Life of Axle Bearings of Railway Motors

A wide variation in the life of railway motor axle bearings, on various types of motors on different properties, should be expected, as this life will depend upon a number of varying conditions. Excessive motor end play, and loose axle caps and bearings will tend to shorten the bearing life. Bearings that are not properly protected from dust and dirt will wear more rapidly than those that have their bearing surface kept clean. Other important details that will affect the bearing life, should be given consideration, as follows:

MATERIAL OF BEARINGS

Depending primarily upon the size of the axle and the size of the axle bearing seat in the motor frame, axle bearings are made either of bronze or malleable iron. The following combinations are most commonly found in service:

Shells	Lining Held By	Babbitt Metal Used
†Malleable Iron	Anchor holes	Lead Base
†Malleable Iron	Anchor holes	Tin Base
Bronze	Shells Tinned	Lead Base
Bronze	Shells Tinned	Tin Base
†Bronze	Shells Tinned	No Lining
Bronze	Shells Not Tinned	No Lining

†These bearings can be improved by tinning the shells before babbitting.

METHOD OF TINNING BRONZE SHELLS

The tinning operation consists of coating the surface with a thin film of half-and-half solder to permit the bearing to seat itself more readily or to hold the babbitt lining if bearing is babbitted. The machined surfaces that are not to be tinned, should be coated with a mixture of red clay and water. When this is dry, swab the parts to be tinned with zinc chloride (saturated solution of zinc in hydrochloric acid), then dip the bearing into the tinning solution, which should be at a temperature between 410 and 440 degrees C. (770 and 824 degrees F.) Leave the shell in the pot until it is just hot enough for the tinning alloy to run off. Remove the shell from the pot and thoroughly rub the surface to be tinned with a swab soaked in the zinc chloride. Be sure that all parts of the bearing surface have a thin coating of the alloy and that no untinned spots are left on the surface. Immerse the shell again in the tinning alloy to remove the acid left from the swab, and clean the tinned surface with waste to remove any oxide or other foreign matter from the bearing surface.

OIL GROOVES

In general, it is not considered necessary to have the axle bearings fitted with oil grooves, as these bearings have large surface areas and windows, and are of the split type, and usually get sufficient oil without grooves. However, a great many operators, who believe these grooves are necessary, are using them as an extra precaution against hot axle bearings.

METHOD OF HOLDING BEARINGS

The bearings should be held tightly in place by means of the clamping action of the axle caps. As an emergency precaution, keys or dowels are also used in the lower half of the bearing shell as follows:

1—A single key in the body of the shell.
2—A single dowel in the body of the shell.
3—Two dowels in the body of the shell.
4—Two dowels in the flange of the shell.
5—Two dowels in the flange of the shell and one dowel in the body of the shell.

PACKING OF BEARINGS

The most common type of bearings are those fitted for oil and waste lubrication. The waste, preferably wool, is first soaked in a good grade of car oil for about 24 hours and then allowed to drain; after which it is packed firmly in the axle cap, up to and around the bearing window. The axle cap is then filled up to within an inch of the top with waste packed in comparatively loose. It is considered good practice to repack these bearings every three months, putting new waste next to the axle. All waste should be removed about once every year and bearings repacked with new waste.

LUBRICATION

An improved grade of summer and winter car oil should be used in oiling these bearings. The most common practice is to use one or two gills of oil at each oiling period, which is on the average every seven days. The best results are obtained by pouring the oil into the separate oil well chamber so it must feed up through the waste to the axle. If poured in on top of the waste, it will tend to flood the bearing and waste the oil. It is poor economy to try to operate with too little oil as any apparent saving is more than offset by the resultant short life of the bearings.

