

OIL SOAKED WOOD BEARINGS

**How To Make Them And
How They Perform**

AGRICULTURAL EQUIPMENT AND TOOLS FOR FARMERS DESIGNED FOR LOCAL CONSTRUCTION



Intermediate

Technology

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1. INTRODUCTION

The purpose of this leaflet is to provide some background information for both constructors and designers who wish to use wood bearings.

The type of wood to use, its treatment, lubrication, and expected performance will be discussed.

2. SOME ADVANTAGES OF OIL-SOAKED WOOD BEARINGS

Made from locally available materials.

Made by local craftsmen with woodworking skills.

Easily assembled.

Do not require lubrication or maintenance.

Operate under dirty conditions.

Easily inspected for wear.

Quickly repaired or replaced.

Can provide a temporary means of repairing a more sophisticated production bearing.

Require low tolerance on both the shafts and the housings.

3. CHOICE OF WOOD

The composition of wood is very complex, but in simple terms it consists of fibrous material bound together with a glue-like substance, water, resins, and oils.

3.1 Initial Selection

D.A. Atkinson (1972) stated that one of the essential characteristics to look for in the choice of wood is hardness.

- The harder the bearing surface, the less the deformation and the smaller the coefficient of friction
- The harder the bearing surface, the lower the rate of wear.
- The harder the bearing surface the less likely it is to breakdown prematurely, singe, and ultimately burn.
- The harder the bearing surface the greater its strength.

It is also worth noting that generally, the harder the wood, the greater its weight and the more difficult it is to work.

The oiliness of the wood is a particularly important consideration when the bearings are unlikely (or not intended) to receive lubrication during their service. Practical indicators that assist the identification of timbers which may have good self-lubricating properties are:

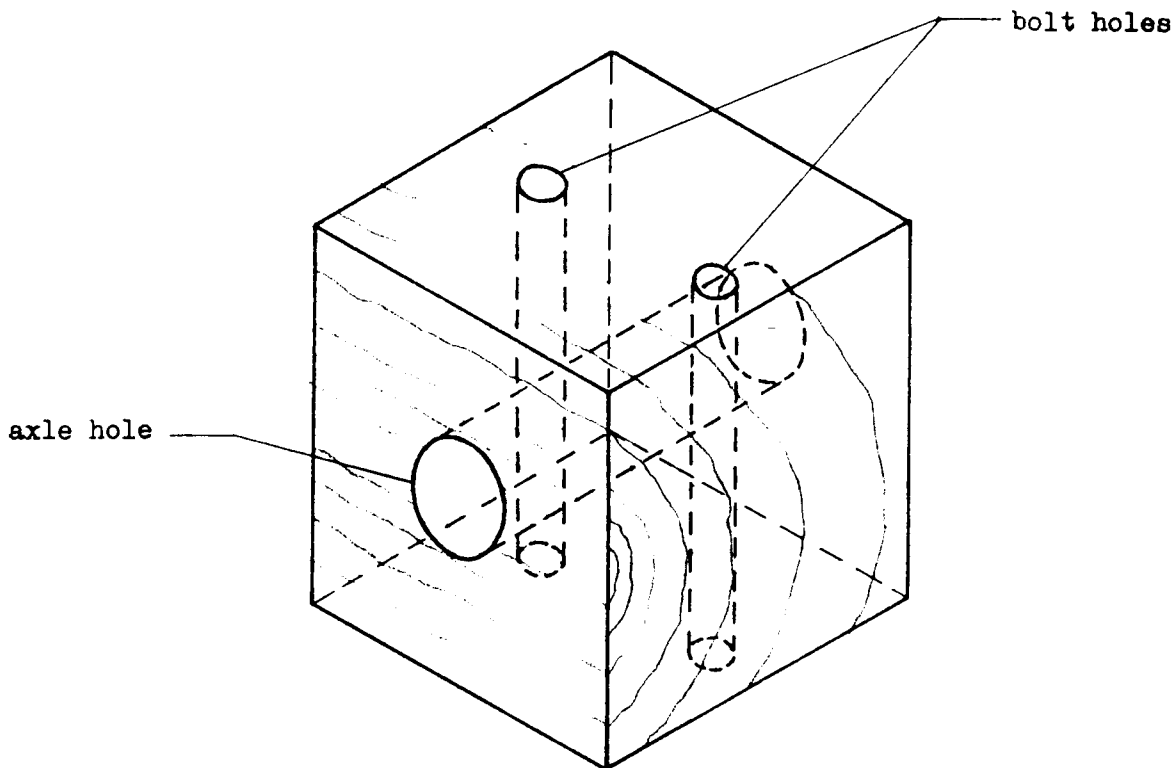
- a) they are easily polished
- b) they do not react with acids
- c) they are difficult to impregnate with preservatives
- d) glue does not easily stick to them

3.2 Other Considerations

High moisture content causes a reduction in hardness and results in greater wear. For most applications low moisture content is preferred and excess moisture must be removed to prevent subsequent shrinkage especially if the bearing is to be used as a bush.

The hardest wood is to be found in the main trunk just below the first branch.

Grain direction should be considered, and if possible advantage taken of the close grain to provide hardness at the wearing surface.



One-piece block bearing (full size)

Fig. 1.

The piece of timber selected for the bearing should be free from cracks. Some suitable timbers are listed in Table 1.

"Greasy " woods	Lignum vitae	(Gualacum officinale)
	Tallowood	(Eucaliptus microcorys)
	Teak	(Tectona grandis)
	Blackbutt	(Eucaliptus pilularis)
Other woods	Poon	(Calophyllum tomentosum)
	Hornbeam	(Carpinus betulus)
	Degame	(Calycophyllum carididissimum)
	Boxwood	(Phyllostylon brasiliense)
	Pear	— (Pyrus communis)
	Oak	(Quercus robur)
	Camphorwood	(Dryobalanops aromatica)

Table 1.

If the timber is not of the self-lubricating variety (or of doubtful self-lubricating characteristics) it can be soaked in oil to minimize the need for subsequent lubrication. It is important to have dry wood to assist maximum absorption of oil.

4. CONSTRUCTION

The following notes relate to experience gained in the "field" manufacture and testing of three types of wood bearing. All were of the oil-soaked variety.

