SAE TECHNICAL
PAPER SERIES

982674

Development and Introduction of Chrysler's New Automatic Transmission Fluid

Dennis W. Florkowski and Tracey E. King
Chrysler Corporation

Anthony P. Skrobul
Texas Lubricants

James L. Sumiejski
Lubrizol Corporation

**Reprinted From: Automatic Transmission Fluids (ATF)
(SP-1394)**

The Engineering Society
For Advancing Mobility
Land Sea Air and Space®
INTERNATIONAL

**International Fall Fuels and Lubricants
Meeting and Exposition
San Francisco, California
October 19-22, 1998**

400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (724) 776-4841 Fax: (724) 776-5760

The appearance of this ISSN code at the bottom of this page indicates SAE's consent that copies of the paper may be made for personal or internal use of specific clients. This consent is given on the condition, however, that the copier pay a $7.00 per article copy fee through the Copyright Clearance Center, Inc. Operations Center, 222 Rosewood Drive, Danvers, MA 01923 for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law. This consent does not extend to other kinds of copying such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale.

SAE routinely stocks printed papers for a period of three years following date of publication. Direct your orders to SAE Customer Sales and Satisfaction Department.

Quantity reprint rates can be obtained from the Customer Sales and Satisfaction Department.

To request permission to reprint a technical paper or permission to use copyrighted SAE publications in other works, contact the SAE Publications Group.

GLOBAL MOBILITY DATABASE

All SAE papers, standards, and selected books are abstracted and indexed in the Global Mobility Database

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

ISSN 0148-7191
Copyright 1998 Society of Automotive Engineers, Inc.

Positions and opinions advanced in this paper are those of the author(s) and not necessarily those of SAE. The author is solely responsible for the content of the paper. A process is available by which discussions will be printed with the paper if it is published in SAE Transactions. For permission to publish this paper in full or in part, contact the SAE Publications Group.

Persons wishing to submit papers to be considered for presentation or publication through SAE should send the manuscript or a 300 word abstract of a proposed manuscript to: Secretary, Engineering Meetings Board, SAE.

Printed in USA

982674

Development and Introduction of Chrysler's New Automatic Transmission Fluid

Dennis W. Florkowski and Tracey E. King
Chrysler Corporation

Anthony P. Skrobul
Texaco Lubricants

James L. Sumiejski
Lubrizol Corporation

ABSTRACT

Chrysler began a limited development program directed toward a new automatic transmission fluid (ATF) early in 1989 and launched a full time effort in 1994. The development process for the new ATF involved a significant level of bench testing and eventually vehicle tests to evaluate the durability and shift quality of the ATF. The bench tests included those that pertain to oxidation and shear stability, anti-wear, frictional properties and torque converter shudder. Vehicle tests were primarily extended durability in both internal vehicle fleets and at external taxi sites. The mileage accumulated in this phase of the development program exceeded two million miles, all with no fluid drains out to 100,000 miles. Additionally, shift feel tests were conducted in Chrysler vehicles to verify compliance to targets. This paper summarizes the tests and results that lead to the development of the new Chrysler fill-for-life automatic transmission fluid.

INTRODUCTION

After evaluating the robustness of Chrysler's current ATF, it became apparent that virtually every aspect of the fluid would require an upgrade to provide "fill-for-life" performance. Therefore, the goal of the project was to develop the new ATF with shift quality equivalent to that of the current fluid but with improved viscosity retention, thermal oxidation stability, low temperature viscosity, antiwear properties and friction and anti-shudder durability.

Typical of this type ATF the viscosity index improver would shear resulting in a fluid with lower viscosity than desired. This in turn affected the performance of the oil system and to a certain extent the anti-wear function. The transmission operating temperatures had increased which put additional thermal stress on the fluid and limited the useful life of the ATF. Certain front wheel drive automatic transmissions required higher levels of anti-wear due to beveled gear sets and chain systems lubricated by ATF and not usually found in rear wheel drive applications. The frictional properties of the ATF would need to remain unchanged for the life of the fluid to maintain shift quality and anti-shudder capabilities and the fluids low temperature viscosity would need to be at a level to allow operation at very low temperatures.

Further challenges were that there would be no friction material revisions, and the new fluid would need to work as a "drop in" and be back serviceable. In addition, the development would need to be done using current industry tests for evaluating these features. At issue was which tests would be appropriate and correlate with actual vehicle operation

Chrysler's partners in this effort were Texaco Oil Company and The Lubrizol Corporation. Texaco had developed a Group III XHVI Base Oil having excellent oxidative resistance and outstanding low temperature fluidity. The base oil approached the performance of a synthetic fluid but at lower cost. Lubrizol was able to tailor an additive system that worked synergistically with the base oil. During the course of the project, Lubrizol also developed a new viscosity index improver to provide the needed stability
.

EXPERIMENTAL

TEST FLUIDS - Table 1 provides elemental analyses and some typical physical characteristics of the two key ATFs evaluated. ATF A represents the current Chrysler Factory-Fill ATF, while ATF B is the new factory-fill ATF.

The additive systems used in these ATFs are quite different as shown by the elements present. The base oil used in ATF A is of the Group II category, while the base oil used in ATF B belongs to the Group III category. The specific base oils used for ATF B will be discussed in the next section.

Table 1
TEST FLUIDS

ATF	A	B
Elements, ppm		
Zinc	850	
Phosphorus	540	460
Calcium	2300	690
Barium	1970	
Boron		130
ASTM D445		
100°C, cSt	7.4	7.43
ASTM D2983		
-28.9°C, cP	2,990	2,460
-40°C, cP	17,200	9,490
ASTM D92, °C	186	214

For comparison purposes, some commercially available ATFs were used during the evaluations. These ATFs will be described as needed in the results and discussion section of the paper.

HYDROISOMERIZED WAX BASE OILS – Automatic transmission fluids and other compounded lubricants are composed of a base stock (s) and an additive system. For many years it was the norm to extend automatic transmission fluid life by increasing additive treat rates and/or additive potency. As OEMs continue to upgrade their factory-fill and service-fill specifications, this approach to driveline fluid performance enhancement is becoming less practical [1]. Improvements in lubricant base stocks are necessary to formulate fill-for-life automatic transmission fluids at an acceptable cost.

Most commercial lubricant base stocks are manufactured from a variety of crude oils using conventional refining processes. As part of the oil refining process the different components of the crude oil are separated primarily by multiple distillation. Atmospheric distillation (at ambient pressure) is followed by vacuum distillation to give distillate cuts of different viscosity, and residual oils. Subsequent processing may include, solvent extracting, propane deasphalting, solvent or catalytic dewaxing and hydrogen finishing (hy-finishing). Solvent extraction is used to remove most of the aromatics and some of the naphthenes (cycloparaffins) and other undesirable materials from the oil. This process improves the viscosity index (VI), color and oxidative stability of the base stocks. Propane deasphalting is used to remove asphalt (bitumen) from the heavy concentrated residue (bottoms) of the vacuum distillation column. The deasphalted vacuum residue is then further refined to give base oils known as “bright stocks”, heavy fractions used in gear oils and other viscous lubricants. Dewaxing (either solvent or catalytic) is used to remove or convert the high molecular weight wax from the oil to improve the low temperature fluidity of the base stock. Catalytic dewaxing is a selective process, which gives a product with superior low temperature properties to solvent dewaxed oils. Hy-finishing is a mild catalytic hydrogenation process used to stabilize the base stock by removing nitrogen compounds, sulfur compounds, olefins and residual aromatics, which could cause darkening, oxidation and sludging of formulated oils in service.[2]

While conventionally processed mineral base stocks are still the predominant base stocks for ATF and other applications, new OEM lubricant requirements are leading product developers to investigate the use of high-performance non-conventional base stocks in formulating automotive lubricants.[1, 3] Synthetic oils such as polyalphaolefins (PAOs) have been used to enhance lubricant performance, but at high cost. Ideally, an advanced refining technology could be discovered to manufacture mineral oil base stocks having performance characteristics approaching PAO but at much lower cost. In response to the demand for much higher performance mineral oil base stocks, a major oil refiner developed and commercialized two high VI hydroisomerized base stocks. These highly refined base stocks, HVI-A and HVI-B, meet the definition of API Group III (≤ 0.03% S, ≥ 90% saturates, ≥ 120 VI), and were developed to satisfy critical low temperature, oxidative and volatility performance requirements in several lubricant product areas.[4, 5] Table 2 shows the Group III definition in relation to all the API base stock categories.

