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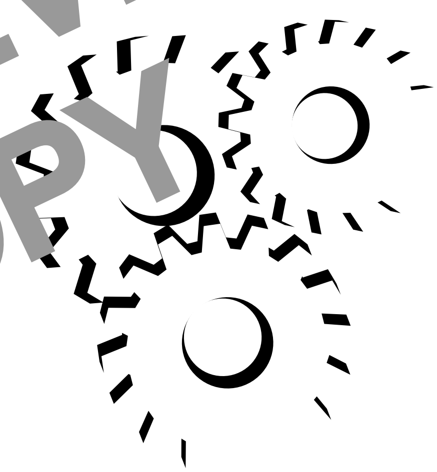
INSTALLING AND REPLACING BEARINGS AND SHAFT SEALS

Lesson One

Plain Bearings



TPC Training Systems

34301

Lesson

1 Plain Bearings

TOPICS

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OBJECTIVES

After studying this Lesson, you should be able to…

- Name the important dimensions of a plain bearing.
- State the source for learning the proper running clearance in a plain-bearing installation and describe how to measure running clearance.
- State the characteristics of bearing and linear material and explain how they influence the choice of bearing for a given application.
- Discuss the steps involved in fabricating a poured babbitt bearing liner and obtaining the correct finished-bore dimensions.
- State the purpose and general principles of plain-bearing installation.
- Identify the symptoms of bearing trouble and describe how to remedy each situation.

KEY TECHNICAL TERMS

Plain bearing 1.01 a bearing that has no rolling elements
Bore 1.02 inside surface of a bearing
O.D. 1.02 outside diameter (of a shaft or bearing)
Running Clearance 1.06 clearance between shaft O.D. and bore of a plain bearing, when the machine is operating
Babbitt 1.11 a softer, tin- or lead-based alloy used in lining bearings

Plain bearings, sometimes called sleeve bearings or journal bearings, were among the first types used to support machine shafts. Their use dates back to the times when hardwoods were the only materials from which bearings could be made. Plain bearings still have many uses, and their materials now range from plastics to fine grades of metal and various alloys.

Lesson One describes the critical dimensions of plain bearings. It details the basic parts of a bearing and the functions of each part. Plain bearings may have to be relined from time to time, and the Lesson explains the techniques and the materials used in relining.

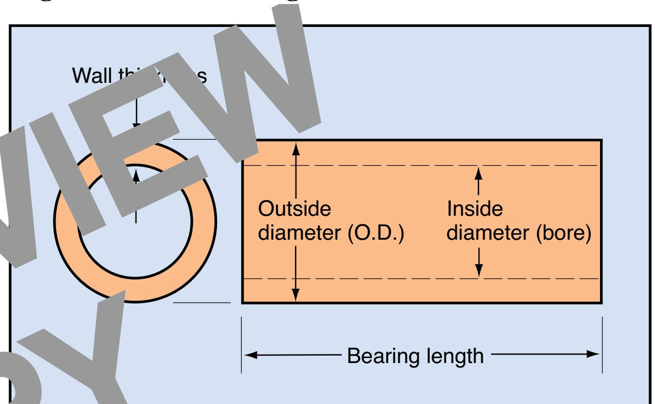
This Lesson also explains the maintenance methods commonly used with plain bearings. The information covers how to troubleshoot the units and how to work safely during a maintenance project.

Plain Bearings

1.01 The term *plain bearing* refers to a bearing that has no rolling elements, such as balls or rollers. (Bearings using balls or rollers are called *antifriction bearings* and will be covered in Lesson Two.) A very basic type of plain bearing appears in Fig. 1-1. Notice that the bearing closely resembles a simple sleeve, which gives it its other name, *sleeve bearing*.

1.02 During operation, a plain bearing supports the shaft along the inside surface, or *bore*, of the bearing. As the shaft rotates, friction develops between the shaft O.D. (*outside diameter*) and the bearing bore. This is the critical area in a plain bearing. Proper types and quantities of lubricants must be supplied to this area, and the materials used in the bearing bore must be able to carry the loads imposed.

