

Bearing designs

Tapered roller bearing units

Extract from the Railway technical handbook,
volume 1, chapter 4, page 76 to 87





Tapered roller bearing units

Tapered roller bearing units (TBUs) consist of two inner rings, one common outer ring, two tapered roller and polymer cage assemblies, a central spacer, grease fill and two sealing systems. In addition, further components like lateral spacers, backing rings and end caps with their locking device can be added to the assembly, based on a customer's request.

TBUs are ready-to-mount units with a pre-defined axial clearance. The unit design offers bogie and vehicle suppliers and railway operators the advantage of a sealed and pre-lubricated unit that is easy to mount. The critical greasing procedure is moved from the wheelset workshop environment to the bearing production where greasing can be done in a very clean environment, using the right grease, grease quantity and distribution inside the bearing.

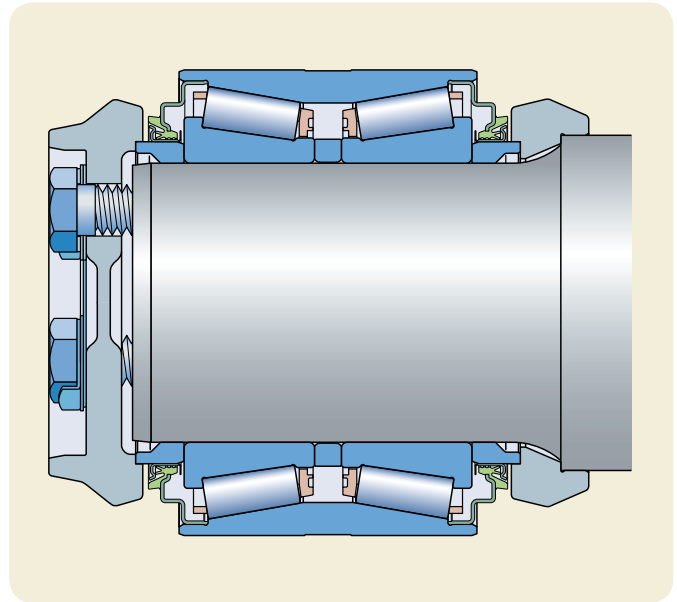
The TBU design offers many options in regard to specific sizes and technical features like grease fill, sealing systems, etc. SKF offers a wide variety of TBU designs that are tailored for specific vehicle types [15, 16, 17].

Design features

Bearing steel

Tapered roller bearing units were originally developed in the 1950s for American freight cars to substitute plain bearings. The Association of American Railroads (AAR) has standardized these bearings for adapter applications and requires case carburized steel for inner and outer rings as well as rollers. SKF offers a special assortment of inch size TBUs which comply exactly with the AAR specifications.

For high-speed and very high-speed applications, both case carburized and through hardened steel is used, depending on the application requirements.



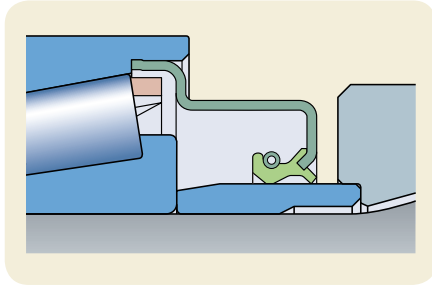
Tapered roller bearing units (TBUs)

consist of two inner rings, one common outer ring, two tapered roller and polymer cage assemblies, a central spacer, grease fill and two sealing systems. Further components like lateral spacers, backing rings and end caps with their locking device can be added to the assembly as well as components based on specific customer requests.

Through hardened steel is usually much cleaner and has less inclusions than case carburized steel. Through hardened steel offers, in many applications, a better performance. For applications like locomotives, multiple units, passenger coaches, mass transit vehicles as well as freight cars with closed axlebox designs, through hardened steel is widely used.

As an alternative, for freight cars with adapter applications, SKF offers special versions based on the advantages of multiple material combinations. The very exposed outer rings are case carburized. The inner rings are either through hardened or case carburized, depending on the specific customer request. The rollers are through hardened. With these material selection options, a higher reliability can be achieved.

