



SAE 50 Long-Life Synthetic Transmission Oil Field Study in Over-the-Road Applications



Overview

Modern manual transmissions installed in heavy-duty, over-the-road (OTR) trucks pose significant challenges to lubricants. Today's manual transmission lubricants must protect heavily loaded gears, bearings and other critical components from wear and the effects of thermal breakdown throughout extended 500,000-mile drain intervals. Lubricants installed in OTR applications incapable of meeting these requirements are largely considered outdated and may lead to costly repairs.

Objective

Determine if AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provides the high level of protection required of manual transmissions installed in heavy-duty, long-haul fleet applications practicing 500,000-mile drain intervals.

Methodology

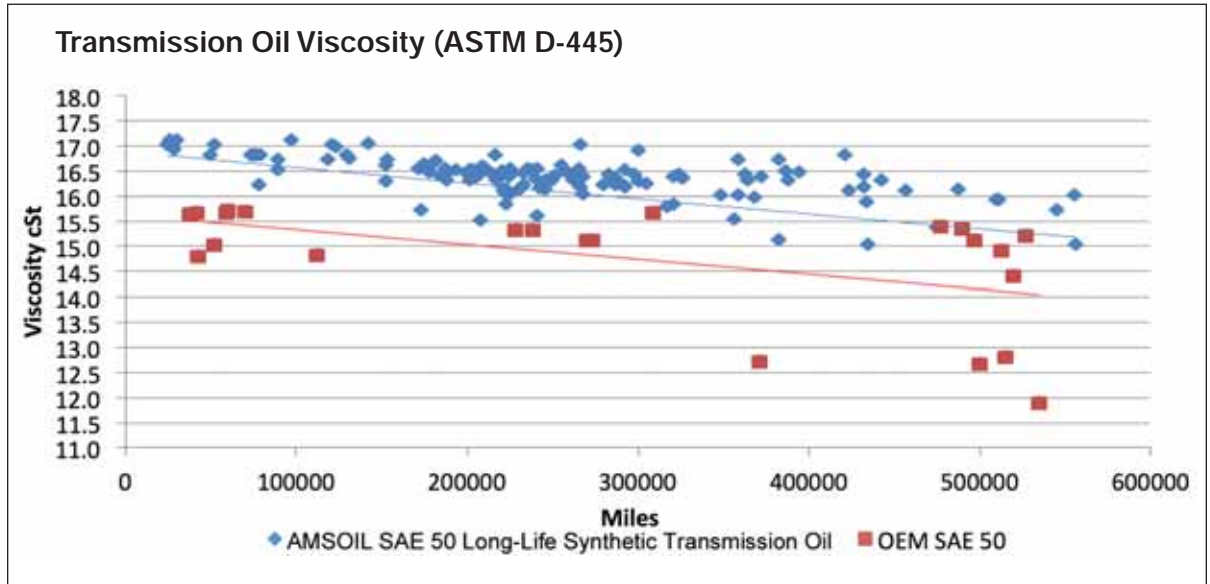
AMSOIL partnered with Superior, Wis.-based Jeff Foster Trucking, which hauls petroleum, aggregate, forest products and other freight throughout the contiguous 48 states and all Canadian provinces. The fleet primarily hauls fully loaded 53' trailers through hot and cold temperature extremes. Vehicles routinely encounter demanding driving conditions, including stop-and-go city traffic and steep inclines, creating the ideal environment for testing transmission fluids.

Beginning July 2006, AMSOIL SAE 50 Long-Life Synthetic Transmission Oil was installed in new model-year 2007 and 2008 Kenworth® trucks equipped with Eaton® manual transmissions. The trucks were used by Foster Trucking between 2006 and 2011, during which oil samples were collected from a cross-section of vehicles at various mileage intervals. Oil samples were also collected from OTR trucks equipped with transmissions factory-filled with an original equipment manufacturer (OEM) SAE 50 transmission oil. The trucks operated in nearly identical conditions to the trucks using AMSOIL SAE 50 Long-Life Synthetic Transmission Oil, and the oil samples drawn helped establish a performance benchmark against which to compare the performance of the AMSOIL product. Oil analysis was conducted according to ASTM methodology to determine viscosity retention (ASTM D-445), iron and copper wear metals content (ASTM D-5185) and total acid number (ASTM D-664).