LIFE OF BEARINGS

Reports from a number of railway properties, both large and small, operating a great variety of different types of motors in city service, give the following information in connection with axle bearing life:

	Conditions Reported
Material of bearing shell.	Mostly bronze shells.
Material of bearing lining.	8 with no lining. 4 with lead base babbitt 4 with tin base babbitt
Type of lubrication.	Oil and waste
Oil grooves used.	13 Yes. 3 No.
Oil grooves extended to the flange.	11 Yes. 5 No.
Period of lubrication.	7 days min. to 15 days max. 7 days average.
Radial wear allowed.	$\frac{1}{16}$ in. min. to ½ in. max. ⅛ in. average.
Flange or end wear allowed.	$\frac{3}{32}$ in. min. to ⅜ in. max. ¼ in. average.
Life of bearings.	5000 miles min. to 150,000 miles max. 55,000 miles average.
Method of holding bearings.	12 use dowels, 4 use keys.
Limit of life.	12 due to radial wear. 4 due to flange or end wear
Finish of bearing surface.	Turned
Are dust shields used.	6 Yes. 10 No.

ALLOWABLE WEAR

The allowable radial wear for axle bearings as reported above is from $\frac{1}{16}$ to ½ in. with an average of ⅛ in., while the flange or end wear reported is from $\frac{3}{32}$ to ⅜ in. with an average of ¼ in. These figures are fairly representative and should be accepted as good practice to be followed.

LIMIT OF LIFE

The axle bearing life is limited in 75 percent of the above cases by radial wear and 25 percent by flange or end wear. There is no doubt in the minds of railway operators that the limit of life of these bearings is more or less influenced by the use of adequate dust shields to protect the bearings and by reliable adjustable axle collars properly maintained. Another very important factor is to see that these bearings get a liberal supply of good clean oil.

Heat Treated Bolts for Railway Service

Many parts of railway equipments are held together by bolts, as this method affords a convenient and efficient manner of mounting, and readily adapts itself to removing the parts for inspection and repairs. Due to the severe operating conditions, considerable trouble has developed in some instances because bolts work loose in service, allowing parts to wear badly before the trouble is found and corrected. In general, this trouble of bolts working loose in service is largely due to some one or more of the following reasons:

1—Not drawn up tight when applied.
2—Lock washers omitted.
3—Presence of dirt at metal surfaces of parts fitted together.
4—Stretching of the bolts due to an inferior grade of material.

The first three conditions can be remedied by careful attention to details during the inspection and overhauling of the equipment. The fourth condition has been overcome by the use of special, high-grade, heat-treated bolts to replace the standard hardware bolts commonly used on some railway equipments.

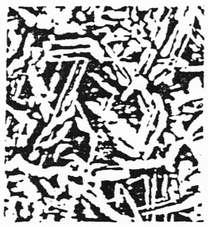

Fig. 1—Standard Hardware Material
Coarse grain structure obtained by slow cooling from rolling heat.

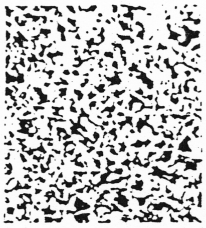

Fig. 2—Annealed Material
Normal grain structure obtained by cooling from annealing heat in air.

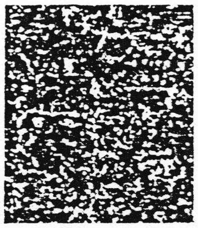

Fig. 3—Heat Treated Material
Heat-treated grain structure obtained by quenching and drawing.

APPLICATION

As the heat treated bolts are more expensive than the standard hardware type, it is not advisable to apply them universally as there are places where the additional strength is not required. There are, however, a number of bolt applications where, if the bolts fail or work loose in service, the riding qualities of the car are affected, operation becomes dangerous and the cost of maintenance rapidly increases. Some of the more important applications for the heat treated bolts are as follows:

1—Truck bolts.
2—Bolts for clamping split frames of motors together.
3—Motor axle cap bolts.
4—Motor housing bolts.
5—Bolts for holding gear case on motor.
6—Motor suspension bolts.

GRADES OF BOLTS

Standard Hardware Bolts are usually made from hot rolled steel, "run-of-mine" stock, which means that the material is not uniform. It is possible to get some good bolts of this type. It is also true that some inferior bolts may be obtained that are brittle and easily broken. In general, they lack uniformity and strength, and cannot be relied upon to stand up in service.