4.1 Types of Bearing

Bush bearing

Split-block bearing

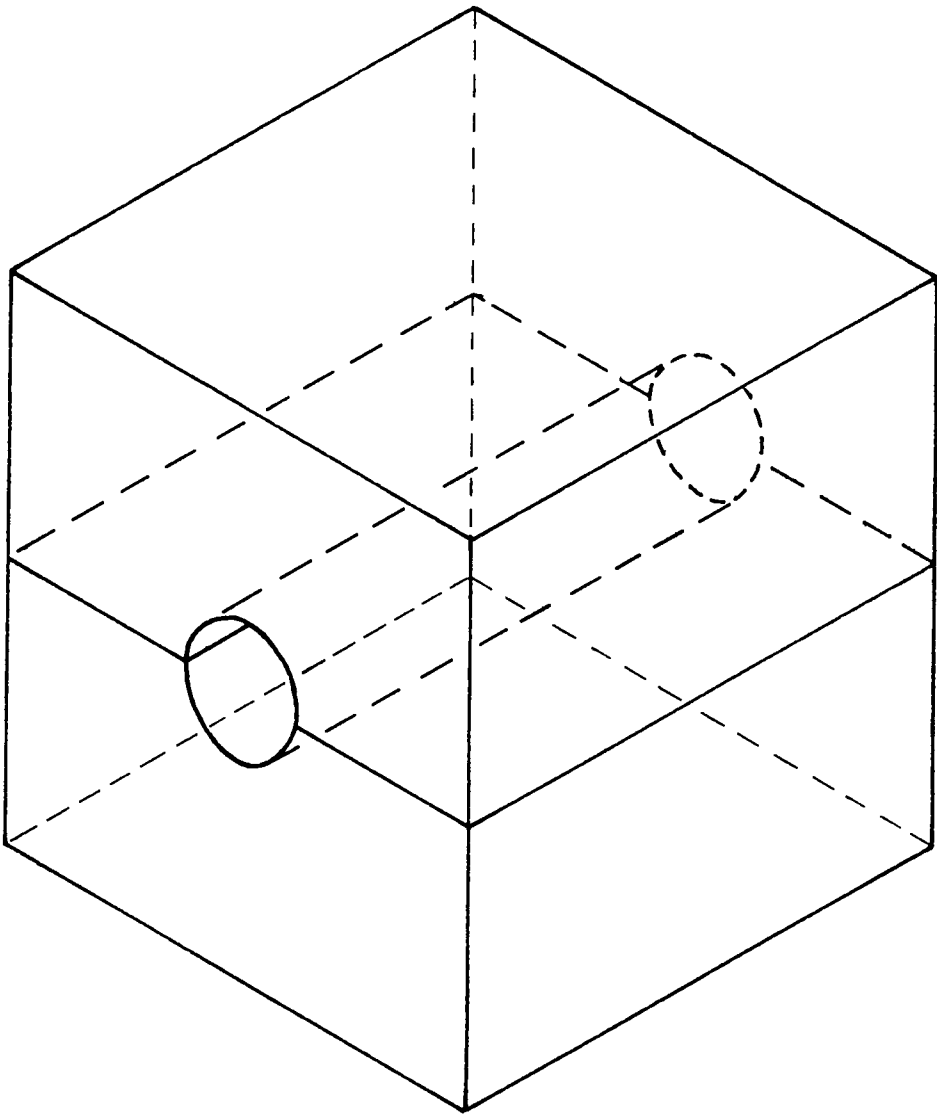
One-piece block bearing

4.2 General Remarks

H.S.Pearson (1975) has suggested that as a general rule-of-thumb guide to the size of timber needed for the bearing, the axial length of the bearing should be at least twice the shaft diameter. For example, for a 25mm diameter axle, the bearing should be at least 50mm long.

In the case of the block bearings, the thickness of bearing material

at any point should not be less than the shaft diameter.



Split-block bearing (half size).

Fig. 2

The drilling of radial holes for lubrication purposes is only recommended by Pearson for the bush type of bearing. He found that if lubrication holes were drilled in block bearings not only were the bearings weakened but also the holes acted as dirt traps.

The bearing should be located whenever possible in a position where falling dirt will not directly enter the bearing. For example, if the axle is carried in bearings mounted under the floor of a cart instead of a fixed axle with bearings at the hub of the wheel, then dirt falling from the rim of the wheel will not fall directly onto the bearings.

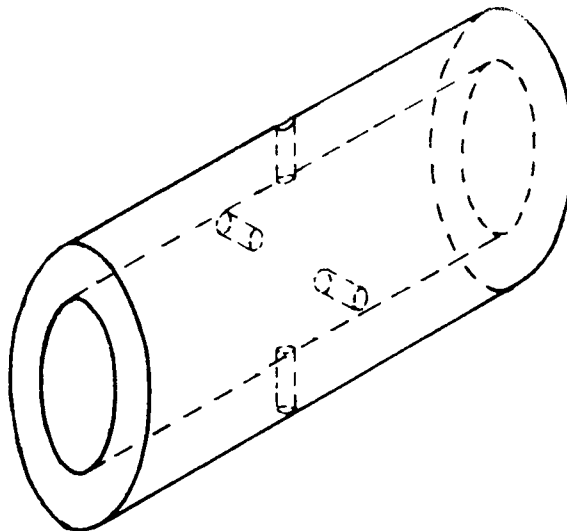
If the bearing is expected to take side-thrust, large flat washers must be used, the one next to the end of the bearing being free to rotate on the shaft.

The bearing surface of the shaft should be perfectly round and smooth and polished in appearance.

4.3 How to Make the Bearings

Available timber often has rather doubtful self-lubricating properties and high moisture content. In this instance, a simple procedure for making an oil-soaked bush bearing has been devised by the Industrial Development Center, Zaria in Nigeria. Excess water is removed and subsequent shrinkage prevented. (Shambaugh, Pearson and Jibril, 1969).

- a) Reduce the timber to a square cross section and bore a hole through the centre the same diameter as the journal on which the bearing will be working.
- b) Place the blocks into a metal container of commercial groundnut oil and keep them submerged by placing a brick on top. Raise the temperature of the oil until the water in the wood is turned into steam - this will give the oil the appearance of boiling vigorously. Maintain the temperature until only single streams of small pin-size bubbles are rising to the surface of the oil. This may take anything from 30 minutes to 2 hours depending on the moisture content of the wood.
- c) Remove the heat source and leave the blocks in the oil to cool overnight if possible. During this stage the wood will absorb oil. BE VERY CAREFUL IF YOU NEED TO HANDLE THE CONTAINER WHILST IT IS FULL OF HOT OIL. If the temperature of the oil is allowed to get too high after the bubbles have ceased to appear, the wood will change to charcoal and the bearings will be ruined.
- d) Rebore the centre hole to compensate for any shrinkage that may have taken place.
- e) Place on a mandrel and turn the outside diameter to the required measurement that will give the bush a press fit into the hub.
- f) Bore four equally spaced holes through the wall of the bush at its mid-point and fill with lubricant - in general terms, the harder the lubricant the better, so animal fat, soap or tallow are preferable although grease is an excellent alternative.

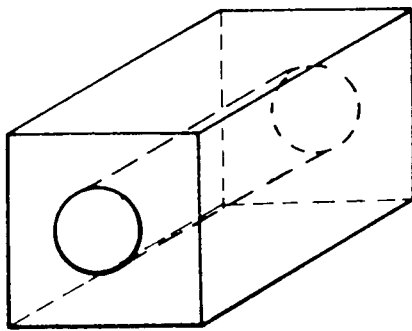


Bush bearing showing the four lubrication holes (full size).

Fig. 3

g) Finally press the bush into the hub.

