

SKF BEARINGS
in Tramway Service


SKF

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THE SKF BALL BEARING COMPANY, LTD.

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CONTENTS

Page

Introduction 7

SKF bearings for tramway axleboxes 9

Types of bearing used 11

Types of axlebox 12

Mounting 16

The fitting of self-aligning roller bearings 17

The fitting of cylindrical roller bearings 19

The lubrication and assembly of roller-bearing axleboxes 20

Inspection 22

The inspection of axleboxes with self-aligning roller bearings 22

The inspection of axleboxes with cylindrical roller bearings 23

Re-turning of the wheel tyres 23

Earth return connection for motor and lighting circuits 24

SKF bearings in tramway motors 25

Types of bearing used 27

Bearing schemes for the armature 28

Bearing arrangements for suspension of the motor 30

Inspection and maintenance of roller bearings fitted in tramway motors 32

Dismantling of the motor 33

Inspection and cleaning of the roller bearings 36

SKF bearings in current collectors 40

Trolley-pole current collectors 41

Tramway motors with SKF bearings: examples from different countries 45

Tramcars with SKF bearings: examples from different countries 52

SKF BEARINGS IN TRAMCARS

In most large cities of the world the tramcar has for several decades been the principal type of public conveyance used, and it continues to occupy that position in spite of keen competition, especially from buses. This competition, however, has had the effect of speeding up the development of the tramcar, so as to enable it to keep pace with modern requirements. The changes thus involved include increases in the capacity, comfort, and speed of the cars on the one hand, and a lowering of the running expenses on the other.

Among the means employed for attaining these ends the use of modern ball and roller bearings is without doubt one of the most effective; and the object of this brochure is to render available in a compact form all the more essential information on this subject, together with particulars of the advantages gained by the use of SKF bearings in tramcars. The design of the different types of bearing used and of the adjacent parts is therefore described and illustrated, and instructions and recommendations for the mounting and maintenance of the bearings are added.

The performance of SKF bearings, whether fitted on the axles of tramcars or in the motors or trolley wheels, is such as to constitute a guarantee that in these bearings the designer will find the best obtainable solution of his bearing problems. Any further information on the subject can be obtained from our Technical Department, whose collaboration and advice are freely offered to all who are interested in the building or running of tramcars.

SKF



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SKF BEARINGS FOR TRAMWAY AXLEBOXES

SKF have been supplying roller-bearing axleboxes for the equipment of tramcars in practically all countries of the world for many years. The total number of SKF roller-bearing axleboxes supplied to date for both tramway and railway use exceeds 250,000, of which more than a quarter is accounted for by tramway axleboxes.

Experience has shown that the benefits accruing from the use of these axleboxes may be summarized as follows:—

Lower running resistance
Minimum maintenance costs
Lower lubrication costs
Increased reliability

Investigations, both practical and theoretical, have shown that the substitution of SKF roller-bearing axleboxes for plain-bearing axleboxes under otherwise unaltered conditions is followed by an appreciable decrease in the kWh.-consumption. This decrease is explained by the small amount of friction attending the operation of SKF roller

bearings, which makes starting easier, increases the capacity of acceleration, and diminishes the running resistance. In order to derive full benefit from these properties, however, it is essential that the car should be driven with due regard to their existence, i. e. the coasting runs or the runs between the breaking of the circuit and the application of the brakes must be considerably longer than when plain bearings are used. If this important point receives adequate attention, the possibilities of easy running afforded by the roller bearings will be utilized to the maximum extent. In the Swedish technical periodical *Teknisk Tidskrift* No. 33, 1928, appeared the results of a very thorough investigation made by the tramway administration of Copenhagen, which show that by employing the correct method of driving tramcars equipped with SKF roller-bearing axleboxes, it is possible to run the cars on 10 to 14 % less power than is required for running similar cars fitted with plain-bearing axleboxes. Even if this point is disregarded, however, and cars equipped with roller-bearing axleboxes are driven in the old way, power will still be saved owing to the extremely small amount of starting friction in the bearings, but the extent of the saving will not of course be as great as indicated above.

The results of several comparative tests conducted under working conditions show that the adoption of roller bearings invariably results in a saving of power. The extent of this saving depends on the mileage, but even the smallest saving revealed by the tests (annual mileage 25,000 miles) suffices to repay the initial cost of the axleboxes at the rate of at least 5 % p. a.

In this connexion it should also be noted that the easy running of roller bearings greatly facilitates the handling of the cars in the depots. Whereas two or three men are needed to move a trailer car with plain-bearing axleboxes, one man can easily do this when the car is equipped with SKF roller-bearing axleboxes.

If roller bearings are lubricated according to the directions supplied by SKF and are also protected against the intrusion of foreign matter, they will undergo no wear. This means that when SKF roller-bearing axleboxes are of the right type for the duty concerned, they last as a rule as long as the vehicle itself, instead of having to be renewed from time to time like plain bearings. The saving in maintenance expenses thus effected is almost equal to that due to the easy running of roller bearings. Figures representing the different items that go to make up the cost of maintaining plain-bearing axleboxes, such as procuring, casting, and machining bearing metal, and renewal of the thrust washers and of the lubrication devices, show that these expenses are capable of assuming

considerable proportions. By the use of SKF roller bearings, however, they are almost entirely eliminated. A reduction in maintenance expenses amounting in the course of a year to about 5 % of the initial cost of the axleboxes may therefore be counted on. This figure, it may be added, is based on the assumption that no overheating takes place in the plain bearings, and that the cost of maintenance is therefore the lowest possible.

A factor contributing to the economic value of SKF roller-bearing axleboxes is the decrease in the consumption of lubricant that follows their installation. This decrease amounts to 80 or 90 %, and is accompanied by a simplification and cheapening of the work of lubrication. Roller bearings are lubricated with grease, which owing to the efficient sealing of the axleboxes, needs renewing or adding to no oftener than when the vehicles themselves are periodically overhauled, no re-lubrication being necessary while the car is in service.

A further saving is accounted for by the employment of a press fit for mounting the roller bearings on the axle journals, which precludes all possibility of wear of the journals such as attends the use of plain bearings, and therefore renders re-turning of the journals unnecessary.

In a different class but of no less importance is the very great increase in general reliability that is secured by the use of SKF roller bearings. For notwithstanding the present day demand for higher speeds of travelling and larger and heavier units, hot bearings are practically unknown where SKF bearings are employed.

TYPES OF BEARING USED

Two types of SKF roller bearing are used for the axleboxes of tramcars, namely the Self-Aligning Roller Bearing and the Cylindrical Roller Bearing.

The Self-Aligning Roller Bearing (fig. 1) has two rows of rollers and the raceway in its outer ring is spherical; hence its faculty for self-alignment. It possesses a very great carrying capacity in an axial as well as a radial direction, which together with its ability to withstand heavy shock loads, renders it particularly suitable for use on the axles of rolling stock. When used for this purpose it always has a taper bore and is fitted on the journal by means of a withdrawal sleeve.

The Cylindrical Roller Bearing (fig. 2) has one row of cylindrical rollers, which are guided between flanges on the outer ring. When used

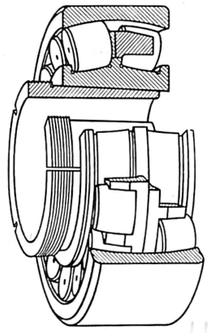


Fig. 1. SKF self-aligning roller bearing.

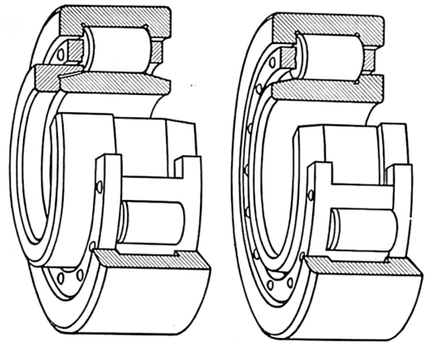


Fig. 2. SKF cylindrical roller bearings.

for axleboxes this bearing is always of the wide type. The inner ring is provided with a fixed or a removable guiding flange, which takes the thrust loads arising while the car is running. This bearing has a cylindrical bore and is shrunk on to the journal.

TYPES OF AXLEBOX

For the purpose of choosing the most suitable type of SKF roller-bearing axlebox for use on a particular car, it is first of all necessary to consider the design of the frame or bogie. If the load is transmitted through a spring resting on the top of the axlebox, the box should be of the so-called rigid type provided with two self-aligning or two cylindrical roller bearings.

Fig. 3 shows a type of tramway axlebox containing *two self-aligning roller bearings*. The bearings are secured to the journal by means of tapered withdrawal sleeves. The advantage of this method is that the axle can be machined to wider tolerances than would be permissible if the

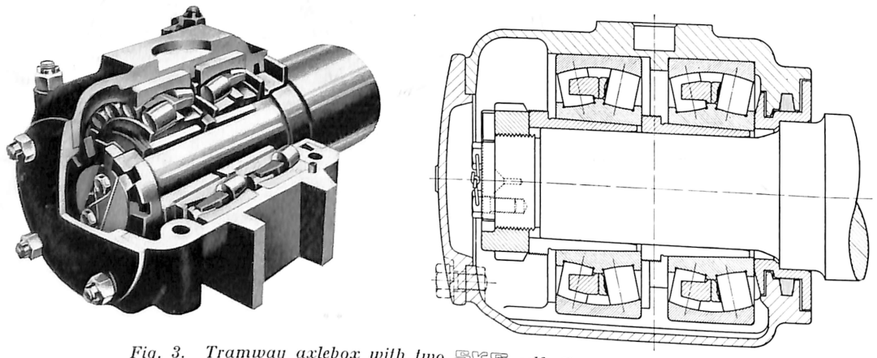


Fig. 3. Tramway axlebox with two SKF self-aligning roller bearings.

bearings were mounted on the journals direct. The axlebox is made in two halves, clamped together by four strong bolts, by which means inspection of the bearings is facilitated.

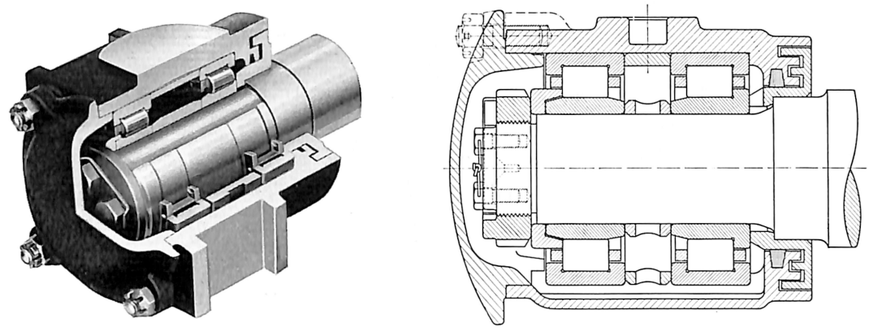


Fig. 4. Tramway axlebox with two SKF cylindrical roller bearings.

A widely used type of two-bearing axlebox is shown in fig. 4. It contains *two cylindrical roller bearings* fitted direct on the journal, which is machined to a specified plus tolerance. The inner ring of the inner bearing has a fixed guiding flange, and the inner ring of the outer bearing a removable guiding flange. The axlebox is made in one piece, but for the purpose of inspecting the bearings it is only necessary to remove the key, nut, and loose flange, whereupon the axlebox together with the outer ring and roller assemblies can be pulled off the journal. This method has much to recommend it, for the inner rings, mounted with an interference fit, remain undisturbed on the journal, and all risk of damaging the bearing seatings is therefore avoided.

In addition to the two-bearing axleboxes just referred to, various types of single-bearing axlebox for tramcars have been developed in recent years. One of these, called *the pendulum axlebox* and fitted with *one self-aligning roller bearing*, is shown in fig. 5. By means of a stirrup movable in a vertical direction in the guides and which supports the spring, the load is transmitted to the axlebox through trunnions or pivotal arms integral with the box at its lower part. Under the influence of thrust shocks, occurring when curves, switches, or crossings are negotiated, the axlebox oscillates about the pivotal points and the self-aligning bearing accommodates itself to the movement. Since, however, the points of application of the load are situated below the centre of the axle, the box retains its equilibrium, being invariably restored to



Fig. 3. Tramway axlebox with two SKF self-aligning roller bearings.

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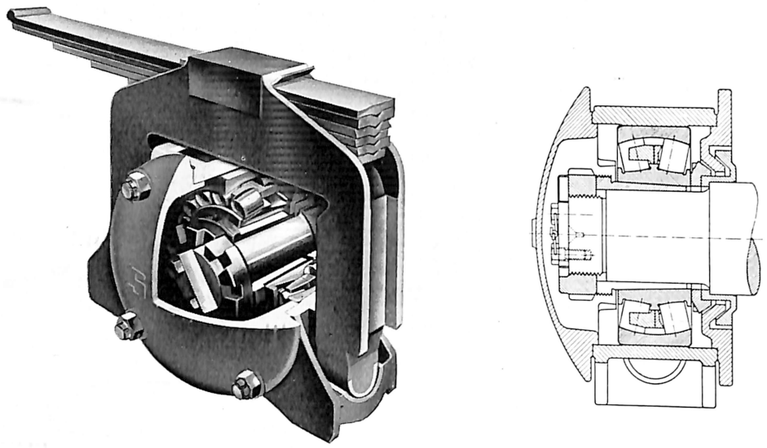


Fig. 5. Tramway axlebox of pendulum type with one SKF self-aligning roller bearing.

the normal position by a force proportional to the angular deviation. By this means the running of the car is rendered smooth and comfortable, and the stresses in wheels and rails are diminished. To restrict its oscillation on being subjected to exceptionally severe thrust shocks, the axlebox is provided with two stops. Fig. 6 shows an SKF pendulum axlebox mounted in the frame of a tramcar.

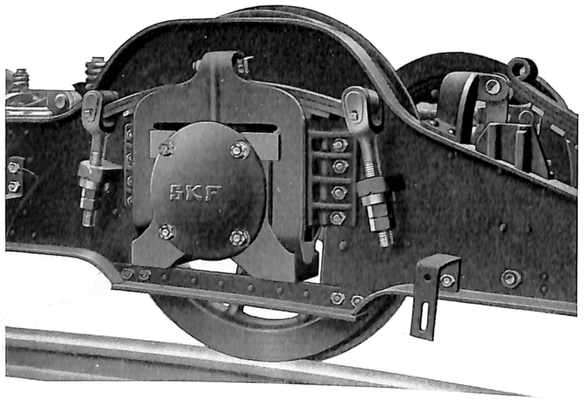
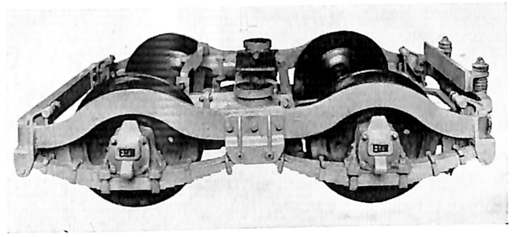
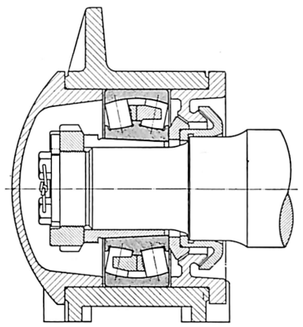


Fig. 6. SKF pendulum axlebox.

