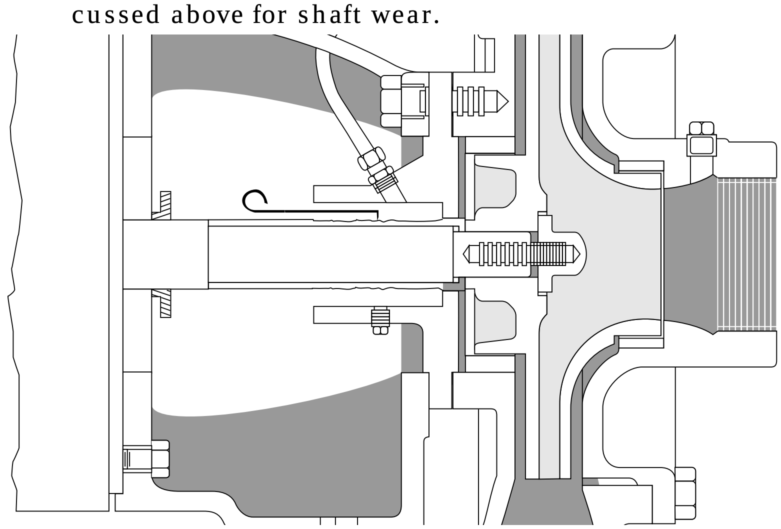
Shaft Wear

The shaft or shaft sleeve should be checked for wear. This can be done with the use of a 90 degree packing hook. The hook is slid along the shaft and the roughness determined by feel. About 1/16" of wear on a 1" to 2" shaft and 1/8" wear on a 3" to 4" shaft is the maximum that can be tolerated. If the wear is greater than this, the pump should be scheduled for shaft or shaft sleeve replacement.



Stuffing Box Wear

The interior of the stuffing box should also be checked for wear and roughness. Excessive roughness or wear caused by corrosion or as a result of the packing seizing to the shaft and turning inside the stuffing box must be eliminated. Roughness in the stuffing box can be removed by metal spraying and turning on a lathe or by replacing the stuffing box. The amount of corrosion or wear that can be tolerated is the same as discussed above for shaft wear.



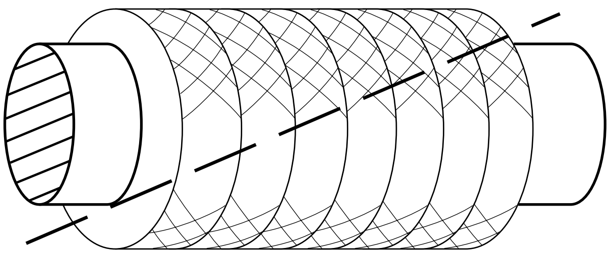
Bottom of Stuffing Box

The last ring of packing removed from the bottom of the stuffing box should be inspected to determine the condition of the stuffing box. If this piece is misshapen or extruded, the bottom of the stuffing box is probably badly worn. A temporary fix is to replace the first ring of packing with metal packing.

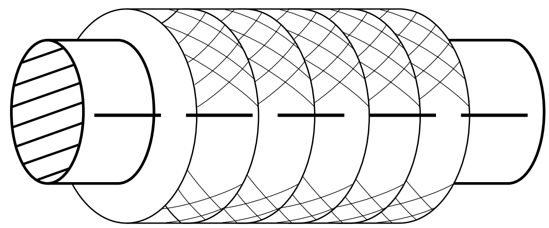
Installing New Packing

Using a Mandrel

Unless individual rings of packing are purchased, the packing must be cut into individual rings from a roll. The most common method of cutting is to wrap the packing several times around a mandrel and then making a “butt cut” or “scarf cut.” The mandrel should have a circumference 1/16" to 1/8" shorter than the circumference of the pump shaft.

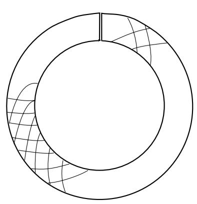


scarf cut



butt cut

Ends Parallel



Parallel Ends

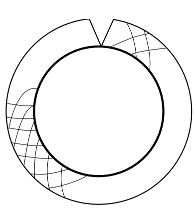
It is important that when the packing is installed in the stuffing box, the ends be parallel but not touching or just barely touching. They should be no more than 1/16" to 1/8" apart. The reason for not using a mandrel the same size as the pump shaft is that it is nearly impossible to pull the packing as tight as it will be in the stuffing box. This will result in the packing rings being too long. Therefore, the rings will bunch up where they meet and cause the packing not to lay in the box evenly.