Table 2
API CLASSIFICATION OF BASE STOCKS

Group I	> 0.03% S, and/or < 90% saturates, 80 to < 120 VI
Group II	≤ 0.03% S, ≥ 90% saturates, 80 to < 120 VI
Group III	≤ 0.03% S, ≥ 90% saturates, ≥ 120 VI
Group IV	Polyalphaolefins (PAOs)
Group V	All others not included in Groups I, II, III or IV

HVI-A/B base stocks are manufactured from slack wax, the oily wax from the solvent dewaxing step mentioned above. The slack wax feed stock typically contains 10 – 20 wt.% oil. The slack wax is isomerized and mildly hydrocracked at high temperature (700 - 800°F) and pressure (about 1000 psig is preferred) to give a product composed of about 80 wt. % oil and 20 wt. % unconverted wax. The product from the isomerization step is stripped to remove light ends produced from the hydrocracking reactions, and solvent extracted with N-methyl-2-pyrrolidone (NMP). Finally, the refined oil from the extraction step is catalytically dewaxed to reduce the pour point and improve low temperature fluidity of the oil. This catalytic dewaxing step accounts for the superior low temperature fluidity (low Brookfield viscosity at -40°C) of HVI-A/B compared to some other Group III base stocks. Following dewaxing, the dewaxed oil is hy-finished to improve stability.[4]

Typical physical and chemical test data for HVI-A and HVI-B are summarized in Table 3 and compared to inspection data for wax-derived base stocks manufactured by two other manufacturers.[4]

Table 3

PHYSICAL AND CHEMICAL TEST DATA FOR GROUP III BASE STOCKS

	HVI-A	HVI-B	HVI-C	HVI-D
ASTM D445 40°C, cSt	13.15	20.7	16.39	29.68
ASTM D445 100°C, cSt	3.30	4.44	3.98	5.79
VI	123	128	146	140
Sulfur, wt. %	<0.01	<0.01	<0.01	<0.01
ASTM D97, °C	-15	-12	-18	-21
ASTM D2983 -40°C, cP [(a)]	3270	8800	>1,000,000	Solid

(a) Base Stock + 0.25 wt.% Pour Point Depressant

Data in Table 3 show that while all of the base stocks belong to API Group III there are differences, particularly in low temperature performance. The excellent Brookfield viscosity results for the HVI-A/B base stocks compared to the other two HVI base stocks is attributed primarily to the catalytic dewaxing step used in the manufacture of HVI-A/B. [4] Detailed compositional data for these base stocks are summarized in Table 4.

Table 4

COMPOSITION OF GROUP III BASE STOCKS [(a)]

	HVI-A	HVI-B	HVI-C	HVI-D
Paraffins	78.5	70.2	83.3	78.42
Mononapthenes	8.8	11.8	10.6	10.86
Dinaphthenes	3.4	5.3	3.5	6.04
Trinaphthenes	1	1.8	0	1.59
Tetranaphthenes	1.3	1.6	0	0.64
Pentanapthenes	0	0.6	0	0.95
Hexanaphthenes	3.3	2.5	0	0
Monoaromatics	2.8	4	0.4	0.5
Diaromatics	0.5	0.9	2	0.5
Triaromatics	0.1	0.2	0	0
Tetraaromatics	0	0.1	0	0
Pentaaromatics	0	0.1	0	0.1
Benzothiophenes	0.12	0.32	0	0.11
Dibenzothiophenes	0.04	0.12	0.1	0.06
Naphthobenzothiophenes	0	0	0	0.01
"Unidentified Aromatics"	0.2	0.6	0.1	0.2
Total Aromatics	3.76	6.34	2.6	1.48

(a) Values are in vol. %

The hydrocarbon type analysis procedure employed to obtain the data in Table 4 is described in detail in Reference 6. Differences in the compositional make-up of the base stocks in Table 4, particularly the aromatic contents, are readily apparent. The slightly higher aromatic content of HVI-A/B has practical implications when formulating products with these base stocks. Finished lubricants with HVI-A/B typically require less added seal swell additive or additive solubilizing agent compared to lubricants with other Group III base stocks.

TEST METHODS – Several tests were selected during the development of the new factory-fill ATF to measure performance improvements over the current factory-fill ATF. The Chrysler MS-9602 specification evolved jointly with the ATF candidate during the developmental phase of the project. In many cases, candidate test results provided guidance in establishing the requirements now outlined in the MS-9602 specification.

<u>Viscosity Retention -</u> Shear stability performance was defined by use of the DIN 51 350 KRL Tapered Bearing Shear Test. The KRL Shear Test was selected by Chrysler as a more accurate predictor of viscosity loss in vehicle performance than the previously used D5275-92 FISST procedure.

<u>Oxidation Stability</u> - An extended version of The Ford Aluminum Beaker Oxidation Test (ABOT) was chosen as the method for predicting the fill-for-life performance desired by Chrysler for the new ATF. The ABOT has been used to predict oxidation performance for many years and is a required test for ATF approval in the Ford MERCON®, MERCON®V and Chrysler MS-7176E

specifications.[7-12] The typical test requires that 250 ml of the test fluid be held at 155°C for 300 hours. Air is introduced at a rate of 5.0 ml/min to promote oxidation of the test fluid. An internal gear pump provides mixing of air and oil. Copper and aluminum test strips are suspended in the fluid and rated for corrosion during the test. The oxidation of the test fluid is monitored by removal of samples from the beaker at specific time intervals.

For the Chrysler MS-9602 specification, the test duration of the ABOT was extended from 300 to 500 hours. In addition, the used oil targets for % viscosity variance, pentane insolubles and total acid number increase were tightened to achieve the superior oxidation performance Chrysler required for a fill-for-life fluid

Table 5 highlights the differences in test method and requirements between the current Chrysler MS-7176E and new MS-9602 specifications.

Table 5

ABOT CONDITIONS AND REQUIREMENTS

SPECIFICATION	MS-7176E	MS-9602
Test Parameters		
Test Duration, h	300	500
Test Temperature, °C	155	155
Air Flow, ml/min	5	5
Gear Pump, rpm	1100	1100
Used Fluid Requirements		
Viscosity Change, 40°C, cSt		
@ 250 h.	20 max	
@ 450 h		10 max
TAN Increase @ 250 h	4.0 max	
TAN Increase @ 450 h		2.0 max.
Pentane Insolubles @ 250 h	Report	
Pentane Insolubles @ 450 h		0.20 max
Copper Strip Rating		
@ 50/300 h	3b max	
@ 50/300/500 h		3b max
Brookfield Viscosity, -40°C, cP		
@ 500 h		Report

Antiwear Properties - Fluid antiwear characteristics were measured using two industry accepted test methods:

Modified D2882 Vane Pump Wear Test
Modified D5182 FZG Gear Wear Test

The Modified D2882 Vane Pump Wear Test consists of a vane pump run for 100 hours at 80°C under 1000 psi. At the conclusion of the test, the wear performance is rated on a basis of maximum weight loss on the rings and vanes.