A modified form of the pendulum axlebox described above is shown in fig. 7. Here the carrying spring is fastened in a stirrup situated below the axlebox, and hornless trucks are used. The axlebox is guided by





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Fig. 7. Tramway axlebox with one SKF self-aligning roller bearing.

the spring alone, and a stop on the top of the box prevents excessive axial movement. The springs are made capable of offering adequate resistance to twist under side-pressure and of returning to their normal position when the pressure is released. The self-aligning bearing can readily adjust itself to the side movement of the spring. With this design the axial loads are cushioned by the spring and the effects of shock loads mitigated. The hornless truck, the use of which is made possible by this design, is very silent-running.

A single-bearing axlebox that lends itself to mounting on either the pendulum or the rigid principle is shown in fig. 8. The carrying spring is also in this case fastened in a stirrup below the axlebox, but the truck is provided with guides. The guides used here guide the axlebox both axially and radially. By providing a certain amount of axial clearance between the box and the guides an oscillating motion is made possible.

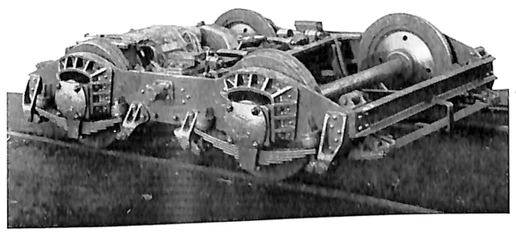
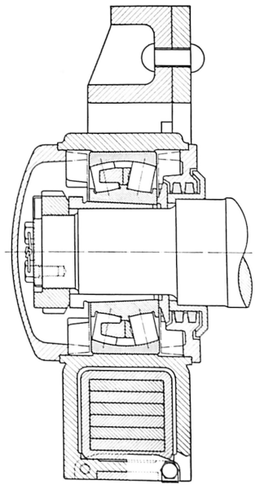
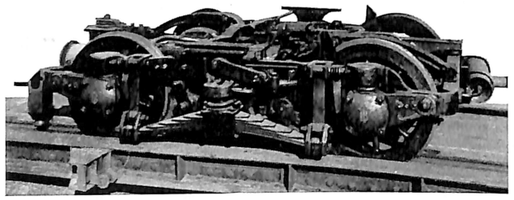


Fig. 8. Tramway axlebox with one SKF self-aligning roller bearing.



Lastly, fig. 9 shows a single-bearing axlebox of special type. This box is on one side provided with a guiding arm, the outer end of which can swivel about a pin in the bogie frame. The design will be clear from fig. 9 (left), in which the axlebox is seen mounted on a bogie. Here also the self-aligning property of SKF roller bearings is very useful, for unevenness of the rails very often causes misalignment of the axles, which in its turn would give rise to severe stresses in the bearings if these could not accommodate themselves to the misalignment.



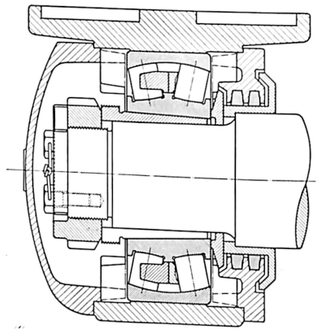


Fig. 9. Tramway axlebox with one SKF self-aligning roller bearing.

MOUNTING

The greatest cleanliness and care should be observed in the mounting of roller-bearing axleboxes. The atmosphere of the shop in which the work is done should therefore be as free from dust as possible, and only skilled fitters employed for the purpose.

Prior to the mounting, the journals and locking devices should be carefully inspected, and any necessary adjustments made. The diameter of the journals should be gauged in several places with a micrometer, to make sure that it is within the tolerances fixed by SKF. It is essential, moreover, that the journals should be truly cylindrical. The maximum permissible variation of the diameter of one and the same journal due to ovality or taper is 0.0008″. Oval, tapering or undersize journal seatings affect the fit of the sleeve or bearing inner ring, so as to entail risk of creep, wear of the journal, and wear accompanied by the development of fractures in the bearing ring.

For the diameter of axle journals on which cylindrical roller bearings are mounted direct, SKF recommend the tolerance n6, and for that

of journals to which self-aligning roller bearings are secured by means of a tapered sleeve, the tolerance h9. The cylindrical part of the journal and also the fillets should have a smooth surface, free from scratches, since these are a frequent cause of fatigue cracks.

Axleboxes and accessories should be carefully inspected and their dimensions checked. Axleboxes supplied by SKF are inspected before leaving the works, and therefore only need examining superficially to ensure that they have not become damaged in transit.

Roller bearings, before being packed, are thinly coated with vaseline to prevent corrosion. There is no need to remove this vaseline before proceeding with the mounting: the bearings may be mounted as they are when taken out of their cardboard boxes. If, however, through having been removed from their boxes too soon or for some other reason, the bearings have remained uncovered for some time and dust or the like has in consequence settled on them, they should of course be carefully washed in benzine or benzol before being fitted.

THE FITTING OF SELF-ALIGNING ROLLER BEARINGS

The collar for sealing the axlebox is shrunk on to the axle, for which purpose it is heated in an oil bath to a temperature of about 265° F. above that of the surrounding atmosphere. The oil container should be provided with a false bottom of wide-mesh wire-gauze, situated a few inches above the bottom proper, to separate any impurities from the oil; overheating of the collar is also avoided by this means.

When the sealing collar has acquired the temperature of the oil bath, it is pushed on to its seating on the journal and then driven against

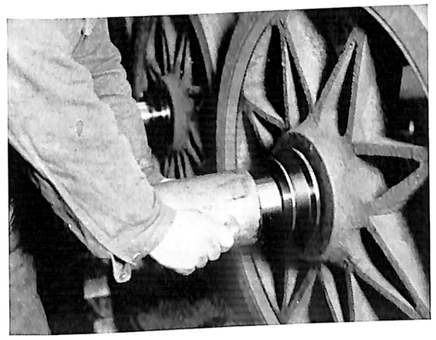


Fig. 10. Mounting the sealing collar.

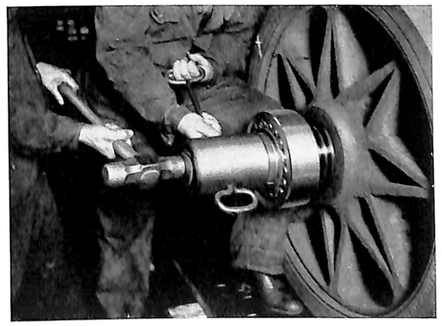


Fig. 11. The roller bearing being mounted.

the shoulder by means of blows, light at first and then harder, delivered with a suitable mounting sleeve (fig. 10) provided with two handles.

After cooling of the sealing collar and axle journal, which latter will have become heated to a certain extent by the collar, mounting of the roller bearing may begin. The contact surfaces of the journal, sleeve, and bearing, are well cleaned and then wiped with an oily rag. The roller bearing with its sleeve is pushed on to the journal against the sealing collar, whereupon the sleeve is driven further into the tapered bore of the bearing by means of heavy blows with a sledge-hammer against a mounting sleeve (fig. 11). This sleeve is bored to give an easy sliding fit on the journal.

To show when the right fit between journal and sleeve has been obtained, the radial play in the roller bearing is gauged before and during the driving-in of the sleeve. A feeler gauge is used for the purpose, and is inserted between the top roller and the outer ring while the ring is lifted to prevent its weight from influencing the result (fig. 12). The extent to which the play must be decreased in order to obtain the correct fits for the different sizes of bearing is as follows:

No. of Bearing	Reduction in Play	No. of Bearing	Reduction in Play
22310 K 22311 K 22312 K 22313 K	0.0012″ — 0.0014″	22317 K 22318 K 22319 K 22320 K	0.0018″ — 0.0022″
22314 K 22315 K 22316 K	0.0016″ — 0.0018″	22322 K 22324 K	0.0020″ — 0.0024″

For the mounting of the outer bearing in axleboxes containing two self-aligning roller bearings, the procedure is the same as described above.



Fig. 12. Gauging the internal clearance.

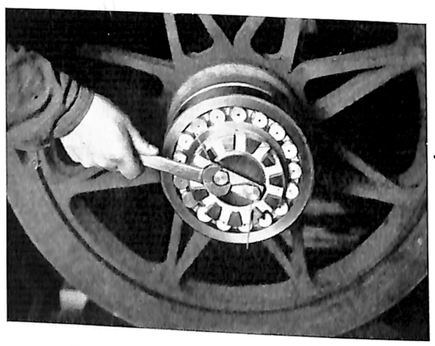


Fig. 13. Final locking operation.

Finally, the bearings and the sleeves are secured by means of an axle nut, which is locked with a key. The key is secured by means of screws, which in their turn are locked with a piece of wire inserted through holes in their heads, and the ends of the wire are afterwards twisted together (fig. 13).

The bearings are removed from the journals in the following manner. The axle nut is removed, and a withdrawal nut or special withdrawal tool screwed on to the threaded end of the sleeve and then tightened up against the inner ring of the bearing until the sleeve is released and the bearing left loose on the journal.

THE FITTING OF CYLINDRICAL ROLLER BEARINGS

The sealing collar is heated in an oil bath as described under the last heading to a temperature of about 265° F. above that of the surrounding atmosphere, and is then pushed on to its seating and driven against the shoulder on the axle by means of blows delivered with a mounting sleeve.

The inner rings of the bearings are at the same time heated in another oil bath to a temperature of about 175° F. above that of the surrounding atmosphere. When the sealing collar and axle journal have cooled, the latter must be well wiped and thinly coated with oil. The inner ring of the inner bearing is then pushed on with its flange facing the sealing collar and followed by the distance sleeve, which is mounted in a cold condition.

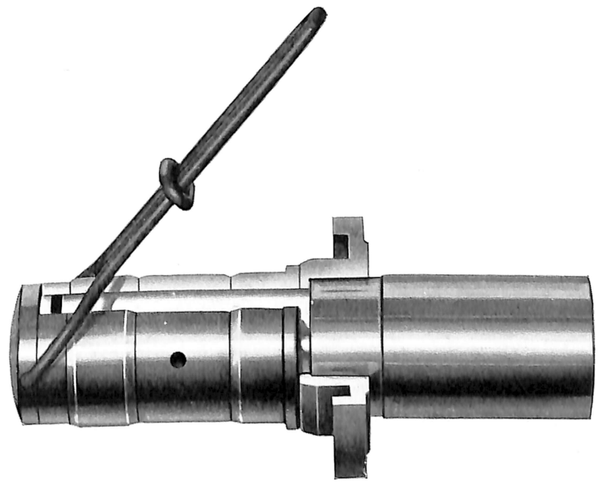


Fig. 14. The inner rings of cylindrical roller bearings being mounted on the journal.

Finally, the inner ring of the outer bearing, also heated, is placed in position, whereupon both rings etc. are registered axially by means of blows with a sledge-hammer delivered against a dolly (fig. 14).

The mounting of the two bearing rings and of the intermediate distance sleeve should be done expeditiously. Before the rings have had time to cool, the loose guiding flange is put on, whereupon the axle nut is tightened up so as to make sure that good contact is maintained between the different parts.

Should it be necessary at any time to remove the inner rings of the bearings from the journal, it is advisable to use for the purpose a withdrawal device similar to that used for pulleys etc. In the distance sleeve and sealing collar recesses or notches are provided for the withdrawal device.

THE LUBRICATION AND ASSEMBLY OF ROLLER-BEARING AXLEBOXES

When the bearings have been mounted on the axles their lubrication and the assembly of the axleboxes should be proceeded with immediately. For axleboxes with *self-aligning roller bearings* the procedure is roughly as follows:

The bearings are carefully coated with grease of a quality recommended by SKF, and the spaces between the bearings and next to the sealing collar and axle nut are nearly filled with the same kind of grease. The felt washer is cut into halves, which are soaked in hot mineral oil containing $^1/_3$ % (weight) of mutton tallow, and then placed in their grooves in the box-halves. The bearing seatings and the joint-surfaces of the box-halves are given a thin coating of grease after having first been carefully wiped, and finally the sealing labyrinth and the lubricant sump in the lower box-half are filled with grease. The outer rings of the bearings are then adjusted so as to be square with the journal. The upper half of the axlebox is placed on the bearings, and two of the box-bolts are placed in position. The bottom half is then placed in position and the nuts of the two bolts are screwed on until the box-halves nearly meet. The two remaining bolts are now inserted and all four nuts are tightened up uniformly and then secured by means of split pins.

When the fitter has satisfied himself, by rotating the axlebox, that the bearings will run freely, the space outside the axle nut is filled with grease, and the cover screwed on.

The outer ring and roller assemblies of *cylindrical roller bearings* together with the distance sleeve are pushed into the axlebox — the bearing seating in the box having previously been thinly coated with grease —

and then temporarily locked by means of a collar (fig. 15). The roller assemblies should be well lubricated with grease of a quality recommended by SKF, and the space on both sides of the bearings nearly filled with such grease. The felt washer, which for these axleboxes is not cut in half, is treated in the same manner as previously described and is placed in its groove, and the whole sealing labyrinth filled with grease. The axlebox with outer ring and roller assemblies is then carefully passed over the inner rings on the journal, for which purpose it is continuously rotated for half a revolution or so to the left and right alternately.

When the axlebox is in position, the mounting collar is removed, and the loose guiding flange together with the axle nut or end washer — temporarily removed to enable the roller assemblies to be passed over the inner ring — is replaced and secured. The cover is then filled with grease and clamped in position after the fitter has satisfied himself that the axlebox rotates freely.

For the lubrication of roller-bearing axleboxes it is advisable to use a grease with good sealing as well as lubricating qualities. The grease should also possess great stability, so that it will not become hard or undergo any chemical change while in use. Through their various branch offices, SKF supply a grease known as SKF -28, which is in every respect fully suitable for the lubrication of axleboxes.

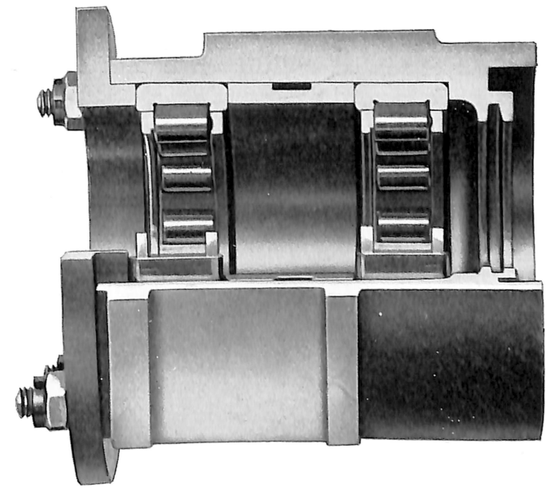


Fig. 15. The outer ring and roller assemblies mounted in the axlebox.

INSPECTION

The inspection and lubrication of SKF roller-bearing axleboxes takes place at the same time as the periodical overhaul of the car itself. The interval between the overhauls varies of course on different tramways, but should not exceed twelve or maximum eighteen months so far as the axleboxes are concerned. Between inspections, however, the boxes do not as a rule need any attention, provided they have been correctly mounted and operate under normal conditions; nor does the lubricant need adding to.

Inspection consists in opening and examining the axlebox and in examining the bearings and other accessible details. It is not necessary to remove the bearings unless the journals are to be inspected. Before the axleboxes are opened, they should be well washed externally with a linen rag soaked in benzine or benzol, in order to remove loose dirt, sand, etc.

THE INSPECTION OF AXLEBOXES WITH SELF-ALIGNING ROLLER BEARINGS

When the cover has been removed and the bolts loosened, the two box-halves are carefully lifted off the bearings. Most of the grease round the bearings is wiped off and its consistency and colour are noted. Under normal conditions the grease should have become softer in consistency near the bearings, while its colour should be unchanged or only slightly darker than that of new grease. If this is the case, all that needs doing is to rotate the bearings to make sure that they run freely and smoothly. If on the other hand any change is noticed in the bearings or grease, the former should be washed in benzine or benzol, and the rings, rollers, and cages examined.