Fig. 1-1. Plain-bearing critical dimensions



Measuring Plain-Bearing Dimensions

1.03 Figure 1-1 shows the critical dimensions of a typical plain bearing. Always be sure that you measure and note each of these when ordering or making a

Fig. 1-2. Correct and incorrect bearing installation

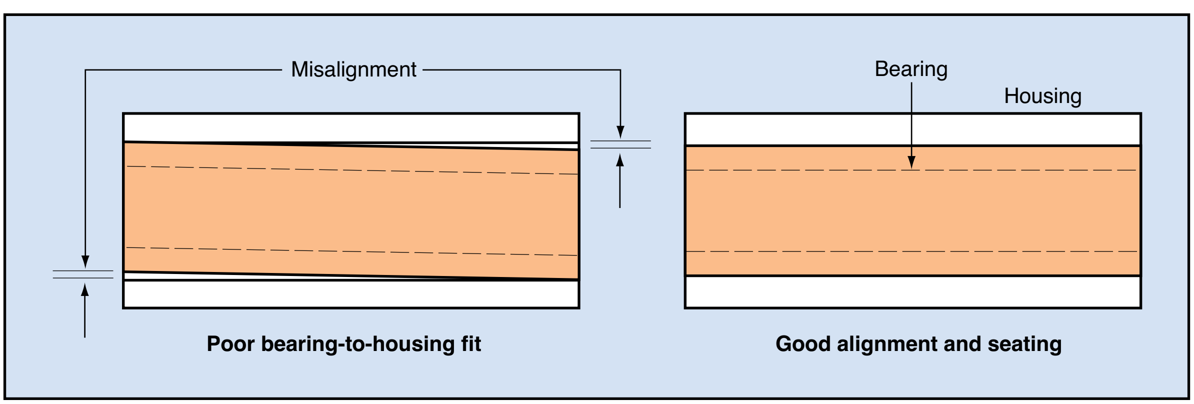
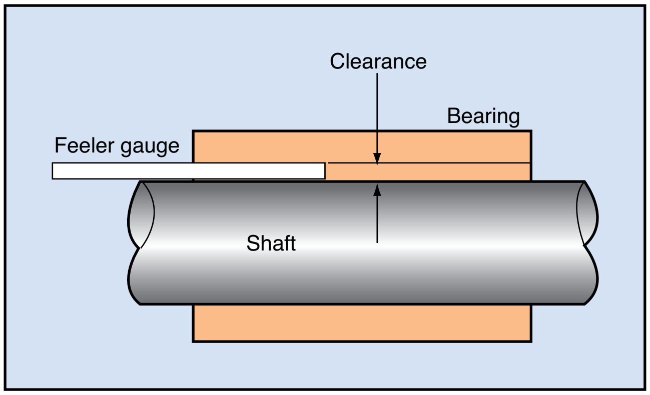


Fig. 1-3. Measuring running clearance with feeler gauge



replacement for a worn bearing. If the replacement bearing is too short, you will lose a portion of the load-carrying surface. If the wall thickness of the replacement bearing is inadequate, you will lose strength.

1.04 Use the proper instruments for measuring an old bearing that is to be replaced. Check the bore, if conditions allow. If the bore shows heavy wear, measure the shaft diameter on which the bearing will seat. Closely inspect the ends of the replacement bearing. Be sure that they are square with the bore and that no nicks or burrs are present. If necessary, rid the bore of surface defects with a file.

1.05 If the bearing to be replaced is in a housing, check the housing bore. Clean up any surface irregularities that could prevent the new bearing from seating correctly. Figure 1-2 on the previous page shows a poorly installed bearing and one that has been installed correctly in the housing.

Measuring Clearances

1.06 The clearance between the shaft O.D. and the bore of a plain bearing is very important. Figure 1-3 shows where the running clearance is usually measured. The *running clearance* is the clearance when the machine is put in operation. Required running clearances vary according to shaft size and the general nature of the application.

Table 1-1. Typical minimum running clearance

Shaft diameter	Minimum clearance
Up to 0.760 in.	0.0005 in.
0.761 to 1.510 in.	0.0010 in.
1.511 to 2.510 in.	0.0015 in.
Over 2.510 in.	0.0020 in.

1.07 The best way to determine the correct running clearance when installing a bearing is to use established charts and tables that exist for this purpose. Table 1-1 provides a typical listing of the correct minimum running clearances for iron-based and bronze-based powdered-metal-sintered plain bearings. This chart refers to oil-impregnated bearings that support ground-steel shafts.

1.08 Similar charts and tables for various other plain-bearing installations are available from the manufacturer. Study your application, and refer to the listing of running clearances that covers those specifications.