The Modified D5182 FZG Gear Wear Test measures the scuffing resistance of the test fluid in an FZG Gear Test machine. The FZG machine operates at a constant speed of 1450 rpm for 15 minutes at each stage with successively increasing loads until the summed total width of scuffing/scoring/adhesive wear damage on the pinion gear exceeds 20 mm or the final load stage (12) is reached. The initial test temperature for the standard FZG test is 90°C, which is controlled at the start of each stage, but allowed to climb (no cooling) during each stage. For the Chrysler MS-9602 specification, the initial test temperature is set at 150°C.

Friction and Anti-Shudder Durability - The friction characteristics of the ATFs were measured using the following test methods:

a) Chrysler SAE No. 2 Friction Test
b) Chrysler Torque Converter Clutch Test
c) LVFA Anti-shudder Durability Test
d) Vehicle Shift Quality Test

Chrysler SAE No. 2 Friction Test - The Chrysler friction test utilizes the standard SAE No. 2 Friction Machine to evaluate the friction performance of the transmission fluid and clutch friction materials. The clutch disc is used as a brake to stop a rotating inertia while torque, speed, apply pressure and stop times are recorded. The test procedure will vary depending on the specific friction material used in the test. For most of the ATF development evaluations, the test conditions shown in Table 6 were used.

Table 6

CHRYSLER SAE FRICTION TEST CONDITIONS

Fluid Temperature, °C	104
Apply Pressure, kPa	124
Energy,	14.2 kJ
Plate Material	BW 2050

The actual Chrysler friction test is divided into three sections. Sections A and C are referred to as the Friction Coefficient Test. The midpoint dynamic and static coefficients of friction are measured for a prescribed number of cycles. The static/dynamic ratio is also determined. Section B is referred to as an abuse or durability phase. For each specific friction material tested with the ATF, Chrysler has specific requirements pertaining to acceptable friction performance. Chrysler also measure the friction retention ability of the fluid-friction material system by comparing the average midpoint dynamic and static coefficients of friction obtained before and after the durability phase of the test. Minimum change in average friction coefficient between the two sections is required for acceptable performance.

Torque Converter Clutch (TCC) Test - The holding capacity of the ATF with the torque converter clutch material is measured in a proprietary Chrysler test. A bench test was developed during the course of the investigation using the SAE No. 2 Friction Machine to simulate the TCC static capacity coefficients of various candidates. Static coefficients were measured at several facing pressures up to 438 psi.

Anti-shudder Test – To evaluate the anti-shudder durability characteristics of the fluids, Chrysler adopted the Low Velocity Friction Apparatus (LVFA) test developed by Lubrizol and Plint & Partners. The Plint LVFA test can accommodate a variety of clutch disc configurations when used with appropriate adapters.

The apparatus consists of a bench-mounted tribometer, a motor control unit and a PC based data acquisition and control unit. Test specimens are mounted onto the drive spindle and the steel reaction disc is mounted in the fluid reservoir. The two discs are loaded together by pneumatic bellows. The frictional torque is determined by measuring the reaction force developed at a load cell that restrains the reservoir as the drive spindle rotates.
The test machine monitors and/or controls oil and plate temperatures, loads frictional torque, speed and test time. LVFA coastdown procedures, discrete speed measurements and continuous slip procedures can all be easily evaluated. A schematic diagram of the Plint LVFA is shown in Figure 1

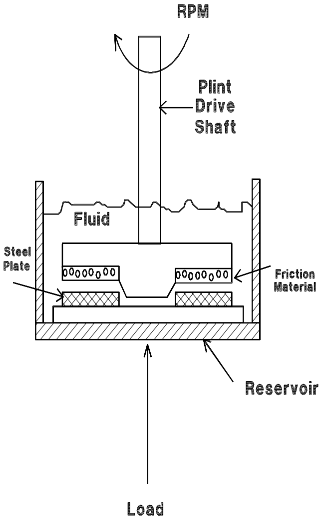


Figure 1 – Plint LVFA Schematic Diagram

LVFA Procedure – The Chrysler LVFA test is currently in the final phases of development. Final test conditions will be determined based on input from Chrysler vehicle data. The test procedure used during most of the additive development program was based on the following test sequence:

Phase I	Initial break-in where the fluid/friction material system undergoes continuous slip for 10 minutes at 128 rpm, a sump temperature of 149°C and load of 4.0 kN.
Phase II	LVFA discrete speed and continuous sweep evaluations are run on the fluid/friction material system at three temperatures (27°, 88°, and 149°C). Discrete speed evaluations are performed at several speeds between 4 and 256 rpm. For the continuous sweep evaluations, speed is held at 300 rpm for 10 minutes before coastdown to 0 rpm over 50 rpm.
Phase III	The Durability (aging) phase involves maintaining the fluid/friction material system under continuous slip at a constant load of 4.0 kN for 6 hours at 100 rpm. Test temperature is maintained at 171°C.

After the Durability (Aging) Phase, the LVFA discrete speed and continuous sweep evaluations from Phase 2 are repeated. If negative slope is not observed, the durability phase 3 is repeated followed by the LVFA evaluations in Phase 2. This test sequence is repeated until negative slope formation is observed.

Vehicle Shift Quality – Evaluations were done in a 3.8 liter, V-6 Dodge Caravan ES equipped with a half shaft mounted torque meter and a data display unit which utilized the vehicle's serial data port. Shift feel maneuvers involved upshifts, kickdowns, and coastdowns at different temperatures and throttle settings. Torque Converter Clutch performance involved gradual unlock and lock-up maneuvers.

RESULTS AND DISCUSSION

VISCOMETRICS AND SHEAR STABILITY – The increased use of electronic controls is one of the main reasons for the push toward improved ATF low temperature fluid performance. At the same time, the retention of high temperature viscosity is required for maintaining film strength for the operation of continuous slip torque converter clutches (CSTCC) as well as maintaining pump capacity by reducing pressure losses.[13-15]

To provide the low temperature performance required by Chrysler, all additive developments were carried out in

Texaco Group III XHVI base stocks. To meet the viscosity retention target, Lubrizol developed a new dispersant viscosity modifier for use with the Texaco base stock. This joint development provided Chrysler with an ATF that was able to satisfy both the high and low viscosity appetite of the transmission.

Table 7 compares the viscosity retention of ATFs A and B, after running in the 20 hour KRL Tapered Bearing Shear Test. Also included in the table are shear results on other commercially available ATFs. The ATF labeled MS-7176D represents Chrysler factory-fill ATF used before 1997.

Table 7

20 HOUR KRL SHEAR TEST RESULTS

	D445 Kinematic Viscosity, 100° C, cSt		
	Initial	Sheared	% Loss
ATF A	7.58	6.50	14.2
ATF B	7.43	6.69	9.9
MS-7176D	7.54	5.10	32.4
DEXRON®-III	7.80	4.67	40.1
MERCON®-V	7.75	6.31	18.6

The data in Table 7 clearly indicates that introduction of the new Chrysler ATF represents a significant upgrade in shear stability performance over other commercial ATFs. In fact, during the course of the MS-9602 ATF development program, Chrysler decided to take advantage of the improved viscosity retention benefits demonstrated by the new shear stable viscosity modifier. This decision resulted in an upgrade to the factory-fill ATF from MS-7176D to MS-7176E (ATF A) in June 1997.