If any defect should be found to have developed in the bearings or sleeves, these should be removed and replaced with new ones. Otherwise the bearings should be regreased and the axleboxes remounted according to the instructions previously given.

THE INSPECTION OF AXLEBOXES WITH CYLINDRICAL ROLLER BEARINGS

When the cover has been removed and also the axle nut or end washer together with the guiding flange, the axlebox together with the outer ring and roller assemblies of the bearings is pulled off the journal. The grease and the bearings are inspected as described under the last heading, and if any defect should be detected in the bearings, the outer ring and roller assemblies and also the inner rings should be removed and new ones fitted.

The bearings must never be left unprotected for any length of time. If, for instance, they have been mounted on the journals and the axleboxes cannot be fitted immediately, they should be coated with grease and covered with a piece of cloth wrapped round them. When the inner rings of cylindrical roller bearings have been fitted on the journals, they are best protected by a sleeve placed over them after they have been coated with grease. Outer ring and roller assemblies fitted in the axleboxes are protected by coating them with grease and then closing up the axlebox with a cover at each end.

RE-TURNING OF THE WHEEL TYRES

If a lathe with twin headstocks is available, removal of the axlebox cover and of the locking key or end washer is the only preliminary necessary when the tyres are to be re-turned. The centres of the axle are thus rendered accessible, and the axleboxes need no further dismantling.

If, on the other hand, the lathe is provided with chucks in which the journals are to be clamped, it is necessary to remove self-aligning roller bearings, unless the chucks can be adapted for chucking the outer rings of the bearings.

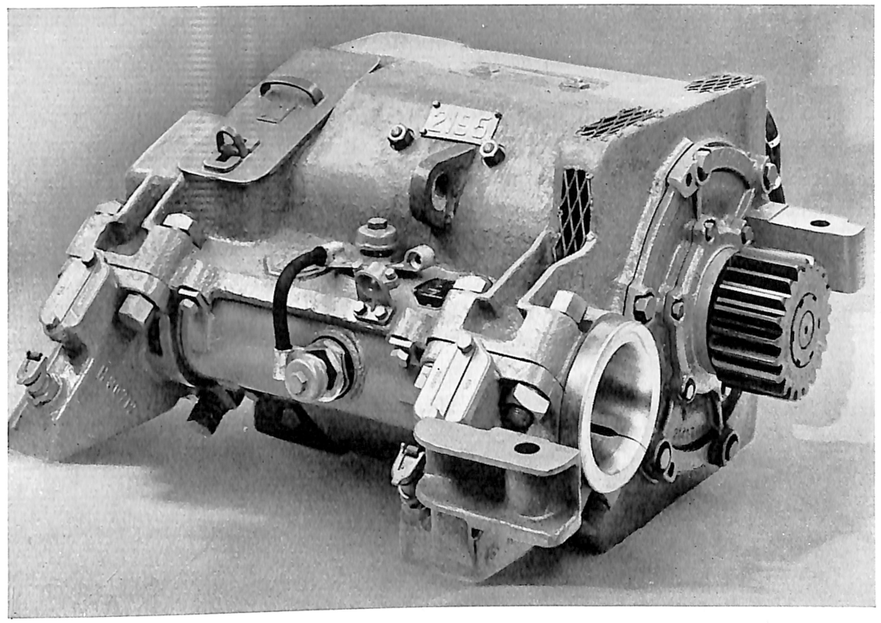
In the case of cylindrical roller bearings, the axles can be chucked in the lathe without removing the inner rings, which may be gripped by the chuck provided that suitable brass or copper foil is used to protect the tracks.

While the work is proceeding it is essential that the bearings, if not previously removed, should be carefully protected against the intrusion of chips or other foreign mater, liquid or solid.

EARTH RETURN CONNECTION FOR MOTOR AND LIGHTING CIRCUITS

An important detail in the construction of a tramcar is the connection of the motor and lighting circuits with the rail system, so as to ensure their being satisfactorily earthed.

It is not advisable to allow currents to pass through axlebox bearings, irrespective of whether they are of the plain or the anti-friction type, since this is apt to result in serious wear and consequent interruption of the service. In view of this risk, it pays to provide the cars with special earth connections insulated from the framework but connected to earth return brush gears on the axles. These brush holders are usually placed between the suspension bearings of the driving motor in accordance with the illustration on the next page.



SKF BEARINGS IN TRAMWAY MOTORS

A tramway motor is furnished with bearings for two purposes, namely, to support the armature and to connect the casing to the wheel axle. Roller bearings are nowadays almost exclusively used for the armature shaft, whereas plain bearings of more or less primitive design are still widely used as suspension bearings. There is much to be gained, however, by using roller bearings for the latter purpose as well, and SKF are in a position to submit simple and reliable schemes for the equipment of tramway motors with suspension bearings.

The chief advantages derived from the application of SKF bearings to tramway motors may be summarized thus:—

Increased reliability
Higher efficiency of the motor
Better functioning of the gears
Reduced maintenance costs
Reduced lubrication costs

Of these advantages, the increased reliability alone is of sufficient value to warrant the adoption of SKF bearings for tramway motors. The difference in this respect between SKF and plain bearings increases with the severity of the conditions under which the bearings have to operate, which in the case of the armature bearings on a tramcar is particularly

great. The speed is generally four to five times higher than that of the axlebox bearings, and the space available for the accommodation of the bearings is very limited. As a rule they also have to operate at high temperatures, much heat being produced by the motor itself. Overheating of the armature bearings invariably entails derangement of the service; and wear must be avoided since it may cause damage to the motor. Owing to the unbalanced magnetic pull due to wear, the air-gap is reduced at one point or other, and the rotor eventually fouls the stator, with the result that the laminated core of the armature and the windings are destroyed. All such trouble and the resulting risk of breakdowns in service are avoided by using SKF bearings, as also are the costly repairs involved.

The efficiency of a tramway motor equipped with SKF bearings is higher than that of motors with plain bearings. This superiority is due not only to the great difference in bearing friction but also to the possibility of using a comparatively small air-gap in motors equipped with SKF bearings, for these bearings are not subject to wear, and risk of fouling of the stator by the rotor is therefore eliminated by their use.

Every shaft fitted with SKF bearings accordingly remains accurately centred Consequently, when a tramway motor is equipped with SKF bearings, the distance between the centre of the axle and that of the motor shaft remains constant, and smooth and silent running and long life of the gears are therefore obtained.

SKF bearings have a much longer life than plain bearings, and the procuring, casting and machining of new bearing brasses, the replacement of worn-out lubrication devices &c., all of which are unavoidable if plain bearings are to be kept in satisfactory working order, are abolished for good by the adoption of SKF bearings, as is also the heavy expense represented by such items. Of the cost of maintaining motors equipped with these bearings, therefore, the proportion for which the bearings are responsible is practically nil. This applies to the suspension as well as the armature bearings.

Another advantage of SKF bearings is that they can be lubricated with grease instead of oil. The substitution of these bearings for plain bearings therefore results in much simplification of the maintenance of the motors and a great reduction in the consumption of lubricant. Grease, moreover, does not leak out of the bearing housings as oil does; on the contrary it serves as an additional means of sealing the housings. By using grease-lubricated bearings, therefore, risk of destruction of the insulation caused by the presence of lubricant on the windings is entirely avoided.

TYPES OF BEARING USED

Both cylindrical and self-aligning roller bearings are used for tramway motors.

The *cylindrical roller bearings* used, which are mostly of the series NU and NH (figs. 16 and 17), have one row of cylindrical rollers accurately guided by flanges on the outer ring. The NU bearings have no flanges on the inner ring; alteration of the relative positions of the outer and the inner ring can therefore freely take place should the length of the shaft vary as a result of changes in temperature. The inner ring of NH bearings has one fixed and one removable flange, and the bearings can deal with a certain amount of thrust load. Both types of bearing have cylindrical bores and are mounted direct on the shaft with a press fit.

The *self-aligning roller bearings* used (fig. 18) have two rows of rollers with their contact surface sphered and a spherical raceway in the outer ring, to which device these bearings owe their self-aligning property. These bearings can deal with very heavy loads, thrust as well as radial, and are therefore particularly suitable for locating the armature. Their self-aligning feature is also of great value when they are used for the suspension of the motor, since it enables them to accommodate themselves readily to deflexions of the wheel axles, the extent of which is as a rule comparatively great. These bearings are supplied with two kinds of bore: tapered, for mounting on withdrawal sleeves, and cylindrical for mounting on the shaft direct. None but taper-bore bearings must be used for the armature. Bearings for armature shafts must have C 003 internal slackness.

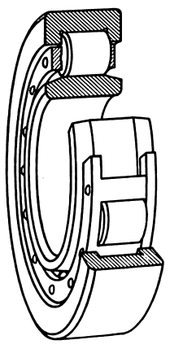


Fig. 16. SKF cylindrical roller bearing of the series NU.

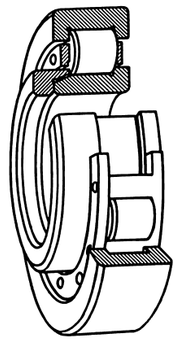


Fig. 17. SKF cylindrical roller bearing of the series NH.

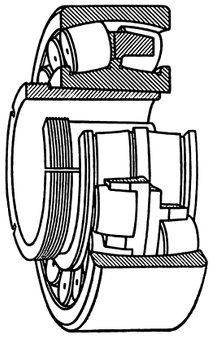


Fig. 18. SKF self-aligning roller bearing.

BEARING SCHEMES FOR THE ARMATURE

The armature of a tramcar motor is supported by two bearings, of which one locates the shaft while the other has axial freedom. This can be done with either of the two following combinations of the bearings mentioned above.

1. A cylindrical roller bearing of the series NH fitted as the locating bearing at the commutator end, and a cylindrical roller bearing of the series NU at the driving end (fig. 19).
2. A self-aligning roller bearing with tapered sleeve as the locating bearing at the commutator end, and a cylindrical roller bearing of the series NU at the driving end (fig. 20).

The first of these alternatives is to be preferred when the motors have spur gears with straight teeth. No great capacity for dealing with thrust is required of the bearings in this case and the shock loads arising can very well be dealt with by the flanged NH bearing. When, on the other hand, the motors have helical or bevel gears, their operation is attended by continuous thrust, and the second alternative must therefore generally be employed. The thrust, which is often fairly heavy, is then dealt with by a self-aligning roller bearing, this type being capable of dealing with very heavy thrust loads.

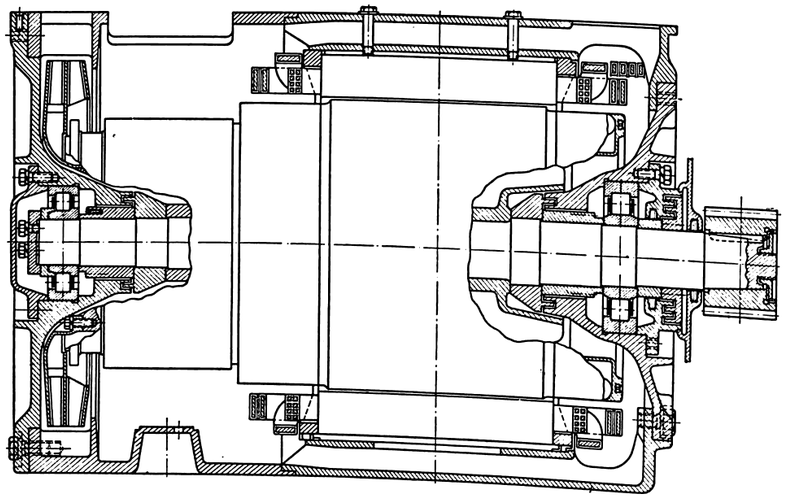


Fig. 19. Tramway motor with SKF cylindrical roller bearings.

When roller bearings are used for tramway motors, their outer rings must not fit too loosely in the housings, or creep and consequent wear of the bearing seating will be likely to occur. The best fit for this purpose, whether the bearings are cylindrical or self-aligning, is a drive fit according to M7—hB. But if the self-aligning bearing has not the usual amount of room in an axial direction and therefore has to be removed for the purpose of inspection, a slightly looser fit, namely K7—hB, should be employed.

The fit on the shaft depends on the method of mounting employed. If a tapered sleeve is used, the shaft should be machined within the tolerance h7, but if the bearings are mounted on the shaft direct, the best fit is KB—n6.

To protect the bearings from dirt and the like, and to prevent the escape of lubricant from the housings and thus avoid risk of destruction of the windings, every care should be bestowed on the sealing arrangements. Labyrinth seals are generally employed for motor bearings. Designs that have proved very effective are shown in figs. 19 and 20. Fig.

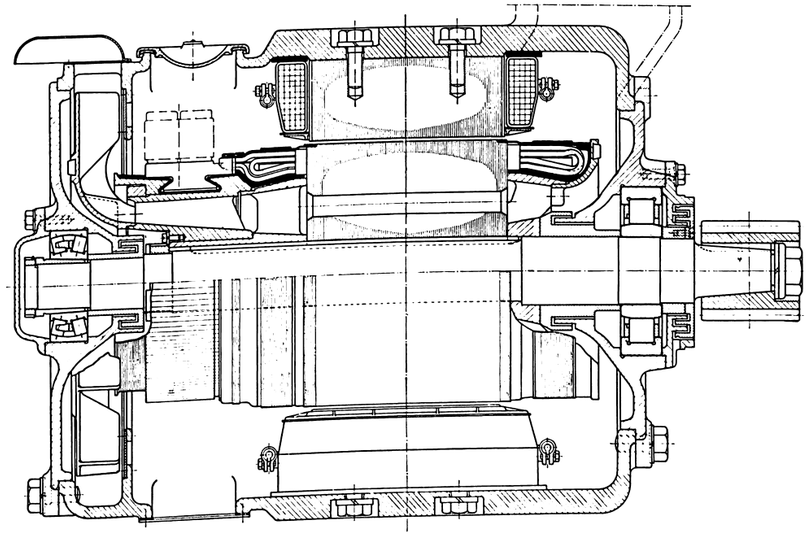


Fig. 20. Tramway motor with an SKF self-aligning roller bearing at the commutator end and a cylindrical roller bearing at the pinion end.

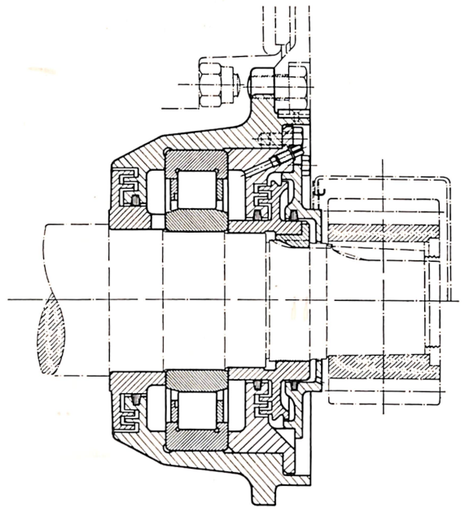


Fig. 21. Sealing device for traction motor bearings.

21 shows another highly efficient sealing device. One of the chief aims of its designer was to prevent oil from the gears, which is generally unfit for the lubrication of roller bearings, from entering the bearing housings. The seal is so designed that any oil finding its way past the outer bearing-cover is stopped before it reaches the inner bearing-cover and conducted towards the drain hole underneath.