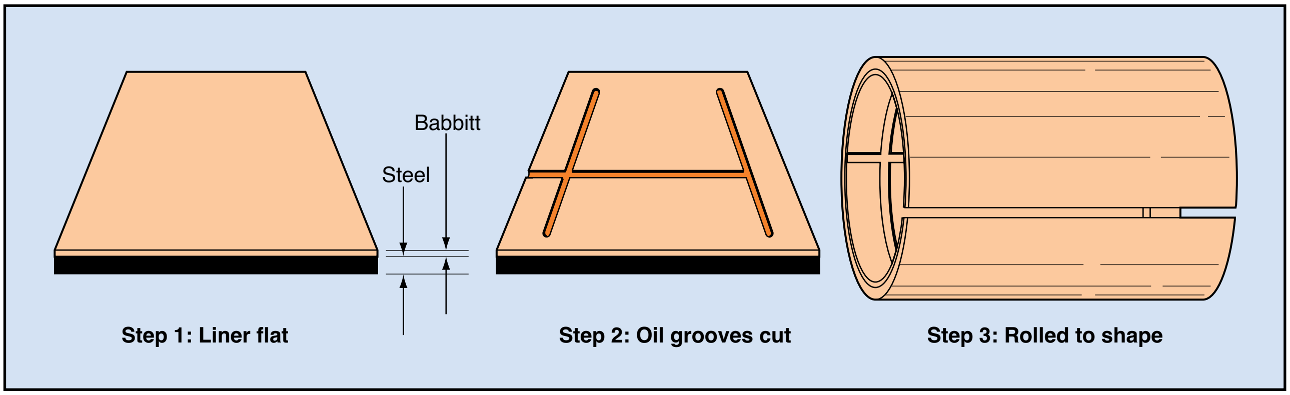
1.09 When you have determined the correct running clearance for your application, use a feeler gauge to measure the clearance, as shown in Fig. 1-3. Be sure that the shaft sits in perfect alignment with the bearing bore as you measure. If the shaft is cocked, you will not get an accurate clearance measurement. Measure the clearances at each end of the assembly. To insure that no out-of-round condition exists, rotate the shaft and measure at 90° intervals if possible.

Plain-Bearing Linings

1.10 The lining materials used to prolong the operating life of a plain bearing at the shaft-and-bearing contact area vary. The selection of a material for a given application will depend on shaft speed, shaft size, loads to be imposed on the bearing, method of lubrication, general operating atmosphere, and desired life.

1.11 Lining materials fall into several general groups: bronze, babbitt, hardened leads, aluminum, cadmium alloys, silver, sintered metals, plastics, wood, and carbon graphite. Within several of these groups, a variety of other selections exist. For example, *babbitt*—a softer metal used to line plain bearings—occurs in many varieties. Load-carrying capacity and maximum operating temperature are factors to consider in the selection of the correct babbitt.

Fig. 1-4. Prefabricted bearing liner



Bearing- and Lining-Material Characteristics

1.12 The various materials used to line plain bearings, and to make the bearings themselves, all have certain characteristics which affect your selection. You should consider the importance of each characteristic according to the requirements of the particular plain-bearing application. Equipment manufacturers normally recommend the most suitable materials for each application.

1.13 The seven major characteristics of plain-bearing and lining materials are:

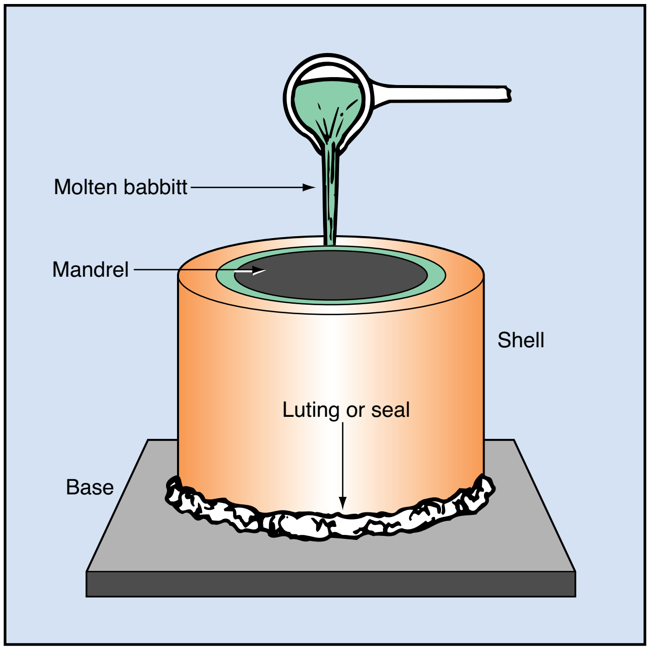
- **Load capacity**—the strength of the material under the various pressures developed by the particular application.
- **Conformability**—the ability of the material to flow slightly when loaded. This feature allows the shaft and bearing contact surfaces to conform to each other, particularly during the initial, or break-in, stages.
- **Compatibility**—the material's resistance to galling (wear) during startup, when lubricants have not yet formed a working film and the shaft and bearing materials are in metal-to-metal contact.
- **Fatigue resistance**—the material's ability to sustain continuous applications of loads without cracking or flaking.
- **Corrosion resistance**—the material's capacity to resist corrosion from acids produced by lubricants under certain operating conditions.
- **Embeddability**—the capacity of the bearing or lining material to pick up and to absorb within itself larger pieces of foreign matter suspended in the lubricant. This foreign matter can score the lining and the shaft surfaces if it is allowed to float in oils or greases.
- **Thermal conductivity**—the material's ability to dissipate any excessive heat generated during operation. This capability prevents seizing of the shaft and bearing.