Alternate Method

An alternative method used by some operators is as follows:

- Cut the end of the packing at a slight angle.
- Make one wrap around the shaft and mark the packing with a knife. The mark should be next to the cut end.
- Remove the packing and lay it out on a board.
- Cut the packing 1/16” to 1/8” short of the mark.

Parallel Joints



the result of a straight cut

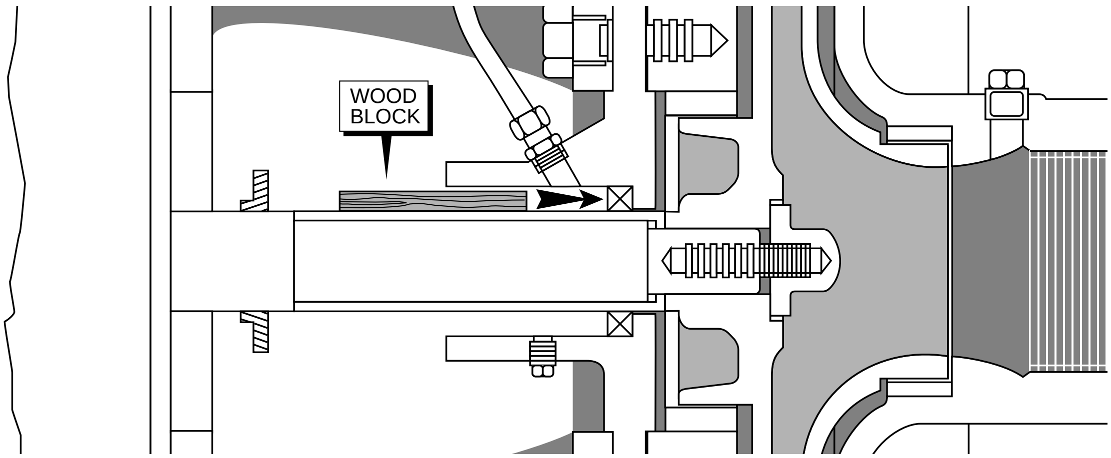
Regardless of the method used, the packing should never be laid out flat on a board and cut square. This will result in a joint that will not seal. However, once a length has been determined, that length can be marked on a board and the remainder of the rings cut. Remember, one of the keys is that the ends must be parallel when installed.

Cut enough rings to fill the box before you install any.

Completing the Installation

The remainder of the installation should follow these steps:

1. Lubricate the first ring with a pre-lube such as Teflon or silicon grease. If the stuffing box is normally lubricated with grease or oil, then that should be used.
2. Install the first ring of packing by starting on one end and coiling the other end around until the two ends meet.
3. The first ring of packing should be pushed into the bottom of the stuffing box with wooden blocks or with split packing gland sleeves.



4. Each successive ring of packing should be rotated 90 degrees so that the joints are 1/4 turn apart. Each of those rings should be lubricated and seated with a wooden block or split packing gland sleeve.

   If a lantern ring is involved, check its location by either passing water through the seal water line, or observing visually through the seal water connection in the stuffing box.

5. After all rings of packing have been installed, the packing gland should be replaced. If you have the proper number of rings of the right size packing installed, the gland should extend into the stuffing box 1/8” to 1/4”.

Start-up Procedure

The life of the packing can be extended or destroyed in a matter of minutes during start-up. This is a critical sequence; follow it with care.

1. Using an end wrench, tighten the packing gland and then back it off so that it is finger tight.
2. Check to see if the shaft can be rotated by hand. (This assumes that it could be rotated before the packing was installed.)

3. If seal water is present, turn it on and allow it to run for 15 minutes. If there is no seal water, turn the water on and allow the water to run through the pump for 15 minutes without the pump being on.

4. Check the packing gland. It should still be finger tight. If it is not finger tight, loosen it before proceeding.

5. Start the pump and allow leakage from the stuffing box for 15 minutes before the gland is tightened.

6. Adjust the gland bolts one flat (1/6 of a turn) every 15 minutes until the leakage is controlled to the proper amount.

Leakage - Non-Synthetic Packing

For non-synthetic packing (flax, jute, cotton, graphite, etc.) the allowable leakage is 5-20 drops per minute for 1" shafts and 10-20 for 2" shafts. You should check the stuffing box at regular intervals to assure that there is no increase in temperature. If the temperature of the stuffing box appears to increase, loosen the packing gland until the temperature drops. Then tighten the packing gland carefully to control leakage.