The transmission from unit 2168 was randomly selected and removed from service following 512,000 miles in service on a single oil change. It was then disassembled and rated for wear, sludge and other distress by an ASTM calibrated rater. This paper displays oil analysis results for both AMSOIL SAE 50 Long-Life Synthetic Transmission Oil and the OEM factory-fill transmission oil, as well as photographic results and analysis of the transmission disassembly.

Oil Analysis – Viscosity Retention

The severe operational environment inside heavy-duty manual transmissions can cause permanent viscosity loss due to mechanical shear. Excessive viscosity loss impairs the oil's ability to form a protective lubricating film between metal parts.

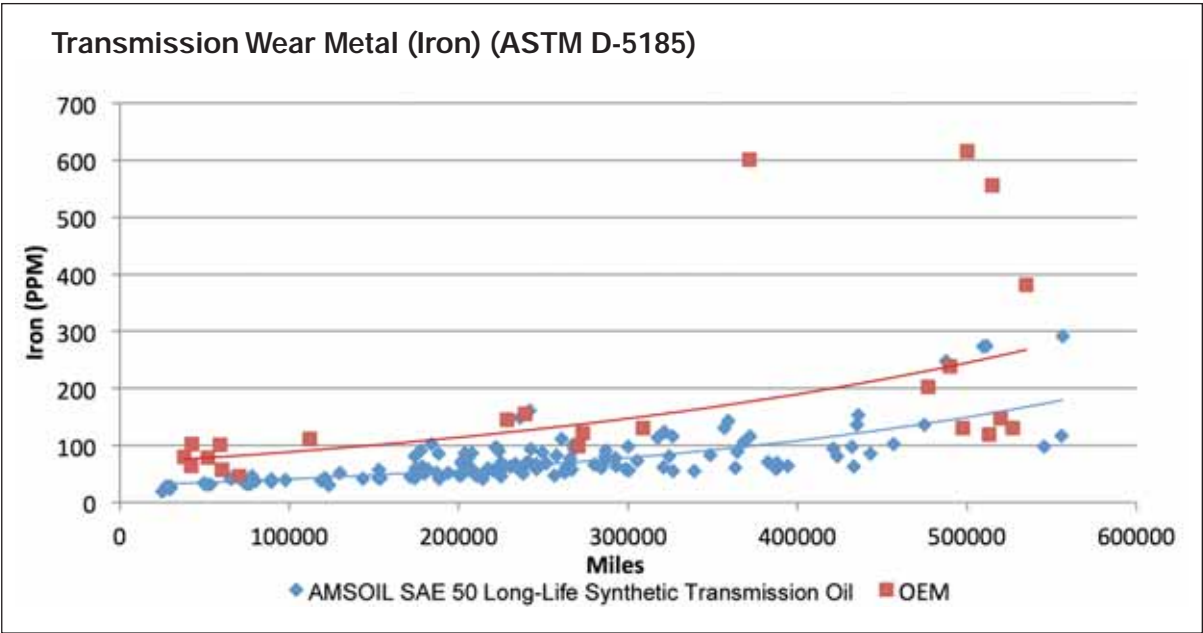


Results

AMSOIL SAE 50 Long-Life Synthetic Transmission Oil resisted shear and viscosity loss as effectively as, or better than, the SAE 50 OEM oil. As the service interval progressed, the viscosity of the AMSOIL product continued only a gradual downward progression. The oil maintained a protective lubricating film throughout its service life.

Oil Analysis – Iron Content

Some iron content in transmission oil is normal. Elevated levels, however, are an indication gears or bearings are suffering abnormal wear.