Prefabricated Bearing Liners

1.14 Various grades of babbitt are most often used for lining and relining plain bearings. Smaller bearings and some bearings used in internal-combustion engines are commonly lined with a prefabricated design, like that in Fig. 1-4. Here, a thin coating of babbitt is laid on a thin steel strip. Oil grooves or other configurations can then be machined into the babbitted surface while the liner is still flat and workable.

1.15 After any required machining has been done, the strip is sized accurately to its final dimensions. It is then rolled or otherwise shaped to the correct profile for mounting in its housing. Prefabricated liners like the one shown in Fig. 1-4 can be used for shaft diameters of 0.5 to 5.0 in. (1.3 to 13.0 cm).

Fig. 1-5. Pouring molten liner material



Poured Bearing Liners

1.16 Larger plain bearings used in heavy-duty machinery must have their liners poured into the housing in a molten state, as Fig. 1-5. After the babbitt is poured, the liner is then finish machined to a thickness of from 0.125 to 0.25 in. (0.3 to 0.6 cm), depending on the application.

1.17 Use an iron pot or kettle when heating babbitt. Bring the temperature gradually up to approximately 870°F (466°C), and maintain it there. Keep stirring the molten babbitt using an overhand motion, as shown in Fig. 1-6.

1.18 Remember to use proper safety devices and to wear proper attire during this process. Any very hot metal can easily cause severe personal injury if it is mishandled in any way. Safety glasses, goggles, or a face shield should be worn, because some splashing and spattering usually occurs during the pouring operation. Good fireproof gloves will protect your hands.

1.19 You must preheat bearing shells before pouring the babbitt. Several steps precede the actual preheating, however.

1.20 Use a chemical or an electrolytic method to clean the inside surface of the shell before preheating it. Be sure to rinse the shell thoroughly if you use a chemical to clean it. Preheating the shell should remove any remaining moisture.

1.21 If the shell material is bronze, you must tin the inside surfaces to make the babbitt cling better. Use a half-and-half-composition solder for tinning purposes. Do not use babbitt for tinning, because it has a higher melting point. The higher temperature prevents the formation of a good molten film on the bronze surface.

1.22 Use a zinc-chloride flux for tinning the shell. Dip the bronze shell into the pot of molten solder. Be prepared to pour the babbitt and form the liner immediately after the shell has been tinned.

1.23 The mandrel (Fig. 1-5) is a steel cylinder of the same diameter as the desired bearing bore. Coat the mandrel to prevent the molten babbitt from clinging to it after it has hardened. One way to coat a mandrel involves holding it near an oily flame. The smoke

Fig. 1-6. Stirring pattern for molten babbitt

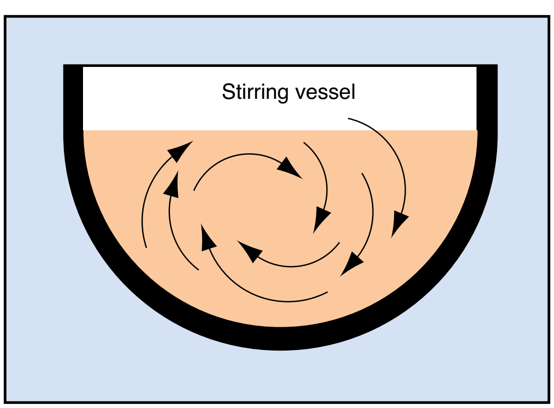
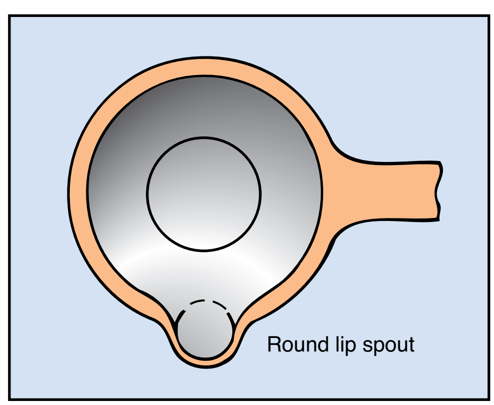


Fig. 1-7. Ladle with rounded lip spout (top view)



will cover the mandrel surface with carbon, a good agent for retarding cling. Coating the mandrel with white lead will also prevent the babbitt from clinging.