BEARING ARRANGEMENTS FOR SUSPENSION OF THE MOTOR

The suspension bearings constitute the means by which the motor casing is suspended from the wheel axle and by which the motor shaft is located both axially and radially in relation to the wheel axle. These bearings are therefore more or less subject to a load to which the weight of the motor and the forces from the gears contribute, and which is occasionally supplemented by quite heavy thrust loads arising when the car negotiates curves, crossings, or switches. Under these conditions no other than a roller bearing capable of dealing with heavy thrust as well as radial loads may be used. Experience has shown, moreover, that the bearings fitted should possess the property of self-alignment, for the deflexion to which the wheel axles are subject is comparatively great.

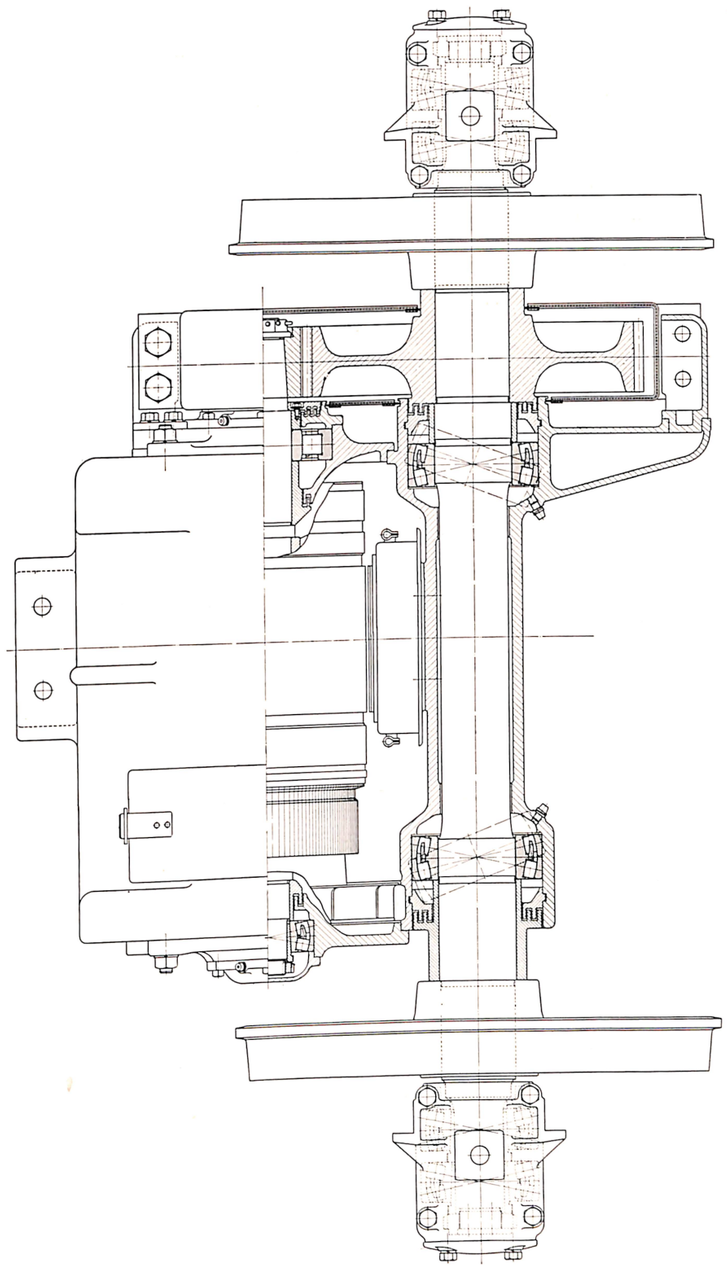


Fig. 22. Suspension bearing arrangement.

The type of bearing that meets these requirements best is the SKF Self-Aligning Roller Bearing. The nature of the prevailing loads and the available space determines whether bearings of the series 222 or bearings of special design occupying a comparatively small amount of space in a radial direction should be used.

For new motors and wheel axles, the best method of fitting suspension bearings is that according to fig. 22. The bearings are mounted on the wheel axle with a press fit, and are located axially by means of distance sleeves placed between the bearings and the wheel hubs. The bearing housings, which are of the split type, form an integral part of the motor casing.

Inspection of the suspension bearings may take place at the same time as that of the armature bearings. Grease, SKF -28 for preference, is used for lubrication, and in order to make the sealing as effective as possible, the bearing housings and the sealing cavities should be well filled with this grease. It is therefore advisable to provide the bearing housings with nipples so that a grease gun can be used for applying small quantities of grease on two or three occasions between the regular inspections.

Suspension bearings should never be utilized as a means of conducting current from the motor to the wheel axle, since this practice is injurious to the bearings. Instead, use should be made of a special earth return brush gear as described on page 24.

INSPECTION AND MAINTENANCE OF ROLLER BEARINGS FITTED IN TRAMWAY MOTORS

To ensure the maximum life for the bearings, it is necessary to inspect them at regular intervals, say once a year. This may as a rule be done at the same time as the motor itself is overhauled. Below are given some general directions for the dismantling and maintenance of roller bearings. More detailed instructions, however, adapted to the design of the different types of motor used, should be obtained from the manufacturers of the motors.

All inspection and mounting to be done with the greatest care and by skilled persons only.

Great cleanliness to be observed throughout the work.
The work to be done in premises as free from dust as possible.

DISMANTLING OF THE MOTOR

The method that should be employed for dismantling the motor is broadly the same for both the bearing combinations referred to above. The following description applies to the designs shown in figs. 19 and 20 and now so widely used. Dismantling of the motor may proceed either vertically or horizontally as shown in figs. 23 and 28 respectively.

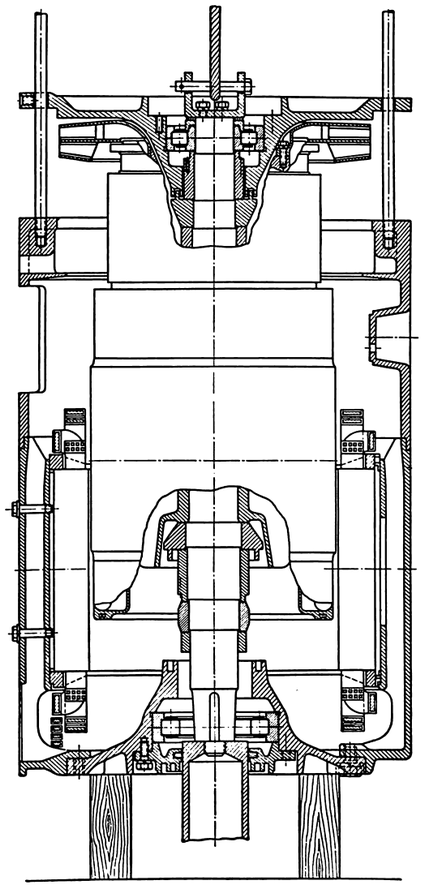


Fig. 23. Vertical dismantling. The armature being withdrawn from the stator.

The advantage of *vertical dismantling* is that the bearings are relieved while the armature is being withdrawn from the stator, and risk of mechanical damage to the raceways of the inner rings is thus reduced to a minimum. When the pinion and the sealing ring have been removed, an extension

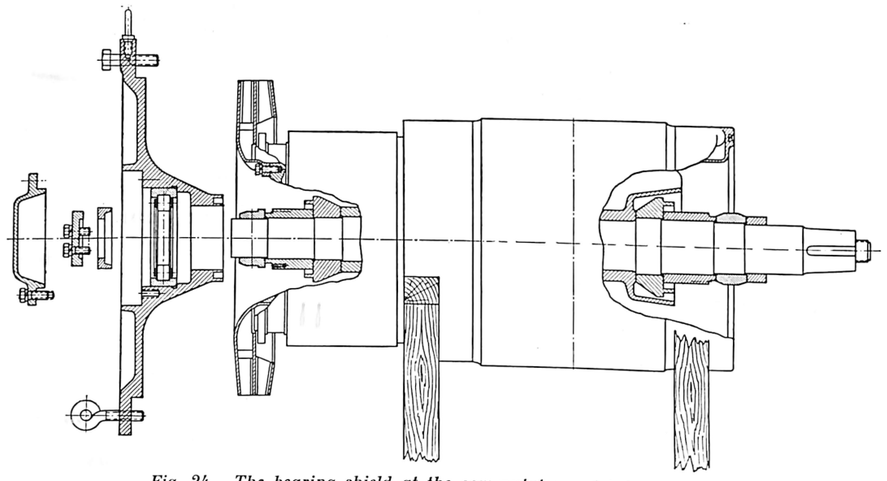


Fig. 24. The bearing shield at the commutator end being removed.

tube is secured to the threaded part of this end of the shaft. The bearing cover and the end washer or shaft nut at the commutator end are then removed and a suspension bracket with cross-pin is secured to the shaft end thus exposed. The motor is placed in a vertical position (fig. 23), and the bolts for securing the bearing shield at the commutator end are loosened and replaced with guide bolts. The carbon brushes are also removed from their holders. The entire armature with the bearing shield can now be lifted out of the stator by means of lifting tackle — the armature meanwhile being centred in the stator by the guide bolts and the

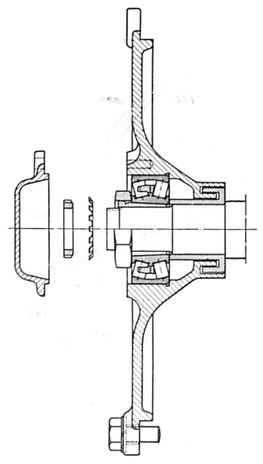


Fig. 25. Loosening the withdrawal sleeve.

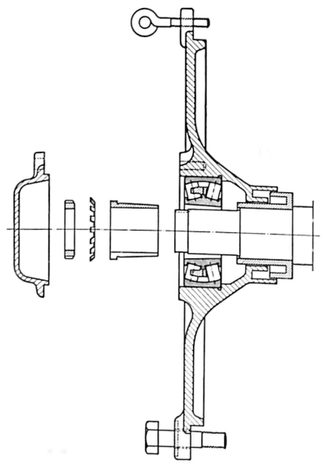


Fig. 26. Removing the commutator end shield.

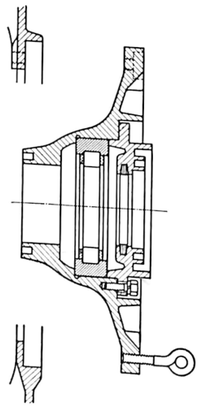


Fig. 27. The driving end shield being removed from the stator.

extension tube at the driving end — and deposited in a horizontal position on wooden supports as seen in Fig. 24.

The next operation is to remove the bearing shield at the commutator end. This is done as shown by fig. 24 or figs. 25 and 26 according as a cylindrical roller bearing of the series NH or a self-aligning roller bearing is fitted at this end of the rotor. If the bearing is of the latter type, the tapered sleeve on which it is mounted is loosened with the help of a withdrawal nut (fig. 25). Finally, the stator is also placed in a horizontal position, and the bearing shield at the driving end loosened as shown in fig. 27.

Horizontal dismantling is illustrated by figs. 28 and 29. When the pinion and the sealing ring have been removed, an extension tube is screwed on to the exposed end of the shaft, to which a chain suspended from a lifting block is then secured. When the bearing shield at the commutator end has been similarly loosened and suspended, the rotor is carefully removed from the stator and placed on a pair of supports whereupon the bearing shield at the commutator end and also the shield remaining on the stator at the driving end are dismantled in the manner previously described.

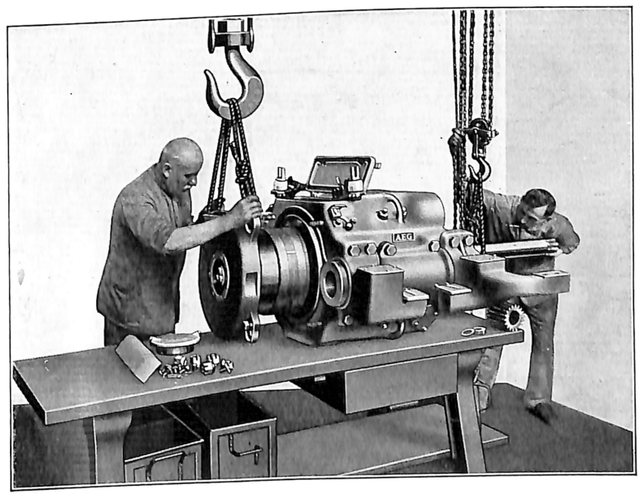


Fig. 28. Horizontal dismantling.

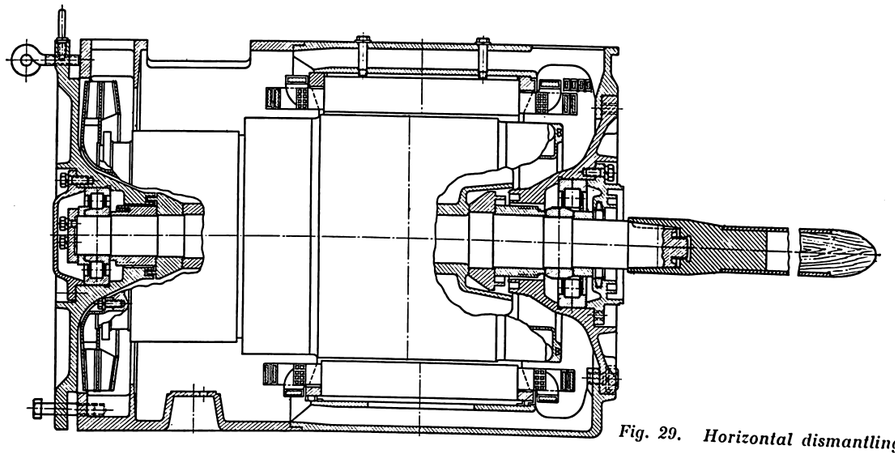


Fig. 29. Horizontal dismantling.

INSPECTION AND CLEANING OF THE ROLLER BEARINGS

When the end shields with the remaining bearings have been removed from the motor by one of the methods described above, inspection and cleaning of the bearings may begin. For this purpose it is as a rule unnecessary to remove the bearings from their housings. Much time is therefore saved, particularly when the bearings are, as is by no means uncommon, mounted with a very tight fit in the housings. If the bearings are fitted in accordance with any of the schemes illustrated in figs. 19 and 20, they can easily be inspected and cleaned without being removed from their shields. This, however, so far as self-aligning roller bearings are concerned, presupposes that there is enough room in the housing for the inner ring and rollers to be swivelled as shown in fig. 30.

The rings, rollers, and cages of the bearings must all be carefully examined, and if any part of them shows signs of defects, the whole bearing should be removed, and replaced with a new one. Dismantling, whether of bearings remaining in the shield or of the inner rings of cylindrical roller bearings remaining on the shaft, should invariably be done in accordance with instructions supplied by the motor manufacturers for guidance in dealing with the particular type of motor concerned. It is usual, however, for the dismantling to be performed with the help of some kind of screw arrangement similar to that used for removing pulleys from the shafts on which they are mounted.

Usually, of course, no defects are revealed by the inspection, and lubrication and re-assembly may therefore begin forthwith. The lubricant used should possess not only a great capacity for resisting heat, but also good lubricating and sealing qualities. SKF-28 is a grease answering to this description. The bearings themselves are entirely filled with grease, and the spaces on both sides of them are filled to about half their capacity. The housings must not be entirely filled with grease, since this would give rise to abnormal bearing temperatures, especially at high speeds. The labyrinth seals are also coated with the grease.