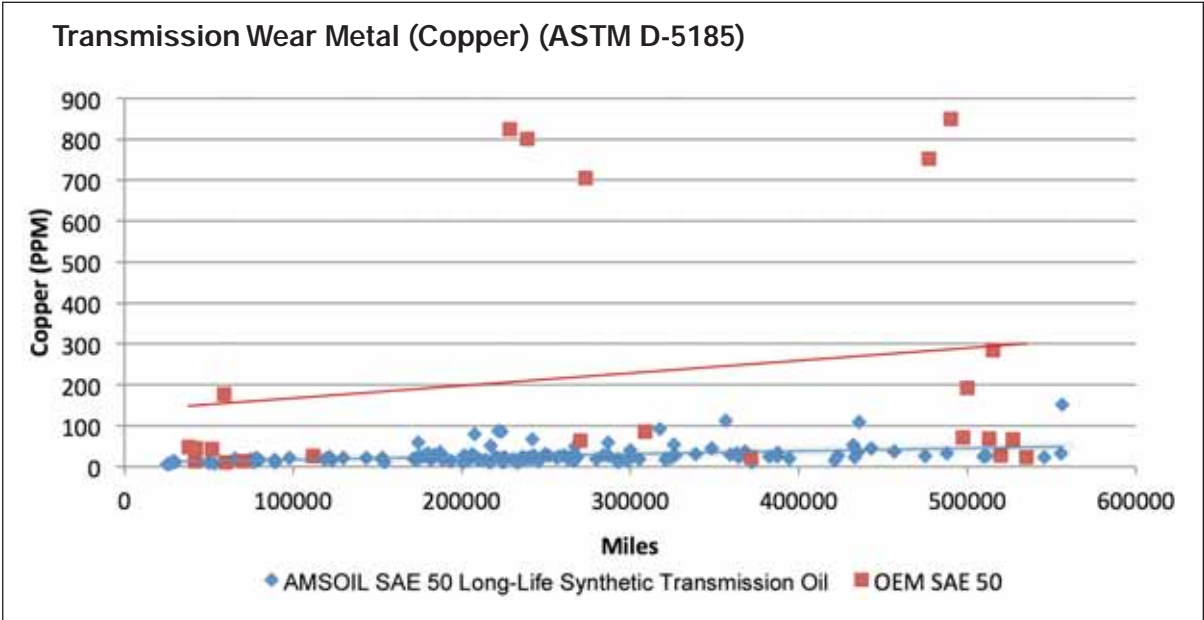


Results

AMSOIL SAE 50 Long-Life Synthetic Transmission Oil effectively limited iron wear metal generation, with iron content remaining low following 500,000 miles in service. Results are consistent with the OEM factory-fill oil and indicate AMSOIL SAE 50 Long-Life Synthetic Transmission Oil limited metal-to-metal contact and met the needs of heavy-duty OTR trucks practicing 500,000-mile drain intervals.

Oil Analysis – Copper Content

The Eaton transmissions (model# FRO-16210C and RTLO-16913A) filled with AMSOIL SAE 50 Long-Life Synthetic Transmission Oil used in this study contain several potential sources of copper wear particles. Copper particles in the transmission fluid can be an indicator wear is taking place.