Special steel bolts—annealed or normalized.—These bolts are made from a special grade of steel, bought under a definite specification insuring a uniform material. After being forged, they are re-heated to a predetermined temperature for a specified time and then removed from the furnace and cooled rapidly and uniformly in air. These bolts are uniform in quality, strong and tough, and give much better results in service than the standard hardware bolts.

Special steel bolts—heat treated.—These bolts also are made from a special grade of steel bought under definite specifications, insuring a reliable uniform material. After being forged these bolts are re-heated to a predetermined temperature and quenched from this temperature in an oil bath. The bolts are then tempered by reheating them to a definite temperature for a definite time and allowing them to cool slowly and uniformly in the air. These bolts are uniform in quality, strong, tough and fatigue resisting. They give good results in service and are used and approved by a number of the larger railway operating companies. A comparison of the structure of the material used in the manufacture of above three grades of bolts is shown in Figs. 1, 2 and 3, which represent polished and etched sections of the steel, enlarged one hundred times. The comparative strength of the above three kinds of bolts is given in Table I.

TABLE I—DATA ON STRENGTH OF BOLTS

Material	Tensile Strength Average yield point	Characteristics
Standard hardware	25 000 lbs. per sq. in.	Brittle and variable
Special steel annealed	38 000 lbs. per sq. in.	Tough and strong
Special steel heat treated	60 000 lbs. per sq. in.	Tough, strong and fatigue resisting

WHY USE HEAT TREATED BOLTS?

Both the annealed and heat treated bolts are being used on the equipments of a number of railway companies in place of the standard hardware bolts, but the present day requirements of railway service seems to demand the adoption and use of the heat treated bolt in preference to either the annealed or the standard hardware bolt. The following are some of the characteristics which tend to make these bolts best fitted for this service:—

1—Made from special approved steel with a guarantee of uniformity of composition.
2—Heads machine forged, insuring uniform size and a good wrench fit.

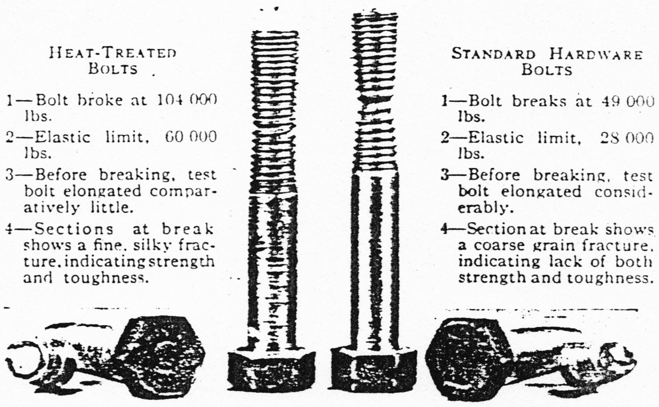

Fig. 4—Comparative Test Results of Sample Bolts

3—Body carefully machined and accurately threaded, being die cut or chased.
4—Heat treated (quenched and drawn) to make the bolts tough, strong and fatigue resisting.
5—One bolt of each heat is tested to insure uniformly high tensile strength.
6—Each bolt is stamped on the head with a distinguished mark for identification.
7—Elastic limit over 100 percent higher than similar standard hardware bolts.
8—The amount the bolt will stretch without taking a permanent set (the rubber band action) is double that of the standard hardware bolt.

The results of a comparative test on heat treated and standard hardware bolts are illustrated in Fig. 4, which shows the superiority of the heat treated bolt.

RELATIVE COST

Depending upon the size, shape and quantities required, the special heat treated bolt will cost from two to three times as much as similar standard hardware bolts. Naturally, there is a tendency on the part of the average operator to raise some objection to this higher first cost of the heat treated bolts, but experience has shown the master mechanics of conservative and well managed railway properties, that it is good economy to use bolts of this type, as they more than pay for themselves in reduced maintenance.

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Loose Gear Case Bolts allow movement of the gear case, which results in wear at the supports. If these parts get badly worn it is difficult to keep the case tight on the supports. The experience of some master mechanics has been that canvas pads treated with white lead placed at the supports enables them to keep these worn cases tight, thus preventing further wear. Gear case bolts should be provided with check nuts which should be kept tight to minimize the trouble due to loose gear cases.

