ADA

INSPECTION OF STRYKER TRANSMISSIONS EVALUATED USING SCPL IN A 20K MILE RAM-D TEST

INTERIM REPORT
TFLRF No. 457

by
Adam C. Brandt
Edwin A. Frame

U.S. Army TARDEC Fuels and Lubricants Research Facility
Southwest Research Institute® (SwRI®)
San Antonio, TX

for
Allen S. Comfort
U.S. Army TARDEC
Force Projection Technologies
Warren, Michigan

Contract No. W56HZV-09-C-0100 (WD28)

July 2014

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This report covers the tear down and inspection of two Allison MD3066 transmissions after being evaluated using a candidate Single Common Powertrain Lubricant and a baseline commercial automatic transmission fluid (ATF) in a 20k mile Reliability, Availability, Maintainability, and Durability (RAM-D) test. Post test inspection of the transmissions support the use of SCPL, and yield valuable information on general compatibility of the SCPL with other medium-duty Allison transmissions fielded by the US Army. The SCPL candidate provided comparable performance to that demonstrated by the commercial ATF, and it is expected that the SCPL could be used as a drop in replacement in the Stryker transmission without negatively impacting performance or resulting component protection.

15. SUBJECT TERMS
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EXECUTIVE SUMMARY

The U.S. Army TARDEC Fuels & Lubricants Technology Team has developed a Single Common Powertrain Lubricant (SCPL) designed to consolidate multiple military lubricant specifications into a single product, or single specification. This report covers the tear down and inspection of two Allison MD3066 transmissions after being evaluated using a candidate SCPL and a baseline commercial automatic transmission fluid (ATF) in a 20k mile Reliability, Availability, Maintainability, and Durability (RAM-D) test. Vehicle and transmission identification numbers are listed below:

- TEST Stryker, Bumper No. IVC-0482, Transmission SN: 6510637907
- CONTROL Stryker, Bumper No. MEV-013, Transmission SN: 6510652367

After the completion of RAM-D testing the Stryker power packs were crated and shipped to the US Army TARDEC Fuels and Lubricants Research Facility (TFLRF) in San Antonio, TX for a full tear down and internal inspection. Post test inspection and analysis revealed that all oil wetted components remained in good condition. Components removed from both the TEST and CONTROL transmissions were found to be in virtually identical condition part by part, and the condition of each was consistent with what would be expected from a normally functioning used transmission. All planetary gear modules removed were found present with only normal contact markings on the gear teeth, and no evidence of excessive wear, or occurrence of gear pitting or spalling. This supports previous SCPL development work that conducted FZG gear wear testing with positive results. [1] For the clutch assemblies, all removed were found to be in good condition, with only minor darkening of the inner diameters of the C3 and C4 composition disks, consistent in both the TEST and CONTROL units. All other clutch assemblies (C1, C2, and C5) appeared to be virtually untouched, and showed no signs of excessive wear, or discoloration in the composition or steel reaction plates as a result of heat from excessive slip. Such little clutch wear was present, that lockup clutch composition material still displayed factory ink markings on its surface.

Through detailed inspection, it was determined that the TEST transmission evaluated had previously undergone some major service or overhaul. This was apparent primarily by unmatched wear of the rotary clutch drum shaft splines and balance piston teeth. Through careful inspection of both components, the shaft spline wear was determined to be pre-existing, and not attributed to the use of SCPL. No evidence was found to support testing bias between the apparent varied operational history of the TEST and CONTROL transmissions. No evidence was found that would suggest the CONTROL transmission had undergone any previous major service.

Findings from the internal transmission inspection support the use of SCPL in the Allison MD3066 transmission, and yield valuable information on general compatibility of the SCPL with other medium-duty Allison transmissions fielded by the US Army. It is the opinion of TFLRF staff that the SCPL candidate did provide comparable performance to that from the commercial ATF used in the CONTROL transmission, and it is expected that the SCPL could be used as a drop-in replacement in the Stryker transmission without negatively impacting performance or resulting component protection.

FOREWORD/ACKNOWLEDGMENTS

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period August 2013 through August 2014 under Contract No. W56HZV-09-C-0100. The U.S. Army Tank Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Eric Sattler (RDTA-SIE-ES-FPT) served as the TARDEC contracting officer's technical representative. Mr. Allen Comfort of TARDEC served as project technical monitor.

The authors would like to acknowledge the contribution of the TFLRF technical and administrative support staff.