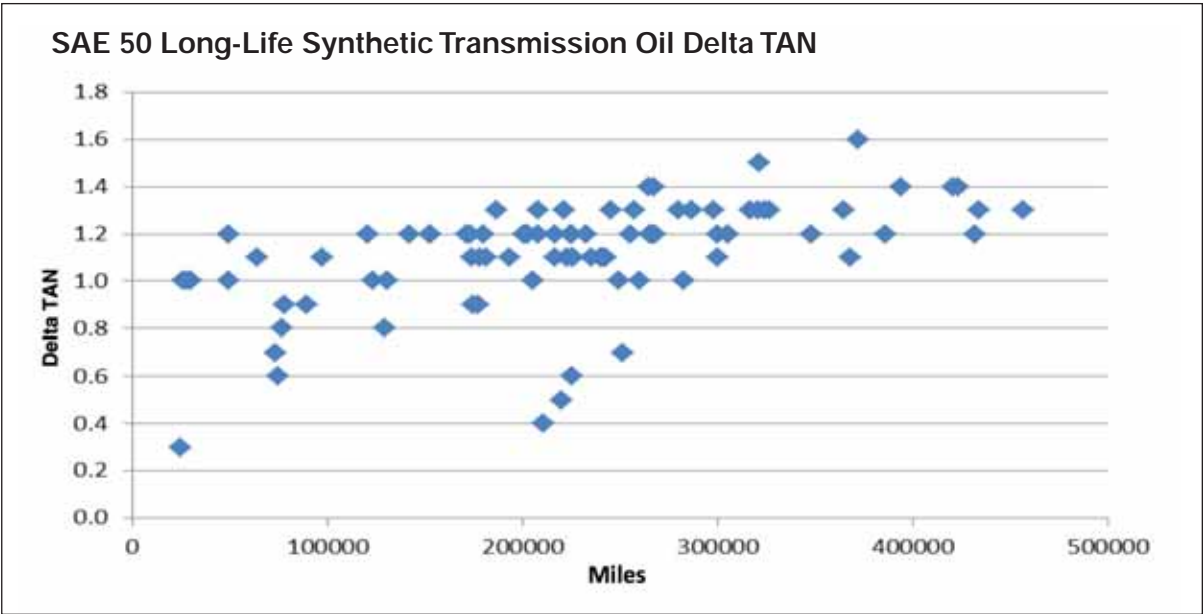


Results

Copper content in AMSOIL SAE 50 Long-Life Synthetic Transmission Oil remained low throughout the test interval and compared favorably to the factory-fill fluid. AMSOIL SAE 50 Long-Life Synthetic Transmission Oil limited copper wear metal generation in each transmission throughout the entire test interval, demonstrating the oil protects components containing yellow metals.

Oil Analysis – Total Acid Number (TAN)

TAN is a measure of the oil's oxidative stability. A lubricant's TAN should increase gradually as the service interval progresses. Sharp increases are an indicator the lubricant is reaching its condemnation limit.



Results

Delta TAN indicates the difference between TAN of used oil compared to TAN of the same oil when new. It demonstrates the performance of the oil independent of additional data, thus values for the OEM fluid are not given. An increase of 2.0 to 3.0 over the SAE 50 Long-Life Synthetic Transmission Oil baseline value is often used as an indicator that the oil is approaching its condemnation limit. TAN remained stable throughout the service interval and showed no appreciable increase. Values indicate AMSOIL SAE 50 Long-Life Synthetic Transmission Oil is capable of safely providing 500,000-mile service intervals.

Transmission Component Ratings

To further evaluate the performance of AMSOIL SAE 50 Long-Life Synthetic Transmission Oil, the transmission in unit 2168 was disassembled after accumulating 512,000 miles on the oil and evaluated by an ASTM calibrated rater. Each component was assigned a merit rating on a scale from 0 to 10, with 10 representing the absence of distress and 0 representing catastrophic distress (see table below). Rating criteria as defined in *ASTM Distress Rating Manual 21* were used and include burnish, wear, rippling, ridging, pitting, spalling, scoring, discoloration, corrosion, chipping and sludge (see table on page 8 for definitions). The following sections display the results.