Poor Rail Joints produce a succession of hammer blows which are transmitted to the supports tending to break the case at these points. Improved track conditions will minimize this trouble.

True up Wheels or Flat Wheels have the same effect as poor rail joints. Change them when this trouble is first reported.

Loose Pinions—Invariably when a pinion works loose it will tend to back off and damage the gear case. See that pinions are put on properly. They should be heated in boiling water before driving them on the shaft.

Worn Gears—Badly worn gears set up a high frequency vibration, which is an added strain on the gear case. Gears should be replaced when badly worn.

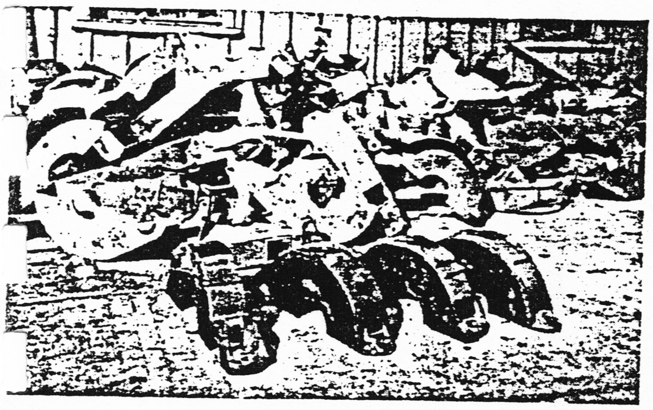

Fig. 2—Discarded Gear Cases Repaired by Electric Welding

REPAIRING GEAR CASES

Since the introduction of electric welding in connection with the repairs on railway equipment, a large number of damaged gear cases have been reclaimed and put back in service. Fig. 2 shows a pile of damaged and discarded gear cases in the background, while in the fore-ground are shown four similar cases that were repaired and put in good operating condition. When this work of reclaiming gear cases was first put into effect on one property, they repaired on an average of sixty cases per month.

Ventilated Railway Motors

In speaking of ventilated motors, we mean those that have a fan mounted on the armature at the pinion end which, when rotating, draws air from the outside of the motor into the frame around the field windings and through longitudinal air ducts in the armature core and forces it out through openings at the pinion end of the frame. Prior to the introduction of the fan on the armatures of railway motors, the armature cores were provided with radial air ducts consisting of ventilating plates made up of small fingers mounted on a heavy armature punching. These ventilating plates were, in reality, small fans which kept the air circulating through the windings. This type of motor is known as the enclosed motor of the radial-air-duct type. In motors of this type, the air circulation was increased and the ventilation made more effective by having some one or a combination of the following arrangements added:

1—Small openings provided in the housings.

2—The use of perforated covers.

3—The solid top commutator cover raised.

This type of motor is known as the ventilated motor of the radial-air-duct type.

TYPES OF VENTILATED MOTORS

The fan type of ventilated motors are commonly divided into two distinct classes as follows:

1—*Series Ventilated Motors*—where the air is drawn in at the op pinion end of the motor frame and passes around the field coils to the commutator end and then back through longitudinal air ducts in the armature core to the pinion end where the air is forced out through the openings in the frame as in Fig. 1. This nethod of ventilation was used on the earlier types of ventilated notors.

It should be understood that the most effective increased rating of a motor due to ventilation, is obtained on the continuous or all-day rating of the motor which is the amount of the work the motor can do continuously in service. The approximate extent to which the continuous rating of railway motors is increased by the various types of ventilation is shown in Table 1, in which the enclosed motor of the radial air duct type is taken as 100 percent in order to provide a basis to more easily make comparisons.