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ACRONYMS AND ABBREVIATIONS

ATF – automatic transmission fluid

FPT – Force Projection Technology

FZG – Forschungsstelle fur Zahnrader und Getriebebau (Technical Institute for the Study of Gears and Drive Mechanisms)

RAM-D – reliability, availability, maintainability, and durability

SCPL – Single Common Powertrain Lubricant

SwRI – Southwest Research Institute

TFLRF – TARDEC Fuels and Lubricants Research Facility

TARDEC – Tank Automotive Research Development and Engineering Center

1.0 BACKGROUND

The U.S. Army TARDEC Fuels & Lubricants Technology Team has developed a Single Common Powertrain Lubricant (SCPL), designed to consolidate multiple military lubricant specifications into a single product, or single specification. The application of the SCPL includes engine lubrication, power shift transmission operation, and limited use in hydraulic systems where MIL-PRF-2104 and MIL-PRF-46167 products are currently used. The SCPL is designed to operate in ambient temperatures ranging from low temperature arctic to high temperature desert conditions, representative of the wide range of potential military operating conditions seen worldwide. The development of the SCPL allows for a single lubricant to be used in tactical and combat vehicles, despite their seasonal or geographical location, while additionally reducing the logistics burden of the Army's supply chain by requiring only one lubricant to be procured and distributed throughout its worldwide operations. In addition, technological lubricant advancements of the SCPL allow for improved oil performance and vehicle efficiency over current military specified lubricants [1,2,3].

This report covers the tear down and inspection of two Allison MD3066 transmissions after being evaluated with a candidate SCPL and a baseline commercially available automatic transmission fluid (ATF) in a 20k mile Reliability, Availability, Maintainability, and Durability (RAM-D) test. The Allison MD3066 transmissions evaluated were utilized in the Army's Stryker vehicle, an 18 ton 8-wheeled armored fighting vehicle and personnel carrier. This medium sized Allison transmission shares many similarities to other comparably sized Allison transmissions common in multiple medium tactical wheeled vehicles, and is expected to provide additional compatibility information regarding the use of SCPL in other similar fielded Allison transmissions.

RAM-D Stryker testing was coordinated and completed by the U.S. Army TARDEC in Warren MI, with testing administered by Force Projection Technology (FPT) team. At the completion of testing, the full engine and transmission power packs were crated and shipped to the US Army TARDEC Fuels and Lubricants Research Facility (TFLRF), located at Southwest Research Institute (SwRI) in San Antonio, TX. The power packs were scheduled for a full tear down and

internal inspection following the SCPL evaluation. Complete findings for the transmission inspection are covered herein. Results from the previous engine inspection were reported under TFLRF Report IR452 [4].

2.0 OBJECTIVE

The objective was to tear down and complete a full internal inspection of two Allison MD3066 transmissions used in the Stryker vehicle after being evaluated using a baseline lubricant and a candidate SCPL. A 20k mile RAM-D test was conducted on the Strykers in an effort to compare the performance of the two tested lubricants. Once the test was completed, the transmissions were sent to TFLRF and subjected to a full internal inspection of oil wetted components. This process included a tear down and visual inspection that occurred at a local Allison certified dealer, conduction of oil wetted component ratings to identify and quantify visual wear, and completion of photographs to document critical component condition. The two vehicles used in the evaluation were split as a TEST vehicle utilizing the candidate SCPL and a CONTROL vehicle utilizing the baseline commercial ATF. This allowed direct comparison between the two products over the course of the RAM-D test. Vehicle and engine identification numbers for the TEST and CONTROL vehicles are listed below:

- TEST Stryker, Bumper No. IVC-0482, Transmission SN: 6510637907
- CONTROL Stryker, Bumper No. MEV-013, Transmission SN: 6510652367

Final results for each transmission inspection are outlined in the following sections. It is worth noting that previous vehicle histories prior to the 20k mile RAM-D evaluation were unknown to TFLRF, thus comparisons and data presented herein assume that the starting conditions of each transmission were roughly identical unless otherwise noted.

3.0 POWERPACK UNCRATING

Each transmission was sent to TFLRF in a fully assembled powerpack, in the same manner they would typically be removed from the vehicle for service. This was done as the Caterpillar 3126 engine was needed to support an earlier work directive that covered the engine inspection. Once received, the shipping containers were opened and moved indoors to facilitate disassembly of the full power pack. Figure 1 and Figure 2 show the powerpack assembly of Stryker MEV-013 (CONTROL) prior to removal. The photos below are representative of the condition that both power packs were received in for inspection.

Figure 1. Stryker MEV-013 Powerpack 1

Figure 2. Stryker MEV-013 Powerpack 2

Once indoors all ancillary equipment was removed from the powerpack to facilitate the extraction of the engines and transmissions. This included removal of all cooling, hydraulic, air conditioning, and electrical control systems. This allowed the engine and transmission to be removed from the main pack frame assembly, and then each separated from one another for storage. All remaining components were then packed back into the power pack containers for disposition. From this point on both engines and transmissions were separately handled to support each work directive.