Numerical Distress Rating Scales for Gears*

| Value | Level of Distress |
|-------|--|
| 10 | None |
| 9 | Trace |
| 8 | Trace-Light |
| 7 | Light |
| 6 | Light-Medium |
| 5 | Medium |
| 4 | Medium-Heavy |
| 3 | Heavy |
| 2 | Heavy to Catastrophic (Up to 50% of the gear tooth surface not ratable) |
| 1 | Heavy to Catastrophic (Greater than 50% and less than 100% of the gear tooth surface not ratable) |
| 0 | Catastrophic (100% of the gear tooth surface not ratable) |

* Applies to all components in this document

Gear Rating Definitions

| | |
|----------------------|--|
| Merit Rating | Definition of a distress or deposit condition in numerical terms on a descending scale from ten (10), which represents absence of distress. |
| Burnish | An alteration of the original manufactured surface ranging from a dull to a brightly polished condition. |
| Wear | The removal of metal, without evidence of surface fatigue or scoring, resulting in partial or complete elimination of tool or grinding marks and/or development of a discernible shoulder ridge at the bottom of the contact area near the root or at the toe or heel end of the pinion tooth contact area. |
| Abrasive Wear | Wear caused by lapping of mating surfaces by fine particles suspended in lubricant, fuel, air, or imbedded in a surface. |
| Adhesive Wear | Wear caused by shearing of junctions formed between operating surfaces in direct metal-to-metal contact; sheared-off particles either remain affixed to either the mating surfaces or act as wear particles between the surfaces. |
| Rippling | An alteration of the tooth surface to give an appearance of a more or less regular pattern resembling ripples on water, or fish scales. NOTE: Examination of the surface with oblique lighting usually is necessary to show this condition. |
| Ridging | An alteration of the tooth surface to give a series of parallel raised and polished ridges running in the direction of the sliding motion, either partially or completely across the tooth surfaces. |
| Pitting | Small irregular cavities in the tooth surface, less than 1 square millimeter, resulting from the breaking out of surface metal. |
| Spalling | The breaking-out of flakes or irregular area of the tooth surface, 1 square millimeter or larger; a condition more extensive than pitting. |
| Scoring | The displacement of metal by local momentary welding from the gear tooth, resulting in the development of a matte or frosted, dull surface. |
| Discoloration | Any alteration in the normal color of rated surfaces. |
| Corrosion | A general alteration of the finished surfaces by discoloration, accompanied by roughening not attributable to mechanical action. Rust is a special case of corrosion. |
| Chipping | Ring and pinion gears – A condition caused in the manufacturing process in which a small irregular cavity is present only at the face/crown edge interface. The edge chipping phenomenon occurs when sufficient fatigue cycles accumulate after tooth surface wear relieves the compressive residual stress on the tooth profile's side of the profile-to-topland interface. Chipping within 1 mm of the face/crown edge interface is to be called chipping, not pitting/spalling. |
| Sludge | A deposit composed of organic residue which may contain fuel, lubricant, and/or water. Such deposits will be found on surfaces operating at bulk unit temperature and exposed to fuels and/or lubricants. These deposits do not drain, but can be removed by wiping with moderate pressure using a clean, dry, soft, lint-free wiping material. Deposits rated as sludge may vary in characteristics – color, transparency, and consistency. |

Table taken from ASTM Distress Rating Manual 21

Mainshaft Overdrive Gear



| Condition | Drive Side | Coast Side |
|---------------|------------|------------|
| Burnish | Dull | Dull |
| Wear | 8 | 8 |
| Rippling | 10 | 10 |
| Ridging | 10 | 10 |
| Pitting | 10 | 10 |
| Spalling | 10 | 10 |
| Scoring | 10 | 10 |
| Discoloration | 9 | 9 |
| Corrosion | 10 | 10 |

Results

Merit ratings for burnish are represented by qualitative terms ranging from *dull* to *brightly polished*. Greater levels of wear to gear teeth are denoted by brighter levels of burnish. The mainshaft overdrive gear earned a burnish rating of *dull*, indicating very low wear. The gear earned perfect 10 merit ratings for rippling, ridging, pitting, spalling, scoring and corrosion. Ratings for wear and discoloration were likewise very high, demonstrating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided an extremely high level of protection.