TABLE I—EFFECT OF VENTILATION ON PERCENT CONTINUOUS RATING

Types of Ventilation of Motors	Motors Up to 75 hp., City Service	Motors Above 75 hp., Interurban & Elevated Service
†Enclosed, Radial Air Duct Type, No Fan.	100	100
†Ventilated, Radial Air Duct Type, No Fan.	115	125
Series Ventilated, Longitudinal Air Duct Type, with Fan.	140	155
Parallel Ventilated, Longitudinal Air Duct Type, with Fan.	150	170

†These are not commonly spoken of as ventilated types of motors. They are included here for comparative purposes only.

For example, to show how the continuous rating of a motor is increased by ventilation, note the following current values of a horse-power railway motor:

Enclosed radial air duct type, no fan, 31 amperes.
Ventilated radial air duct type, no fan, 34 amperes.
Series ventilated, longitudinal air duct type, with fan, 40 amperes.
Parallel ventilated longitudinal air duct type, with fan, 52 amperes.

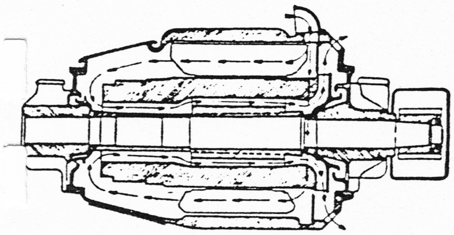

Fig. 1—Series Ventilation

Armature with single fan and longitudinal air ducts. Air inlet located at the pinion end on the top side of the frame.

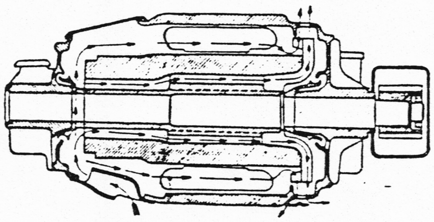

Fig. 2—Parallel Ventilation

Armature with fan and longitudinal air ducts. Air inlet located at the commutator end on the under side of the frame.

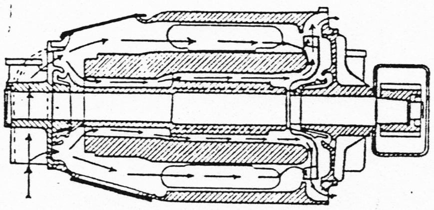

Fig. 3—Parallel Ventilation

Armature with fan and longitudinal air ducts. Air inlet located at the commutator end on the under side of the frame.

2—*Parallel Ventilated Motors*—where the air is drawn in at the commutator end of the motor through openings either in the frame or the housing. The air upon entering divides, some of it passing around the field coils to the pinion end and some of it rough the longitudinal air ducts to the pinion end, where all the air is forced out through openings in the frame, as in Figs. 2 and 3. This method of ventilation is used on the more modern types of ventilated motors.

INCREASED RATING DUE TO VENTILATION

Railway motors are usually given two ratings:

First—A nominal rating expressed in horsepower which the tor will develop without overheating, when operating at full ed voltage on a one-hour stand test. This is the basis on which railway motors are sold.

Second—A continuous rating expressed in current which the tor will carry continuously without overheating when operat- at a reduced voltage as determined by an eight-hour test.

COVERS FOR VENTILATED MOTORS

During the winter months, there is more or less danger of drawing moisture and snow into the motor. To keep out the snow moisture entirely, it would be necessary to totally enclose the motors, which would reduce their continuous rating to such an extent as to cause overheating of the windings.

The lower openings of the motor are the ones most exposed to the snow and water. Tests have been made on parallel ventilated motors with solid covers placed on the lower commutator end air intake opening and the lower pinion end outlet opening with the top pinion end air outlet cover unchanged. As no gaskets are used under these covers, some air is still drawn through the motor, but the snow is almost entirely kept out. The resulting temperature under these conditions shows 20 to 25 degrees C. higher than with the motor fully ventilated. However, since the air temperature is very much lower in winter, the actual temperature of the windings operating under these conditions, during the cold winter season, does not reach the danger point. In other words, the increased temperature rise with the motor partly closed, is offset by the lower outside air temperature.

Just when these covers should be changed must be decided by the various operators, considering climatic conditions, and past experiences. A fairly good and general rule to be followed, is to apply these solid covers between November 20th and December 1st, and to remove them by the end of the following March.

