Failure analysis:

An important step in achieving Wheel End TFO®.

Failure analysis of prematurely failed seals is one of the best means to discover the cause of failure and to avoid a similar fate for the replacement seal.

The cross sectional drawings at right illustrate the critical components of each member of the Scotseal® family. The captions identify these components as described in the following pages.

For Scotseal® PlusXL, failures most likely result from these common errors:

- Improper installation
  - O.D. and/or I.D. not lubed
- Lube contamination as listed above
- Spindle not fully prepped
- Use of a hammer

Note: replacing a narrow footed seal like the Scotseal® Classic and Scotseal® Longlife requires cleaning the spindle along the new area where the wider Scotseal® PlusXL will sit.

Below are the key failure modes for Scotseal® Classic and Scotseal® Longlife. These account for the lion’s share of premature seal failures.

- Improper installation
  - Wrong or no tool used
- Cocked installation
- Lubricant contamination
  - Metal flakes
  - Dirt or water
  - Mixing of lube types
- Improper bearing adjustment
- Seal spinning on spindle
  - Damaged spindle
- Hub imperfections
- Installed over a wear ring

Consult the following pages for examples of Failure Analysis.
Failure analysis:

Scotseal® Classic / Scotseal® Longlife

External inspection – outer diameter

Normal scuffing: The surface will show some scraped areas, that’s normal. But signs of nicks, scratches metal particles, or any foreign material are warning flags that something else is amiss. Make sure the hub bore is smooth and free of burrs or nicks.

O.D. radial grooves: If the Bore-Tite® film has been scored all the way across the width of the seal, you should inspect the hub for burrs or damage. Before installation, the hub should be inspected and cleaned with emery cloth or a fine file.

Lines in the Bore-Tite: If you see lines around the seal, several things could have happened. If the lines are etched to the metal, the seal could have spun as a result of being the wrong application or, more likely, it was installed crooked or cocked.

As you can see in this example, the grooves run from high on the left to low on the right, indicating a cocked installation. Most likely, the seal was not properly “bottomed-out” or a centering tool was not used — common causes of premature seal failure.

Shiny leading edge: Occasionally someone will try to improve seal installation by changing the shape of the seal. They’ll round off the leading edge of the outer cup on a grinder. This distorts the outer diameter and can possibly cause the seal to disassemble.

Outer cup damage: If you see dents, nicks, or a bent casing you can bet that the seal was installed without the proper tool or the tool was damaged. Gashes indicate the use of a sharp object, like a screwdriver or punch.
Failure analysis:

Scotseal® Classic / Scotseal® Longlife
Reference the Scotseal® installation wall poster (457626) as a convenient seal and bearing installation guide.

External inspection – inner diameter

I.D. wear: If the I.D. of the packing is shiny, or has axial scratches, the seal has spun on the shaft. That can be caused by not bottoming-out the seal properly, leaving it cocked in the bore or installing the wrong part number.

Installed backwards: The only way that the packing can be worn shiny, as shown here, is by rubbing against the bearing race. The only way that can happen is by putting the seal in backwards.

Severely damaged I.D.: Scratches or dents in the I.D. are signs that the seal has struck the spindle or axle tube during installation. Rushing the installation and not lining up the wheel dolly is the usual suspect. Or a rough shop floor may be the problem.

Distorted packing: One way to damage the packing of a Scotseal® is to try to install it over a wear ring. The wear ring will deform the inner surface and ruin the seal. Any previously installed wear ring must be removed prior to installing a Scotseal.

Foreign matter on I.D.: Occasionally, you will come across a seal with a shaft leak that has a mysterious, tacky substance on it. Most likely someone added a silicone sealant to “improve” the seal. Old habits die hard.
Failure analysis:

Scotseal® Classic / Scotseal® Longlife

Internal inspection

Opening a Scotseal

Use pliers or end cutters and work your way all the way around the seal, straightening the outer cup flange.

Remove the inner cup. Be sure to wear gloves or use a shop rag to protect your hands, the open flange edges are sharp.

Remove the packing without disturbing the lip surfaces, as shown.

Internal inspection – the major clues

Lip grease: Every Scotseal® comes with grease between the primary and dirt lip. If it’s not there, it’s very likely oil has washed it away. Suspects are excessive end-play, a cocked seal or improper ventilation of the wheel end (dirt, corrosion or paint-plugged vent).

Brittle primary seal lip: After cleaning the entire seal, use your fingers to curl the primary seal lip back. Run your finger completely around the circumference. The oil lip should be smooth and pliable. If not, the seal has overheated; lack of lubrication or overtightened bearing adjustment could be the cause. Be sure to inspect bearings carefully.

Broken dirt lip: Using the same technique, check the dirt lip. If it’s dry and brittle, most likely it’s been baked. It will probably split away from the seal at some point around the circumference. Lack of lubrication may have fried the bearings as well.
Failure analysis:

**Scotseal® Classic / Scotseal® Longlife**

Internal inspection – wear tracks

**Good pattern:** What you will see in a good Scotseal® are the two parallel lines that look like they’ve been drawn with a sharp pencil. They’re approximately the same size and equidistant from the edge all the way around the inside of the outer cup.