Upper Right Countershaft Overdrive Gear



| Condition | Drive Side | Coast Side |
|----------------------|---------------|---------------|
| Burnish | Medium Bright | Medium Bright |
| Wear | 8 | 8 |
| Rippling | 10 | 10 |
| Ridging | 10 | 10 |
| Pitting | 10 | 10 |
| Spalling | 10 | 10 |
| Scoring | 10 | 10 |
| Discoloration | 9 | 9 |
| Corrosion | 10 | 10 |

Results

The upper right countershaft overdrive gear showed no signs of excessive distress and achieved perfect 10 merit ratings in six of eight applicable categories. Ratings for wear and discoloration were likewise very high, demonstrating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided an extremely high level of protection.

Mainshaft Input Drive Gear



CLOSEUP

| Condition | Drive Side | Coast Side |
|---------------|---------------|---------------|
| Burnish | Medium Bright | Medium Bright |
| Wear | 8 | 8 |
| Rippling | 10 | 10 |
| Ridging | 10 | 10 |
| Pitting | 10 | 10 |
| Spalling | 10 | 10 |
| Scoring | 10 | 10 |
| Discoloration | 9 | 9 |
| Corrosion | 10 | 10 |

Results

The mainshaft input drive gear showed no signs of excessive distress and achieved perfect 10 merit ratings in six of eight applicable categories. Ratings for wear and discoloration were likewise very high, demonstrating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided an extremely high level of protection.

Upper Right Countershaft Mating Gear



| Condition | Drive Side | Coast Side |
|---------------|---------------|---------------|
| Burnish | Medium Bright | Medium Bright |
| Wear | 8 | 8 |
| Rippling | 10 | 10 |
| Ridging | 10 | 10 |
| Pitting | 10 | 10 |
| Spalling | 10 | 10 |
| Scoring | 10 | 10 |
| Discoloration | 9 | 9 |
| Corrosion | 10 | 10 |

Results

Again, the upper right countershaft mating gear showed no signs of excessive distress and achieved perfect 10 merit ratings in six of eight applicable categories. Ratings for wear and discoloration were likewise very high, demonstrating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided an extremely high level of protection.

Upper Right Front Countershaft Bearing



Upper Right Front Countershaft
Bearing Merit Ratings

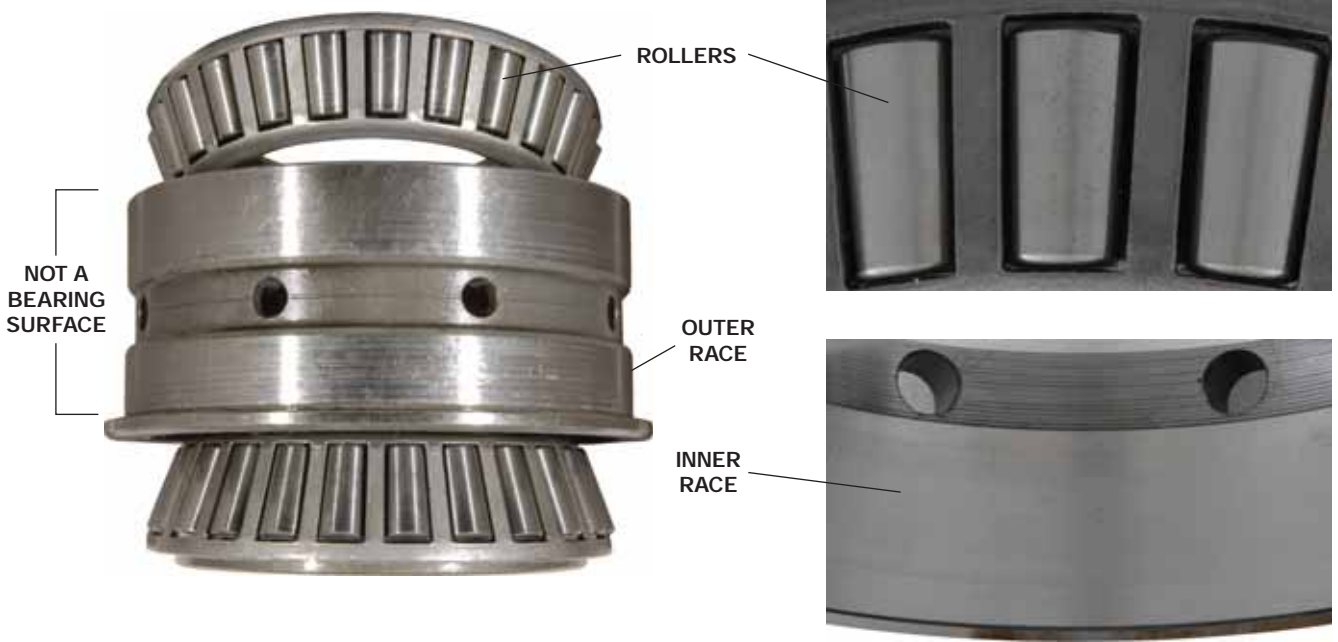
| Condition | Cups | Rollers |
|-----------------|------|---------|
| Wear | 8 | 8 |
| Scoring | 10 | 10 |
| Pitting | 10 | 10 |
| Spalling | 10 | 10 |
| Discoloration | 8 | 8 |
| Corrosion | 10 | 10 |
| Roller End Wear | - | 8 |

