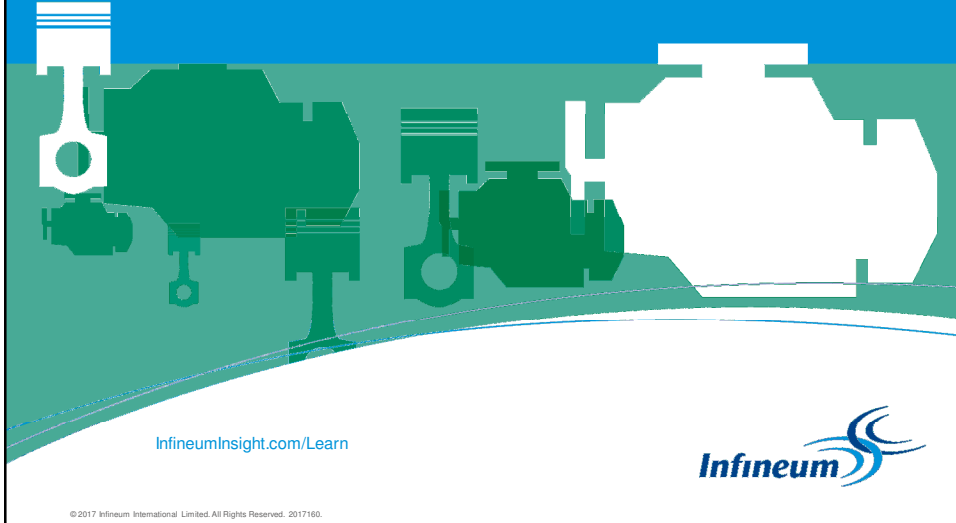


Performance you can rely on.

Power Transmission Fluids



InfineumInsight.com/Learn



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Performance you can rely on.

Outline

Transmission and Market Trends

- Hardware overview
- Market overview and market drivers
- Driveline types by region

Automatic Transmissions – Stepped Planetary (AT)

- Hardware components and their impact on ATF
- Testing for ATF
- Service Fill specifications
- ATF formulations

Automatic Transmissions – Dual Clutch (DCT)

- Hardware components and their impact on DCTF
- DCTF formulations

Automatic Transmissions – Continuously Variable (CVT)

- Hardware components and their impact on CVTF
- CVTF formulations

Summary



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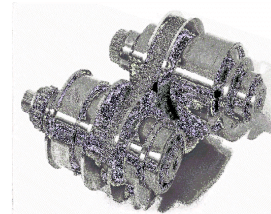
What Does A Transmission Do?

- A transmission adapts the output of the internal combustion engine to the drive wheels.
 - Important element in the “feel” of driving for consumers
- **Power Transmission Fluids (PTF)** relate to fluids necessary for proper operation of automatic transmissions including: stepped automatic transmissions, dual clutch transmission, continuously variable transmission, etc.
- **Automatic Transmission Fluids (ATF)**, generally, relate specifically to fluids for stepped automatic transmissions



Types of Transmissions

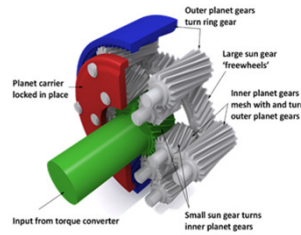
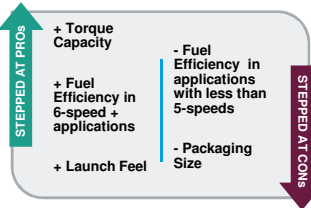
- **Stepped Automatic Transmission (AT)**
 - Most common automatic transmission that uses a planetary gear set and a torque converter
- **Continuously Variable Transmission (CVT)**
 - Automatic transmissions that use variator pulleys with an unlimited number gear ratios
- **Dual Clutch Transmission (DCT)**
 - Automatic transmissions that use manual gearbox architecture with dual clutches
- **Automated Manual Transmission (AMT)**
 - Manual transmissions that use servos to engage clutch and change gears automatically
- **Electrical Variable Transmission (EVT)**
 - Combines stepped automatic transmission with electric motor (e.g. Toyota's Hybrid Synergy Drive)
- **Reduction Transmission (Electric)**
 - Transmissions used by purely electric vehicles to reduce torque output from electric motors (Nissan Leaf)
- **Manual Transmission (MT)**



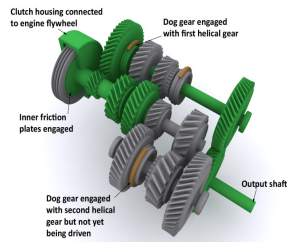
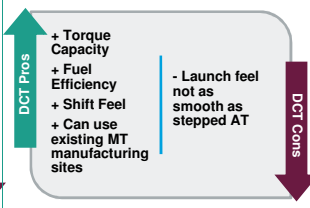
Automatic Transmissions

Performance you can rely on.