If felt washers are used for sealing, they should be examined before re-assembly, and any of them found to have become worn replaced with new ones. These washers should have a loose fit on the shaft, and before being placed in their grooves should be soaked in pure mineral oil. The use of felt washers that fit too tightly on the shaft is attended by the generation of heat due to friction, and by rapid wear of the shaft.

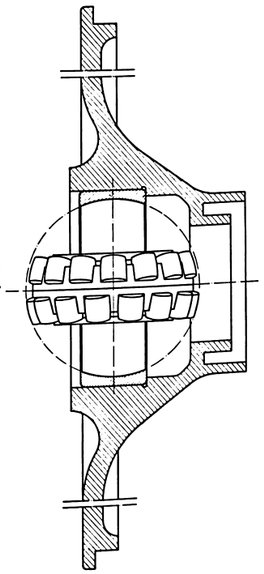


Fig. 30. Self-aligning roller bearing ready for inspection.

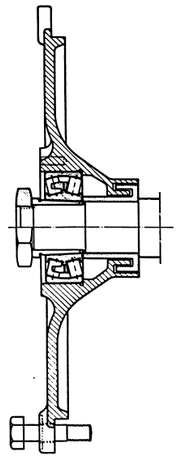


Fig. 31. Self-aligning roller bearing being fitted on shaft.

Re-assembly of the motor should proceed in accordance with the instructions previously given for dismantling, but in the reverse order. Should the rollers of a cylindrical roller bearing offer any resistance to the inner ring when the armature is being replaced in the stator, violence

must on no account be used in order to overcome the resistance, but steps must immediately be taken to ascertain, and if possible remove, its cause. If this operation is performed without due care, the roller tracks are liable to become scratched or otherwise blemished. Such damage, though apparently trifling at first, gradually develops during operation, with serious consequences affecting the whole motor.

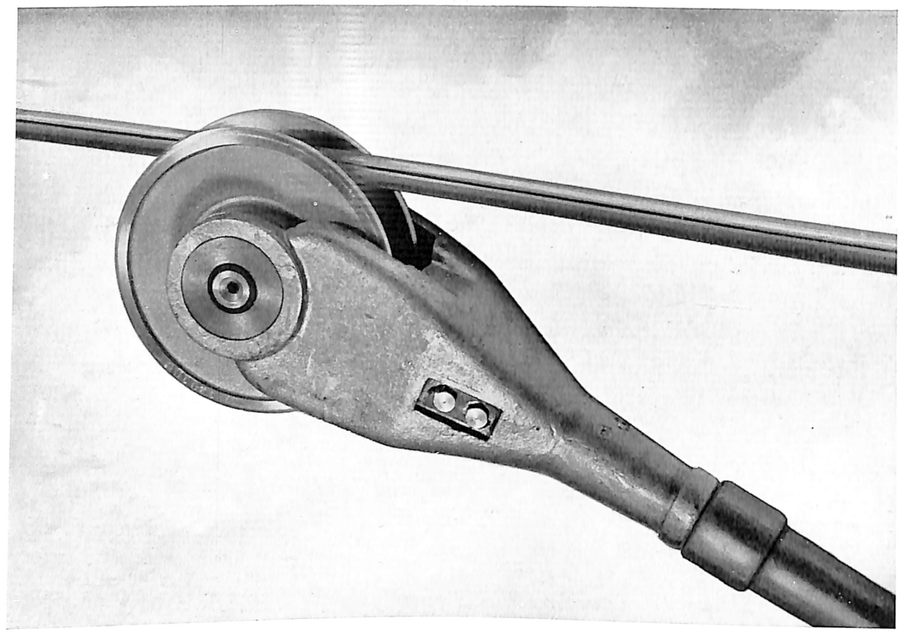
Fig. 31 shows how a self-aligning roller bearing is fitted at the commutator end. If the armature is placed on supports so as to leave the shaft ends free, all that is necessary is to place the bearing shield complete with bearings in position and insert the tapered sleeve. If, on the other hand, the armature is already inserted in the stator, it should first be pushed back in the direction of the commutator, so that the shield will clear the stator. While mounting is proceeding, steps should be taken to make sure that the bearing makes good contact with the shoulder or distance sleeve on the shaft. If mounting is attempted while the bearing shield is secured to the motor casing, misleading results may be obtained when the bearing clearance is gauged.

The withdrawal sleeve, after having been pushed over the shaft into the bearing bore, is pressed home with the help of the nut shown in fig. 31, which is tightened up by means of a strong spanner assisted by blows from a sledge hammer of copper or lead. Whether or not the nut has been sufficiently tightened up, so as to give the right fit, is best ascertained by gauging the reduction in the radial play of the roller bearing as the sleeve is being driven in. For this purpose the radial play between one of the rollers and the spherical raceway of the outer ring is gauged by means of feelers on the unloaded side of the bearing, both before and during the driving in of the sleeve. This should continue until the play has been reduced to the extent specified on page 18.

For cylindrical roller bearings, which are almost invariably fitted on the shaft direct, the mounting procedure is as follows. The inner rings, and also the sealing rings, are first heated in an oil bath to about 175° F. above the temperature of the surrounding atmosphere, and then pushed into position. While cooling they must be pressed against the shoulder on the shaft. The easiest way of doing this is to use a distance sleeve and nut. For mounting the outer ring and roller assemblies, a screw device fixed in the bolt holes of the bearing-covers and which forces the rings into position may be used. But on no account may the cages or rollers of the bearings be subjected to blows from a hammer or similar implement.

Before the re-assembled motor is put into service again, it should be given a short test run to make sure that the bearings are free from all

potential causes of breakdown. The increase in the bearing temperature should be noted first. If this increase is noticeably great, the cause should be ascertained. It will then as a rule be found that there is too much grease in the housing, or that new felt washers fit too tightly on the shaft. The sound produced by the bearings while running should next receive attention. This is done by placing one end of a screwdriver, spanner, or similar implement against the ear and the other end against the bearing shield as close to the bearing as possible. Scraping or irregular sounds then heard show that swarf, sand, or similar matter has got into the bearings, while a uniform shrill whistling sound indicates an insufficiency of lubricant in the bearing. A humming sound on the other hand shows that everything is in order.



SKF BEARINGS IN CURRENT COLLECTORS

Besides axleboxes and electric motors, current collectors are included in the mechanical equipment of tramcars for which SKF bearings are used with advantage. As current collectors have to maintain contact with the overhead cable while the car is in motion, it is necessary that all their movements should be made with the utmost freedom. The height of the cable always varies more or less; so that if the resistance offered by the bearings to vertical movement of the collector is excessive, momentary interruptions in the contact, accompanied by sparking, take place, and craters are thus burnt in the cable, which in consequence undergoes rapid wear. By the use of SKF bearings in all positions, both sparking and wear are reduced to a minimum and lubrication is greatly simplified.

For current collectors of the pantograph or sliding type, SKF bearings have long been used. This applies especially to the bearings by means of which the collector is attached to the roof of the car, which, besides supporting the whole weight of the collector, have to serve as the hinges enabling the collector to be raised or lowered. Collectors of the pantograph type have in the upper portion of the fork a number of joints, for all of which SKF bearings are used with advantage. These bear-

ings in fact constitute the best means of securing the freedom of movement mentioned above as being one of the essentials making for efficiency on the part of current collectors. As pantograph collectors are designed with a view to keeping down weight as much as possible, such collectors are subject to much deflexion while the car is running and should therefore be equipped with bearings of the self-aligning type. For this purpose SKF Self-Aligning Ball Bearings are particularly suitable.

TROLLEY-POLE CURRENT COLLECTORS

This is one of the commonest types of current collector and consists of the familiar pole mounted on the roof of the car and movable both

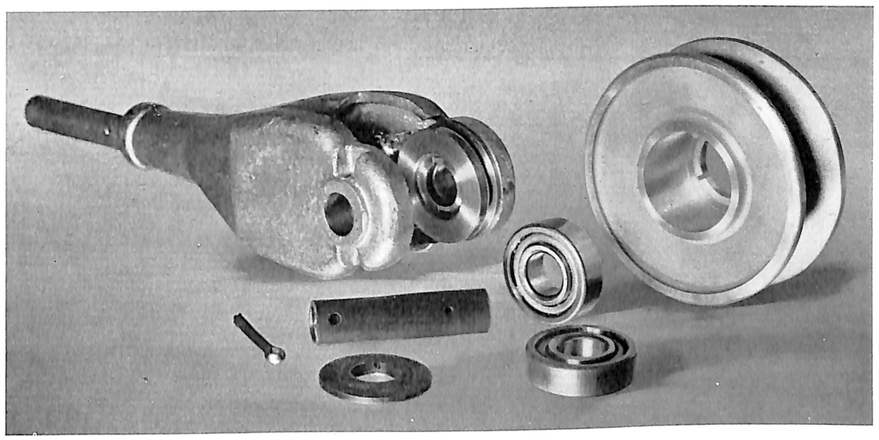


Fig. 32. SKF ball bearing trolley-head dismantled.

vertically and horizontally. At its upper extremity it carries a trolley wheel provided with a groove for the reception of the overhead cable.

Trolley wheels have so far generally been fitted with some type of plain bearing, which besides serving as the means by which the wheel is mounted in the trolley head, transmits the current. As such bearings are subject to much friction, and both they and the contact groove of the wheels to much wear, the use of these plain-bearing wheels is attended by many disadvantages, which, moreover, repeated attempts have failed to eradicate. With a view to solving the problem thus presented, SKF recently investigated the possibilities of employing ball bearings for this

duty. By means of comprehensive practical tests they found that the use of SKF bearings for trolley heads is not only practicable but affords an extremely satisfactory solution of the whole problem. The advantages by which it was thus found to be attended may be summarized as follows:—

Increased life of the trolley wheel
Less wear of the conducting cable
Less sparking between wheel and cable
Less risk of dewirement
Greatly simplified maintenance and lubrication

The decrease in wear of the contact surface of the trolley wheel and in that of the cable is due to the small amount of friction in SKF bearings, which enables the wheel always to roll freely along the cable, instead of merely sliding for long distances as often happens when the wheels are

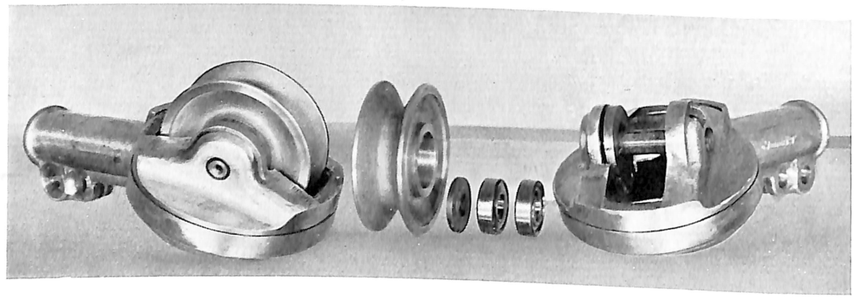
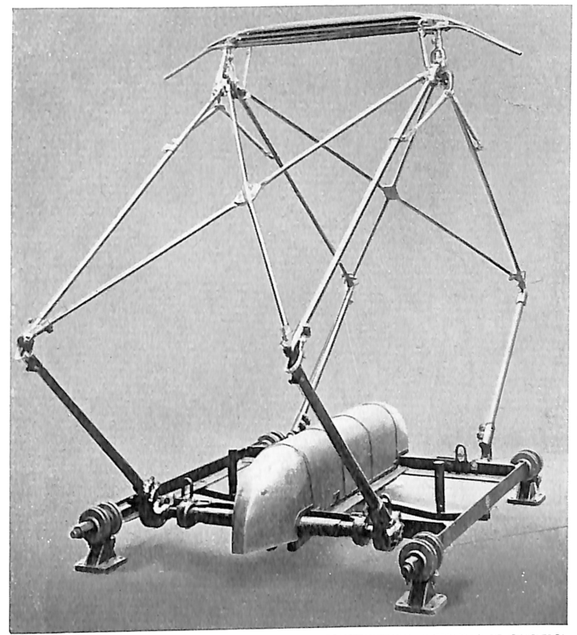


Fig. 33. Pivoted trolley heads with SKF ball bearings.

fitted with plain bearings. Such sliding, besides causing rapid wear, results in the formation of facets in the contact groove, which in their turn make the wheel run unevenly at the best of times and gradually increase the amount of sparking. Sparking in its turn causes pitting on both the wheel and the cable, and thus helps still further to increase the wear. Comprehensive tests with SKF ball-bearing trolley-wheels, on the other hand, have shown that both the balance of such wheels and the evenness of their contact groove are retained undiminished during service.

The use of trolley heads equipped with SKF bearings also enables the pressure of the wheel against the cable to be increased without risk of seizure on the part of the bearings, which is always present when plain-bearing wheels are used. This increase in pressure, besides decreasing the risk of dewirement, ensures uniform and good contact between wheel and cable.

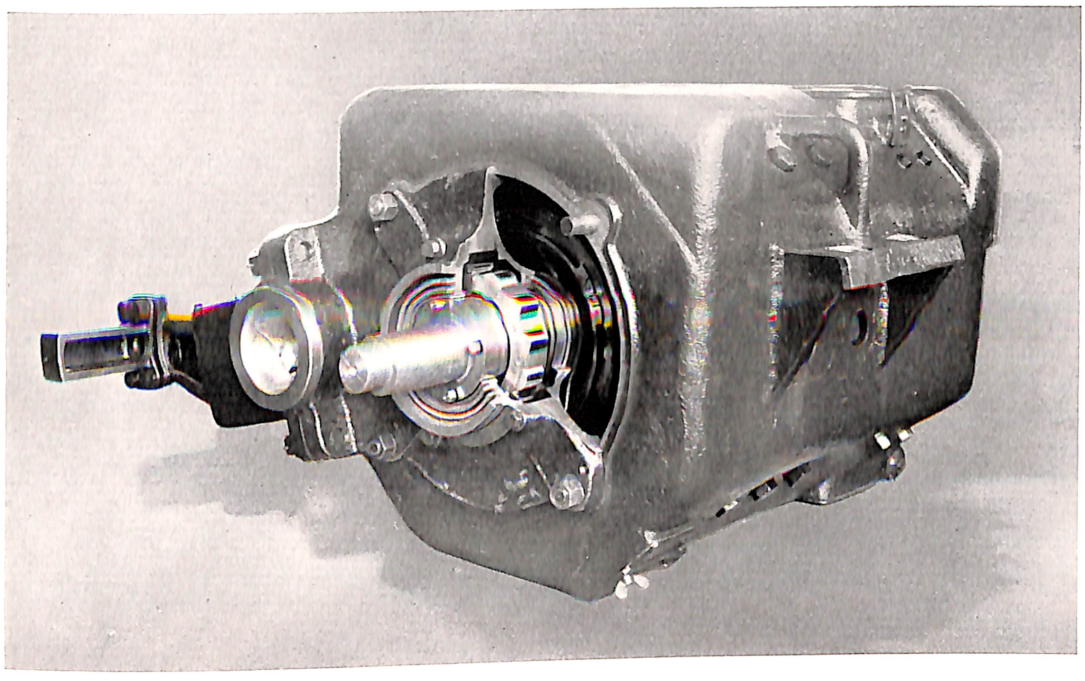
The maintenance of trolley heads fitted with SKF bearings is very simple. The ball bearings themselves are lubricated with grease at the time of mounting and need no inspection while in use. All that is necessary is to inspect and lubricate the sliding contact against the wheel at certain intervals, but the time and labour this entails is but a fraction of what is necessary in order to maintain plain-bearing wheels in good working order.