**Wide, wide:** If both lines are wider than pencil lines, it means that the primary lip and dirt lip have been allowed to move in and out on the outer cup. The cause of this is excessive endplay, indicating that the bearing endplay is greater than the recommended range of .001” and .005”.

**Metal shavings in lip area:** Before cleaning the seal, inspect the seal area for traces of metal particles. A magnet can attract metal particles. Sharp edges of metal may have cut the seal primary lip causing the seal to leak.

**Cocked seal—inner markings:** Holding the outer cup just below eye level and flat, like a bowl, rotate your wrist through 360°. If the seal has run cocked, the two lines will be parallel to each other, but they appear to move closer and then farther from the outer cup flange.
Failure Analysis:

Scotseal® PlusXL

External inspection – checking the beads

**Normal exterior:** The tough nitrile covering on the Scotseal® PlusXL doesn’t supply clues as readily as Bore-Tite does. But it can still reveal problems and lead to corrective measures. There should be lubrication in each of the O.D., I.D. beads.

**Dry exterior:** If, in good illumination, you cannot see any residual lubrication between the beads of the outer sleeve, the seal may have been installed dry. A Scotseal® PlusXL does not need special tools, but it does need lubrication for proper installation.

**Damaged O.D. beads:** If the external ridges appear damaged, most likely someone has tried to force the seal in place without proper lubrication. Burrs or dirt in the bore can also cause problems, but they’re not as visible with the thick nitrile rubber protection.

**Worn I.D. beads:** A worn I.D. indicates the seal has been slipping on the spindle. Look for three main causes: a cocked seal, a bent seal section, or poor spindle preparation in changing from another seal to the Scotseal® PlusXL.

**Damaged I.D. beads:** Cuts or scarring in the I.D. is caused by jamming the seal into the spindle or axle place without proper lubrication. Misaligning the wheel dolly is usually the result of haste, however the work area should be checked to make sure the floor is smooth and free of clutter.

**Dented, scarred sleeve assembly:** A dimpled or dented surface indicates damage caused by a problem during installation. Lack of lubrication would be a prime suspect, but a poorly prepared hub or the use of hard-faced tools or seal driver could be the culprit.
Failure analysis:

Scotseal® PlusXL

Opening a Scotseal® PlusXL

Use pliers to straighten the flange on the sleeve section. Be sure to wear gloves or use a shop rag to protect your hands. The opened flange is extremely sharp.

Pull the two components apart. Then set the sleeve assembly aside (the top component shown above). Place it carefully where it is out of the way, but won’t be disturbed.

Internal inspection – sealing lip condition

Check for grease: Locate the primary sealing lip and radial dirt lip. If the area between them is dry, something has allowed oil to wash away the grease. The cause could be excessive end-play or a cocked seal. Or internal pressure from a blocked vent.

Normal lip flexibility: Check the primary sealing lip and dirt lips by pressing downward on them with your thumbs, sliding them around the entire circumference. The rubber should remain soft and flexible in normal use.

Cracked lips: If, when you check the primary and dirt lips the nitrile feels rough and dry, it has probably been subjected to excessive heat. Loss of lubrication and overtightened bearing adjustment are the prime suspects.

Flattened bumper lip: Scale or rust on the spindle will prevent the wider Scotseal® PlusXL from sealing properly. This creates extra pressure on the bumper and axial dirt lips. The spindle must be fully cleaned and all wear rings removed before installing a Scotseal® PlusXL.
Failure analysis:

Scotseal®PlusXL

Internal inspection –
Primary and radial dirt lip wear patterns

**Good primary lip pattern:** You should see two parallel lines. The primary lip line is slightly wider than the radial lip marking, because it's a SKF Waveseal® design.

![Good primary lip pattern image]

**Wide, wide:** If both of the tracks formed by the primary and dirt lips are wide, chances are the whole wheel assembly is moving in and out at an excessive rate. End-play like this causes leaks as well as increased tire wear. The solution, of course, is proper bearing adjustment.

![Wide, wide image]

**Wide, thin:** If the primary seal lip line (bottom) is extra wide, while the radial dirt lip line (top) is light, there is excessive pressure on the primary lip. For steer and trailer axles that can be a plugged vent, on drive axles the tube vent may be locked.

![Wide, thin image]
Failure analysis:

Scotseal® PlusXL

Internal inspection – Axial dirt lip and bumper lip wear patterns

Good axial and bumper lip patterns: When you examine the axial face, you have two more wear patterns to learn from. About half way up on the face you should see a pencil line track from the axial lip, and at the top edge a gently scuffed pattern from the bumper lip.

Wide, shiny: If both lines are wide or polished clean, then you should suspect that the seal has been compressed. This will happen if the I.D. of the seal isn’t lubricated before installation, if the sleeve wasn’t sealed fully on the spindle, or if the bearing adjustment is too tight.