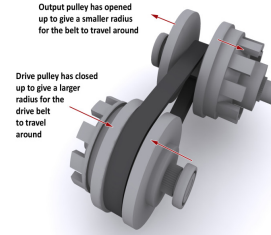
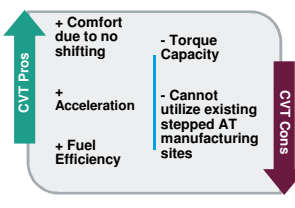
Stepped Automatic



Dual Clutch



Continuously Variable



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Transmission Trend Drivers

Performance you can rely on.

Fuel Economy And Emissions

- Development of CVT, DCT and Higher Gear Ratio spreads
- Improvement of friction clutch, pump, seal efficiencies
- Hybrid / Electrification
- Low viscosity fluids

Driving Performance

- Shift Quality / Noise-Vibration-Harshness (NVH) / Comfort
- Safety/Fun-to-Drive – sporty – dynamic driving style – adapts to suit your individual driving style

Compact Size And Reduced Weight

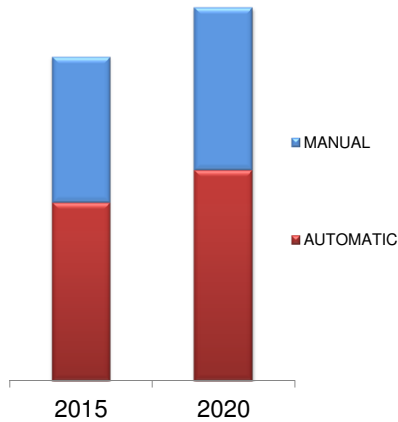
- Smaller Transmissions – Less fluid
- Increased Torque Density



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Global Transmission Production

Global Transmission Production
by Transmission Type



Passenger Car And Light Duty Transmissions

Production increasing with global vehicle population.

Manual Transmissions

Market share slowly declining with inherent lower cost now being offset by fuel economy *debit*.

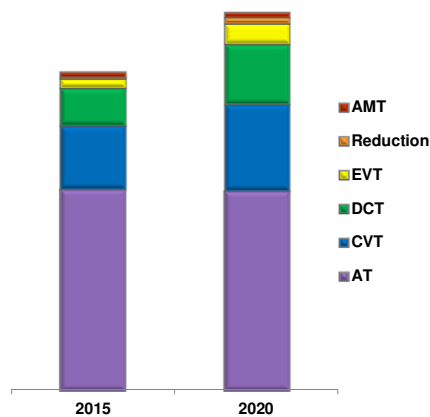
Automatic Transmissions

Market share increasing with fuel economy often better than manual. Increasing diversity in design.



Global Automatic Transmission Production

Global Automatic Transmission
Production by Transmission Type



Source: IHS

Automated Manual Transmission (AMT)

Some production increase, market share low and stable

Reduction Transmission (Electric)

Large production increase, market share remains low

Electronically Variable Transmission (EVT)

Large hybrid production increase, market share remains low

Dual Clutch Transmission (DCT)

Large production increase, market share gain

Continuously Variable Transmission (CVT)

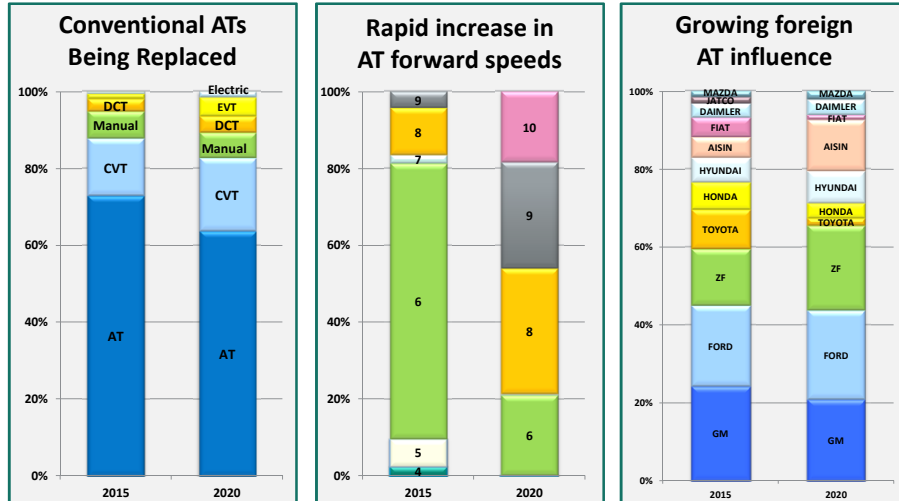
Large production increase, large market share increase