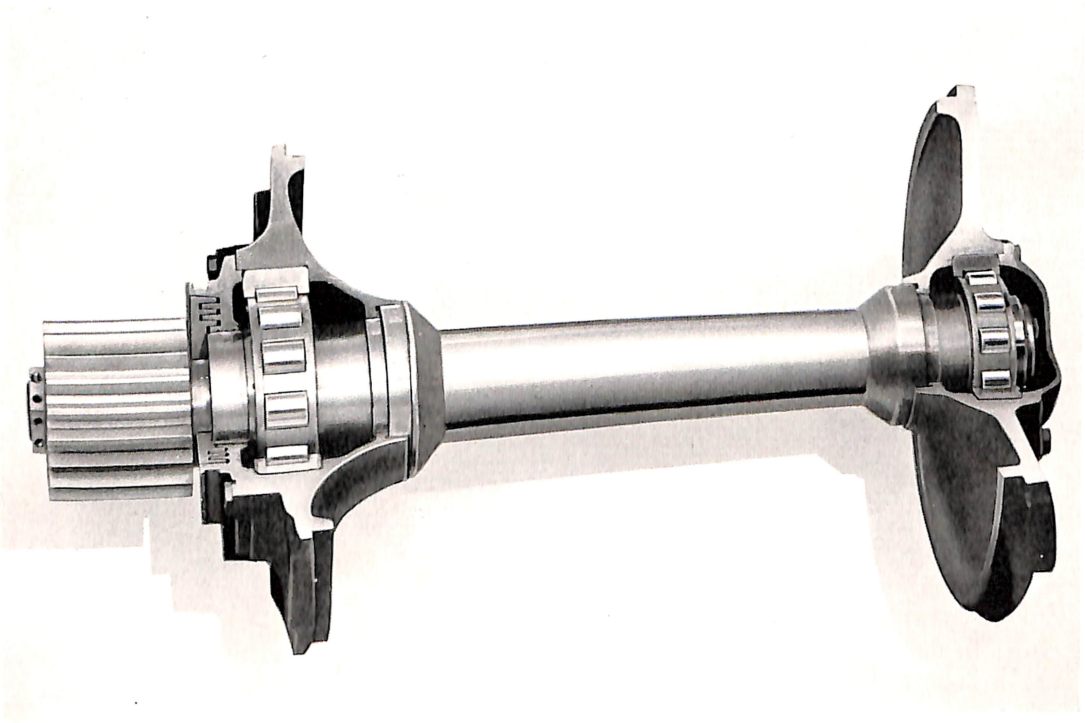
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Fig. 34. Panlograph collector with SKF bearings.

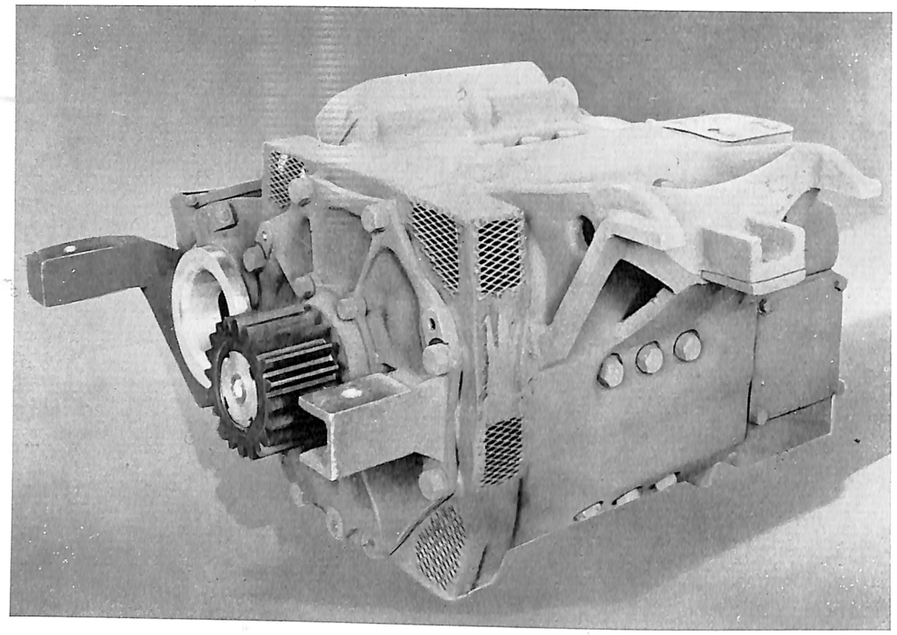
TRAMWAY MOTORS WITH SKF BEARINGS: EXAMPLES FROM DIFFERENT COUNTRIES



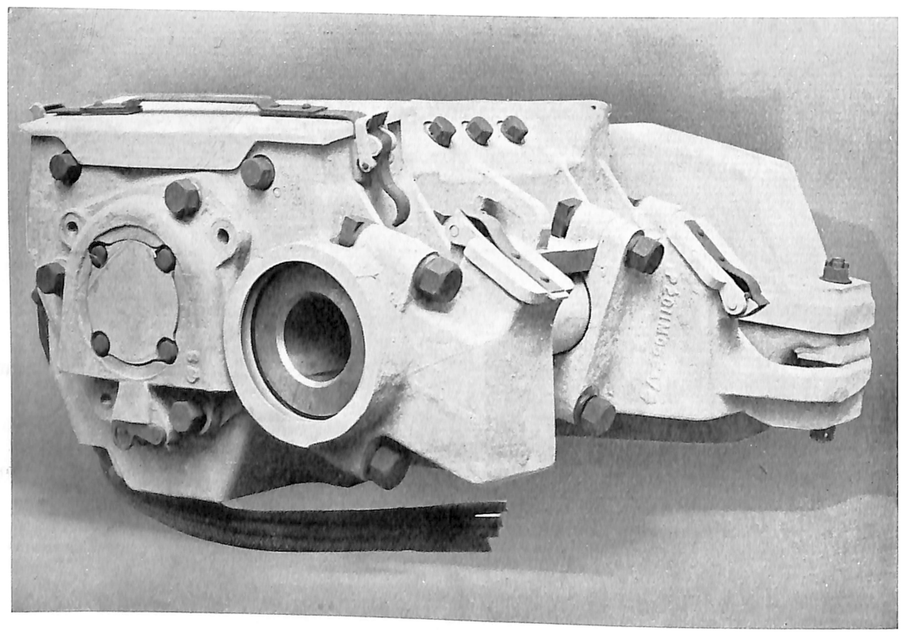
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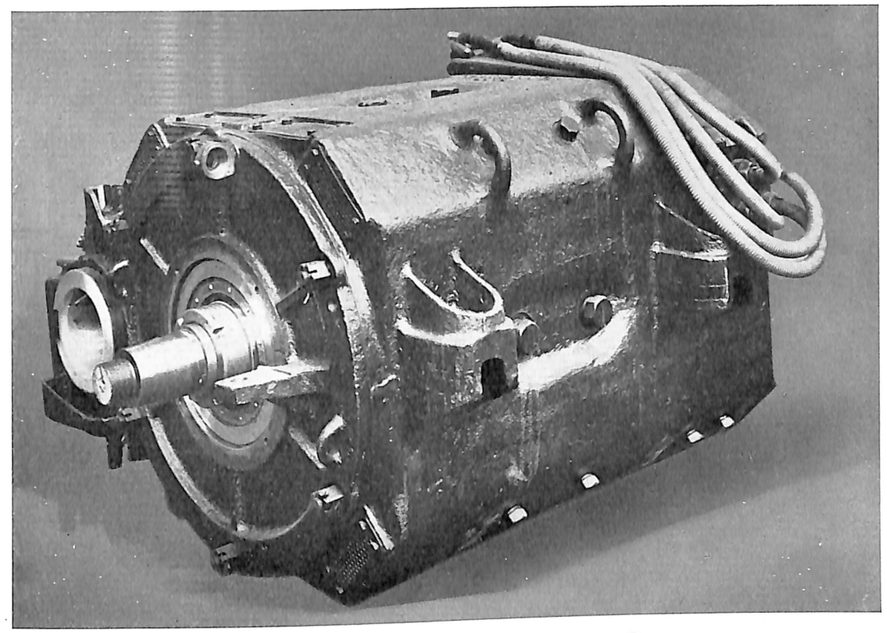
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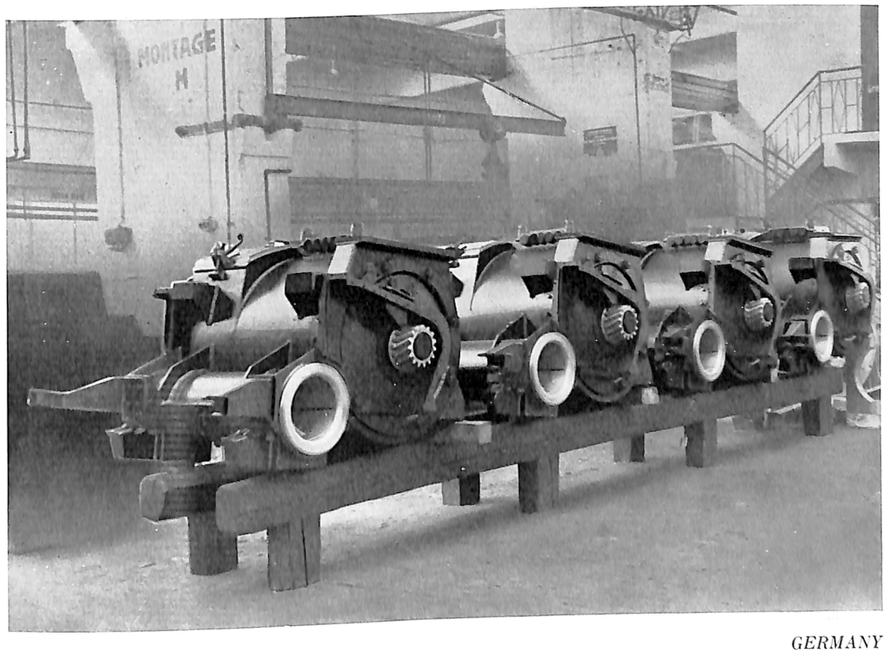
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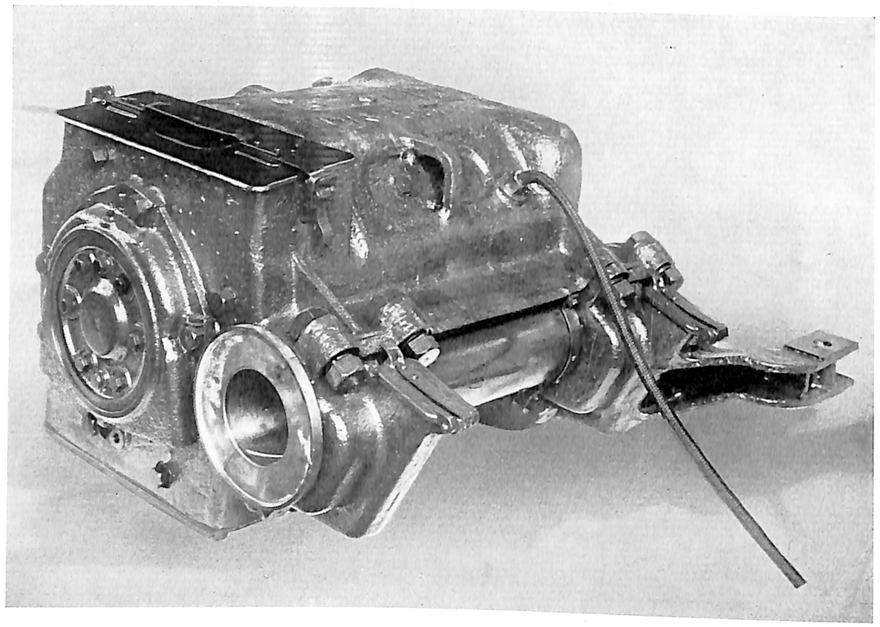
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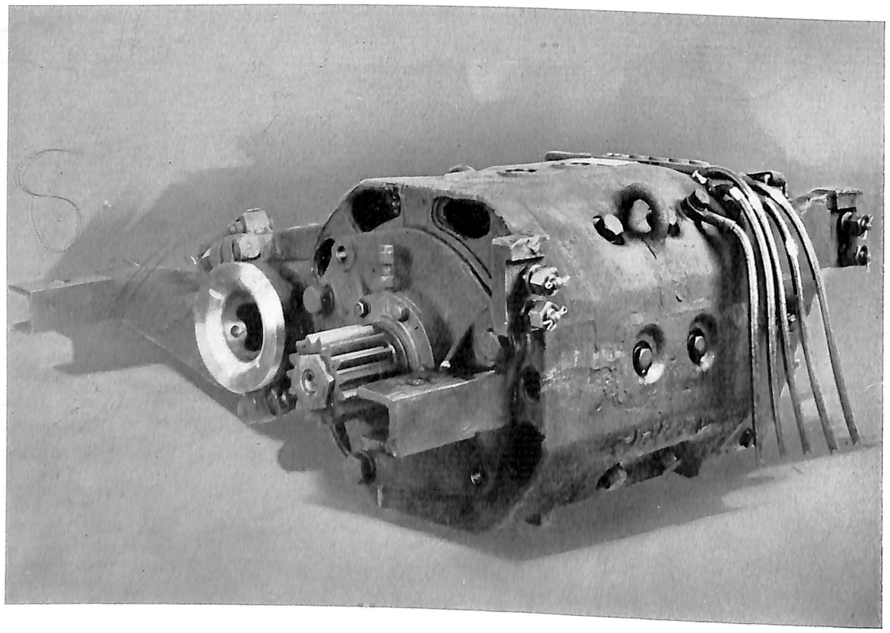