1.24 For preheating the prepared pouring shell, use a temperature range of from 200° to 300°F (93° to 149° C). If the shell is of a material other than iron, consult with your babbitt supplier for the correct preheating temperature.

Pouring the Babbitt

1.25 Pour the babbitt when it has reached its molten temperature of 870°F (466°C). Do not let the temperature rise above this level, because the babbitt will then shrink excessively when poured into the shell. Shrinkage causes porosity in the finished liner, thereby reducing the bearing's wear qualities. However, too low a pouring temperature will give the liner a coarse structure throughout.

1.26 Use a ladle with a round lip spout, like the one shown in Fig. 1-7. Sharp-lipped ladle spouts produce a broad, thin stream of babbitt. This, in turn, tends to create blow holes and other inclusions in the finished liner.

1.27 You should place the bearing to be lined in a vertical position. With the shell preheated and tinned as needed, pour the molten babbitt into the shell in a continuous stream.

1.28 Allow the newly poured liner to cool before you attempt to remove it from the mandrel. Work slowly and carefully so that you do not damage the shell or liner during removal. Transport the newly made assembly to a suitable work area for further inspection.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the REVEAL KEY from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. Plain bearings are sometimes called __________ bearings.	1-1. SLEEVE Ref: 1.01
1-2. During operation, the shaft of a machine is supported in the __________ of a plain bearing.	1-2. BORE Ref: 1.02
1-3. In addition to bore, O.D., and wall thickness, the critical dimensions of a plain bearing include its __________.	1-3. LENGTH Ref: Fig. 1-1
1-4. The space between the shaft O.D. and the bearing bore is called the __________.	1-4. CLEARANCE Ref: 1.06
1-5. Clearance is commonly measured with a(n)__________.	1-5. FEELER GAUGE Ref: 1.09
1-6. The ability of a bearing or lining material to flow slightly under load is called __________.	1-6. CONFORMABILITY Ref: 1.13
1-7. Failure of bearing materials due to repeated flaking or cracking is called __________.	1-7. FATIGUE Ref: 1.13
1-8. Dissipation of excessive heat generated during operation is the result of a bearing material's __________.	1-8. THERMAL CONDUCTIVITY Ref: 1.13

Cleaning the Bearing

1.29 After it has been allowed to cool, inspect the newly lined bearing carefully. A firm seal should exist between the bearing liner and the shell. Look at the ends of the bearing assembly. Clean excess babbitt from these areas using a scraper or a fine file.

1.30 Inspect the bore for any obvious defects or very high spots. If the liner-to-mandrel contact was properly prepared, the bore will have a smooth surface. Scrape the surface lightly to remove any dirt. High spots will be removed when the liner is finish-machined.

Measuring the Bore

1.31 Use accurate instruments that are in good condition when checking the rough-bore size. Calculate the required finished-bore diameter, and determine the amount of babbitt to be machined out to obtain the appropriate finished-bore dimensions. After you have made these calculations, measure the shaft journal on which the bearing will seat. Check these dimensions against your calculations.

1.32 The rough-bore bearing can be mounted in a lathe or boring mill. Certain smaller bearings may be finish-bored on a drill press, if they are worked carefully and accurately. The bearing can then be finish-bored to the desired size.

Measuring and Inspecting the Shaft Journal

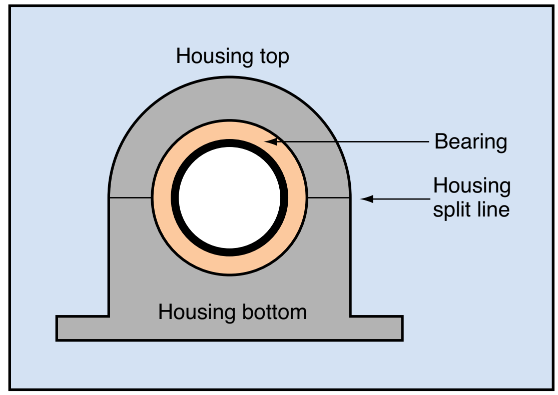
1.33 Before installing a new bearing or replacing one that has been relined, inspect the shaft journal closely. The shaft O.D. should be perfectly smooth and free from nicks, scratches, gouges, or other defects. If any are found, remove them with a file or an emery cloth.