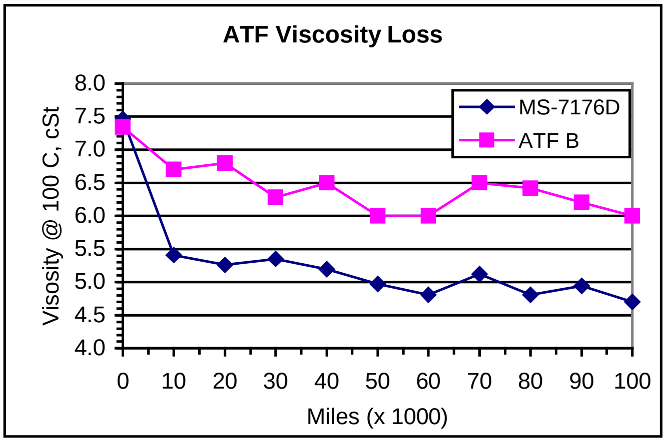


Figure 2 – Vehicle Data

The viscosity loss data in Figure 2 showing performance of two ATFs is from Chrysler durability vehicles and taxi fleets and is a sampling of fifty vehicles. The ATF identified as MS-7176-D is the Chrysler ATF prior to the viscosity index improver change while ATF B is the new factory fill with shear stable viscosity index improver. The data indicates ATF B experiences less initial viscosity loss and exhibits better control than MS-7176-D out to 100,000 miles. This vehicle data also verifies the performance benefits identified in Table 7 for ATF B versus MS-7176-D.

OXIDATION STABILITY – Improvements in oxidation performance continues to be a major focus of the North American OEMs.[13] The trend is to require longer test duration and tighter acceptance limits which reflect the fill-for-life goals of the OEMs. Table 5 shows how Chrysler has followed this trend in their ABOT requirements for the new factory-fill ATF. Figures 3 and 4 show the oxidation stability of ATFs A and B with regard to viscosity increase and Total Acid Number change

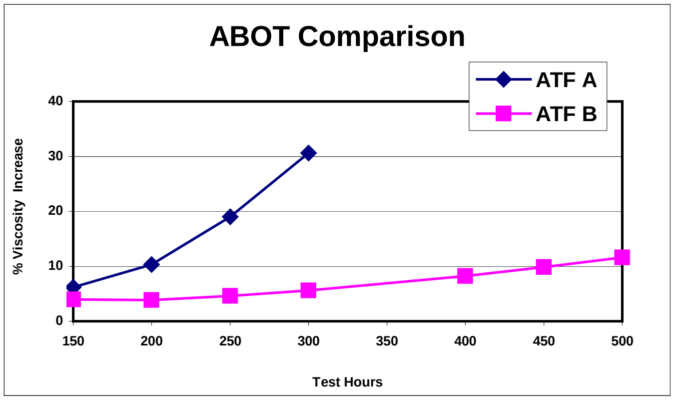


Figure 3 – ABOT Viscosity Increase Comparison

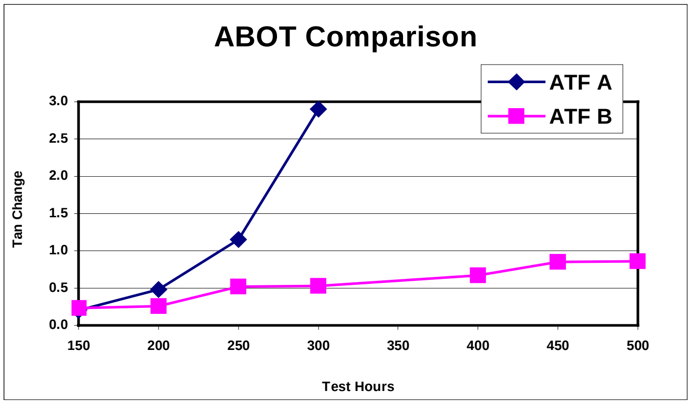


Figure 4 – ABOT TAN Change Comparison

The data shows that ATF B is more oxidatively stable over the current Chrysler ATF A. The improved antioxidant performance of the new ATF B additive coupled with the excellent oxidative resistant properties of the API Group III base stocks provides the fill-for-life performance required by Chrysler for the new ATF.

To further demonstrate the enhanced oxidation stability of the new Factory Fill Fluid, ATFs A, B and three other ATFs were evaluated in an extended test beyond the 500 hours currently required by the Chrysler MS-9602 specification. The results of this evaluation are shown in Figures 5 and 6. ATF C is the General Motors DEXRON®-III Reference. ATF D is MERCON®-V. ATF E is the Chrysler MOPAR ATF+ Type 7176® from 1993.

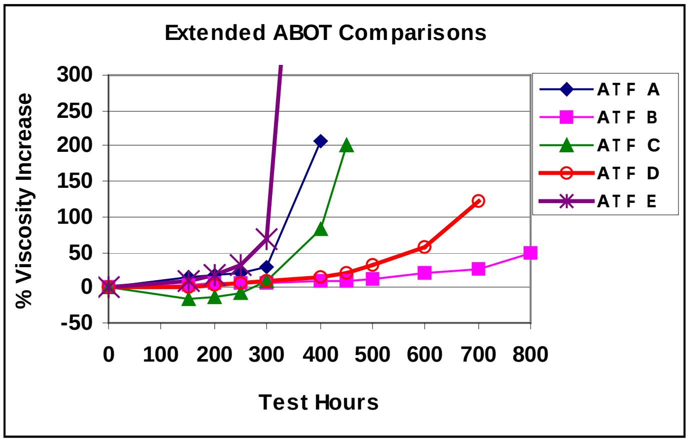


Figure 5 Extended ABOT Viscosity Increase evaluations

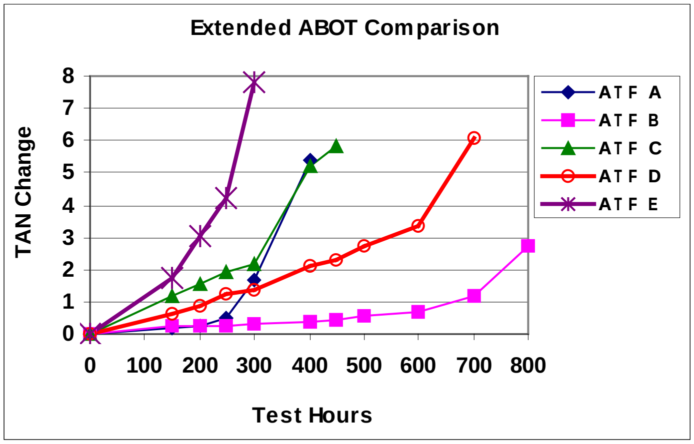


Figure 6 - Extended ABOT TAN Change evaluations

Based on these results, ATF B clearly demonstrates superior oxidation stability over current commercial ATFs.

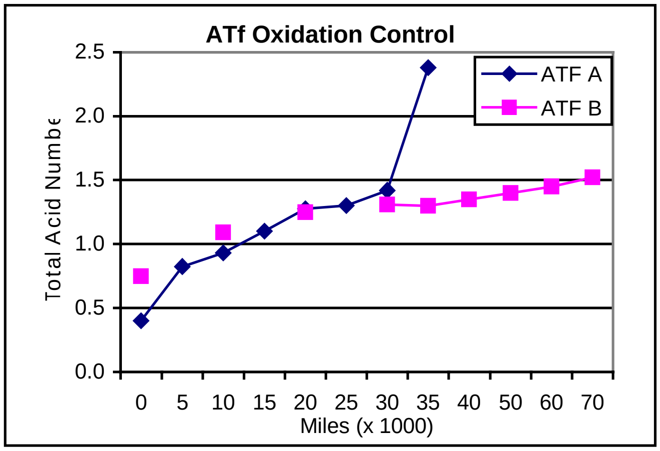


Figure 7 – Vehicle Data

The data in Figure 7 shows Total Acid Number of ATFs A&B from Chrysler fleet vehicles previously described under Figure 2. ATF A, the current service fluid has a significant TAN increase at approximately 30,000 miles while ATF B remains relatively stable going out to extended mileage. This data indicates that the ATF B is superior to ATF A in field performance relative to oxidation control and confirms the ABOT data shown previously in Figure 4 comparing these ATFs.