Leakage - Synthetic Packing

For synthetic packing (Kelvar, Teflon, GFO, etc.) the leakage can be controlled to approximately 30 drops per minute per inch of shaft diameter.

Routine Inspection

The stuffing box temperature should be checked on a regular basis. If any rise in temperature is noted, the packing gland should be loosened, and the tightening process repeated cautiously.

Why Packing Fails

Normal Deterioration

Packing is designed to wear and will deteriorate with normal use. A portion of this deterioration is caused by the loss of the lubricant which is in the packing material. This is normal and is expected.

Premature Failure

The question, then, is what causes packing to fail prematurely? There seems to be four general causes of premature packing failure. They are:

1. Improper selection of packing materials or sizes. This can be solved only by checking with the manufacturer.

2. Excessive amounts of abrasive material entering the stuffing box from the fluid being pumped, or not removed by the flushing action of the seal water. Pumps pumping raw water or wastewater should be equipped with an external source of seal water.

3. Pump conditions such as runout or vibration caused by bad bearings, bent shaft, loose base bolts, misalignment, imbalanced motor or shaft flexing at high rpm. worn or damaged shaft, shaft sleeve or stuffing box interior.

4. The loss of the seal water or other packing lubricant will cause the packing to burn and thus be destroyed.

High Pressure Problems

The Problem

When pumping at high pressure, it is necessary to exert considerable pressure on the packing to keep the leakage in check. This excessive pressure causes a premature loss of the natural lubricants in the packing.

Using a By-pass Line

The need to apply considerable pressure to the packing can be alleviated by reducing the pressure differential between stuffing box pressure and atmospheric pressure. This can be done by installing a bypass line with a throttling valve in the seal water line and exiting this line to atmosphere. By adjusting the throttling valve you can control the leakage from the stuffing box and increase the life of the packing.

Lineshaft Turbines

On some lineshaft turbines this by-pass is built into the stuffing box. A component similar to the lantern ring is inserted where the first ring of packing would be placed. This device is connected to a copper line that exits to the atmosphere.

Lubrication of Packing with Grease or Oil

Using Oil or Grease

Under conditions of heavy use and at the recommendation of some manufacturers, packing is lubricated and cooled with grease or oil. Various types of grease cups and auto motor oiling arrangements are used. Regardless of the type of installation, care should be taken to obtain the proper type of grease or oil. This can usually be determined from the O & M manual.

Need for Constant Pressure

The proper operation of a pump installation with grease or oil lubrication at the stuffing box includes the assurance that the grease is under a pressure slightly higher than the pressure in the stuffing box. Therefore, grease cups should be tightened regularly and automatic oilers should be checked periodically.

Selection and Replacement of Packing **Worksheet**

1. The area that contains the packing and/or mechanical seal is called the ___________________ _________________.

2. The purpose of the packing is to control _________________ .

3. Packing is made from five materials. Name three:

   a) ___________________________

   b) ___________________________

   c) ___________________________

4. Two common packing lubricants are:

   a) ___________________________

   b) ___________________________

5. Packing should be replaced when tightening the _________________ _________________ will no longer control the leakage.

6. What three calculations are used to determine the right packing size and the correct number of rings?

   a) ___________________________

   b) ___________________________

   c) ___________________________

7. External packing lubricant can be grease, oil or ____________________ .

8. List five special tools or pieces of equipment you should have to replace packing.

   a) ___________________________ b) ___________________________

   c) ___________________________ d) ___________________________

   e) ___________________________

9. Packing should always be cut in ______________ rings and never wound ________________ around the ________________ .

10. When replacing packing, how much of the old packing should be removed?

    ______ a) None

    ______ b) First two rings

    ______ c) All above the lantern ring

    ______ d) All

11. The lantern ring is used to supply water to the __________________ __________________ .

12. Each ring of packing should be ____________ and seated with a ____________ ______________ or _______________ __________________ .

13. New packing should be replaced so that the ____________________ are staggered 90 degrees.

14. Packing should be tightened only enough to___________ leakage. With non-synthetic packing, this leakage should be________ to ________ dpm for a 1-inch shaft and ________ to _______ dpm for a 2-inch shaft. Synthetic packing should leak approximately ________ dpm per inch of shaft diameter.

15. When replacing packing, you should:

    a. Tighten the packing gland _____________ tight.

    b. Turn on the _____________ water.

    c. Wait _____________ minutes.

    d. Tighten the gland __________ of a turn every ______________ minutes.

16. List the three primary causes of packing failure.

    a) ____________________________

    b) ____________________________

    c) ____________________________

17. In order for packing to have a long life, the shaft runout should not exceed __________ inches.