1.34 Refer to a shaft drawing or other specifications to determine the correct shaft diameter and the length of the bearing journal. Check the actual shaft measurements against this information. After you have cleaned the shaft journal, if you are not going to install the bearing immediately, cover it with a clean cloth to protect it from dust, dirt, and moisture.

Installing Split-Housing Bearings

1.35 Some types of plain bearings have a split housing, like the one shown in Fig. 1-8. The split design makes them easier to remove from and install on bearing journals that are located some distance in from the shaft end. The two-piece design, with its ease of assembly and disassembly, also saves downtime of the machine.

Fig. 1-8. Split-housing bearing (end view)



1.36 Split-housing bearings require greater care during assembly than do bearings having a solid housing. The housing halves must be aligned accurately so that a completely round bore results. After final assembly, check the housing clamping bolts to be sure they are firmly installed and that they hold the halves together precisely and securely. Do not tighten the bolts excessively, however, because the bearing liner could be crushed and deformed.

Deformation

1.37 Plain bearings, because of the way they support loads, are often deformed as wear progresses. This results in an egg-shaped bore in the bearing and allows the shaft to pound the bearing bore or liner.

1.38 Replace any deformed bearings immediately. If the bearing continues to wear excessively, measure the clearances and check the lubrication system. You should also check the lubricant for contamination from dirt, grit, water, or other foreign material.

Lubrication of Plain Bearings

1.39 A supply of the proper lubricant in adequate amounts is very important to the life of most plain bearings. Some wood bearings and plastic bearings are run dry (without lubrication), but these represent a minority of plain bearings. Many methods exist for getting lubricant to the bearing. Some types of bearings use rings or grooves, cut into the liner, through which the lubricant circulates. Other systems use grease or oil (depending on the application) under pressure.

1.40 The flow paths must be kept clear so that the lubricant supply is always free to move into the area between the shaft and the bearing bore. Figure 1-9 shows several typical groove patterns used for introducing lubricants into a plain bearing. When installing or servicing a plain bearing, always check to determine the lubricant-flow system and groove pattern involved. Replacement bearings should have the same pattern as the old.

1.41 The function of a plain-bearing lubricant is to provide and maintain a film between the shaft and the bearing bore. Both oils and greases may serve this purpose. The selection of one or the other for a given application depends on several factors.

Oils as Lubricants

1.42 The ability of an oil to form an ideal film depends greatly on its viscosity. In general, you should use an oil of the lowest viscosity that will still maintain an unbroken film between the shaft and the bearing bore. If you use an oil with a higher viscosity than necessary, some of the shaft power is used up in trying to overcome friction within the oil itself.

1.43 Lubricant manufacturers publish charts and reference tables to aid in selecting the correct oil for a specific application. Most suppliers can advise you on any unusual bearing applications. Before selecting an oil for a plain-bearing installation, you need first to determine three things:

- the type of application and driven machine
- the shaft surface speed in feet per minute
- the loads imposed on the bearing.

1.44 Also, consider the materials from which the bearing is made. Some additives to oils can cause a corrosive reaction in certain metals.