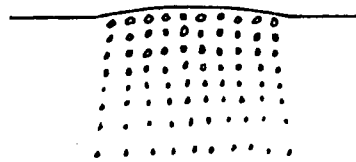
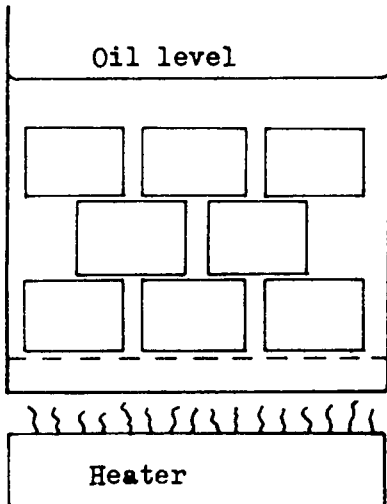
The forty bush bearings made and tested at Zaria were $2\frac{1}{2}$ " long by 1.550" outside diameter with a 0.855" bore. They were pressed into $1\frac{1}{2}$ " seamless black iron Class C pipe, and turned on a $\frac{1}{2}$ " pipe journal. The wood used was mahogany (being the most readily available) and rig tests with a loading of 100 lbs and a speed of 100 - 200 rev/min indicated sufficient lubrication. These test conditions were chosen to simulate the working forces on a 7" gauge wheel of an ox-drawn plough. Tests performed on bush bearings without the four radial lubrication holes again indicated sufficient lubrication.



INITIAL PREPARATION.

Saw timber into shape of an oblong block somewhat larger than the O.D of the finished bearing to allow for shrinkage and bore being off centre. Bore hole through centre of block the size of the journal.

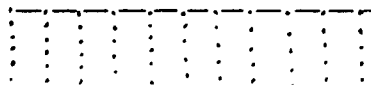
DEHYDRATION



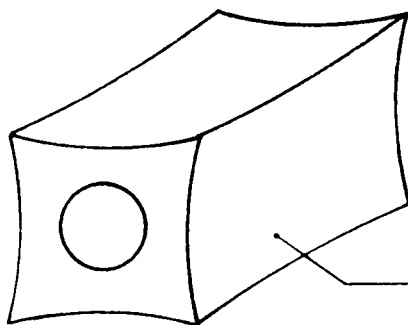
Soon after submerging the bearing blocks in hot ground-nut oil, many surface bubbles 1" in diameter, made from a multitude of smaller bubbles, will appear on the surface.



As the moisture content of blocks is reduced, the surface bubbles will become smaller in size.

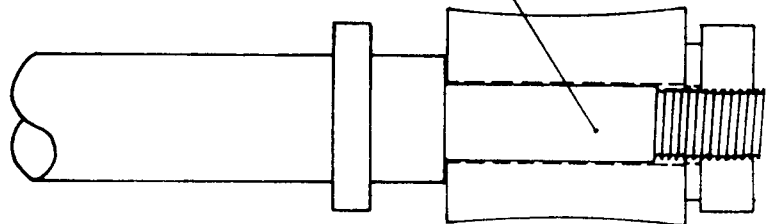


When the surface bubbles are formed from single streams of pin-size bubbles, the dehydration process has gone far enough. Stop heating, and let blocks cool in the oil overnight.



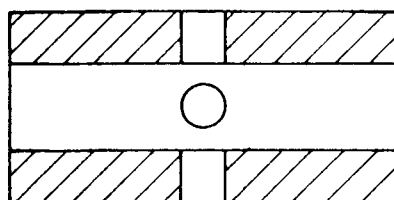
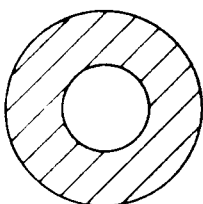
Shrunken block

Mandrel



FINISHING

Re-drill centre hole and place shrunken oil-soaked bearing block on mandrel and turn to the desired size.



Cross section of the finished oil-soaked wood bearing showing grease reservoir holes.

On heavy equipment such as ox-carts or where it is not possible to push the axle through a bush bearing, the split-block bearing provides a more practical solution.

It is simple to fit and replace, and if wear takes place the two halves can be changed around. After further wear, the life of the bearing can be extended by removing a small amount of material from the matching faces.

A simple procedure was devised by the GRZ/ITDG Project at the Magoye Regional Research Station in Zambia for the production of such a bearing, again using an oil soaking technique. The timber in this case was teak, and used engine-oil provided a satisfactory alternative to groundnut oil. (Coombs & Pearson, 1974)

- a) Reduce the timber to a square cross-section and cut lengthwise into two halves.
- b) The two halves of the bearing must be clamped firmly together for the drilling operation. It is most important that the hole for the axle is bored exactly square through the blocks. For the best results an electric powered pillar-drill should be used although a hand powered pillar-drill would be quite satisfactory. If neither of these is available, a jig would have to be made to keep the drill bit in line.

After drilling, the two halves should be tied together to keep them in pairs.

- c) For soaking in oil an old 20 litre (5 gal.) drum is needed. Fill it three-quarters full with used engine-oil and bring to the boil over an open fire. GREAT CARE is needed when handling the drum of hot oil. Lift the drum off the fire and carefully place the pairs of bearings into the hot oil. Put a brick on top of the last pair to stop them floating, and leave the drum and contents to cool slowly overnight.

The split-block bearings measured 150mm x 150mm x 75mm with a 38mm diameter bore. They were field tested for reliability by installing them on ox-carts fitted with iron or pneumatic wheels and carrying loads of up to 2 tons.

A radial clearance on one of these assemblies of about 1mm was found to be essential. If carefully run in at low speeds (ox work),

the clearance is increased to 1.5-2.0mm and the bearing surface attained a highly polished glass-like appearance. Having reached this condition it was found capable of withstanding journeys of a few kilometers at higher speeds (Landrover towing).

A soft pine-wood oil-soaked bearing was tested as an alternative to the hardwood bearing, and this also gave satisfactory performance but might have a shorter life.

For lower load, lower speed applications such as the seed-drive mechanism on a small planter, a smaller one-piece oil-soaked block bearing was used measuring 50mm x 50mm x 50mm with a 16m diameter bore, and this gave satisfactory results, although tests were not extensive.

The possibility of boring the axle hole by hot irons was not investigated but there should be no serious objections to this alternative.

5. PERFORMANCE

The following general points can be concluded:-

- a) The running-in period is of critical importance. It is characterised by a high initial rate of wear whilst smoothing and polishing of the bearing surface takes place, after which wear becomes approximately proportional to time.
- b) The greater the speed of rotation, the greater the wear, especially during the running-in period.
- c) The greater the axle loading, the greater the rate of wear.

More specifically, wear is approximately proportional to load, BUT increases rapidly for small increments in speed.

Very high loading and low speeds should be avoided since this results in a jerking movement of the journal in the bearing and subsequent shaking and vibration will result in wear of other parts.

6. REFERENCES

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MAKE THE WOOD BEARINGS

Bearings, for attaching the shaft to the wheel, will last longer if they are made from the hardest wood available locally. Generally, hardwoods are heavy and difficult to work. A local wood-craftsman should be able to provide information on the hardest woods. If there is doubt concerning the hardness or the self-lubricating quality of the wood that is going to be used in the bearings, thoroughly soaking the wood with oil will give longer life to the bearings.