Garter seal design for inch size TBUs



Seal designs

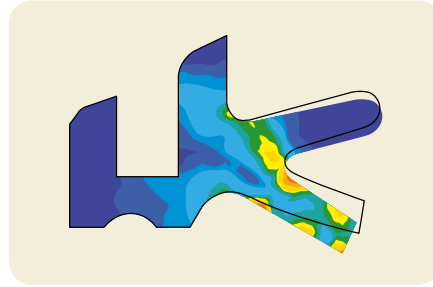
Garter seal

As mentioned earlier, the first tapered roller bearing units were designed to replace plain bearings. These inch size TBU designs had to match the existing relatively long journal dimension. This design enables the integration of a seal wear ring on both sides where the garter seals are riding.

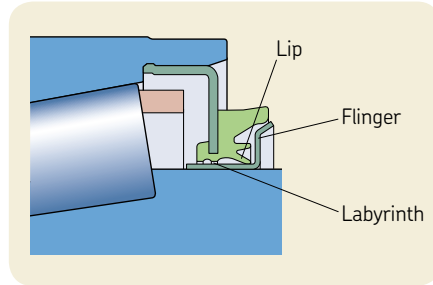
AAR has standardized these garter seals and seal wear rings, which are interchangeable with components from different bearing manufacturers. Today, SKF offers special LL seal designs for inch size TBUs that generate much lower friction.

LL seal

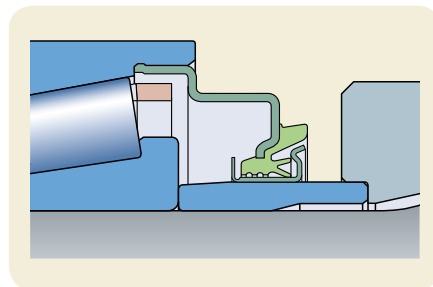
The LL (labyrinth-lip) seal design is based on a low-friction rubber seal principle that is applied to TBU and CTBU designs. The main features are a combination of labyrinth, lip and flinger elements and improved protection against contaminants to extend bearing service life. The frictional moment can be reduced by up to 75%, compared to a garter seal arrangement. As a consequence, the bearing operating temperature is reduced by 20 °C, which contributes to longer grease life and energy savings. Results from the SKF seal test, which evaluates water and dust exclusion, confirmed that the design is very effective in excluding contaminants. Long-term endurance tests have successfully been conducted under very severe operating conditions.



LL (labyrinth-lip) seal design
Display of the FEM calculation result



LL seal design for compact TBU



LL seal design for inch size TBU

LL seal benefits

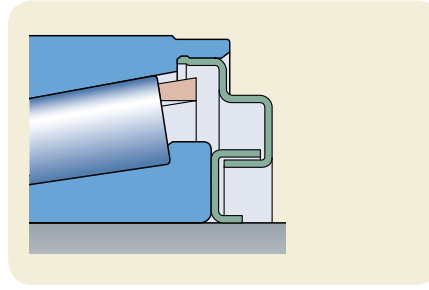
- improved protection against contaminants
- longer grease life
- better and longer performance

LL E2 (Energy Efficient) seal

The LL E2 seal design is based on extensive research to further reduce the frictional moment and wear (abrasion resistance) and to achieve optimized thermal conductivity. This design contributes further to a lower energy consumption by hauling railway vehicles. Because of the lower temperature in the contact zone, this seal can be used for higher speeds. Another advantage of the lower temperature is the increased grease life which enables extended maintenance intervals.

Main features of this seal are an enhanced geometric design, optimized choice of the seal material and surface roughness of the contacting areas.

This seal design fulfils the requirements of UIC 515-1 in regard to the restricted contaminant ingress, especially water.



Labyrinth seal design

Labyrinth seals

Non-contacting labyrinth seals have no friction in the sealing system and are used for full bore axleboxes protected with a front cover. This design is mainly used for metric size TBUs.