4.0 RESULTS/DISCUSSION

Upon receiving funding for the transmission inspection, both the TEST and CONTROL MD3066 transmissions were individually crated and transported from TFLRF to a local Allison transmission certified dealer/servicer for teardown. The initial teardown and inspection was completed at the Allison dealer as they were equipped all the special tools required to disassemble these medium duty transmissions, and they provided valuable insight into assessing the internal condition of the transmission due to their vast experience servicing real-world operated units. An additional SwRI transmission technical expert was brought in for the inspection to provide added input and physical ratings of the oil wetted components for reporting. The following sections cover the visual inspection, component ratings, photographs captured, and special considerations derived during the inspection.

4.1 VISUAL INSPECTION

As components were removed from each transmission during the teardown, very little distinguishable differences were identified between the TEST and CONTROL transmissions. It was immediately evident that the CONTROL transmission had indeed been utilizing a commercial ATF (which is typically dyed red) based on its residual fluid coloration. Similarly the coloration of the TEST transmission residual fluid was found consistent with the SCPL. Neither transmission showed signs of the fluid being over worked or burned, with residual fluid from both transmissions remaining respectively clean and clear, absent of any typical burned

coloration or odors. Post test oil samples had already been collected and analyzed by TARDEC, so no additional effort was conducted to collect residual oil for analysis during the inspection.
As teardown progressed, signs that the TEST transmission had previously undergone major service, repair, or rebuild began to appear. This was first noted with small circumstantial things such as inconsistent date codes between what appeared to be factory installed filters in the CONTROL transmission versus newer dated filters installed in the TEST transmission, and coloration differences of valve body shift solenoid connectors indicated that the TEST transmission solenoids/harness did not appear to be aged/darkened consistent with hardware from the CONTROL transmission. This was followed by other more significant items noted by the Allison factory technician and the SwRI technical expert, which consisted of unpaired wear patterns on balance piston and rotary clutch drum, and tell tale machining and tooling mark orientation on planetary gears. From these more detailed observations, both the Allison technicians and TFRLF/SwRI staff believe that the TEST transmission had previously undergone some sort of repair or service prior to the RAM-D testing. These more prominent signs will be discussed in further detail with accompanying photos in the following sections. No similar evidence was found in the CONTROL transmission to support major service had occurred on it.

Despite the above, all other components removed from each transmission showed generally the same condition upon inspection, with little difference between critical parts. None of the planetary gear modules in either the TEST or CONTROL were found to have major wear, or presence of pitting or spalling on the gear teeth that would suggest lubricant incompatibility. This was generally expected, as previous FZG gear testing had been completed during SCPL development and yielded positive results [1]. Primary concern with SCPL use was more focused over the clutch condition, as the SCPL had the potential to have varying frictional properties from the commercial ATF as a result of additive pack differences. This had potential to cause excessive slipping and increased wear in the clutch assemblies, but overall condition between the two transmissions suggested otherwise. With the exception of the C3 and C4 clutches, all clutch components removed from both the TEST and CONTROL units showed little to no signs of wear or discoloration. The C3 and C4 assemblies did however show some light darkening on the inner diameters of the friction disks, but since this appeared on both the CONTROL transmission using commercial ATF as well as the transmission using SCPL, it was considered to be a normal

result of the operational duty cycle. None of the clutch assemblies showed signs of excessive heat or glazing of the steel plates or friction disks, and both the TEST and CONTROL showed such little clutch related wear that the lockup clutch assembly still retained the factory ink stamping/marking numbers on the composition material. Overall clutch condition was found to be very positive.

When SCPL compatibility testing was discussed with Allison professionals, general comments received were that these types of transmissions are designed to be million mile transmissions, and that the 20k mile RAM-D test would have difficulty distinguishing finer differences of two well performing fluids. This is to say although the commercial ATF might actually be a higher performing fluid over the long term, over the course of the 20k mile RAM-D test (which is significant compared to the typical military vehicle life span) it is unlikely that 20k mile testing can distinguish the fluids unless their performance was drastically different, or one fluid was fundamentally unsuitable. This suggests that in terms of the acceptability for military use, that the SCPL can be used successfully, and that it will provide the appropriate performance and protection required for these transmissions.

4.2 COMPONENT RATINGS

After disassembly each critical component underwent a ratings process to quantify the condition of the TEST and CONTROL transmissions. Table 1 on the next page shows the full ratings for each transmission component:

Table 1. Allison MD3066 Transmission Ratings

Component	CONTROL, SN6510652367	TEST, SN6510637907
C1 Clutch	**Steel Plates** – no abnormal wear, few, very light surface scratch marks with no depth **Composition Plates** – no abnormal wear, no glazing, no discoloration	**Steel Plates** – no abnormal wear, few, very light surface scratch marks with no depth **Composition Plates** – no abnormal wear, no glazing, no discoloration
C2 Clutch	**Steel Plates** - no abnormal wear, few, very light surface scratch marks with no depth **Composition Plates** – no abnormal wear, no glazing, no discoloration	**Steel Plates** - no abnormal wear, few, very light surface scratch marks with no depth **Composition Plates** – no abnormal wear, no glazing, no discoloration
C3 Clutch	**Steel Plates** –some grey discoloration on 35 to 40% on inner diameter of plates, no abnormal wear **Composition Plates** – brown to black discoloration on 35 to 40% on inner diameter of plates, no abnormal wear, no glazing	**Steel Plates** – some grey discoloration on 35 to 40% on inner diameter of plates, no abnormal wear **Composition Plates** – brown to black discoloration on 35 to 40% on inner diameter of plates, no abnormal wear, no glazing
C4 Clutch	**Steel Plates** - some grey discoloration on 35 to 40% on inner diameter of plates, no abnormal wear **Composition Plates** - brown to black discoloration on 35 to 40% on inner diameter of plates, no abnormal wear, no glazing, no abnormal wear	**Steel Plates** - some grey discoloration on 35 to 40% on inner diameter of plates, no abnormal wear **Composition Plates** - brown to black discoloration on 35 to 40% on inner diameter of plates, no abnormal wear, no glazing, no abnormal wear
C5 Clutch	**Steel Plates** - no abnormal wear, light surface scratch marks with no depth around circumference of plates **Composition Plates** – no abnormal wear, no glazing, no discoloration	**Steel Plates** - no abnormal wear, light surface scratch marks with no depth around circumference of plates **Composition Plates** – no abnormal wear, no glazing, no discoloration
Converter Lock-Up Plate	**Damper Springs** – all springs intact, and in good working order **Composition Material** – no abnormal wear, no glazing, identification stamping is still visible on plates	**Damper Springs** – all springs intact, and in good working order **Composition Material** – no abnormal wear, no glazing, identification stamping is still visible on plates
P1 Planetary Module	Polished gear teeth, no abnormal wear	Polished gear teeth, no abnormal wear
P2 Planetary Module	Polished gear teeth, no abnormal wear	Polished gear teeth, no abnormal wear
P3 Planetary Module	Polished gear teeth, no abnormal wear	Polished gear teeth, no abnormal wear
Bushings	Very light wear	Very light wear
Bearings	Very light wear	Very light wear
Thrust Washers	Very light wear	Very light wear
Rotary Clutch Drum	**Balance Piston** – no wear **Shaft** – Light contact marks where clutch plate inner teeth mesh	**Balance Piston** – No Wear **Shaft** - Heavy wear at piston contact area*, light contact marks where clutch plate inner teeth mesh

*Refer to section 4.4 for detailed discussion

As seen above, specific component ratings were functionally indistinguishable. With the exception of the wear noted on the TEST transmission rotary clutch drum shaft, no other abnormalities were noted between the two units. The shaft wear on the TEST transmission relates back to the previous mention of signs that the TEST transmission did appear to have had undergone major service or repair sometime in its history. Further detail and description, as well as photographs, are included in the next section.

4.3 PHOTOGRAPHS

The C1 and C2 clutch assemblies for the TEST and CONTROL transmissions showed nearly identical condition upon removal. No discoloration or glazing was noted on the friction disks, and the reaction plates showed no unusual wear or signs of heat from excessive slipping. Figure 3 through Figure 6 show an overview photo of each C1 and C2 clutch assembly for the TEST and CONTROL units.

Figure 3. CONTROL Transmission C1 Clutch Assembly

Figure 4. TEST Transmission C1 Clutch Assembly

Figure 5. CONTROL Transmission C2 Clutch Assembly

Figure 6. TEST Transmission C2 Clutch Assembly

Figure 7 through Figure 10 show close up photos of the C1 and C2 clutch composition surfaces for both the TEST and CONTROL. As shown, both assemblies were found to be in excellent condition, without evidence of excessive heat, wear, or distress of the friction or steel reaction plate surfaces.

Figure 7. CONTROL Transmission C1 Clutch Assembly (Close-up)

Figure 8. TEST Transmission C1 Clutch Assembly (Close-up)