Some advantages in using oil-soaked bearings are that they:

- * Can be made from locally available materials.
- * Can be made by local people with wood-working skills.
- * Are easily assembled.
- * Do not require further lubrication or maintenance in most cases.

- * Are easily inspected and adjusted for wear.
- * Can be repaired or replaced.
- * Can provide a temporary solution to the repair of a more sophisticated production bearing.

The oiliness of the wood is important if the bearing is not going to be lubricated. Woods having good self-lubricating properties often are those which:

- * Are easily polished.
- * Do not react with acids (e.g., teak).
- * Are difficult to impregnate with preservatives.
- * Cannot be glued easily.

Usually the hardest wood is found in the main trunk just below the first branch. Wood freshly cut should be allowed to dry for two to three months to reduce moisture content. High moisture content will result in a reduction in hardness and will cause greater wear.

SIZE OF THE BEARING

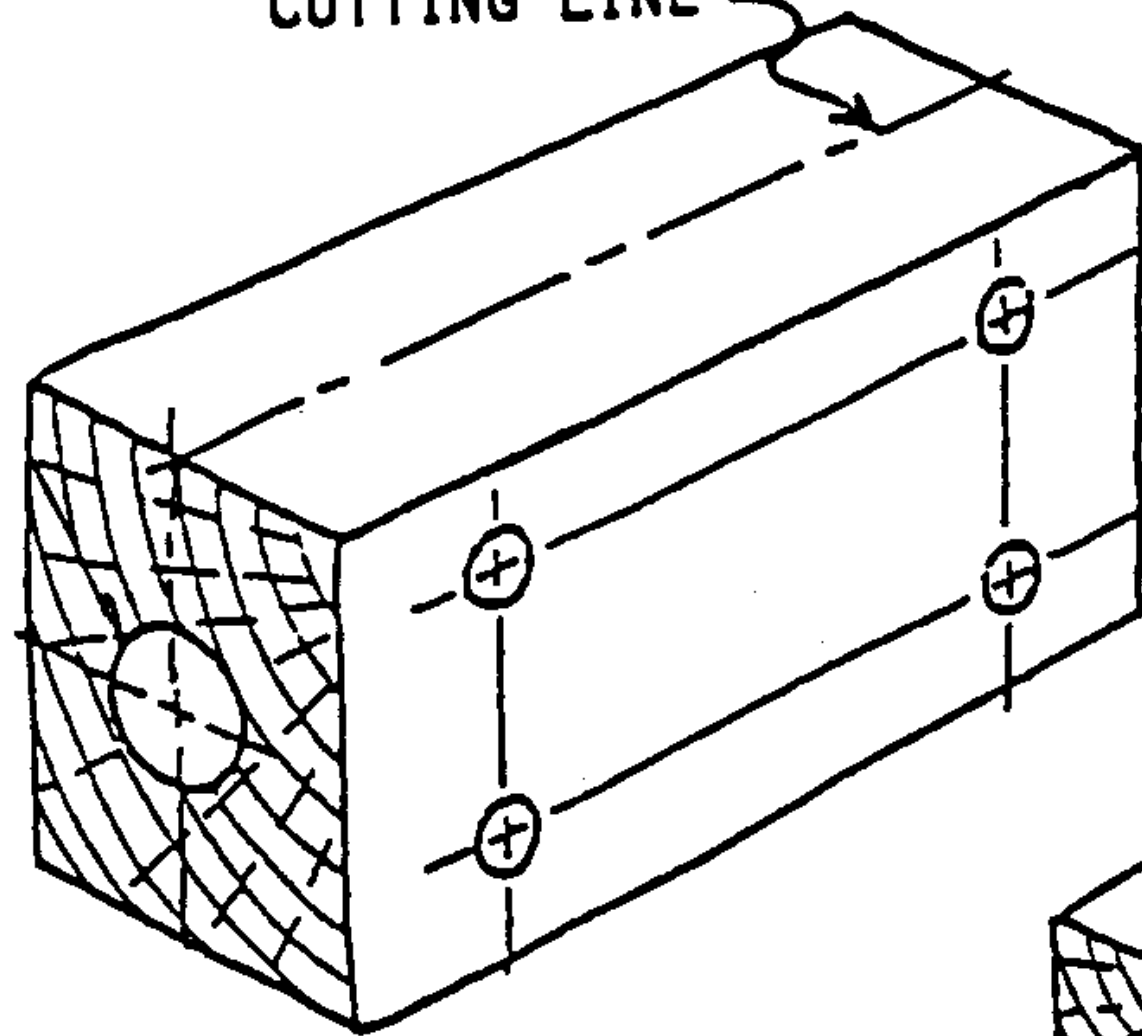
The length of the wood bearings should be at least twice the shaft diameter. For example, for the 5cm dia axle or shaft of the waterwheel presented here, the bearing should be at least 10cm long. The thickness of the bearing material at any point should be at least the shaft diameter (i.e., for a 5cm dia shaft a block of wood 15cm X 15cm X 10cm long should be used).

Split block bearings (see Figure 14) should be used for the waterwheel because it is a heavy piece of equipment and can cause a great deal of wear. These bearings are simple to make and replace.

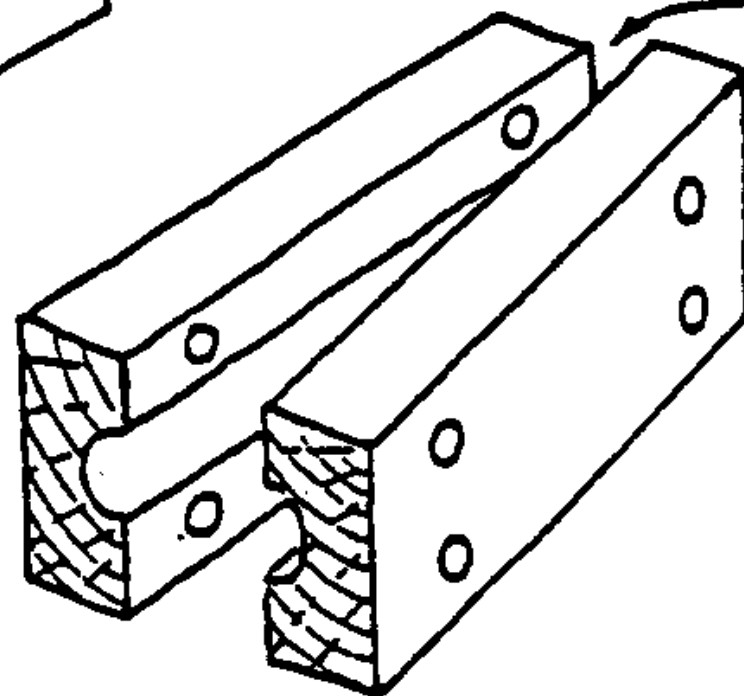
The following steps outline the construction of a split-block bearing:

- * Saw timber into an oblong block slightly larger than the finished bearing to allow for shrinkage.
- * Bore a hole through the wood block the size of the axle/shaft diameter.
- * Cut block in half and clamp firmly together for drilling.
- * Drill four 13mm or larger holes for attaching bearing to bearing foundation. After drilling, the two halves should be tied together to keep them in pairs.
- * Impregnate the blocks with oil.
- * Use an old 20-liter (5-gal) drum filled two-thirds full with used engine oil or vegetable oil.