For some application requirements, improved protection against water ingress is requested. In this case, a combination of a labyrinth seal and an LL seal on the wheel side, where the backing or labyrinth ring is located, can combine both features and provide relative low friction and better protection.

Labyrinth seals are preferably used for high and very high-speed applications.

LL E2 seal benefits

- lower energy consumption of hauled rail vehicles because of a lower frictional moment compared to an LL seal
- reduced seal wear rate, better performance and longer maintenance intervals achievable
- better thermal conductivity, lower bearing operating temperature and longer grease life, longer maintenance intervals

Polymer spacer

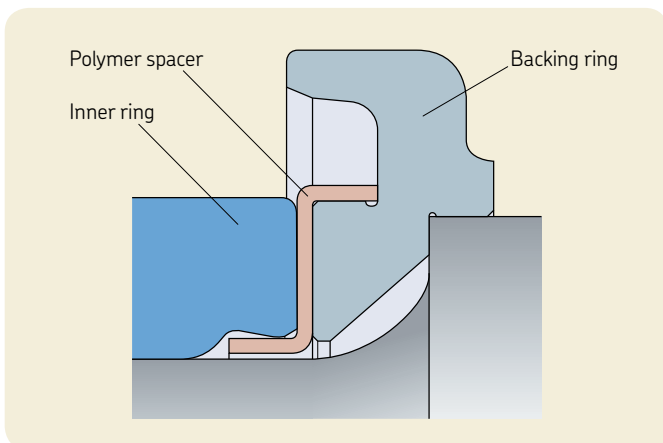
Fretting corrosion between the backing ring and the inner ring side face is caused by journal bending during operation. This corrosion not only causes foreign particles to enter the bearing, but also increases axial bearing clearance, resulting in reduced performance and reliability.

The development target was to avoid fretting corrosion by changing the steel-to-steel contact between the backing ring and the inner ring side face to steel-to-polymer contact. The polymer spacer of reinforced polymer material is clamped onto the bearing components. Extensive field experience confirmed the expectations. As a result, longer maintenance intervals can be scheduled. This design was first introduced for compact TBU designs. Today, the polymer spacer can be offered for nearly all TBU designs and sizes.

Polymer spacer benefits

- fretting corrosion avoided
- lower wear rate of the inner ring side face/backing ring contact zone
- longer performance and longer maintenance intervals achievable because of longer grease life

Polymer spacer design principle



Without polymer spacer:
strong fretting corrosion after 800 000 km



With a polymer spacer:
no fretting corrosion after 800 000 km

Polymer cage

The cage is a key component in achieving reliability and safety of tapered roller bearing units. Cages in rolling bearings perform several tasks:

- During operation, the rolling elements pass from the loaded into the unloaded zone where the cage has to guide the rolling elements.
- Provide and distribute lubricant and dampen vibrations.
- Provide correct retention of the rolling elements during mounting and maintenance operations, thus enabling easier handling.

Historically, pressed steel cages were applied for TBUs. Today, mainly polymer cages are used. They have been in operation since 1990 with excellent results. Pressed steel cages are fitted only on specific customer requests [18, 19].

Safe failure mode

The SKF “oil-off test” simulates a TBU running under impaired conditions. The test starts with some oil lubrication feeding that is stopped after a certain period; the bearing is progressively starved of lubricant and eventually runs dry. The pressed steel cage failed after 70 km with a continuously increasing operating temperature, up to complete seizing of the bearing. Under the same conditions, the polymer cage can be operated at least five times longer than a pressed steel cage. The operating temperature of the TBU equipped with a polymer cage rose after a certain time up to 235 °C and was very stable. After about 500 km, the test was stopped.