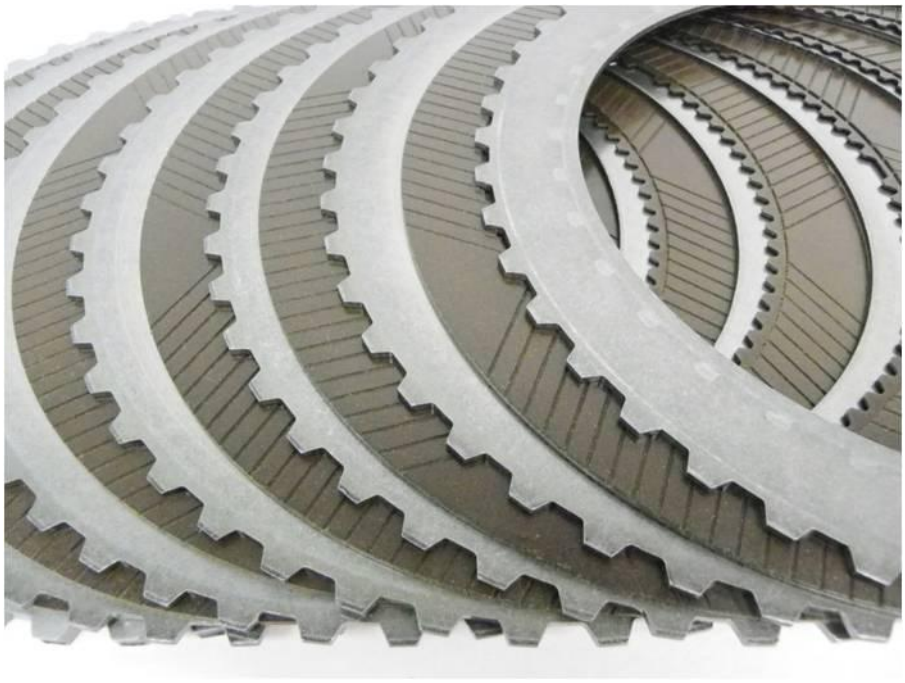

Figure 9. CONTROL Transmission C2 Clutch Assembly (Close-up)

Figure 10. TEST Transmission C2 Clutch Assembly (Close-up)

As previously mentioned, the C3 and C4 clutch assemblies for both transmissions did show some discoloration of the friction material. This was found to be relatively minor, and only occurred

on approximately 35-40% of the inner disk diameter on each clutch assembly. As would be expected, the steel reaction plates also showed some light grey discoloration from the additional heat, but results were functionally identical between both the TEST and CONTROL transmissions, suggesting that the SCPL demonstrated comparable performance to the commercial ATF. Figure 11 through Figure 14 show the C3 and C4 clutch assemblies for the TEST and CONTROL transmissions respectively.

Figure 11. CONTROL Transmission C3 Clutch Assembly

Figure 12. TEST Transmission C3 Clutch Assembly

Figure 13. CONTROL Transmission C4 Clutch Assembly

Figure 14. TEST Transmission C4 Clutch Assembly

Figure 15 through Figure 18 (next 2 pages) show close up photos of the C3 and C4 clutch disks composition and reaction plates for both transmissions. This close-up shot better shows the discoloration present on the composition disks, but also conveys its overall minor nature.

Figure 15. CONTROL Transmission C3 Clutch Assembly (Close-up)

Figure 16. TEST Transmission C3 Clutch Assembly (Close-up)

Figure 17. CONTROL Transmission C4 Clutch Assembly (Close-up)

Figure 18. TEST Transmission C4 Clutch Assembly (Close-up)

Figure 19 and Figure 20 show the C5 clutch assemblies. Like the C1 and C2 clutches, overall condition was found to be good, and both the TEST and CONTROL yielded similar component conditions. Figure 21 and Figure 22 (next page) show the close-up shots of the composition and reaction plates for the C5 assembly.

Figure 19. CONTROL Transmission C5 Clutch Assembly

Figure 20. TEST Transmission C5 Clutch Assembly

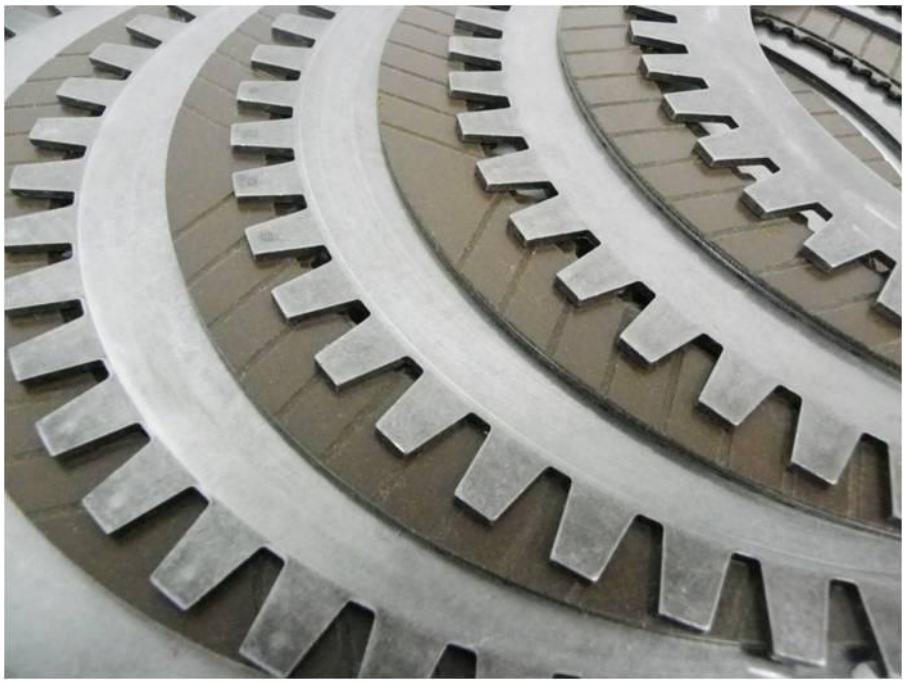

Figure 21. CONTROL Transmission C5 Clutch Assembly (Close-up)