ANTIWEAR PERFORMANCE - Table 8 compares the wear performance of ATFs A and B in the modified D2882 Vane pump wear test and shows typical values based on several tests. This test was not required for the current factory-fill specification. The results in Table 8 show that the antiwear additives used in the new ATF B will provide greater wear protection for the Chrysler transmission

Table 8
MODIFIED D2882 RESULTS

ATF	A	B
Wt. Loss, mg.	98.2	0.4

Table 9 compares the scuffing performance of the ATFs in the modified D5182 FZG gear wear test. During the development of ATF B, the FZG wear test was run at three temperatures to assess the antiscuffing performance of the candidates. From this investigation, Chrysler chose 150°C as the temperature for determining the performance of the ATFs.

Table 9
Modified D 5182 Results

ATF	A	B	
At 90°C			
Load Stage Pass	5	12	
Scuffing, mm	234	None	
At 100°C			
Load Stage Pass	5	12	
Scuffing, mm	38	7	
At 150°		**1**	**2**
Load Stage Pass	5	11	12
Scuffing, mm	266	220	None

Two results on ATF B at 150°C are shown in Table 9. These results show the superior anti-scuffing performance of ATF B over ATF A. This improved performance has been confirmed in vehicle fleet tests conducted by Chrysler and shown in Figure 8.

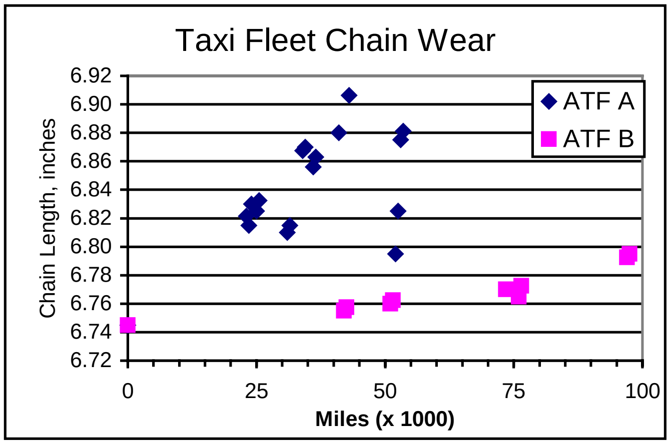


Figure 8 – Anti-Wear Field Performance

Vehicle Wear Performance- The difference in transmission wear protection is clearest with the improvement in the taxi fleet chain stretch performance of the 42LE transmission as shown in Figure 8. Transfer Chain stretch has been observed in vehicles used in taxi service only, normal customer service is not severe enough to induce this level of wear. If the chain length exceeds 6.81 inches the internal lash may cause the reverse piston to fail. Figure 8 shows how ATF B exceeds the wear protection performance of ATF A. The transmissions operated on ATF A had fluid changes at 15,000-30,000 miles. 15,000 mile oil change intervals slowed but did not eliminate the chain wear. The transmissions operated on ATF B did not show high chain stretch levels even after nearly 100,000 miles of taxi operation without a fluid change. The field data demonstrates the superior wear performance of ATF B and directionally agrees with the bench test data shown in tables 8 and 9.

FRICTION PERFORMANCE – Longer transmission life is the ultimate goal of the equipment manufacturers.[13] ATF compatibility with the hardware components, which includes the friction materials, is also required to insure acceptable vehicle performance and back serviceability. For the new Chrysler ATF, the challenge was to match the accepted frictional performance of the current ATF yet provide the enhancements needed for the fill-for-life goals.

Chrysler Friction Test – ATF friction characteristics were measured in the SAE No.2 Friction machine using the Chrysler Friction test. Table 10 shows several test runs on different batches of the new ATF B along with current Factory Fill ATF A. From the results obtained, ATF B meets the friction retention requirements defined by the Chrysler test. ATF B also provided the slightly higher friction coefficients desired by the transmission engineers as compared the ATF A. Variations of this test procedure were used by Chrysler to evaluate the performance of the ATF with several other friction materials used in the Chrysler transmission designs. Therefore the new fluid had to demonstrate acceptable performance with these other materials during the development phase of the program as well.

Table 10
Chrysler SAE No.2 Friction Test (Overdrive Clutch)

	ATF A	ATF B*		
		#1	#2	#3
Dynamic Coefficient				
Before Durability	0.119	0.127	0.124	0.126
After Durability	0.115	0.127	0.125	0.126
Static Breakaway				
Before Durability	0.105	0.115	0.113	0.115
After Durability	0.104	0.111	0.114	0.112
Static/Dynamic Ratio				
Before Durability	0.88	0.91	0.91	0.91
After Durability	0.90	0.87	0.91	0.89

*Different batches of ATF B were tested

Torque Converter Clutch Performance –The goal was to develop a fluid that would match or exceed the holding capacity of ATF A. During the course of the program, many candidates were screened for clutch holding capacity. Figure 9 shows how the new ATF B compares to the current ATF A in the bench test developed to simulate the holding capacity of the torque converter clutch. Also shown are the results on two other potential ATF candidates from the development program. ATF F gave lower coefficients in this test compared to ATF A. and also caused some slippage in the proprietary Chrysler TCC test. However vehicle shift quality performance of ATF F was acceptable. On the other hand ATF G gave acceptable TCC performance but provided harsher shifts in the vehicle evaluations.

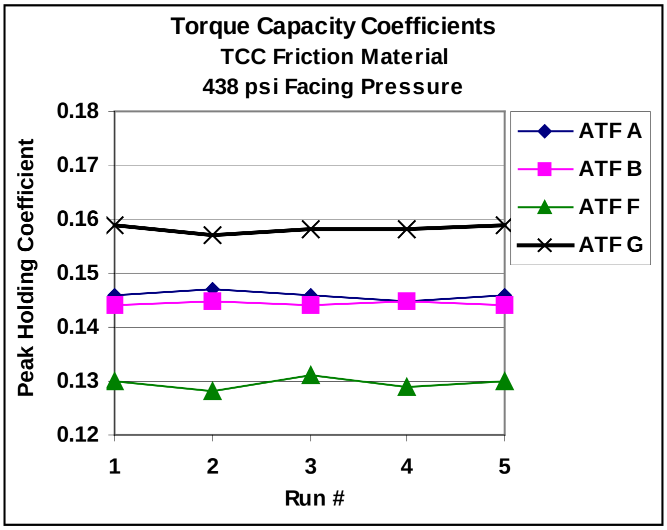


Figure 9 – TCC Capacity Coefficient Comparison

From this test, it became clear that the new ATF required a frictional balance that would have to satisfy both the Torque Converter Clutch and the vehicle shifting clutches. Through extensive testing to date, ATF B has demonstrated the ability to satisfy all the frictional demands put on the fluid by the automatic transmission.