SKF polymer cage for TBUs

Polymer cage benefits

- reduced friction and roller slip, reduced wear and lower operating temperature
- improved safety and performance
- safe failure mode without seizing

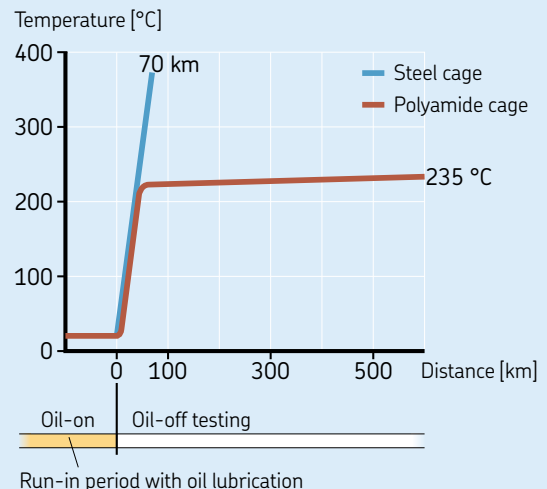
Universal polymer cage

The new Universal Polymer Cage (UPC) design widely replaces the conventional steel cages within a tapered roller bearing unit. This cage design meets the requirements of typical AAR inch size TBUs and is used to upgrade existing bearings during remanufacturing.

This cage also helps to extend the service life, performance and reliability of the bearing. Positive field-test results in North American rail services led to an unconditional approval from the AAR for SKF to retrofit and upgrade existing class F bearing units, manufactured by all major bearing suppliers to the North American market, with the SKF UPC cage [20].

SKF “oil-off test”;

the comparison between a TBU steel cage and a polymer cage

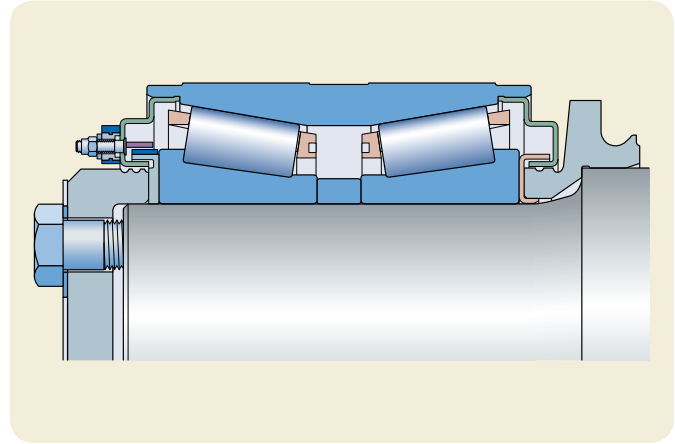


Grease

When selecting the correct axlebox bearing execution, one of the main tasks is the choice of the right grease and quantity of grease. There are quite different application parameters to be considered, such as the engineering requirements for high-speed operation as well as heavy loads, different climatic and track conditions etc. In addition, standards and grease requirements like European EN and American AAR standards have to be fulfilled. Also, there are national requirements, such as in many European countries, in China and Russia, as well as individual customer specifications.

The grease has to pass all chemical, mechanical and tribology testing procedures in accordance with the European Standard EN 12081. In addition, endurance testing of the TBU has to fulfil the requirements of EN 12082. Extended endurance and dynamic simulation tests are being carried out on SKF railway test rigs, to confirm the expected high mechanical and thermal stability as well as resistance to corrosion. More information is provided in the testing section of this chapter (→ [page 99](#)).

The global trend is to achieve a no field lubrication (NFL) maintenance regime and to combine grease renewal with complete TBU remanufacturing, which is in most cases embedded into the complete wheelset overhaul cycle. For some specific applications like high-speed trains with very high mileage, field relubrication is performed to extend main overhaul intervals.



Metric size TBU with a labyrinth seal on both sides as used for high-speed applications

On the right side, a polymer spacer is applied which is part of the sealing system design. On the left side, an impulse wheel is flanged for the sensor application.

Application-specific designs

High-speed trains

For high-speed and very high-speed trains, SKF offers a TBU design equipped with a labyrinth seal on both sides. For some selected applications, a special contacting seal like the LL E2 seal is used.