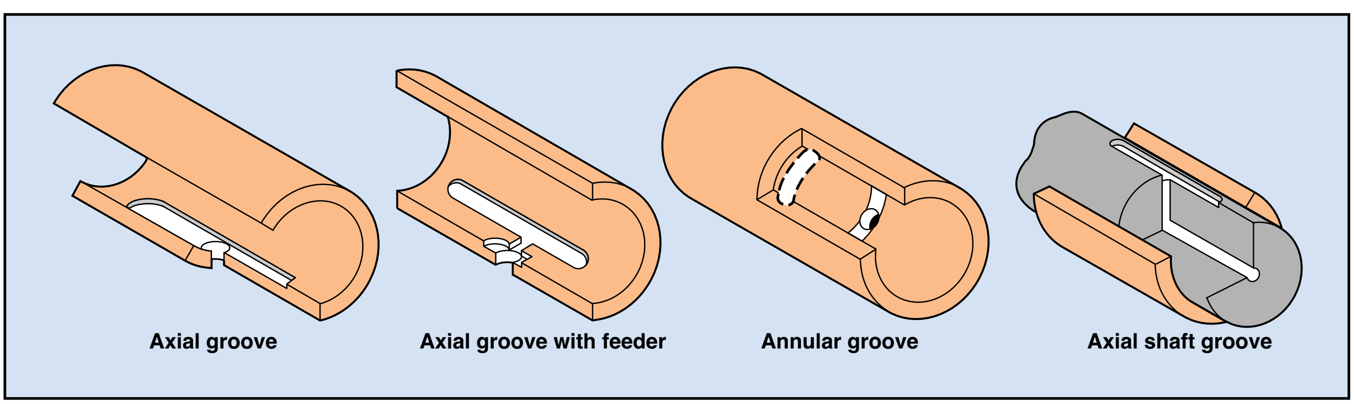
Greases as Lubricants

1.45 Solid lubricants—various types and grades of grease, for example—are frequently used to lubricate plain bearings. Grease is a good lubricant because it does not seep from the bearing, and contamination of materials or working spaces is avoided. Under extremely hot or cold conditions, greases work better than do most common oils.

1.46 Usually, grease-lubricated bearings do not have to be relubricated as often as do those using oil. Also, the purging action of the newly applied grease tends to flush out old lubricants from the bearing surfaces. The greases used to lubricate plain bearings usually consist of a compound of a mineral lubricating oil and a thickening element, such as a metallic soap.

1.47 If a bearing is to operate in a relatively high-temperature application, consider using one of the solid lubricants available. Keep a close watch on solid lubricants at very high temperatures, however. They

Fig. 1-9. Typical lubricant groove patterns



tend to deteriorate rapidly and may lose their lubricating qualities.

1.48 In general, you should rely on the information published by lubricant manufacturers and suppliers when selecting a lubricant for a plain-bearing installation.

Initial Run-In

1.49 After you have installed a new or relined plain bearing, the system should be allowed to run for a short time under no-load conditions. Be sure that all hold-down fasteners are tight. Clear the working area of tools, rags, and other items, and clean up spilled oils or greases. Start the machine and the flow of the proper lubricant to the bearing.

1.50 If an adjustable-speed drive controls the shaft, bring the drive up to speed gradually. Listen for any unusual noises as the shaft rotates. If you detect any pounding or screeching sounds, stop the machine at once. Determine the source of the noise, and correct the condition.

1.51 Check for overheating by placing a pyrometer or other suitable temperature-measuring instrument on the bearing. Look for seepage of oil at various locations. If the bearing is equipped with grease or oil seals, be sure they are in good working condition. Replace worn or defective seals.

1.52 When the bearing functions properly under no-load conditions, apply the full load gradually and repeat the inspection procedures. Do not allow a faulty or poorly installed bearing to continue to operate. It can result in severe damage to the driven machine or in personal injury.

Scheduling Inspections

1.53 Every shop should have a schedule for inspecting and maintaining the plain bearings in the plant. Such a routine will help you spot trouble before it becomes serious enough to cause a total machine shutdown.

1.54 Figure 1-10 on the following page shows a sample bearing-maintenance schedule. Such a chart can be helpful in assuring regular inspection and maintenance of a bearing installation.

Removing Faulty Bearings

1.55 Plain bearings often operate in dusty, dirty atmospheres. A suspected faulty bearing must be inspected, and it may be necessary to measure a bad bearing for replacement. If you must cut or destroy a bearing to remove it, obtain the size, model number, and other relevant data before removal.

1.56 Handle the bearing carefully as you remove it from the machine. Use proper lifting equipment to carry heavier housings and shells. If dropped, they can be ruined. Try to protect the critical areas (bore, ends, and shell) so that your measurements will be accurate.

1.57 Pay particular attention to how the bearing is mounted on the machine. Inspect such supporting

Fig. 1-10. Sample bearing-maintenance schedule

BEARING MAINTENANCE RECORD

Dept. ___________ Machine ______________________________

Bearing location	Date installed	Lube checks	Clearance checks	General inspection	Date last overhaul

structures as baseplates and pedestals. Be sure they are solid and not cracked or broken.

Signs of Overheating

1.58 After removing a faulty bearing, look for signs of high, localized heat. Excessive wiping of the liner material and discoloration are signs that usually accompany higher than normal heat in the operating area.

1.59 Check to be sure that the bearing has been getting the right amount of the correct lubricant for the application. If the surrounding area is very hot, consider installing a baffle to deflect the heat away from the bearing.

Troubleshooting

1.60 Certain common signs indicate trouble in a plain-bearing installation. Watch for the following signals of problems:

- **Rapid wear**. This usually means that the bearing is overloaded, is not properly lubricated, or is operating in extremely dirty conditions. Check the loadings in the system against the bearing's capacity. Check also to see that the bearing is being properly lubricated. Are all dust covers and seals in place?
- **Pounding**. This usually indicates excessive wear in the bearing. Check clearances between the shaft and the bearing bore.
- **Bearing runs hot**. Inspect the lubrication system and lubricant type. Be sure that the correct lubricant is being used in sufficient quantity for the application. Also, check for shaft binding.
- **Excessive oil leakage**. This condition is a symptom of either too much lubricant or faulty seals.
- **Bearing out of alignment**. Check to see that hold-down devices are properly installed and tightened.
- **Screeching**. This usually signals that clearances are too tight or that lubrication is inadequate.