Anti-shudder Performance – Anti-shudder durability has evolved over the past several years as a new requirement for ATFs. Shudder is a low frequency vibration which occurs mainly between 20 and 30 Hz. Shudder can occur in both shifting and lock-up torque converter clutches. The introduction of the continuously slipping torque converter clutch (CSTCC) has accelerated the need for tests that assess the anti-shudder durability of the fluid/friction material system. Many recent papers have been published discussing this phenomenon.[16-20]

Chrysler introduced an anti-shudder test based on the Low Velocity Friction Apparatus (LVFA) as part of the friction test requirements of the new MS-9602 specification. However unlike some of the currently used LVFA type tests which use small friction discs, the Chrysler test uses actual clutch plates fitted with adapters. Data generated from LVFA-type tests has shown correlation with actual vehicle data related to anti-shudder durability.[16,19,21]

Figures 10, 11 and 12 show the LVFA characteristics of ATFs A and B with the Chrysler Torque Converter Clutch friction material at 88°C. Figure 10 shows the LVFA curves for the new fluid / new friction material system. Figures 11 and 12 show the LVFA characteristics that develop after the system has been aged 18 and 36 hours respectively. The observation of negative slope (an increasing coefficient of friction as the sliding speed decreases) has been shown to correlate with transmission shudder [16-22]

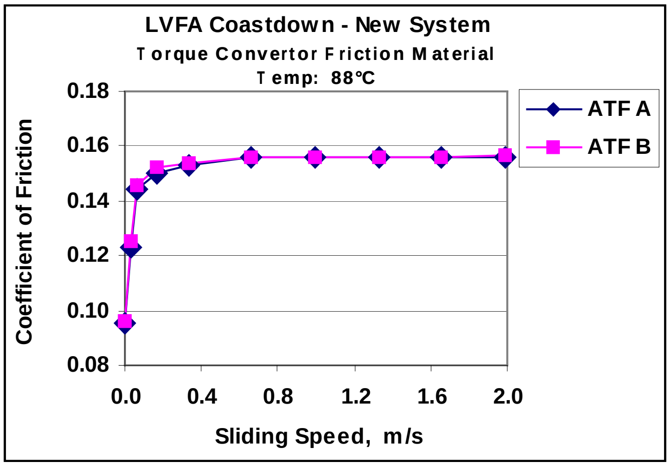


Figure 10 – LVFA Characteristics for New System

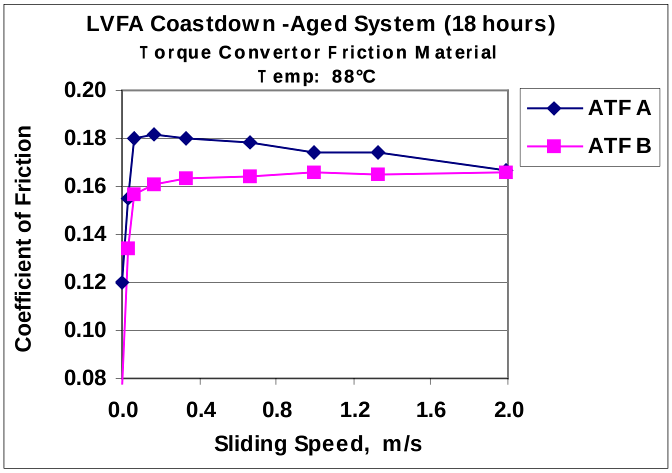


Figure 11 – LVFA Characteristic for 18 Hr. Aged System

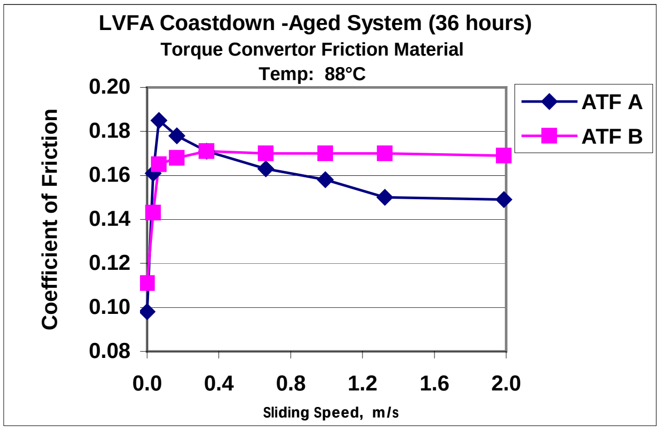


Figure 12 –LVFA Characteristics for 36 Hr. Aged System

Chrysler's goal was to have the new ATF provide extended anti-shudder durability over the current ATF. Figure 11 shows that ATF A develops negative slope characteristics after 18 hours while ATF B still has a positive slope. After 36 hours, ATF B still has retained the positive friction characteristics associated with good anti-shudder performance.

Figure 13 depicts the LVFA friction performance of ATF B after 72 hours at all three temperatures evaluated in the Chrysler LVFA anti-shudder test.

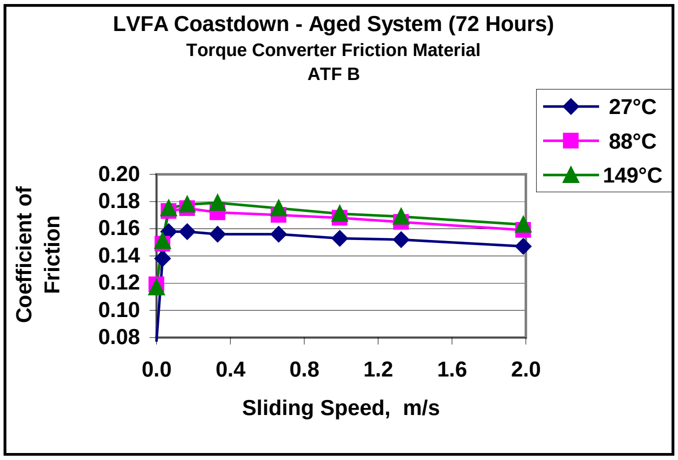


Figure 13 – ATF B LVFA Characteristics After 72 Hours At Three Different Temperatures

Figure 14 summarizes the results obtained on ATFs A and B at all three temperatures. The LVFA curves for ATFs A and B at 27°C and 149°C are shown in Appendix A. From the results obtained, ATF B provides approximately 3 to 4 times longer anti-shudder durability improvement over ATF A at higher temperatures. At the lower temperatures where shudder is often times more noticeable, ATF B provided almost 10 times the anti-shudder durability performance of ATF A.

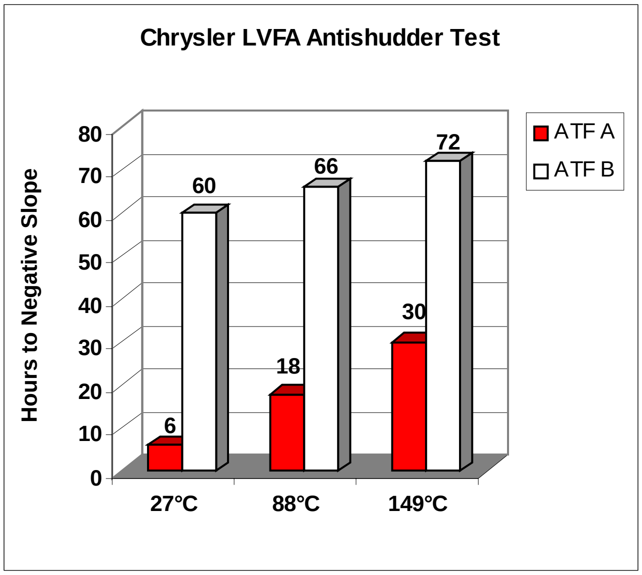


Figure 14 - Summary Of ATF A and B Anti-shudder Performance At All Three Temperatures

From vehicle data taken from several Chrysler taxi fleets, Chrysler has not experienced any shudder problems from vehicles that have accumulated greater than 95,000 miles with ATF B. To date Chrysler has achieved over 2 million miles of vehicle durability experience with the new ATF without encountering any shudder problems. However shudder problems have been reported in some vehicles containing the current ATF after 30,000 miles. Although ATF candidate evaluations with the Chrysler LVFA test were primarily focussed on the anti-shudder performance with the friction material used in the torque converter clutch, additional tests were also run using the actual overdrive clutch plates from the Chrysler 41TE transmission. Similar data was obtained showing the extended anti-shudder durability performance of the new ATF. An example of the overdrive LVFA data at 88°C after the system has undergone 18 hours of aging per the test procedure is shown in Figure 15

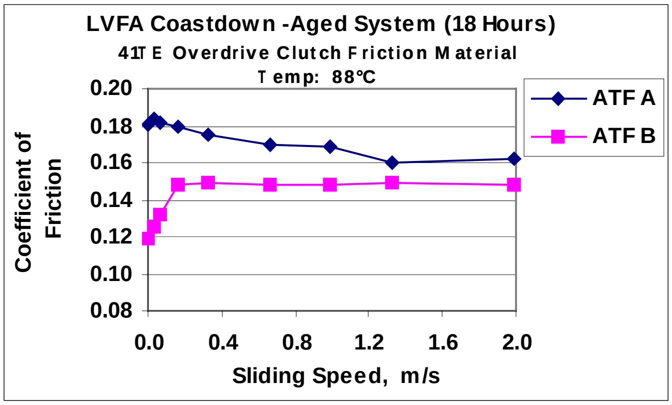


Figure 15 – LVFA Comparison of ATFs A and B After 18 Hours Aging With Overdrive Clutch Material

<u>Vehicle Shift Quality Performance</u> – How a fluid shifts in actual vehicle performance can be somewhat subjective. The data generated is usually based on a rating system whereby the candidate fluid is run through a series of maneuvers and then compared to the reference fluid which is usually the current factory fill ATF.