Results

Heavily loaded, high-temperature operation can result in bearing distress and, ultimately, failure. In the areas of scoring, pitting, spalling and corrosion, the upper right front countershaft bearing received perfect merit ratings of 10, indicating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided superior critical-component protection.

Merit ratings of 8 (*trace-light*) for wear and discoloration are likewise high. AMSOIL SAE 50 Long-Life Synthetic Transmission Oil demonstrated excellent protection.

Output Shaft Bearing



Output Shaft Bearing Merit Ratings

| Condition | Cups | Rollers |
|-----------------|------|---------|
| Wear | 8 | 8 |
| Scoring | 10 | 10 |
| Pitting | 9* | 9* |
| Spalling | 10 | 10 |
| Discoloration | 7 | 8 |
| Corrosion | 10 | 10 |
| Roller End Wear | - | 8 |

* Disassembly damage on output bearing cup

Results

The output shaft bearing earned similarly high merit ratings compared to the upper right front countershaft bearing. The cups and rollers achieved perfect 10 merit ratings for scoring, spalling and corrosion. Ratings of 9 for pitting (*trace*) and 8 for wear (*trace-light*) were also high, demonstrating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil maintained a durable lubricating film. Discoloration was kept to low levels, further confirming the protection provided by the lubricant.

Auxiliary Sliding Clutch



CLOSEUP

Auxiliary Sliding Clutch Merit Ratings

| Condition | |
|-----------|---|
| Wear | 6 |
| Chipping | 9 |
| Sludge | 8 |

Results

The auxiliary sliding clutch locks in high- and low-range gears, subjecting it to repeated sliding motion. Consequently, it represents an area susceptible to high levels of wear and distress.

The auxiliary sliding clutch earned a *light-medium* merit rating of 6 for wear. The rating for chipping was very high and denotes a *trace* amount of metal removal. AMSOIL SAE 50 Long-Life Synthetic Transmission Oil limited wear to the auxiliary sliding clutch effectively despite the component's challenging operating conditions. Sludge was likewise minimized, demonstrating the ability of AMSOIL SAE 50 Long-Life Synthetic Transmission Oil to resist thermal degradation and help components remain clean throughout a 500,000-mile drain interval.

Direct Sliding Clutch



CLOSEUP

Direct Sliding Clutch Merit Ratings

| Condition | |
|-----------|---|
| Wear | 7 |
| Sludge | 7 |

Results

Direct sliding clutches lock and unlock the appropriate gears to their shafts depending on the gear the driver selects. Like the auxiliary sliding clutch, they routinely encounter sliding motion and are prone to high levels of wear and distress.