1-9. Two-piece plain bearings are known as __________ bearings.	1-9. SPLIT-HOUSING Ref: 1.35
1-10. In some plain bearings, rings or grooves are used to circulate the __________.	1-10. LUBRICANT Ref: 1.39
1-11. A plain bearing lubricant should form a film between the shaft and the bearing __________.	1-11. BORE Ref: 1.41
1-12. The ability of an oil to form a film depends largely on its __________.	1-12. VISCOSITY Ref: 1.42
1-13. Shaft surface speed is expressed in units of __________.	1-13. FEET PER MINUTE Ref: 1.43
1-14. Greases are generally classified as __________ lubricants.	1-14. SOLID Ref: 1.45
1-15. A newly installed or relined bearing should be run for a short time under __________ conditions.	1-15. NO-LOAD Ref: 1.49
1-16. Pounding between the shaft and bearing is usually a sign of __________.	1-16. EXCESSIVE WEAR Ref: 1.60

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. A plain bearing has no

- ☐ a. bore
- ☐ b. housing
- ☐ c. specific length
- ☐ d. rolling elements

1-2. During operation of a plain bearing, friction occurrs between

- ☐ a. bearing O.D. and the housing
- ☐ b. shaft O.D. and the bearing bore
- ☐ c. bearing O.D. and the bore
- ☐ d. shaft and the housing

1-3. Strength will be diminished if the _________ of a replacement bearing is inadequate

- ☐ a. lubrication
- ☐ b. housing material
- ☐ c. heat
- ☐ d. wall thickness

1-4. Running clearance is measured between the

- ☐ a. shaft O.D. and the bearing bore
- ☐ b. bearing O.D. and the housing
- ☐ c. bearing ends
- ☐ d. bearing O.D. and I.D.

1-5. The strength of a bearing material under a particular pressure is called its

- ☐ a. compatibility
- ☐ b. fatigue resistance
- ☐ c. load capacity
- ☐ d. heat resistance

1-6. A bearing material's resistance to galling during startup is called its

- ☐ a. compatibility
- ☐ b. coefficient of friction
- ☐ c. fatigue resistance
- ☐ d. thermal conductivity

1-7. Tightening the bolts excessively on a split housing bearing could cause crushing of the bearing

- ☐ a. housing
- ☐ b. shaft
- ☐ c. bore
- ☐ d. liner

1-8. The two most common bearing lubricants are oils and

- ☐ a. water
- ☐ b. greases
- ☐ c. hydraulic fluids
- ☐ d. compressed air

1-9. A purging of old lubricants takes place when a bearing is lubricated with

- ☐ a. grease
- ☐ b. oil
- ☐ c. air
- ☐ d. water

1-10. Overloading or improperly lubricating a bearing usually results in

- ☐ a. shaft failure
- ☐ b. housing failure
- ☐ c. rapid wear
- ☐ d. excessive thrust

SUMMARY

Plain bearings are widely used as supports in many machines. They have no rolling elements as do ball or roller bearings. Plain bearings require an adequate film of lubricant between the shaft and the bearing bore. Choice of the correct lubricant for a given application is an important factor in achieving long bearing life.

Bearing linings may be made of bronze, babbitt, hardened lead, aluminum, plastics, or other materials. Prefabricated bearing liners are often used for small bearings. Larger plain bearings, however, usually need linings which are poured to fit, using molten babbitt. This procedure requires the use of safety glasses and protective clothing.

Maintain bearings properly to obtain their optimum service life. Always make sure you obtain the correct bearing for an installation, and replace worn bearings with bearings of the same critical dimensions.

Answers to Self-Check Quiz

1-1. d. Rolling elements. Ref: 1.01

1-2. b. Shaft O.D. and the bearing bore. Ref: 1.02

1-3. d. Wall thickness. Ref: 1.03

1-4. a. Shaft O.D. and the bearing bore. Ref: 1.06

1-5. c. Load capacity. Ref: 1.13

1-6. a. Compatibility. Ref: 1.13

1-7. d. Liner. Ref: 1.36

1-8. b. Greases. Ref: 1.41

1-9. a. Grease. Ref: 1.46

1-10. c. Rapid wear. Ref: 1.60