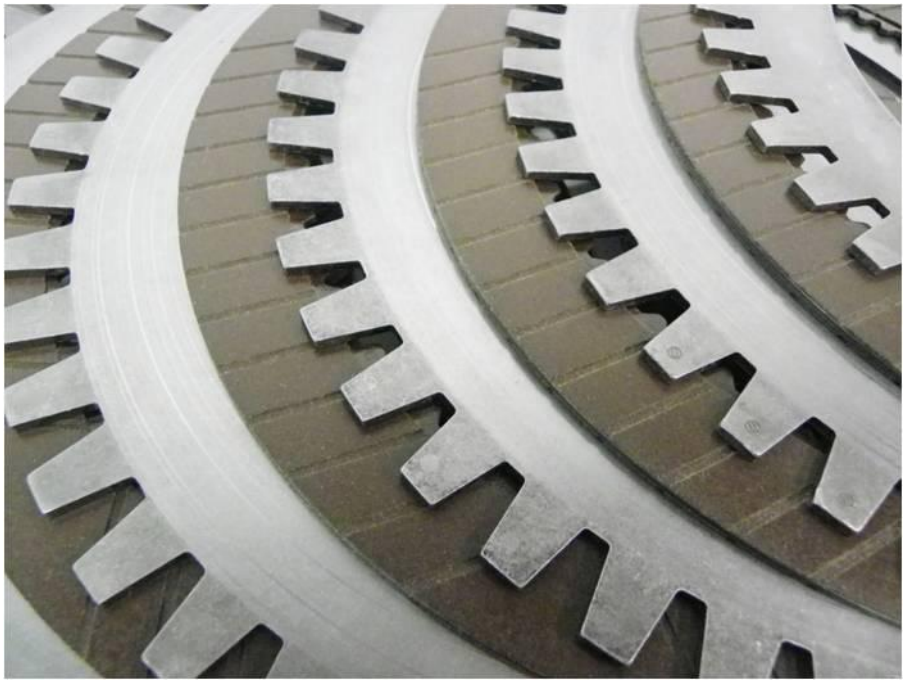

Figure 22. TEST Transmission C5 Clutch Assembly (Close-up)

For the lockup clutch, neither of the assemblies showed excessive wear or signs of glazing consistent with results seen in all other clutch assemblies. Figure 23 and Figure 24 show the CONTROL transmission lockup clutch. As previously mentioned, factory markings can still be seen on the composition surface indicating little wear occurred to the composition material.

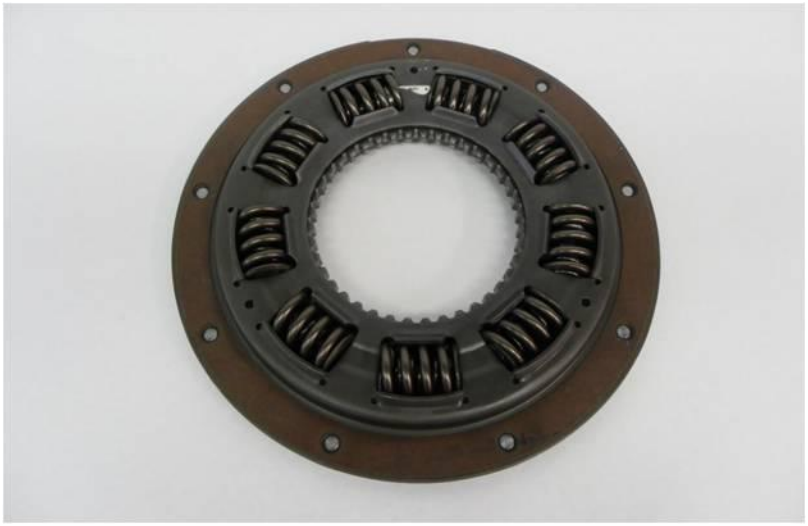

Figure 23. CONTROL Torque Convertor Lockup Clutch

Figure 24. CONTROL Torque Convertor Lockup Clutch (Close-up)

Figure 25 and Figure 26 show the lockup clutch photos for the TEST transmission. Like the CONTROL unit, factory markings can still be seen on its composition surface as well.