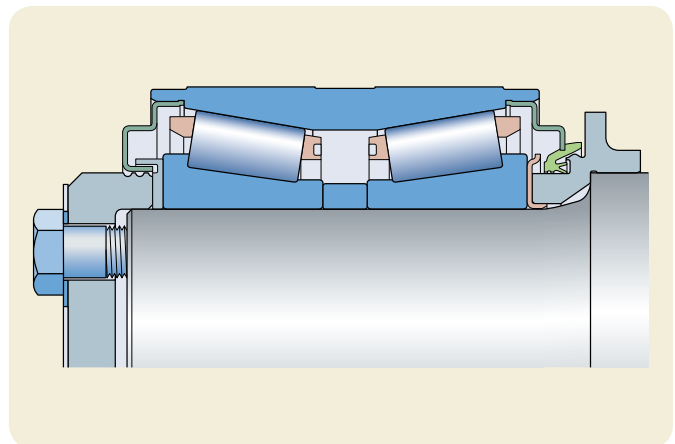
The TBU designs can be equipped with impulse wheels and sensors to detect operating parameters (→ [chapter 7](#) and [chapter 8](#)).

Locomotives and multiple units

For locomotives with speeds up to 120 km/h, compact TBUs with an LL seal on both sides are used. This design requires less space in axial direction compared with a standard TBU design. In the case of

Metric size TBU with a labyrinth seal on the end cover side and an LL seal on the wheel side as used with multiple unit applications

On the right side a polymer spacer is applied which is part of the sealing system design.



compact TBUs, shorter axle journals can be applied, which results in reduced axle bending and less wear in the journal/bearing contact area. For applications in very cold environments, special seal material is necessary.

For electrical and diesel multiple units with speeds up to 160 km/h, compact TBUs with an LL seal on both sides are used, as for locomotives, but smaller sizes are applicable because of lower axleload.

For higher speeds, full bore axleboxes with a front cover are used. For these applications, TBUs with labyrinth seals are used as shown in the previous application.

For some application requirements, improved protection against water ingress is requested. In this case, a combination of a labyrinth seal and an LL seal on the wheel side, where the backing or labyrinth ring is located, can combine both features with relative low friction and improved protection.

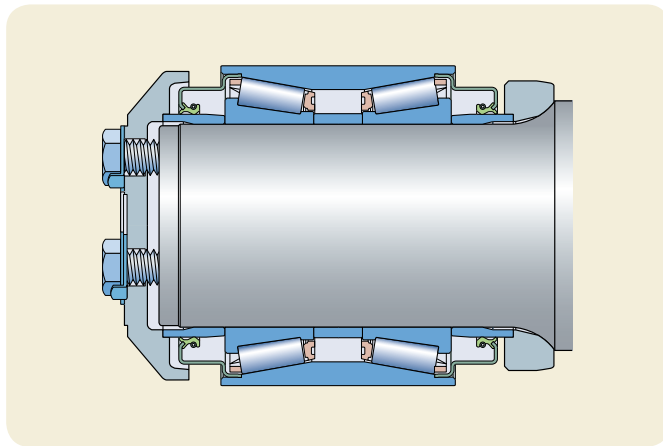
The TBU and compact TBU designs can be equipped with impulse wheels and sensors to detect operating parameters (→ **chapter 7** and **chapter 8**).

AAR freight cars

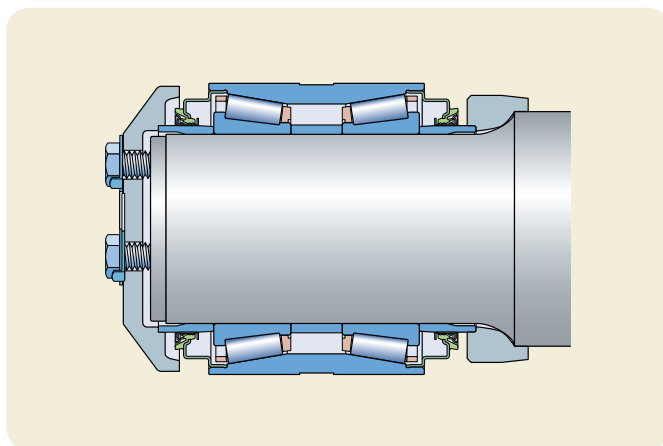
The classic TBU design for American freight cars is following the enveloped size of Association of American Railroads (AAR) where initially the tapered roller bearings replaced plain bearings. This is the reason for a relatively long axle journal. SKF offers the inch size TBU design in two versions:

- traditional inch size TBU design following the AAR specification
- enhanced inch size TBU design with LL seals and special material selection for customers where AAR requirements are not compulsory

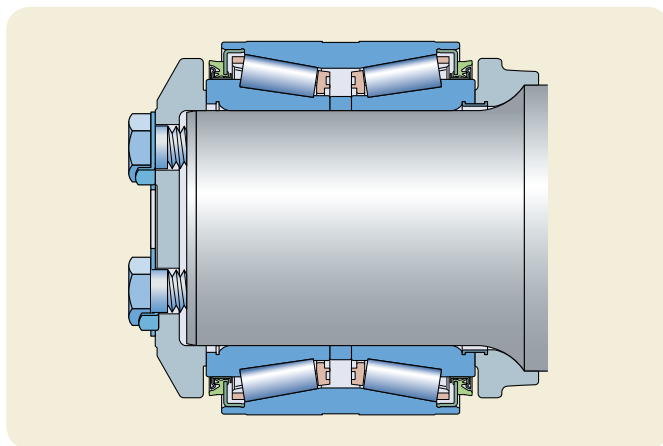
For new freight cars with increased cargo, the inch size compact TBU class K is used. This SKF design is fitted with LL seals, and a polymer clip ring and is approved by AAR.



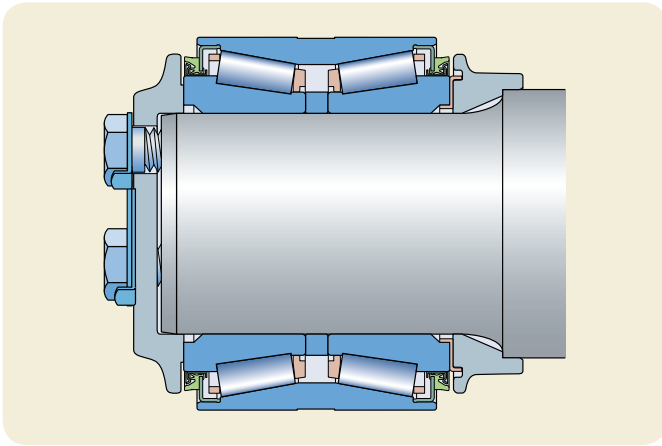
Traditional inch size TBU design following the AAR specification
fitted with a garter seal on both sides



Enhanced inch size TBU design with LL seals and special material selection
for customers where AAR requirements are not compulsory



Inch size compact TBU class K for freight cars



Metric size compact TBU for Chinese freight cars

Chinese freight cars

SKF has developed special TBU designs for the Chinese freight car bogie designs to meet the Chinese Railways' standards. This special design is based on a TBU fitted with an LL seal on both sides, a polymer spacer and polymer cages.

These TBU 130 x 230 x 150 are interchangeable with other TBUs in China.

New generations of Chinese freight cars are designed for 80 t cargo and 120 km/h, compared to the previous generation of cars that were designed for 60 t cargo and 80 km/h. To meet these targets and to further improve operating safety, the Chinese Ministry of Railways has selected SKF as a technology partner.

The new bogies for freight cars are equipped with a special execution of CTBU 150 x 250 x 160 size [21].