The direct sliding clutch pictured represents a typical example from the transmission and earned a wear merit rating of 7, indicating *light* surface fatigue and metal removal. The rating is consistent with the elevated demand required for wear protection of clutch components in heavy-duty, OTR applications. The rating for sludge reflects a *light* amount and confirms AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided a high level of protection.

Synchronizer Assembly Ratings



Synchronizer Ring – High Range



CLOSEUP



Synchronizer Ring – Low Range

Synchronizer Rings Merit Ratings

| Condition | High Range | Low Range |
|----------------|------------|------------|
| Wear | 8 | 8 |
| Sludge | 9 | 9 |
| Discoloration | Not Rated | 8 |
| Fiber Material | Not Rated | 9 (Matted) |

Results

For the transmission to shift between low and high range, the synchronizer assembly must first match the speeds of the appropriate gears to provide smooth gear engagement. This process requires the fiber material on the synchronizer rings to bear friction repeatedly, providing ample opportunity for wear. The fiber material on the low-range ring earned a merit rating of 9, indicating only a *trace* amount of wear. Merit ratings for both the high- and low-range rings themselves were likewise high in the areas of wear and sludge, indicating AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provided a high level of protection.

Range Shift Yoke



Range Shift Yoke Merit Ratings

| Condition | |
|---------------|---|
| Wear | 8 |
| Discoloration | 8 |

Results

The range shift yoke slides onto the synchronizer assembly and is responsible for engaging either high or low range. As a result, it encounters sliding contact repeatedly and represents an area prone to wear. AMSOIL SAE 50 Long-Life Synthetic Transmission Oil limited metal-to-metal contact and wear to *trace-light* amounts and provided superior protection. The merit rating for discoloration was similarly high.

Output Assembly

Speedo Rotor Assembly



OUTPUT
SHAFT
OPENING

*Normal condition
due to exposure
to environment.*

Output Seal



Output Yoke & Seal
Merit Ratings

| Condition | Yoke | Seal |
|----------------|------|------|
| Wear | 7 | 8 |
| Sludge | 9 | - |
| Grease Packing | - | 100% |

Results

The output yoke and seal undergo nearly constant rotational stress at varying speeds and loads, presenting the opportunity for elevated wear. The output seal earned a wear merit rating of 8, indicating *trace-light* distress. The seal also maintained 100 percent grease packing, demonstrating no leaking throughout the transmission's service interval. The output yoke achieved similarly high merit ratings for wear (*light*) and sludge (*trace*).

Conclusion

Used oil analysis results and a complete visual inspection of components from a transmission by an ASTM calibrated rater demonstrate the effectiveness of AMSOIL SAE 50 Long-Life Synthetic Transmission Oil in over-the-road applications practicing 500,000-mile drain intervals. The AMSOIL transmission oil resisted shear effectively despite 500,000 miles of rigorous use. Wear protection was likewise superior; samples of AMSOIL SAE 50 Long-Life Synthetic Transmission Oil contained very low levels of iron and copper wear particles, indicating it maintained its protective lubricating film throughout service. Total acid number also remained stable throughout service.

A complete transmission disassembly and visual inspection offers further proof of performance. Bearings received perfect merit ratings of 10 for scoring, spalling and corrosion, indicating a complete absence of distress. Gears earned perfect 10 ratings in the areas of rippling, ridging, pitting, spalling, scoring and corrosion. Ratings for other components prone to elevated wear, including the high- and low-range synchronizer rings and the output seal, are likewise high. None of the transmissions operating with AMSOIL SAE 50 Long-Life Synthetic Transmission Oil demonstrated any leaking from any of the seals. The ASTM calibrated rater deemed all inspected components suitable for continued use.

Results of this field study prove AMSOIL SAE 50 Long-Life Synthetic Transmission Oil provides excellent protection in modern heavily loaded, over-the-road manual transmissions throughout extended 500,000-mile drain intervals.



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