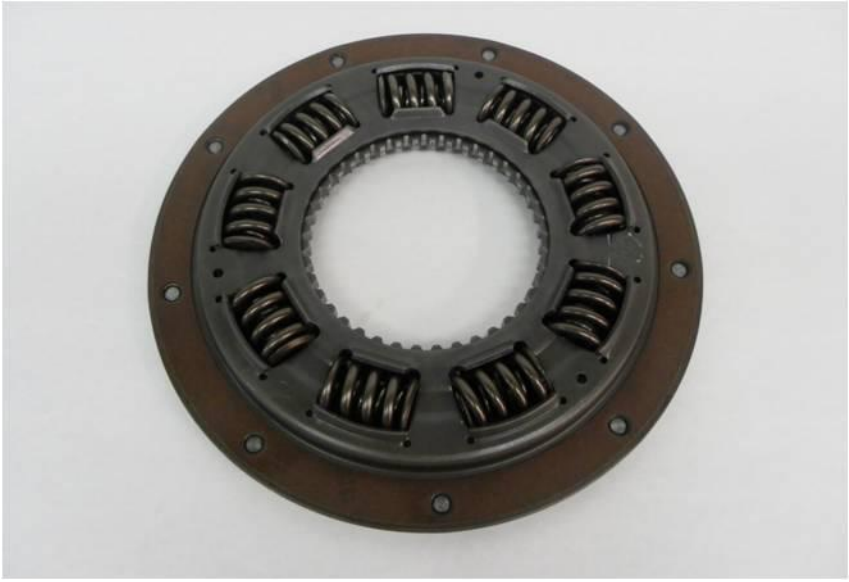

Figure 25. TEST Torque Convertor Lockup Clutch

Figure 26. TEST Torque Convertor Lockup Clutch (Close-up)

Consistent with all previous observations, inspection of the planetary gear sets also showed little discrimination between the two evaluated lubricants. All preliminary SCPL candidates had previously undergone standardized FZG gear wear testing during early lubricant development phases yielding positive results, so there was little expectation that the SCPL would show any unusual compatibility with the transmission gear sets themselves. Figure 27 and Figure 28 (next page) shows the P1 planetary module removed from the CONTROL and TEST transmissions, and confirm the SCPL provided adequate protection. As reporting in the ratings, both modules were noted to have normal polishing on the contact surfaces of the planetary gear teeth, but both were found void of any abnormal wear that would suggest lubrication issues. Likewise the outer ring gear of the P1 module which engages the internal splines of the C3 clutch assembly showed no abnormal wear, with only normal contact markings visible on the gear faces from engagement with the internal clutch disk teeth. These same general observations proved true for the P2 and P3 modules as well. All results suggest that the SCPL successfully provided adequate protection of the internal gear sets, and provided performance levels comparable to the specifically tailored commercial ATF. (Note - As a result of their unremarkable nature, photographs of the P2 and P3 modules were not included in reporting).

Figure 27. CONTROL P1 Planetary Gear Module

Figure 28. TEST P1 Planetary Gear Module

4.4 SPECIAL CONSIDERATION

As previously mentioned, the main area that did stand out during inspection were signs that the TEST transmission had undergone some sort of previous service or rebuild. The primary support of this was wear noted on the splined shaft of the rotary clutch drum assembly. During its inspection, heavy contact wear was noted on every other spline on the shaft in the area where the balance piston rides and engages. This can be seen below in Figure 29, and again in a close up photo in Figure 30.

Figure 29. TEST Transmission Balance Shaft Spine Wear

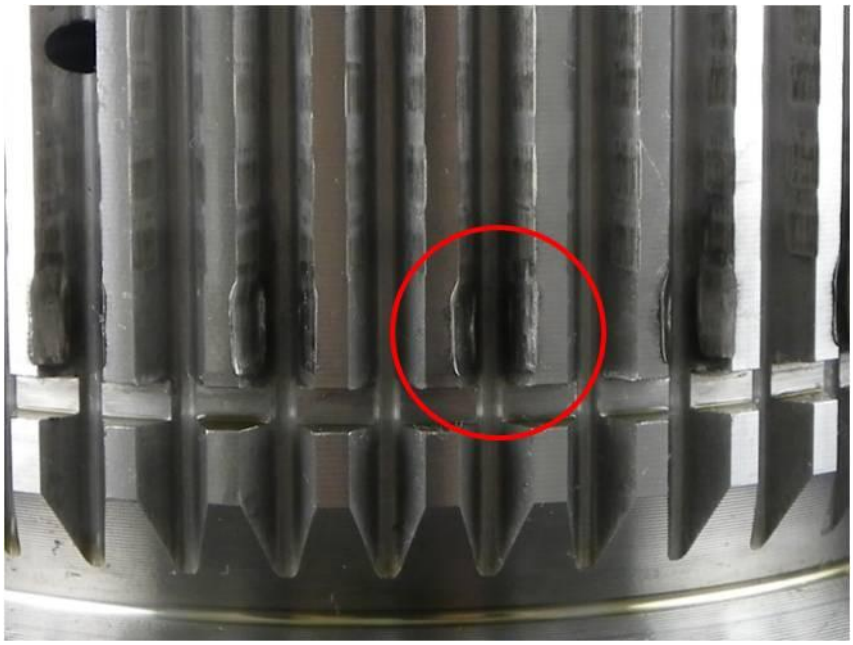

Figure 30. TEST Transmission Balance Shaft Spline Wear (Close-up)

As shown, the wear was found present on every other spline tooth on the shaft, and is consistent with the skip tooth engagement of the balance piston that rides on the shaft and engages the splines (Figure 31).