CUTTING LINE



SAW BEARING
BLOCKS IN HALF
AS SHOWN



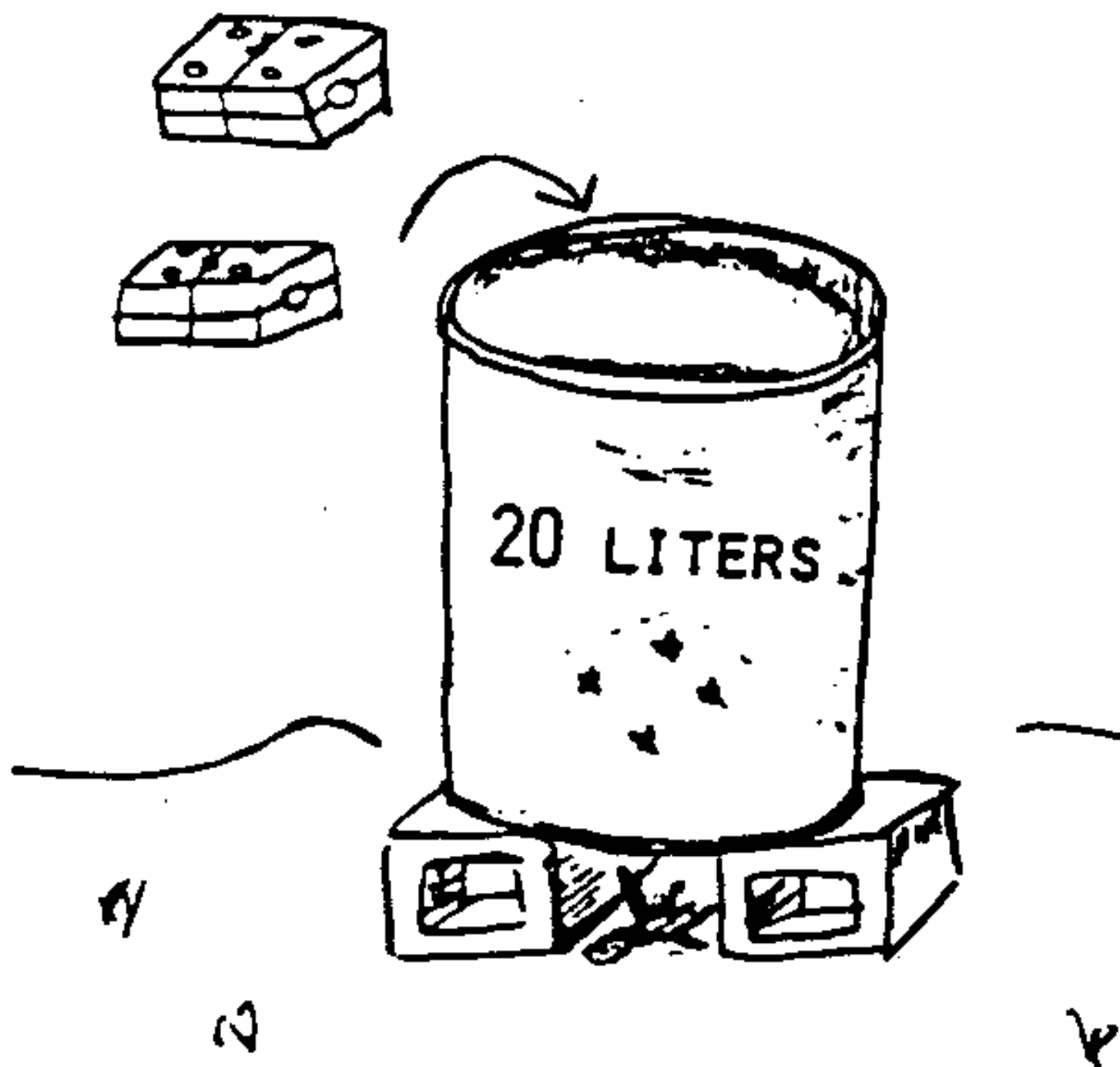


Figure 15. Heated Oil



Figure 16. Surface Bubbles

- * Place wood blocks in oil and keep them submerged by placing a brick on top (see Figure 15).
- * Heat the oil until the moisture in the wood is turned into steam--this will give the oil an appearance of boiling rapidly.
- * Maintain the heat until there are only single streams of small pin-sized bubbles rising to the oil's surface (see Figure 16). This may take 30 minutes to 2 hours, or longer, depending on the moisture content of the wood.

Soon after heating the bearing blocks in oil, many surface bubbles one-inch in diameter, made from a multitude of smaller bubbles, will appear on the surface.

As the moisture content of blocks is reduced, the surface bubbles will become smaller in size.

When the surface bubbles are formed from single streams of pin-sized bubbles, stop heating.

- * Remove the heat source and leave the blocks in the oil to cool overnight. During this time the wood will absorb the oil.

BE VERY CAREFUL IN HANDLING THE CONTAINER OF HOT OIL.

- * Remove wood blocks from the oil, re-clamp and re-bore the holes as necessary to compensate for shrinkage that may have taken place. The bearings are now ready to be used.

20. OIL-SOAKED WOOD BLOCK BEARINGS

For moderate speeds and loads an oil-soaked block from such woods as mahogany, oak, walnut, or maple can make satisfactory bearings. The wood must be thoroughly dry. Scraps of these woods may be obtained from lumberyards, furniture factories, or even from old pieces of furniture that are beyond repair. Scraps of oak flooring are especially easy to obtain.

Design your installation, if possible, so that the major load comes on the end grain of the wood—it has the greatest crushing strength. Drill the hole for the shaft, drill an oil hole to connect with that hole, and then add some form of mounting holes.

When drilling the hole for the shaft try to make it perpendicular to the mounting surface. If the hole needs enlarging slightly for an easy fit on the shaft, do *not* use sandpaper or emery cloth. Particles become imbedded in the wood. Enlarge the hole with a small round rattail file or use a half-round rasp.

The mounting holes may be round to accommodate bolts, or screws, or, if it is anticipated that adjustment will be needed, an extra large round hole may be used with a round head screw and washer—or perhaps an oblong hole for greater movement. See Figure 1. After the holes are all correctly done, soak the

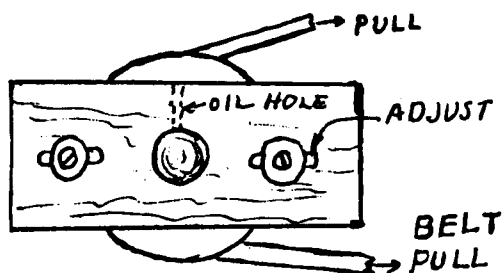


FIG. 1

block in engine oil, number 10, either new or used, for one to three days, depending on your patience and the size of the block. New oil will smell better but the *cost* of the oil might smell worse.