To remove some of this subjectivity, the test vehicle, a 1998 Dodge Caravan ES equipped with 3.8 liter, V-6 engine was instrumented with torque meter mounted to the half shaft. With this set-up, data could be recorded and downloaded to a computer for later assessment. At the same time a subjective rating based on the driver's perception was also given for the maneuver performed.

Figures 16 and 17 show the type of data obtained from the torque meter. Figure 16 shows a torque trace for the target reference ATF A. Figure 17 shows a version of ATF B that was judged not acceptable. In the TCC gradual unlock maneuver, the torque converter clutch is unlocked at a specified vehicle speed, throttle setting and temperature. Figure 16 shows the smooth unlocking of the converter clutch that would be given a rating for acceptable performance. Figure 17 shows a harsher unlock maneuver that can often be felt as a bump with some shaking of the steering wheel by the driver.

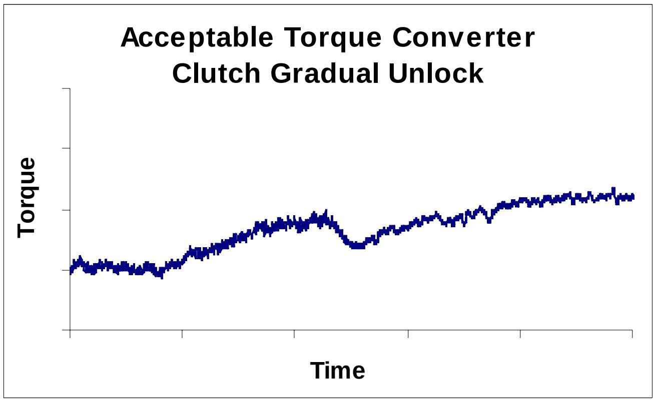


Figure 16 – Torque Meter Shift Trace For Acceptable Gradual Unlock Maneuver

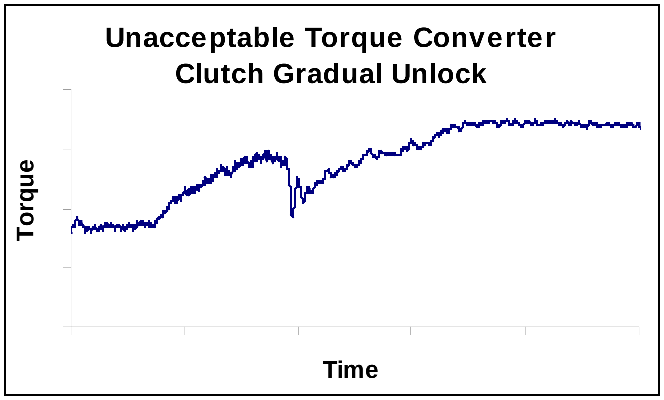


Figure 17 – Torque Meter Shift Trace For Unacceptable Gradual Unlock Maneuver

The data generated by the torque meter was useful in several ways. Other vehicle shift maneuvers were captured by the meter and downloaded for evaluation. With this information, other areas of concern could be studied. Formulations could then be adjusted and reevaluated to see the effect of the changes.

Another example where the vehicle data was used to improve the performance of the ATF is shown in Appendix B. The two figures shown highlight the data generated between acceptable and unacceptable 2-1 Kickdown performance.

CONCLUSIONS

This paper describes the development of an ATF that is considered fill-for-life. The bench and field test data presented above supports the following conclusions:

1. The Group III XHVI base stock used in ATF B provides superior low temperature performance when compared to other ATFs in the same category.
2. ATF B has excellent shear stability and viscosity retention as defined by the 20 hour KRL test and shown in the vehicle data.
3. The oxidation stability of ATF B has shown significant long term improvement over other fluids as shown in the ABOT test and vehicle data.
4. The anti-wear properties of ATF B have been improved measurably over ATF A as defined by the Modified ASTM D2882 and D5182 tests and shown in the vehicle data.
5. The frictional properties of ATF B closely match those of ATF A and are substantiated by various bench and vehicle tests.

ACKNOWLEDGMENTS

The authors would like to thank the many people who were both supportive of us and patient with us during the long development process.

REFERENCES

[1] C.W. Cornish, R.F. Watts, Basestock Requirements of Evolving Automatic Transmission Fluid Specifications," NPRA Paper AM-96-34.

[2] Product Review, "Oil Refining and Lubricant Base Stocks," Industrial Lubrication and Tribology, Vol. 49, No. 4, July/August 1997, 181-188.

[3] T. Sasaki et al, "Development of Automotive Lubricants Based on High-Viscosity Index Base Stock," SAE Paper 951028.

[4] J.A. Patel, M.P. Smith, J.R. Powers, J.R. Whiteman, G.F. Prescott, "Composition and Performance of a Hydroisomerized Wax Base Oil," PREPRINTS-Division of Petroleum Chemistry, American Chemical Society, Vol. 42, No. 1, February, 1997.

[5] A. Sequira, J.R. Whiteman, J.B. Holland, D.G. Roy, G.F. Prescott, U.S. Patent 5,292,426, March 8, 1994.

[6] A.J. Stipanovic, M.P. Smith, G.P. Firmstone, J.A. Patel, "Compositional Analysis of Re-Refined and Non-Conventional Lubricant Base Oils; Correlations to Sequence VE and IIIE Gasoline Engine Tests," SAE Paper 941978.

[7] Chrysler Corporation, "Engineering Specification MS-7176 Change E", May 14, 1997

[8] Ford Motor Company, "MERCON® Automatic Transmission Fluid Specification trademarked for Service", September 1, 1992

[9] Ford Motor Company, "MERCON®V Automatic Transmission Fluid Specification Trademarked for Service", February 1, 1996

[10] P. A. Willermet, L. R. Mahoney, S. K. Kandah, A. W. Sever, "The Prediction of ATF Service Life from Laboratory Oxidation Test Data", SAE Paper 801363, 1980

[11] P. A. Willermet, S. K. Kandah, "The Aluminum Beaker Oxidation Test for MERCON® World-Wide Service ATF", SAE Paper 881673, October, 1988

[12] T. S. Derevjanik, "Improvements to the Aluminum Beaker Oxidation Test (ABOT) for Automatic Transmission Fluids", SAE Paper 941884, October, 1994

[13] W. C. Ward, Jr., J. J. Nunnari, K. A. Murray, "OEM Developments – ATF For Better Transmission Durability", NPRA AM-97-41, March 16-18, 1997

[14] R. Fewkes, D. G. Hughes, I. E. Joseph, J. L. Sumiejski, "Diversification of Automatic Transmission Fluid Technology", Technische Akademie Esslingen 10th International Colloquium, January 9-11, 1996

[15] J. W. Sprys, D. R. Vaught, E. L. Stephens, "Shear Viscosities of Automatic Tansmission Fluids", SAE Paper 941885, October, 1994