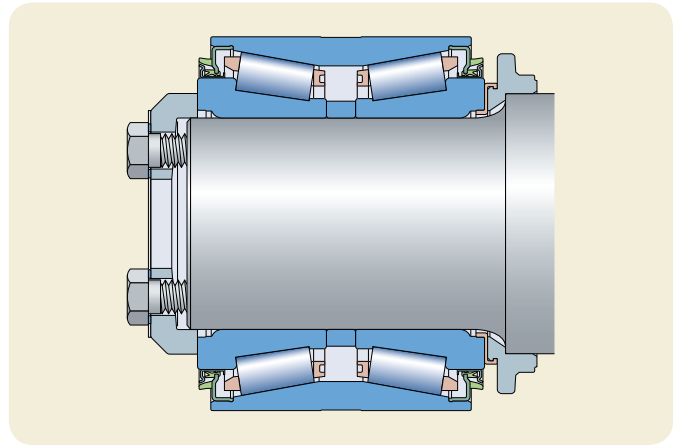
Russian freight cars

SKF has developed special compact TBU designs for Russian freight car bogie designs. This special design is based on an LL-seal on both sides, a polymer spacer and polymer cages. Several technical features were redesigned to meet Russian operating requirements such as poor track conditions, a maximum speed of 120 km/h and extreme climate conditions, e.g. winter temperatures down to -60 °C.

The Russian freight cars 12-132-03 with axleload 23,5 t are equipped with CTBU 130 x 250 x 160 in special execution. These compact TBUs are used for full bore axlebox designs.

The new generation of Russian freight cars is designed for 25 t axleload. SKF developed a special bearing solution for adapter applications.

This CTBU 150 x 250 x 160 provides lower life cycle cost and easier maintenance.

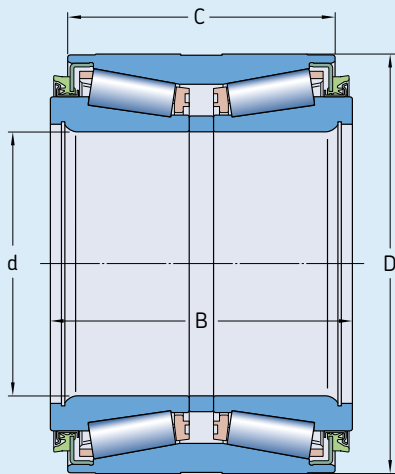


Compact TBU for Russian freight cars

Mass transit vehicles

For mass transit vehicles, like metro cars, light rail vehicles and tram cars with speeds up to 120 km/h, compact TBUs and TBUs with an LL seal on both sides are used. This design requires less space in axial direction. In case of compact TBUs, shorter axle journals can be applied, which results in reduced axle bending and less wear in the axle/bearing contact area. For applications in very cold environments, special seal material is necessary.

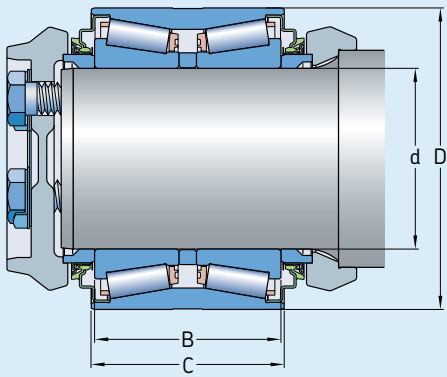
CTBU compact tapered roller bearing units



| Size | Principal dimensions | | | |
|--------------------------------------|----------------------|------------------|-----------------|-----------------|
| | d | D | B | C |
| Metric sizes | mm | | | |
| CTBU 100 x 175 | 100 | 175 | 130 | 120 |
| CTBU 110 x 180 | 110 | 180 | 142 | 142 |
| CTBU 130 x 210 | 130 | 210 | 148 | 132 |
| CTBU 130 x 220 | 130 | 220 | 145 | 135 |
| CTBU 130 x 230 | 130 | 230 | 166 | 150 |
| | 130 | 230 | 176 | 160 |
| CTBU 130 x 240 | 130 | 240 | 172 | 160 |
| CTBU 130 x 250 | 130 | 250 | 172 | 160 |
| CTBU 140 x 220 | 140 | 220 | 150 | 140 |
| CTBU 150 x 250 | 150 | 250 | 180 | 160 |
| CTBU 160 x 280 | 160 | 280 | 195 | 180 |
| Inch sizes | mm (in) | - | - | - |
| CTBU Class K 6 1/2" x 9" | 157 (6.1880) | 250 (9.8420) | 181 (7.1102) | 160 (6.2992) |
| CTBU Class G 7" x 9" and 7" x 12" | 178 (7.0005) | 276 (10.8750) | 200 (7.8740) | 186 (7.3120) |

These figures are for information only. Contact SKF for detailed product specifications.