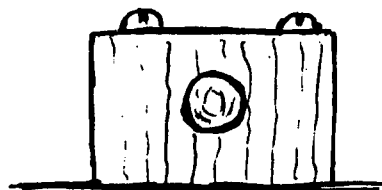


FIG. 2

Figure 2 shows a mounting with the screw holes running with the grain. Notice that the load is still on the end grain.

For temporary jobs, or jobs in which the bearings will not be in constant use, the wood block bearings may be ideal. They are also quiet bearings. For "hand crank" jobs where the speed and load are low they can be ideal.

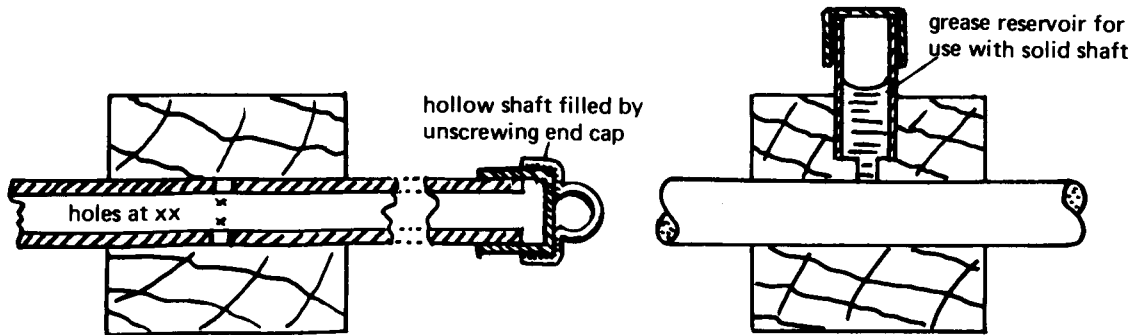


Fig. 36 Grease lubrication systems for wooden bearings

PLATE NO. 15

Hard wood bearings are used in many developing countries as axle bearings in wagons. They are also used on modern grain harvesting combines of the larger variety. The point is, that they work and they work well.

Note the “thrust bearing”, or back bearing, in fig. 5, 6 and 7 which is essential to absorb the “push” of the wind on the sails that is translated to the axle.

The “screw on” cap must be smoothed and polished to reduce friction, and fitted into the widened portion of the axle hole. The “back piece” that it rotates against should be simmered in crank case oil like the rest of the bearing.

Use the hardest wood you can find, like oak, maple or birch. Oak is the best.

- THE WOODEN MULTIBLADE - XIII
- THE WOODEN BEARINGS

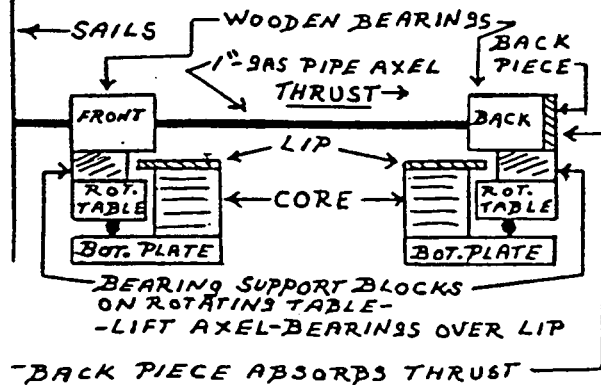
① PRINCIPLES - THRUST-

- DIRECTION OF WIND →
 = DIRECTION OF THRUST →
 = DIRECTION OF FORCE EXERTED BY THE WIND ON THE SAILS →

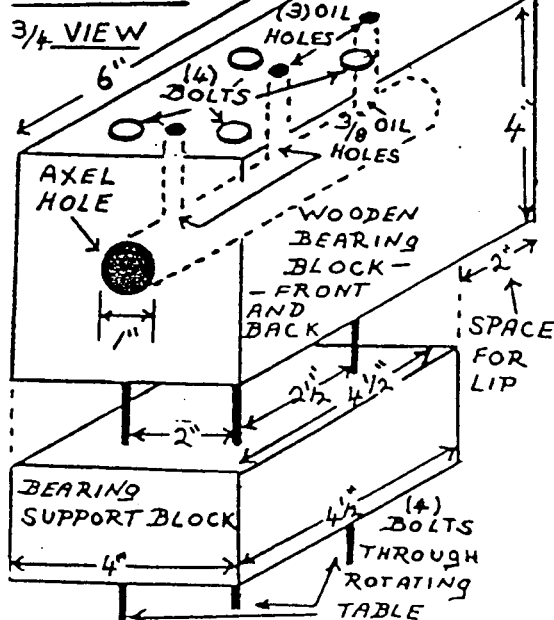
- THIS THRUST MUST BE ABSORBED BY A THRUST BEARING OF SOME KIND - OR THE EXCESSIVE SIDE PRESSURE ON ORDINARY BEARINGS WILL CAUSE PREMATURE WEAR - AND MAY EVEN STOP THEM TURNING -

② WOODEN BEARINGS -

SIDE VIEW



③ WOODEN BEARING

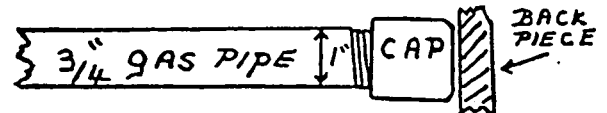


④ WOODEN BEARING - PRINCIPLES

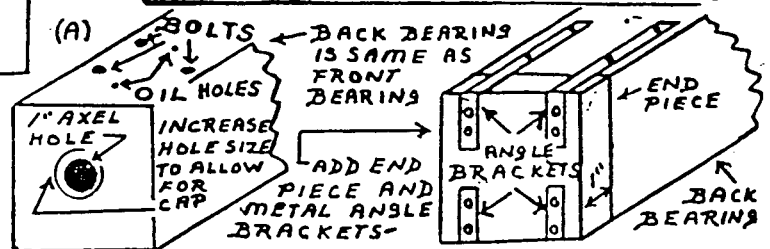
- WOOD BEARINGS ARE SIMPLY HARD WOOD BLOCKS - WITH HORIZONTAL HOLES DRILLED LARGE ENOUGH TO ALLOW AXEL TO PASS THROUGH AND TURN FREELY -
 - 3 OIL HOLES MAY BE DRILLED DOWN FROM THE TOP SIDE -

- FINISHED BEARING SHOULD BE SIMMERED FOR SEVERAL HOURS IN USED CRANK CASE OIL - THE GRAPHITE IN THE USED OIL WILL PROVIDE LONG TIME LUBRICATION - COMING OUT WHEN BEARING GETS WARM -