Stepped Automatic Transmission (AT)

Production stable, market share decline



Transmission Hardware Trends North America Installations – CAFE Impacts



DATA SOURCE: IHS

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ATF Market Review Low-Viscosity ATF Growth

DEXRON®-III/MERCON®: decline

- Last used in pre-2006 vehicles now being retired; not suitable for newer transmissions.

HIGH VISCOSITY MULTI-VEHICLE: peaking

- Ford MERCON®-V, Chrysler ATF+4, Honda Z-1, Nissan Matic J, Hyundai SP-III last used ~2010.

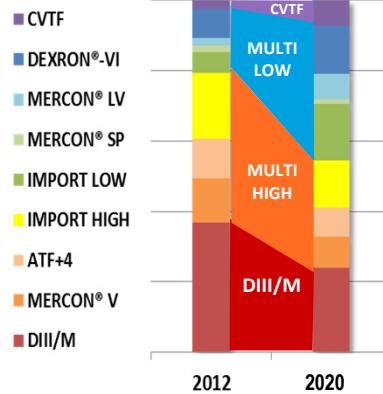
LOW VISCOSITY MULTI-VEHICLE: rapid growth

- Most OEMs have moved to using lower viscosity synthetic ATF, to improve performance and fuel economy while extending drain intervals.

CONTINUOUSLY VARIABLE : gaining steam

- Nissan vehicles with CVTs now reaching end of extended warranty period. Toyota and Honda adding CVTs.

ATF SERVICE FILL PROJECTION

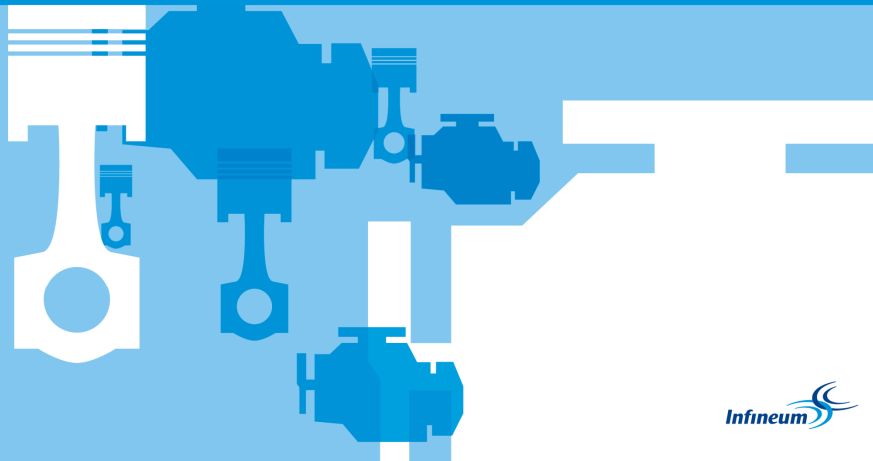


Market Summary

- Market Trends
 - Automatics are gaining market share globally
 - Manual transmission production is lower than automatics
- Stepped Automatics (AT) are still the majority for automatics
 - ATs are gaining more gears – most will be 8, 9 and 10-speeds
 - Major manufacturers are Ford, GM and ZF
- CVT and DCT are taking market share away from AT
- Automatic transmission fluids are shifting to lower viscosity to aid in fuel economy
- More Universal ATF products are making their way into the marketplace



AT Hardware & ATF Performance Requirements



Stepped Planetary Automatic Transmission

Hardware

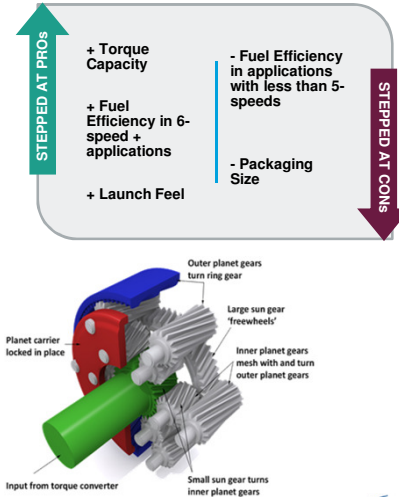
- **Planetary Gearset** – gear ratio control
- **Torque Converter** – fluid-coupling to transfer power from engine to transmission
- **Clutch Packs**
- **Valve-Body**