Figure 31. CONTROL Transmission Balance Shaft and Piston Engagement

Despite the wear seen on the shaft splines, the engagement teeth of the TEST transmission balance piston (shown in Figure 32 and Figure 33) did not show corresponding damage when inspected. This is inconsistent with what would be expected based on the shaft spline wear.

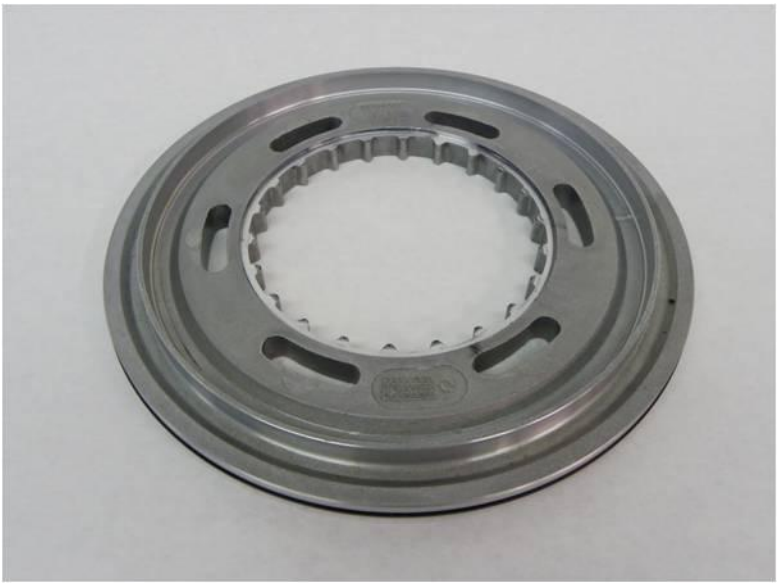

Figure 32. TEST Transmission Balance Piston

Figure 33. TEST Transmission Balance Piston (Close-up)

This unusual wear discrepancy serves as the single biggest indicator that the TEST transmission had sometime in its history received major service/rebuild prior to the RAM-D testing. The balance piston, which is comprised of a relatively soft aluminum alloy, would have been expected to show significant corresponding wear to that seen on the harder splines if in fact the spline wear was a result of current testing. As the TEST transmission balance piston teeth appear to be virtually unworn, this indicates that the orientation of the balance piston upon installation was such that the piston teeth were NOT in contact with worn shaft splines, and had instead sometime previously been re-indexed during service to the unworn splines. As stated by the Allison transmission technicians, this is common practice in transmission overhaul, as the skip tooth engagement allows reinstallation of a new piston and reuse of the partially worn shaft by changing the engagement orientation to the unworn teeth. This type of action reduces the cost of an overhaul, as the rest of the balance shaft would still remain in usable condition apart from the localized wear that cannot be avoided. Since the balance piston removed from the RAM-D TEST transmission showed virtually no wear, it can only be surmised that the wear seen on the balance shaft splines was pre-existing. There was no evidence that the wear occurred as a result of SCPL use, and nothing was found to suggest that this issue could have biased the results of testing.

5.0 CONCLUSIONS

The two transmissions removed from Stryker IVC-482 (TEST) and MEV-013 (CONTROL) were found to be in similar overall condition after the completion of the 20k mile RAM-D evaluation. Residual fluid removed from the transmission showed no signs of excessive heat or burning that would be expected as a result of excessive clutch slipping. When inspected, all clutch frictional and reaction surfaces were found in good condition, with no signs of excessive heat, glazing, or composition material failure. In addition, all planetary modules were found absent of anything apart from normal wear, which supports previous SCPL development studies. In general, the conditions of both transmissions were considered typical for a used transmission in good working order, and the majority of components were found in nearly indistinguishable condition upon inspection. All results suggest that the SCPL can be used in this type of transmission in military applications while providing adequate component protection, and acceptable performance standards.

After the completion of the tear down, inspection, and review of all test results, it is the opinion of TFLRF staff that the SCPL candidate evaluated provided comparable performance to that of the commercial ATF used in the CONTROL transmission. It is expected that the SCPL could be used as a drop in replacement in the Stryker's transmission without negatively impacting performance or resulting component protection, and similar results could be attained in other military fielded Allison medium duty transmissions.

6.0 REFERENCES

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