As a protection against snow and water trouble, improved malleable iron ventilated covers have been developed to replace the perforated sheet steel covers. These new covers embody improvements based on investigation and experience of the past few severe winters, and are designed to give better protection against scooping and drifting in of snow, or the entrance of wheel wash, with the ultimate object of using the cover the entire year round.

OPERATING PRECAUTIONS

The following precautions should be taken in connection with the operation of the ventilated type of railway motors:

1—Keep the inside of the motor clean.

2—Cars equipped with ventilated motors should not be used to buck snow.

3—It is more dangerous to push in crippled cars, using cars equipped with ventilated motors, than with non-ventilated motors as the motor windings will more rapidly overheat.

4—The openings on the underside of the motor frame should be closed in the winter time to prevent the entrance of snow and water.

5—The openings on the underside of the motor frame should be opened in the summer time to prevent the windings from overheating.

ADVANTAGES AND DISADVANTAGES OF THE VENTILATED MOTOR

The following are some of the advantages of the ventilated type of railway motors:

1—The continuous current rating of the motor is increased.

2—The weight of the motor for the same continuous output is greatly reduced.

3—This saving in weight makes it possible to reduce the weight of the trucks and of the complete car.

4—The reduced car weight means a saving in power consumption.

5—The lighter weight makes it easier to handle the motor during repairs and overhauling.

The following are some of the disadvantages:

1—The motor must be blown out and kept clean.

2—Ventilated motors, compared with non-ventilated motors of the same continuous capacity, can be overloaded for a shorter period of time, because the continuous rating of the ventilated motor is nearer its hour rating and its heat storage capacity is less in proportion.

3—On some ventilated motors it is necessary to apply solid covers during the winter months, to protect the motor windings from snow and moisture.

4—Unless these solid covers are removed in the summer months, the windings are likely to be overheated.

5—The life of the carbon brushes is relatively short.

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Revamping Loose Armature Bearings

Most operators have experienced some trouble with railway motor bearings working loose in service, which, when left to operate in this condition for any length of time, will rapidly wear the bearing shell and the bearing seat in the motor frame or housings, depending upon the type of construction of the motor. In general, the beginning of this trouble can be traced to some one or more of the following causes:

1—Poorly fitted bearings in frame or bearing seat when installed.

2—Inferior grade of metal in the bearing shells when made of bronze.

3—Carelessness in not keeping frame or housing bolts tight in the case of split-frame motors.

4—Neglecting to change bearings when badly worn either for end or radial wear.

5—Hot bearings, especially in the case of bronze bearing shells, due to unequal expansions.

When bearing shells become loose and badly worn, the best practice is to replace them with new bearings having the correct fit in the bearing seat. This is not always possible, due to the expense and sometimes because new bearings are not available. It is the custom on a large number of properties to revamp and tighten the worn bearings by one of the methods given below, thus prolonging their life and at the same time improving their operation under service conditions.

METHODS USED TO TIGHTEN LOOSE BEARING SHELL

The following are some of the methods used by various operators to secure tight bearing shells.

1—*Rebore the Bearing Seat and Use Over-Size Bearings*—The bearing seat in the frame of the split-frame motor where no housing is used, or in the housing, is machined to about $\frac{1}{16}$ inch larger than standard and an over-size shell is used. This method is used quite extensively and gives very good results in service, but has the objection in that two sizes of bearings must be carried in stock.

2—*Rebore the Bearing Seat and Bush to Standard Size*—The bearing housing is bored out about one-half inch larger and a steel bushing is pressed in the housing, which is then machined to a fit to take a standard size bearing shell. This method is not commonly used, as it is difficult to hold the steel bushing tight in the housing. However, this method does not require carrying two sizes of bearings in stock. This scheme cannot be used on split-frame motors of the old type as they do not use housings.

3—*Build Up the Bearing Seat in Housing or Frame By Welding*—The bearing seat in the frame of the split-frame motor, where no housing is used, or in the housing, is welded and then machined to the standard size. This method has the advantage of using the standard size bearing shells on all motors.