⑤ AXEL WITH (POLISHED) SCREW ON CAP TAKES THRUST AGAINST BACK PIECE

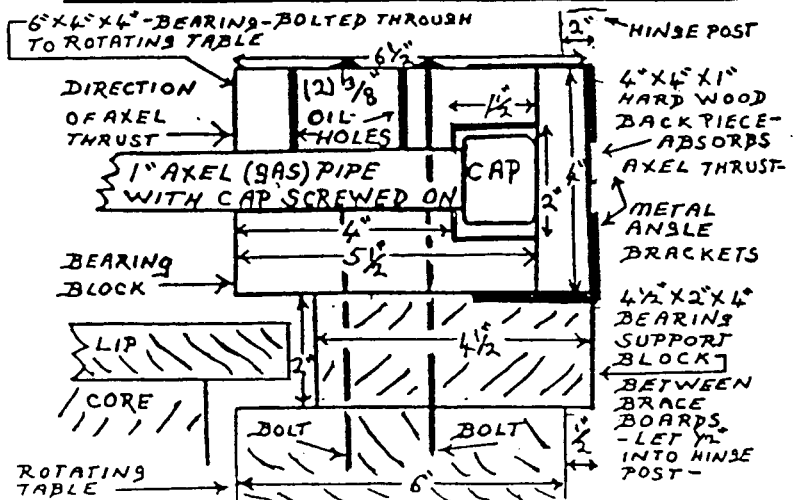


⑥ BACK PIECE - HELD ONTO BEARING WITH METAL ANGLE BRACKETS



⑦ SIDE VIEW - WOOD BEARING

ASSEMBLY - SHOWING SPACE FOR CAP



Bearings can be made from sections of copper pipe, $\frac{1}{2}$ inch size and type L. Also available is type M, but this has thinner walls, and is therefore too loose on a $\frac{1}{2}$ inch shaft. Type L may also be a little loose. This condition is easily corrected by cleaning the inside of the pipe, heating, and coating with solder. This coating is even a better bearing surface than copper as the bearing metals are largely a mixture of lead and tin.

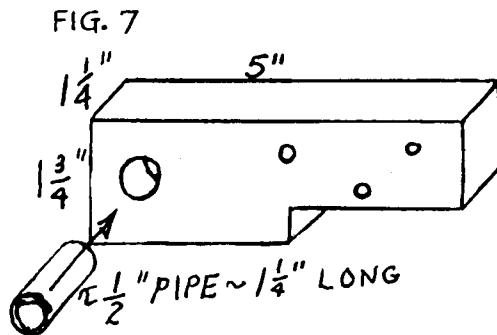


Figure 7 indicates the method of making up the fixed bearing. After the bearing is inserted, if it is not a tight fit, it may be necessary to drill through and place a small nail to anchor it. Drill the oil hole through the wood and copper. If you have not drilled copper before, exercise care, as the drills may easily be broken by too rapid a feed. The dimensions given are approximate, and you may want to change them.

economies can be made in bearing design, and in substitutes for the copper pipe and fittings which may not be readily available in your community.

The fixed bearing may be modified as follows. Bore the $\frac{1}{2}$ inch hole for the

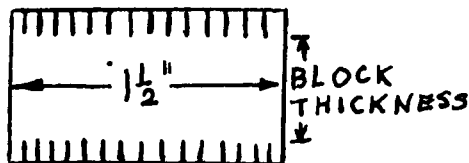


FIG. 13

shaft, and enlarge this hole about $\frac{1}{8}$ inch or less. Cut four strips (Figure 13) from a tin can (the smooth part, with no corrugation). Bevel one end of the shaft and wrap a strip around the shaft. There will be a gap at the top of the wood block, where the oil hole is located (Figure 14). Slip the strip off the shaft, slide the cylinder into the hole, letting the cuts be even with the wood surfaces on each side. Insert the shaft, bevel end first. Keep the strip in place with the gap under the oil hole in the block. With a screwdriver, push the tabs away from the shaft and

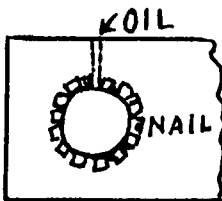
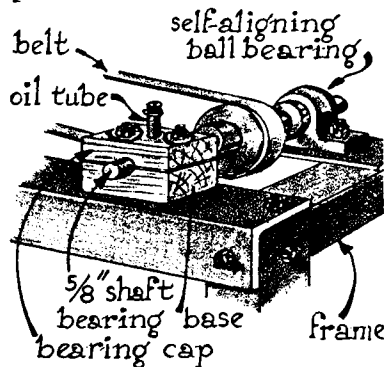


FIG. 14

onto the wood. Drive a small nail into one of the tabs so the "bearing" cannot rotate. Bending the tabs down may "freeze" the shaft, but do not worry. When each tab was bent, a flat piece formed at the bend, so instead of having a circle, you have a series of short lines. With a mallet, tap the shaft against the metal lining, while slowly rotating the block. (The greater number of tabs, the less flattening effect when they are bent over.)

emergency bearings made of hard, close-grained pearwood



MAKING A BEARING OUT OF WOOD

If a bearing breaks down in the shop and if you are located very far from stores where they are sold, you can make one out of wood.

First Step

Choose a dry branch of fruitwood from orchard prunings or some comparable fine-grained wood that has the closest grain possible. As a rule, pearwood is best. Cut from it two blocks and glue them together with thin cardboard in between. Bolt this block onto the location of the bearing that is to be replaced. Mark off the exact center of the hole to be drilled through the wood to fit the shaft.

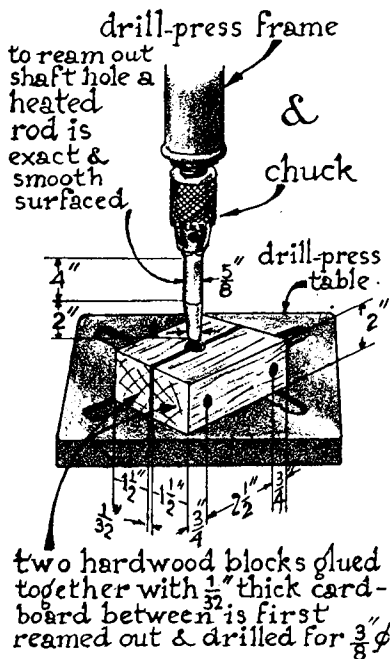
Drill the hole *slightly undersized* at first but as well aligned with the axis of rotation of the shaft as possible.

Second Step

Use a steel rod the size of the shaft and taper it gently so that the small size of the taper fits in the predrilled, undersized hole. Place the block on the table of the drill press and put the tapered rod in the drill chuck to test the setup. When you are satisfied that all is ready, remove the tapered rod and heat it in the forge fire to the point that it will scorch wood.

Quickly transfer the rod to the drill chuck and burn it through the wood, making sure that the heat is not so great that the smoke combusts into flame. The heating does two things: momentarily it *softens* the wood; and, while it scorches, makes the final surface of the hole exact, smooth, and hard.

If all has gone well and the block barely fits onto the shaft, grease the hole and let the shaft run into it with its tight fit. The grease, upon heating, will penetrate the wood.