Uneven patterns:
If the bumper lip path is shiny in one sector but dull in the opposite sector, you can be sure the seal was cocked.
The bumper lip is making hard contact through half the revolution and almost no contact through the rest of it.
**Inspection:**

**Bearing cup**

The most commonly damaged portion of the bearing cup is the tapered raceway surface inside the cup. Make a careful inspection and look for the following:

- Evidence of corrosion
- Metallic debris
- Pitting of the surface
- Metallic flakes
- Any other signs of damage or foreign matter

Severe sliding wear due to presence of hard abrasives.

Dent across the race indicates a sharp high impact.

Cup shows considerable corrosion. This will develop in spalling.

Dings and dents in the bearing surfaces indicates a drift was used during installation.

Typical surface appearance with repeated effects of vibration (called "false brinelling").

Surface appearance caused by electrical arcing during welding.
**Inspection:**

**Bearing cone**

The cone of the bearing is a composite assembly consisting of taper rollers and a metal or polymer cage. This cage contains the rollers and an inner ring which is the interface surface with the shaft or spindle.

Since there are many moving parts on the cone, you should slowly rotate the cone assembly for proper inspection of all surfaces of the components.

Make a careful inspection and look for the following:

- Corrosion
- Metallic debris
- Pitting
- Metallic flakes
- Other signs of damage or wear

Roller end fracture due to heavy stress peaks caused by slackness of too loose bearing adjustment.

Roller end wear caused by over tightening, lubrication degradation, or lack of lubricant.

Roller end cracks indicate excessive loading or excessive misalignment.

Scoring indicates contamination by dirt, grit or metallic particles.

Coloration indicates an overheated bearing - from straw brown to deep purple. Causes are lack of lubricant, misadjustment or excessive loading.

Wear marks in bands are due to foreign particles causing mild abrasive wear.
The bearing cage is made of either pressed steel or polymer and is therefore subject to various forms of damage. These cages are deformed due to rough handling (dropping on the floor, being thrown in a box with other hard components, etc.) or poor installation with shock loads caused by hammering during removal or installation.

Inspection of the inner ring often requires a sharp eye because the damage can be very subtle. The most common types of fatigue damage are shown below.

Examine the inner ring raceway by holding the bearing against a light and turning the cage slowly. Look for pitting, flaking, discoloration and corrosion.
Failure analysis for bearings

Improper bearing adjustment

Large end of roller shows scoring, the result of excessive preload.

Large end of the roller shows spalling, the result of insufficient lubrication and/or excessive preload.

Pitting

Small end of the roller shows excessive wear, the result of loose bearing adjustment.

Pitting of the race, as a result of debris in the lube causing surface deformation.

Misalignment

Misalignment occurs when the center lines of the two bearings are not parallel to each other. The causes can be an improperly seated bearing, where dirt or burrs prevent a flush mount; an outer cup installed without the proper tool; a warped shaft; or nut faces that are out of line.
Failure analysis for bearings

**Misalignment**

Uneven wear on the roller, the result of improper installation.

**Contamination**

Circular wear in the race, the result of hard particle contamination in the lube.

Vertical etching on the race, the result of moisture contamination within the lube.

Circular wear on the roller, the result of hard particle contamination in the lube.
Lubrication

Installation damage

Peeling, the tearing away of metal from the race, the result of the breakdown of lubrication.

Discoloration indicates high levels of heat, the result of improper lubrication or improper bearing adjustment.

Deformation of the cage, the result of improper installation or mishandling prior to installation.

Cage damage, the result of abuse prior to or during installation.

Cracked cone, the result of misapplication or cocking the cone at installation.

Damage to the cup front face, the result of installation damage through use of a hardened driver.

Failure analysis for bearings
Failure analysis for bearings

Brinelling

Brinelling, the result of severe impact to the bearing, causing one or more of the roller bodies to deform the surface of the race.

Other damage

Fretting corrosion of the outer surface is often the result of a worn hub or spindle.

Light pitting can be caused by electrical arcing. The probable cause is electrical welding grounded through the shaft.

Spalling, the wearing away of metal from the bearing surface, the result of contamination, brinelling, improper installation, improper lubrication, or the normal end of bearing life.
Failure analysis for hubcaps

Inspection of lubricant and hub cap

The hub cap is constantly exposed to the environment. That means hot, cold, wet, dry and salty. But some of it’s roughest treatment can come from inside. A lack of lube or an over-tight bearing adjustment can cook the hub cap and permanently damage it. Here are a few of the clues to indicate why a hub cap has failed.

**Distorted bolt hole:** Bolt hole, or flange distortion, may be the result of excessive bolt torque during installation. The use of an impact wrench may damage the flange at the bolt hole area during assembly.

**Milky window:** The view window in the hub cap will become nearly opaque white when subject to heat. The heat comes from inside and spells trouble. You’ll want to pull the wheel and check the bearing adjustment, check for low lube or a change to an incompatible lubricant.

**Melted window:** With the hub cap removed, inspect the edges of the view window for damage or discoloration. If the edge has a rippled look, chances are it has started to melt from excessive heat. Heat build-up could be from running low on lube, excessive pre-load on bearing or a recent switch to an incompatible lubricant.

**Warped Flange:** Place hubcap on a flat surface. When flange is distorted it will not hold contact all the way around. Proper torque specifications may not have been followed.
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