[16] W. C. Ward, Jr., J. L. Sumiejski, C. J. Castanien, T. A. Tagliamonte, E. A. Schiferl, "Friction and Stick-Slip Durability Testing of ATF", SAE Paper 941883, October, 1994

[17] H. Ohtani, R. J. Hartley, D. W. Stinnett, "Prediction of Anti-Shudder Properties of Automatic Transmission Fluids using a Modified SAE No.2 Machine", SAE Paper 940821, February, 1994

[18] R. C. Lam, Y-F Chen, "Friction Material for Continuous Slip Torque Converter Applications: Anti-Shudder Considerations", SAE Paper 941031, February, 1994

[19] W. C. Ward, Jr., M. Higashi, "The Effect of Lubricant Degradation on Frction Charateristic in the SAE No.2 Tester and Low Velocity Friction Apparatus", International Tribology Conference, Yokohama 1995

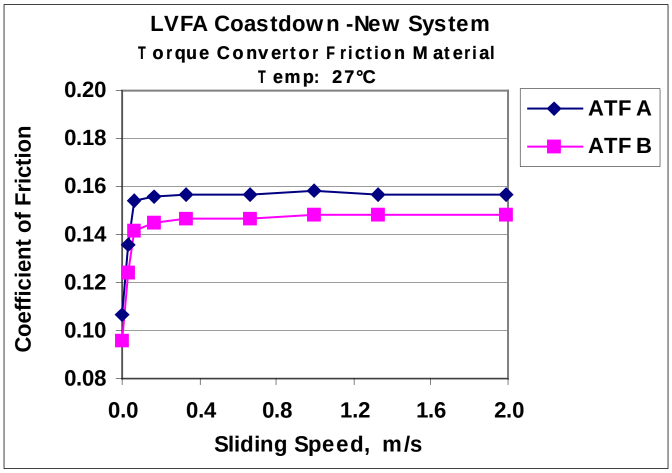
[20] R. F. Watts, R. K. Nibert, M. Tandon, "Evaluation of Anti-Shudder Characteristics and Anti-Shudder Durability of Automatic Transmission Fluids", International Tribology Conference, Yokohama 1995

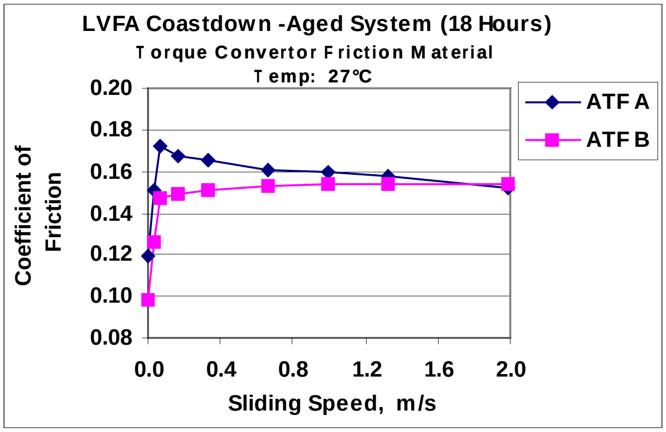
[21] R. F. Watts, et al, "Prediction of Low Speed Clutch Shudder in Automatic transmissions Using the Low Velocity Friction Apparatus", 7th International Colloquium Automotive Lubrication Technische Academie, June 17. 1990

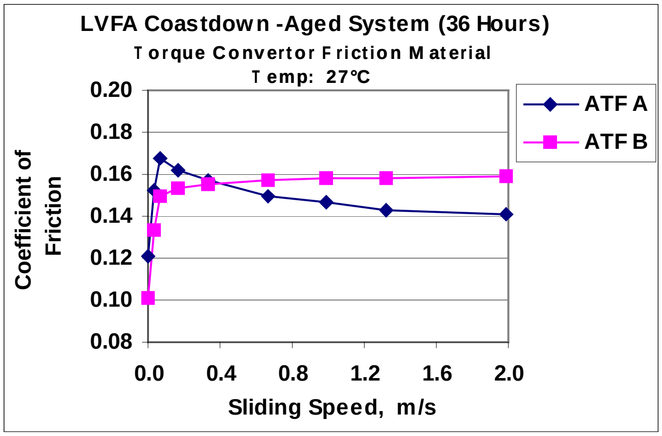
[22] R. Ashikawa, T. Naruse, H. Kuroshina, T. Matsuoka, T. Adachi, T. Nakayama, "ATF Characteristics Required for the Latest Automatic Transmissions", SAE Paper 932849

APPENDIX A

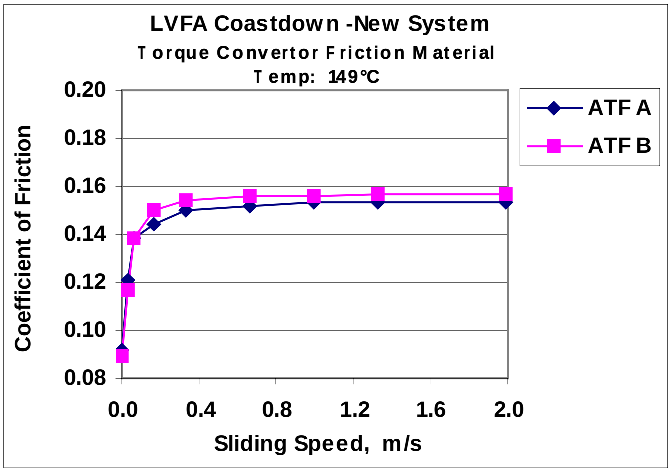
LVFA Coastdown Friction Curves for ATF A and ATF B at 27°C with Chrysler TCC Friction Material

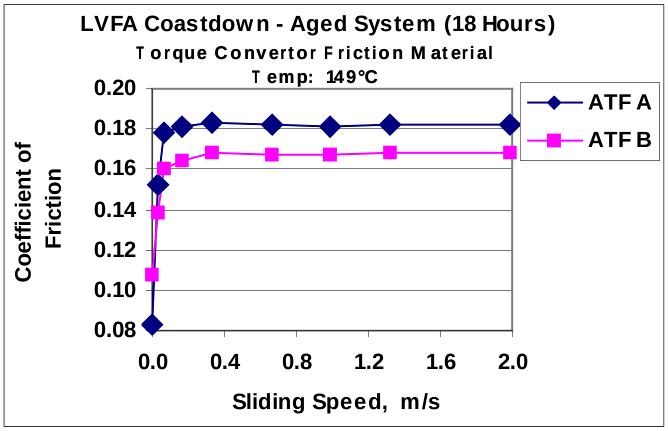


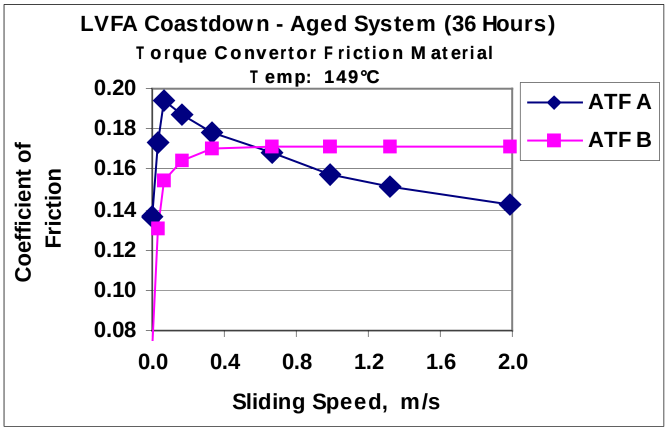




LVFA Coastdown Friction Curves for ATF A and ATFB at 149°C with Chrysler TCC Friction Material







APPENDIX B

2-1 Kickdown Torque Meter Curves showing acceptable and unacceptable performance.