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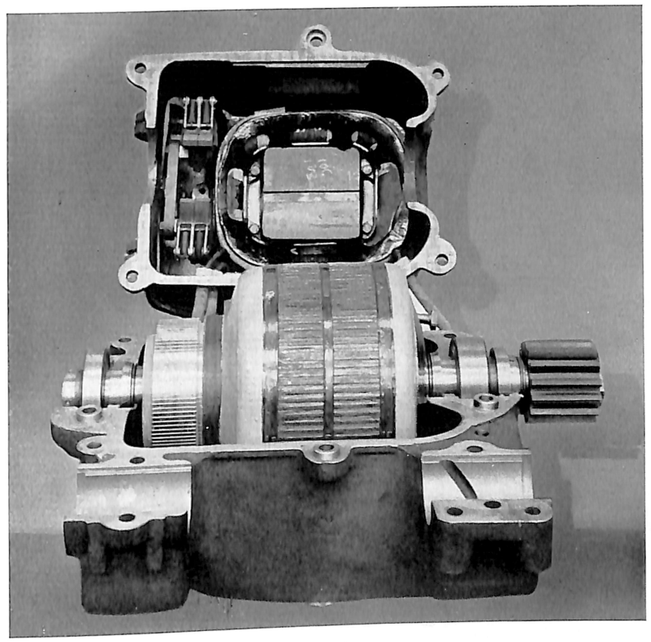
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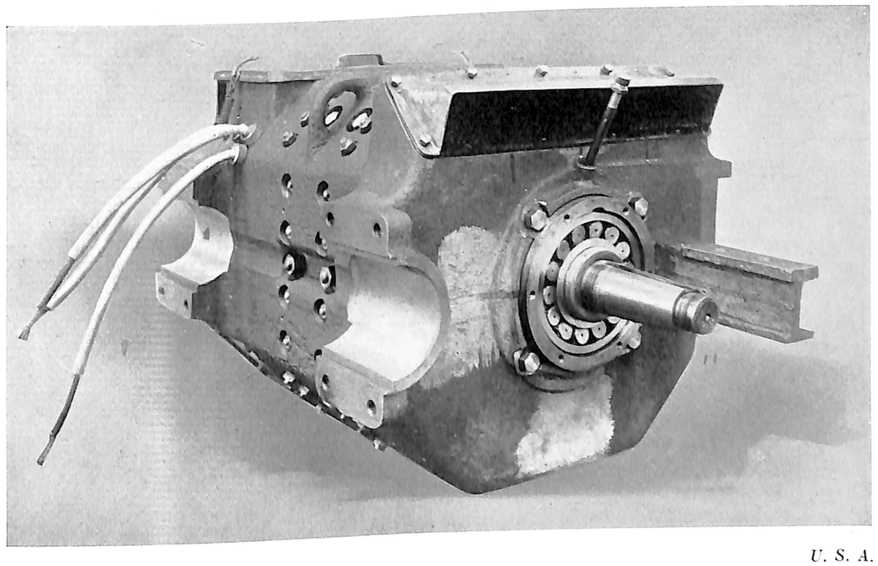
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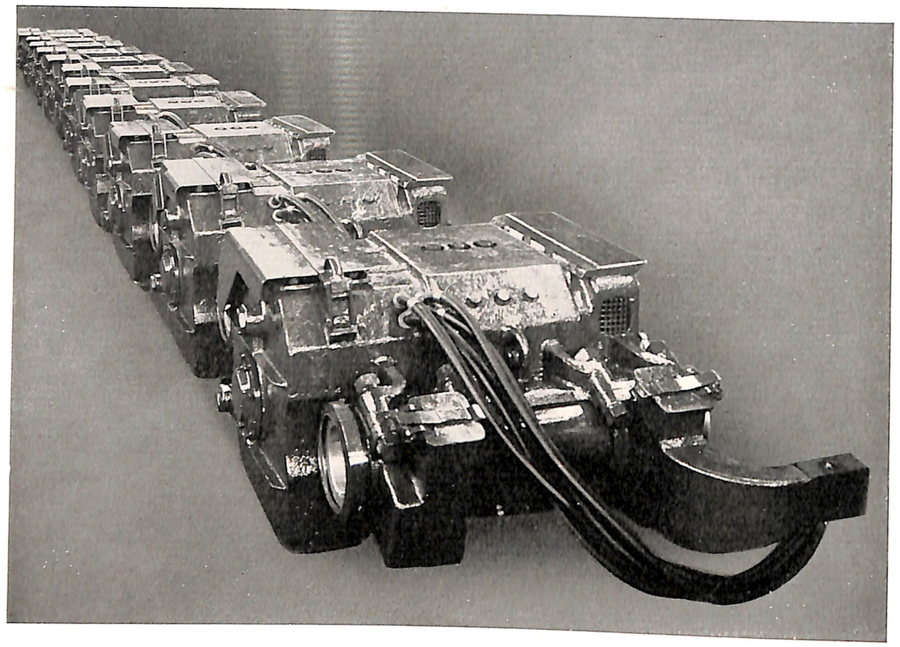
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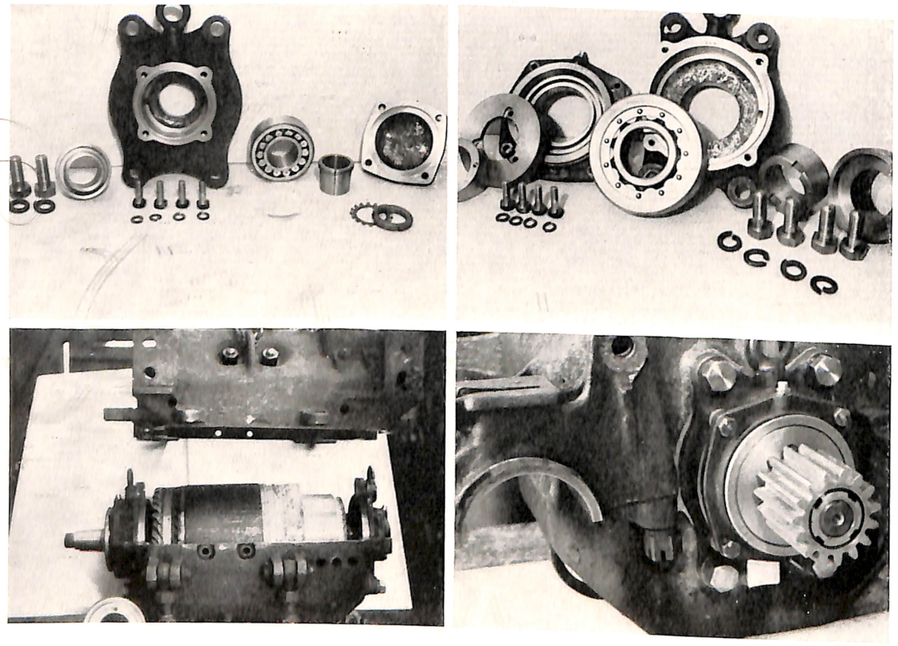
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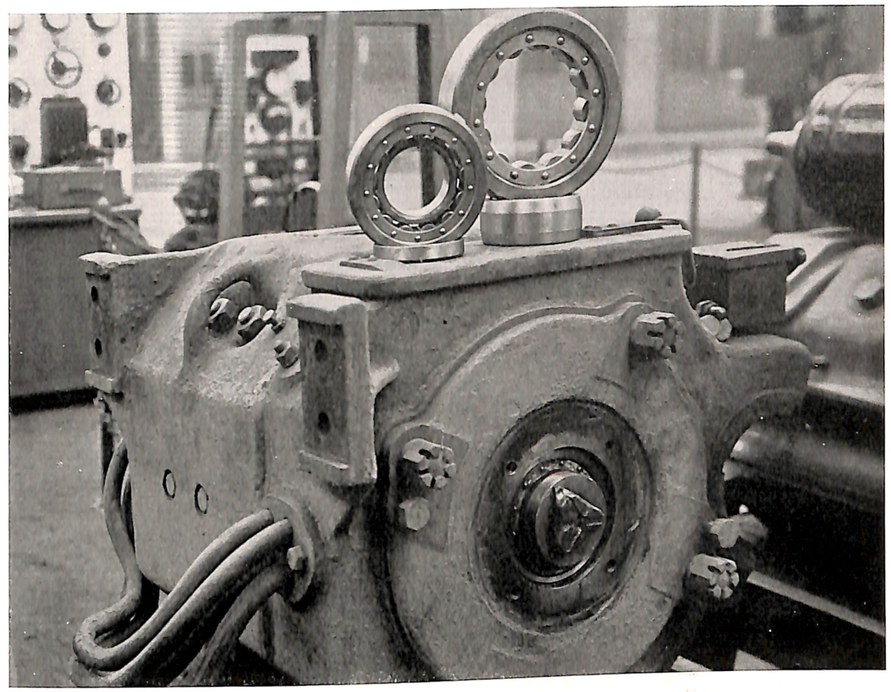
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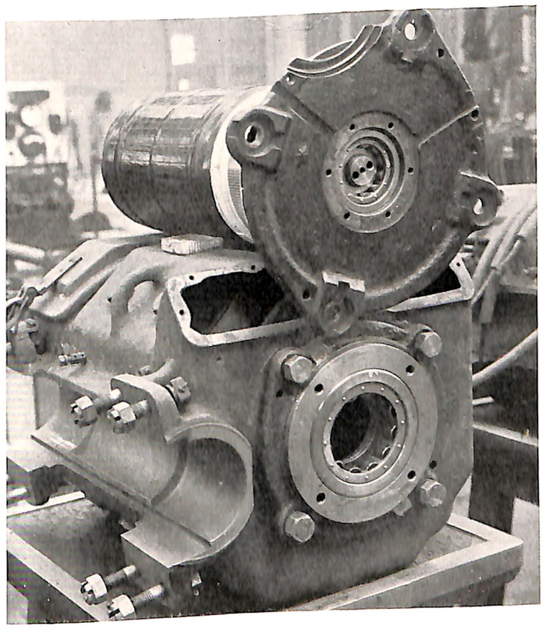
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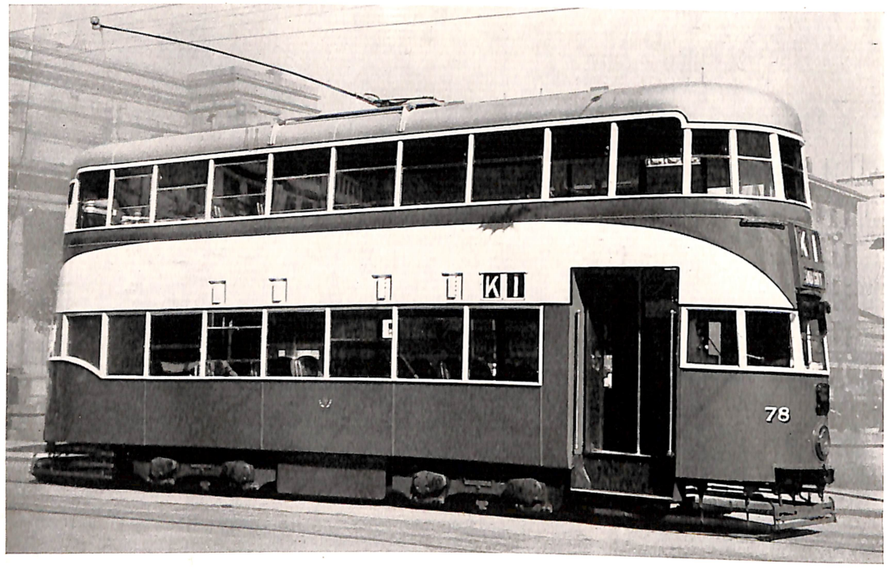