Third Step

After the bolt holes have been drilled, split the block in two along the cardboard. The top part of the block is the *bearing cap*.

Drill the bolt holes with some clearance, so that you can make a slight adjustment in the placement of the bearing if necessary. If, in assembling, you find that the shaft hole is still too tight, placing thin shims between the bearing cap and bearing pillow will eliminate the friction. Provide the bearing with a lubrication hole and groove.

When installing the bearing, spin the shaft freehand and you will notice immediately whether or not the bearing is well aligned and if adjustments are called for.

Such a bearing will stand up under regular use for a long time. I have used one in my own shop for years.

Adjustments

If the bearing is too low, you may have to place below it strips of thin metal in the pattern of its footing, with the holes corresponding to the bolts. Or if, on the other hand, it is too high, plane or sand off enough wood to lower the bearing to the correct height.

The thickness of the cardboard must be made up for with two shims of wood or metal of that same thickness. If that is a little too thick, try progressively thinner shims until the bolted-down cap does not bind onto the rotating shaft. The shim's edge should just touch the rotating shaft.

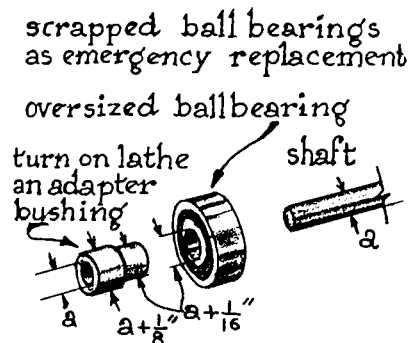
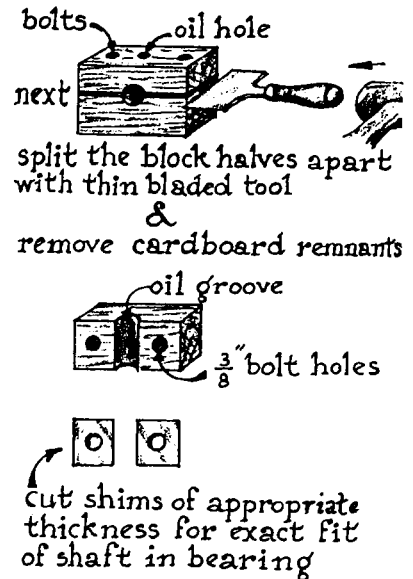
USING DISCARDED BALL BEARINGS

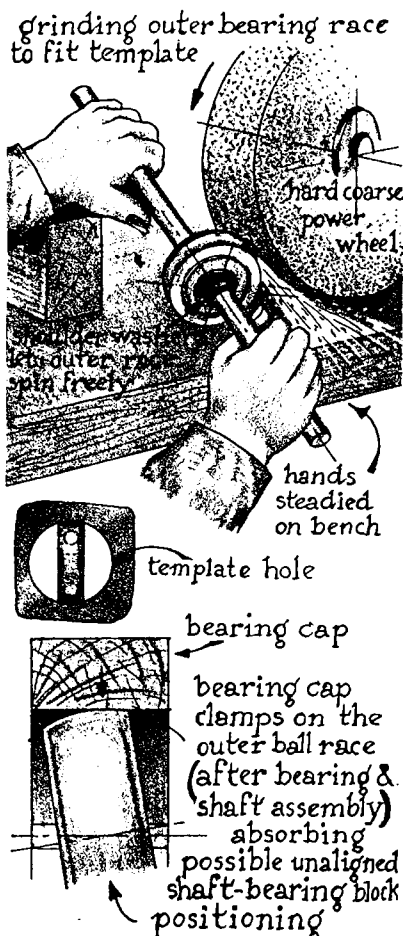
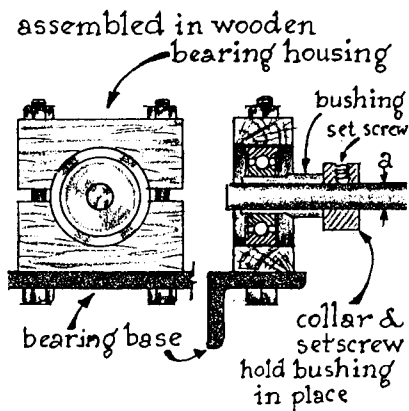
Electrical motor and automotive repair shops quite often discard noisy ball bearings; some are from burned-out motors and are hardly worn at all. If proprietors of such shops are sympathetic with your efforts, they will let you rummage through their scrap barrels. You will be surprised how often you will find unexpected treasures in addition to the things you are looking for.

Bearing shaft holes that are slightly too large

Often you can locate a thin-walled tube that fits over the shaft but may be a little too thick to fit within the bearing hole. Slip the tube section onto a tight-fitting wooden rod and clamp it in the lathe chuck or the drill press chuck. Turn or grind down a small section of that outer tube surface, testing the bearing over it for a fit. If that section is left to taper outward somewhat it will act as a wedge between the bearing opening and the shaft diameter. In assembly, you can tap it into the space it is to fill between bearing and shaft.

After assembly, clamp a little collar onto the shaft to hold the protruding section of the tube shim in position.





How to install the ball bearing

The illustration shows the wooden pillow block that holds down the ball bearing. Since the wood in this instance is not used as a bearing itself but simply as a seat for the ball bearing, the wood can be hard-grained; it need not be close-grained. Oak, maple, or ash will do.

After the height of the bearing has been determined and the whole assembly has been positioned, do not cinch the hold-down bolts until you are certain that the ball bearing itself is perfectly aligned with the shaft. This will protect the ball races from wearing at their sides.

NOTE: The outer ball races in self-aligning ball bearings have spherical outer surfaces representing the central section of a sphere measuring the width of such an outer ball race. Examine a self-aligning ball bearing in a ball bearing supply store, if the three-dimensional aspect of the spherical outer surface of the bearing is too difficult to visualize from drawn illustration.

In the case of these you do not need to make the surface of the bearing seat spherical. The illustration shows that a two-part cylindrical seating can be clamped onto the approximate spherical outer race in a test run. This allows the spherical surface of the outer race to seek its own aligned position just before the bearing seating is clamped down onto the ball bearing.

Grinding the Spherical Surface of the Outer Ball Race

Cut a template with a circular opening the size of the outer diameter of the outer ball race. Fit a wooden rod tightly into the ball bearing. Cut two cardboard discs with central holes to fit snugly on the wooden rod. These discs are to keep abrasive dust from entering the vital parts of the ball bearing; they are placed on each side of the ball bearing with thick grease in between. The discs do not interfere with the spinning of the outer race.

Holding the assembly in both hands, move the outer race into contact with a rotating hard and coarse grinding wheel. The ball bearing race, spun by the wheel, is at the same time being ground down. Aim to grind the steel while it rotates at maximum effectiveness by slanting it, as shown.

The grinding job can be called finished when the outer bearing race can slip through that hole, evenly touching the portion of the circle in the template.

NOTE: The foregoing methods of improvising makeshift bearings to replace broken ones are only two of the many possibilities one can inventively resort to in an emergency.