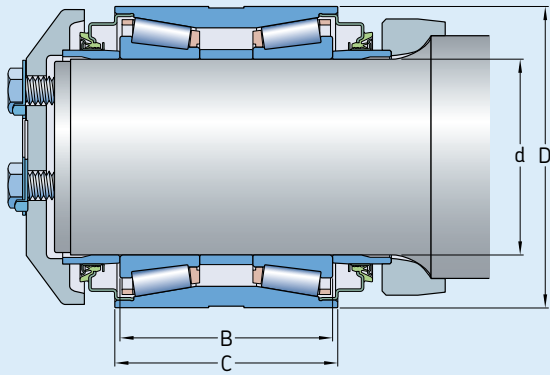
TBU tapered roller bearing units, metric sizes



| Size | Principal dimensions | | | |
|----------------------|----------------------|---------|-------|-----|
| | d | D | B | C |
| - | mm | | | |
| TBU 90 | 90 | 154 | 106 | 115 |
| TBU 100 | 100 | 175 | 113,5 | 120 |
| TBU 120 | 120 | 195 | 126 | 131 |
| TBU 130 x 210 | 130 | 210 | 126 | 132 |
| TBU 130 x 220 | 130 | 220 | 145 | 150 |
| TBU 130 x 230 | 130 | 230 | 150 | 160 |
| TBU 140 | 140 | 220 | 133 | 140 |
| TBU 150 | 150 | 250 | 154,5 | 160 |
| TBU 160 x 270 | 160 | 270 | 160 | 150 |
| TBU 160 x 280 | 160 | 280 | 180 | 180 |
| TBU 178 x 265 | 178,62 | 265,137 | 134 | 139 |

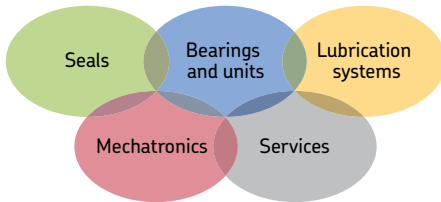
These figures are for information only. Contact SKF for detailed product specifications.

TBU tapered roller bearing units, inch sizes



| Size | Principal dimensions | | | |
|-----------------------------|----------------------|---------------------|---------------------|---------------------|
| | d | D | B | C |
| – | mm (in) | | | |
| Class B 4 1/4" x 8" | 101,600 (4.0000) | 165,100 (6.5000) | 106,35 (4.1870) | 114,30 (4.5000) |
| Class C 5" x 9" | 119,088 (4.6885) | 195,263 (7.6875) | 136,525 (5.3750) | 142,875 (5.6250) |
| Class D 5 1/2" x 10" | 131,775 (5.1880) | 207,963 (8.1875) | 146,75 (5.7780) | 152,40 (6.0000) |
| Class E 6" x 11" | 144,475 (5.6870) | 220,663 (8.6875) | 155,575 (6.1250) | 163,51 (6.4370) |
| Class F 6 1/2" x 12" | 157,175 (6.1879) | 252,413 (9.9375) | 177,80 (7.0000) | 184,15 (7.2500) |

These figures are for information only. Contact SKF for detailed product specifications.



The Power of Knowledge Engineering

Drawing on five areas of competence and application-specific expertise amassed over more than 100 years, SKF brings innovative solutions to OEMs and production facilities in every major industry worldwide. These five competence areas include bearings and units, seals, lubrication systems, mechatronics (combining mechanics and electronics into intelligent systems), and a wide range of services, from 3-D computer modelling to advanced condition monitoring and reliability and asset management systems. A global presence provides SKF customers uniform quality standards and worldwide product availability.

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