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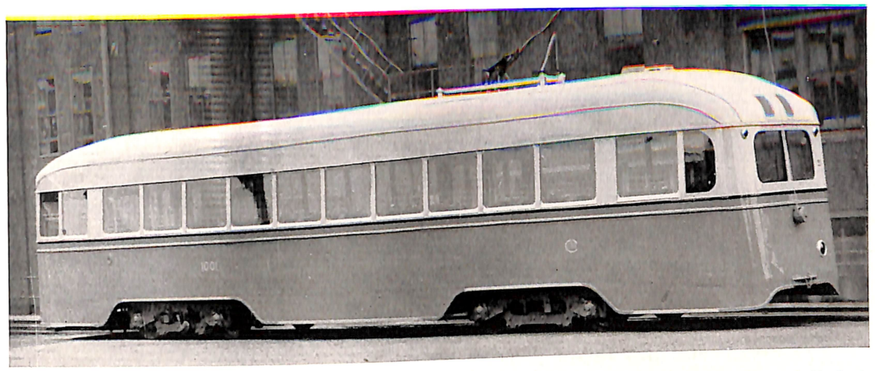
TRAMCARS WITH SKF BEARINGS:
EXAMPLES FROM DIFFERENT COUNTRIES



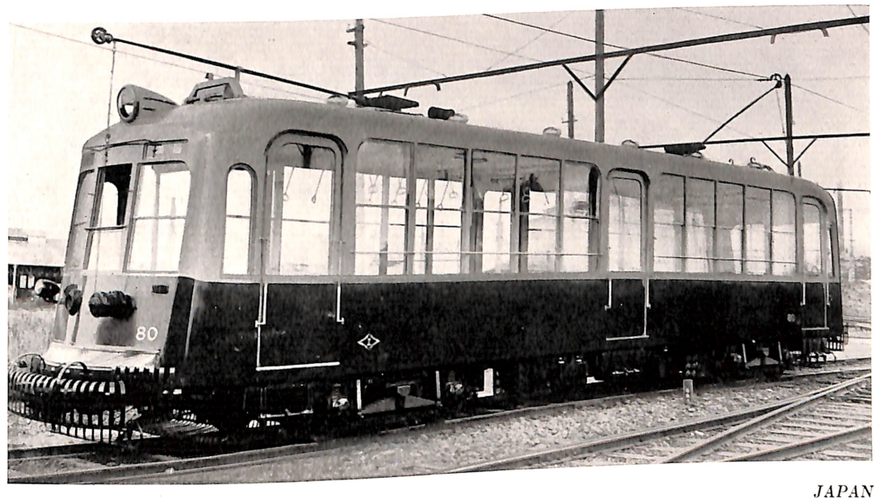
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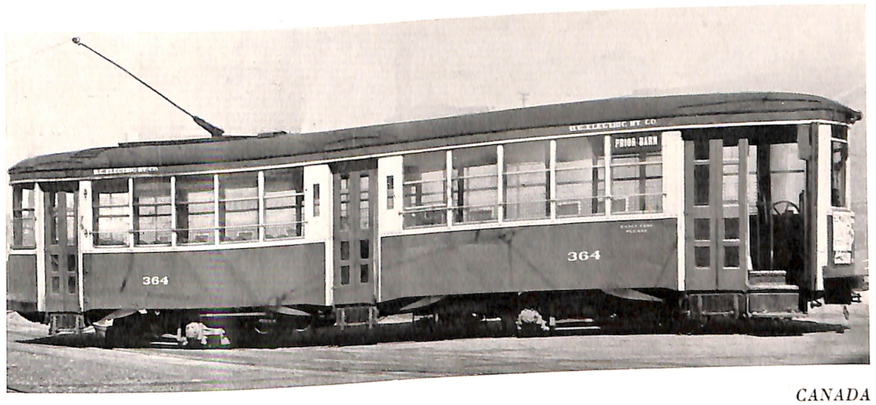
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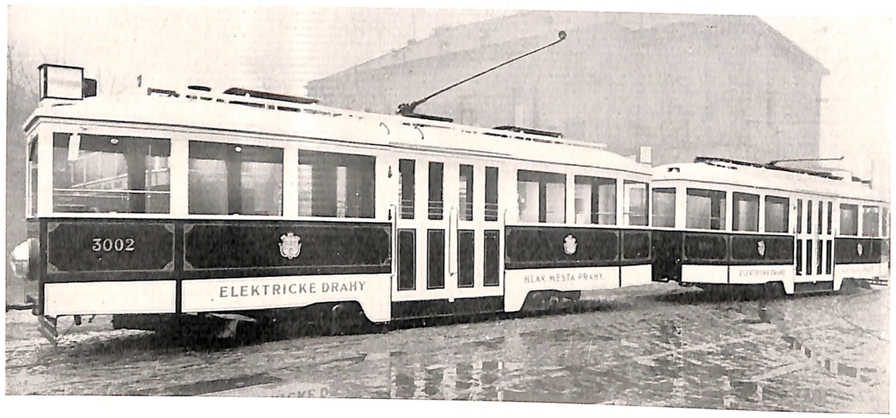
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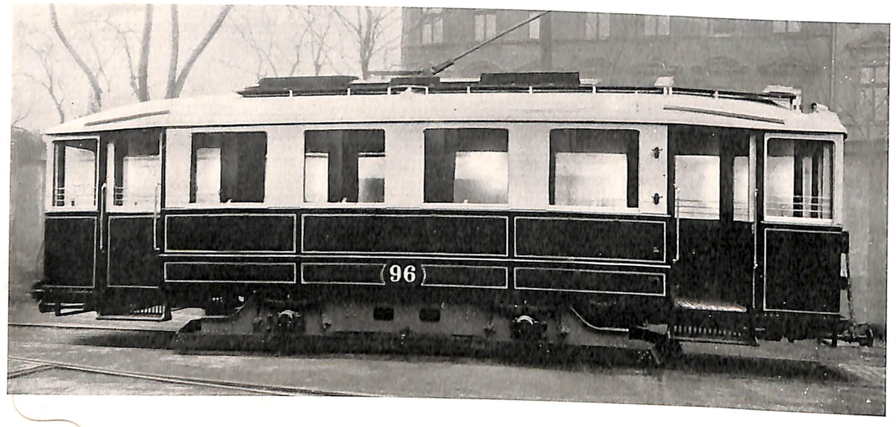
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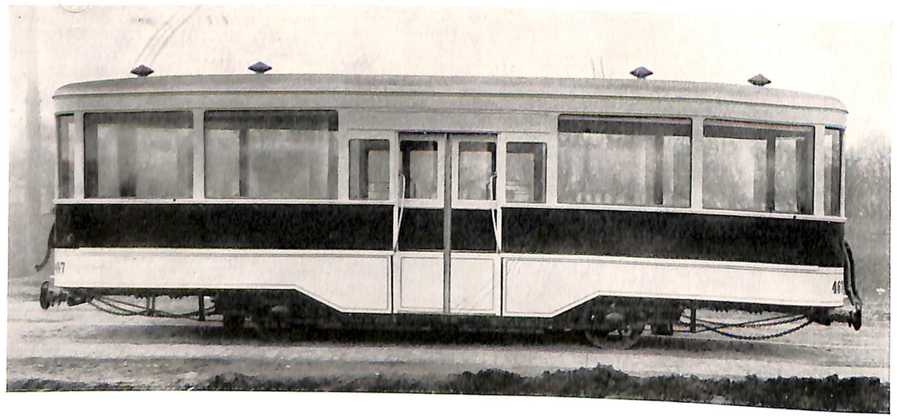
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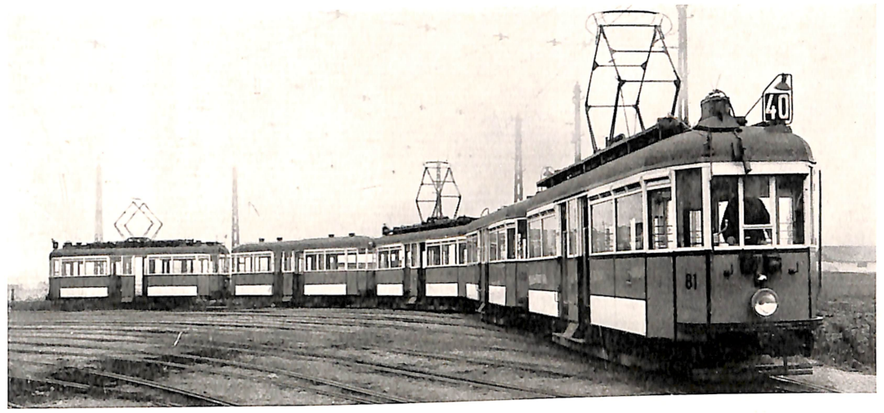
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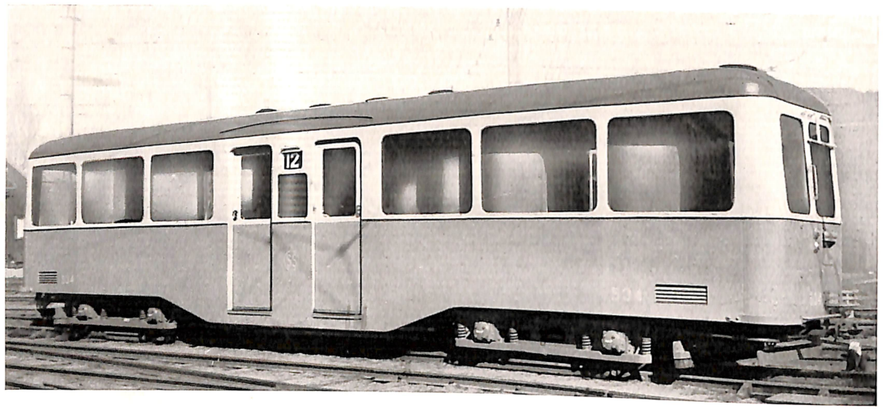
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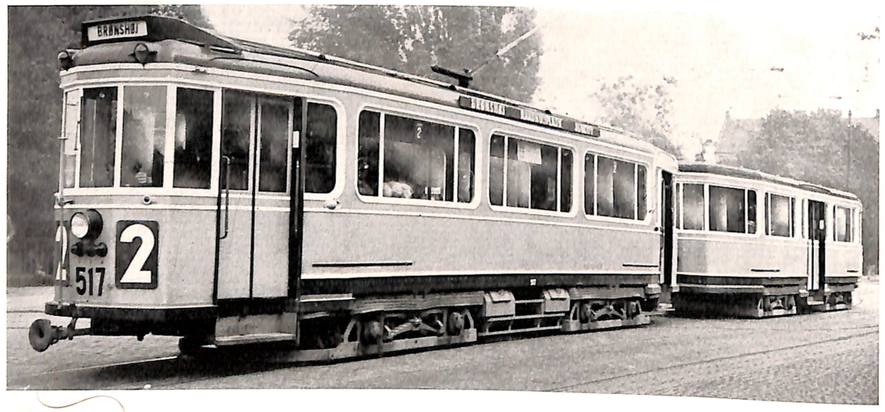
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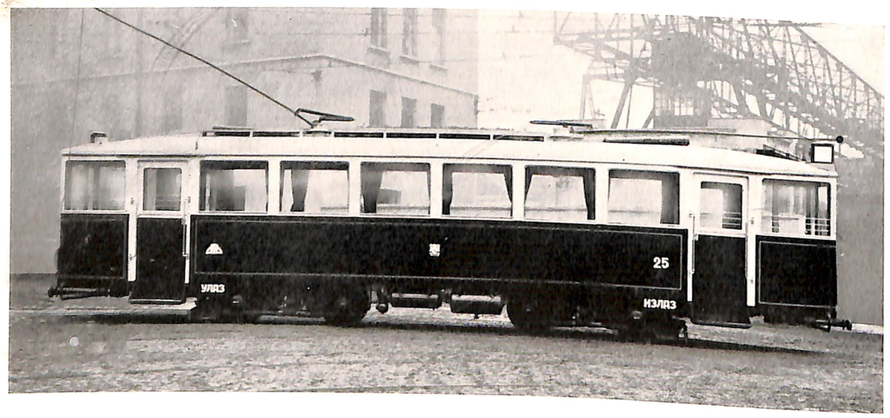
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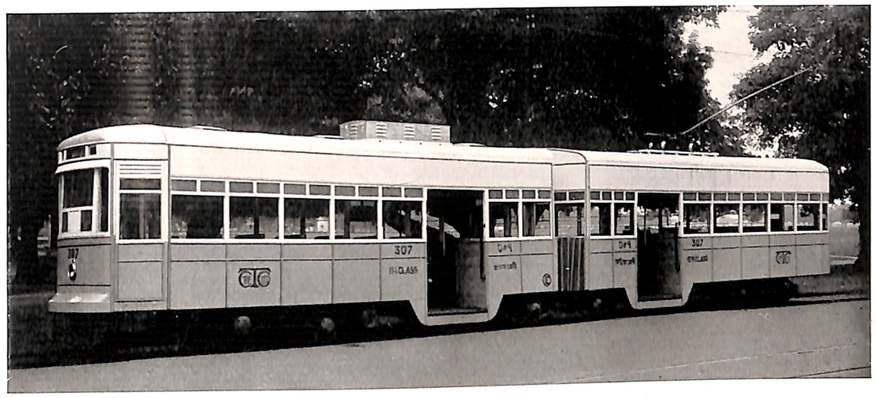
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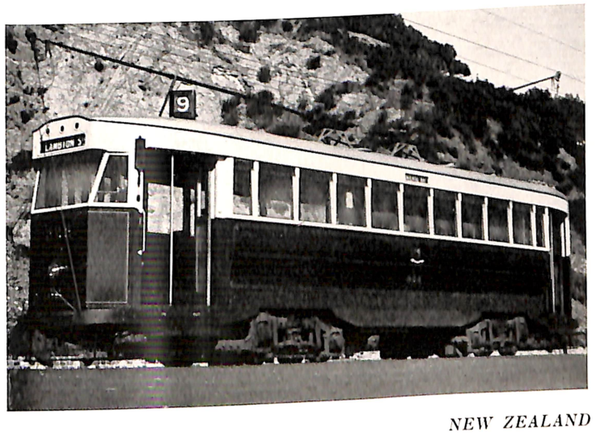
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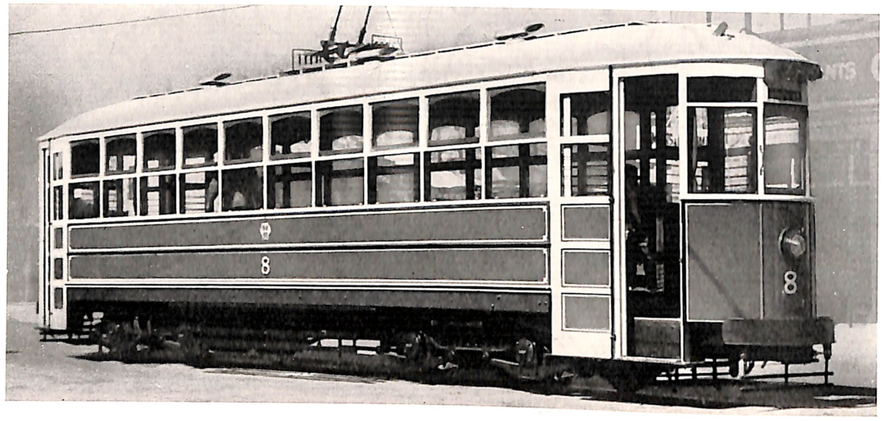
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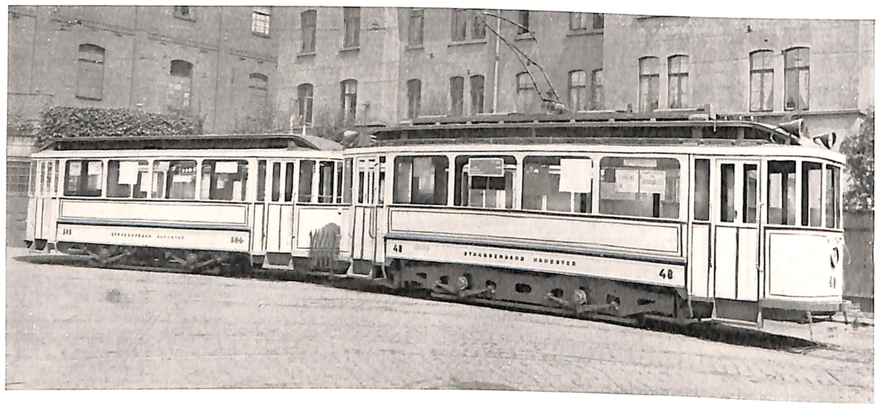
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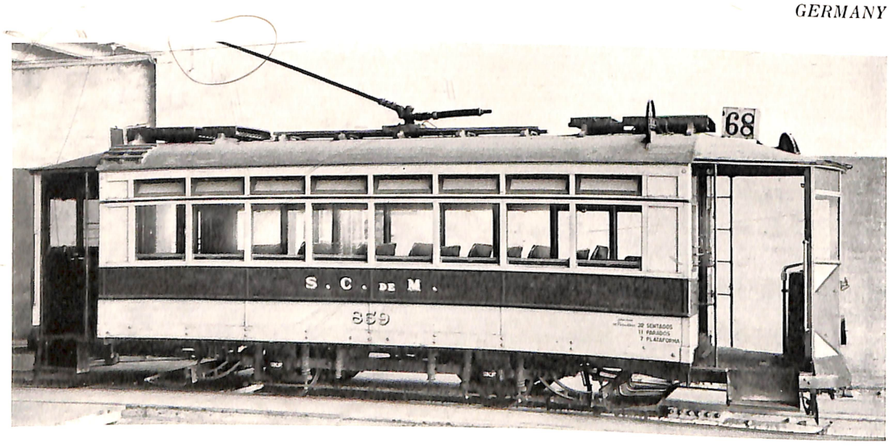
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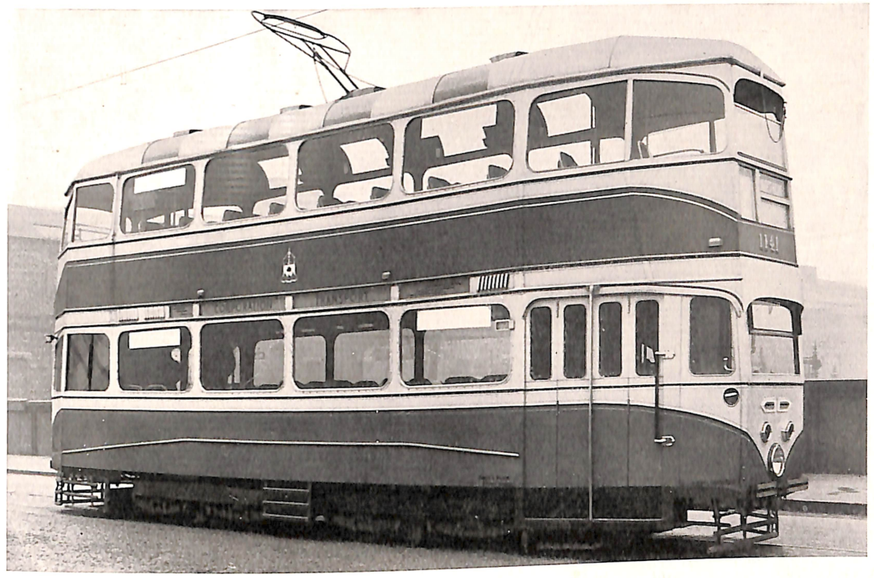
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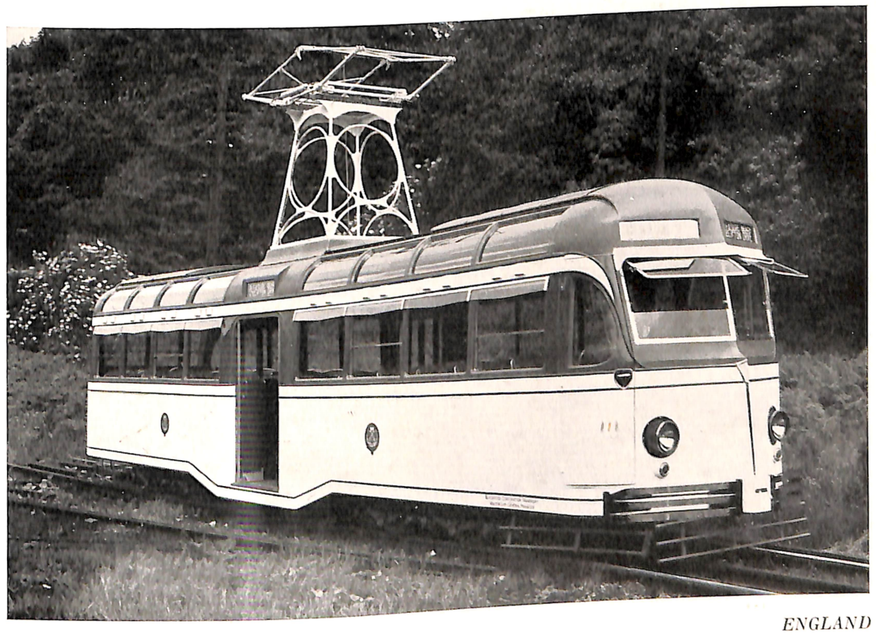
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URUGUAY



ENGLAND



ENGLAND