4—*Build up the Bearing Shell by Welding*—The bearing shells are built up on the outside by welding and then machined to standard size to fit the bearing seat in the motor. If desirable, they can be machined over-size to be used in the housings, or the frames rebored to take a larger bearing. This method is used with bronze bearing shells, and the results in service are reported to be very satisfactory.

5—*Expanding Bearing Shells*—After the bronze shell has been re-babbitted, and before boring, force a tapered mandrel through the shell by means of a press. A mandrel suitable for this purpose may be made from a piece of axle steel 10 to 12 inches long, having a taper of approximately 0.030 in. to the foot. It is advisable to oil the mandrel before forcing it through the bearing. The babbitted shell should be bored out to the same diameter as the small end of the tapered mandrel, which should have a $\frac{1}{8}$ in. radius to prevent cutting of the babbitt. In doing this operation, a four inch bearing will require a pressure from one to five tons, and a six inch bearing from five to ten tons. However, these pressures will depend upon the amount of babbitt, the thickness of the shell and the quality of bronze in the shell. With certain types of bearings, it is advisable to place a jack (a three-quarter inch bolt and nut may be used) in the window in an axial direction to stiffen the shell while expanding.

It should be understood that this method of repair applies only to bronze bearing shells that have worked loose and are not badly worn, as the maximum of safe expansion that can be obtained by this method is from 0.010 to 0.015 in. The success of this method will depend largely upon the quality of the bronze from which the bearing shells are made. One operator, who had experienced considerable trouble with this method due to the shells cracking, bored out an old pinion to the exact size to which he was expanding his bearings in which he placed the shells while forcing the mandrel through them. By this means, he limited the expansion and thus saved a large number of shells from being scrapped.

TEMPORARY METHODS OF REPAIR

The above methods of repair are more or less permanent and require a first-class machine hand, with the necessary tool equipment to make a good job, which means that such repairs must be made at the main shops. On the other hand, it is common practice with many operators to change bearings at the operating barns, and the following are some of the more or less temporary methods used to keep armature bearings tight in service:

1—*Shim With Sheets of Metal*—In the case of a motor having housings, a sheet of tin or iron is placed between the bearing and the bearing seat in the housing, and the bearing is forced into the housing. In the case of a split-frame motor not using housings, sufficient metal shims are placed between the bearing shell and the bearing seat in the frame, that the halves of the motor frame, when bolted together, produce a clamping action on the bearing shell. This method is applicable to either bronze or malleable iron shells and is used extensively on many properties.

2—*Outside of Bearing Shell Tinned*—The outside of the bearing shell is tinned rather roughly and the bearing is then forced into the housing. This method ordinarily applies only to bronze shells, but also can be used on malleable iron shells in connection with motors having housings. Bearings treated in this manner are not likely to remain tight very long while in service.

3—*Outside of Bearing Shells Knurled or Roughened*—The outside of the bearing shell is roughened, using a cold chisel which raises a number of high spots on its surface, making a more or less temporary contact when pressed into the housing. This method applies to either bronze or malleable iron bearing shells, and is not in very general use, as it is not considered a satisfactory job.

SUGGESTIONS TO PREVENT LOOSE BEARINGS

As "an ounce of prevention is better than a pound of cure," we make the following suggestions that will tend to prevent loose armature bearings in railway motors:

1—Bearing shells should have from 0.002 to 0.004 in. allowance for a press fit; this allowance should be made on the bearing shell.

2—Bearings should go into the housing with an average pressure of from three to five tons for the commutator end, and from five to eight tons for the pinion end.

3—Insist upon smooth finish on the outside of new bearing shells and on the bearing seat in the housings to insure tight-fitting bearings.

4—Bearing castings should be made from a good, uniform non-porous material of an approved grade of bronze or malleable iron.

5—To prevent pounding and vibration in service, keep the frame and housing bolts tight.

6—It is advisable to remove from service bearings that show either a $\frac{1}{16}$ in. radial wear, or a $\frac{1}{8}$ in. end wear.

7—Aim to keep the bearings cool by carefully packing them with a good grade of clean wool waste and the use of a liberal supply of high grade oil.