Market

- Most common automatic transmission globally

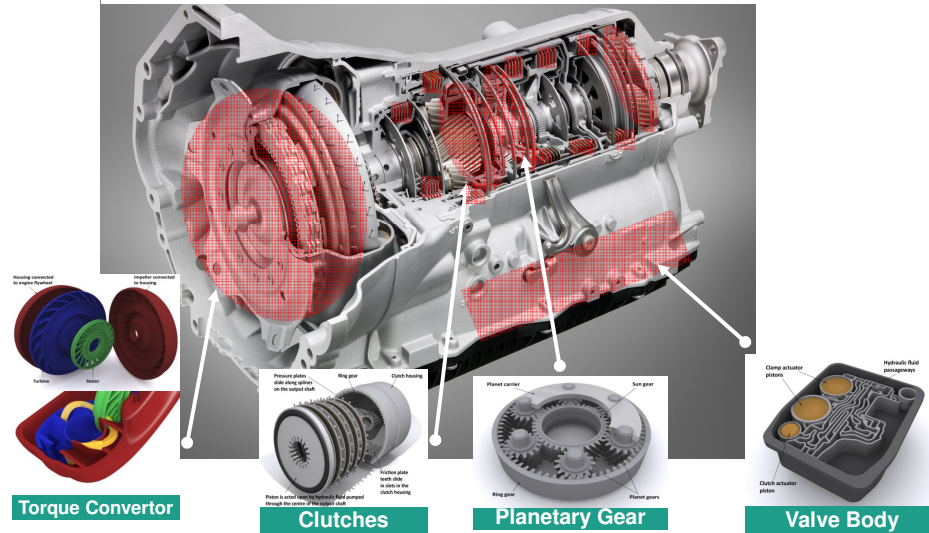
Manufacture

- GM Hydra-Matic was the first mass-produced fully automatic planetary AT



Automatic Transmission Hardware

Photo source: BMWBLOG.COM



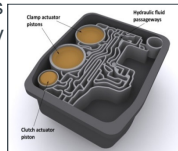
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Automatic Transmissions Hydraulics

Hydraulic System

- Components
 - Valve body
 - Pump
 - Filter
 - Cooler



- Used to pressurize piston plate for clutches
- Used to move band-activation pistons up and down

ATF requirements

Act as a Hydraulic Fluid

Antifoam properties

Large operating range
(-40C to 175C)

Resist oxidation

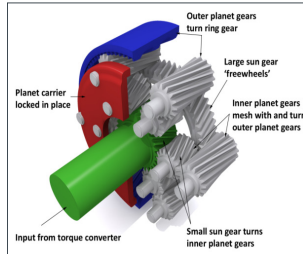
Remove Heat Efficiently

Ensure seal performance

16

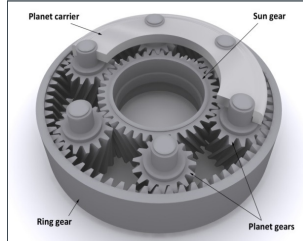
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Automatic Transmission Gear Reduction



Planetary Gearsets

- Three Main Components
 - Sun Gear
 - Planet gears (and carrier)
 - Ring Gear
- Any one of these components can be locked in place; more importantly, any one can be an input or output drive
- Different gear ratios possible from one planetary gear set



Planetary Gear

ATF requirements

Provide anti-wear performance

Shear Stability

Corrosion protection

Automatic Transmissions Clutches

Shifting

- Plate Clutches
- Band Clutches



Fuel Economy

- Torque Converter Clutches



Automatic Transmission Clutches Plate and Band Clutches

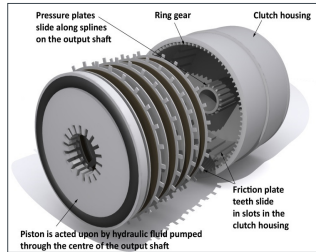
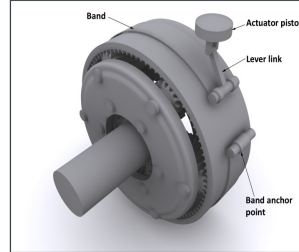


Plate Clutch



Band Clutch

ATF requirements

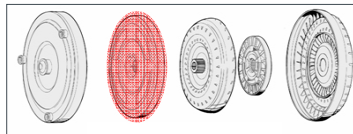
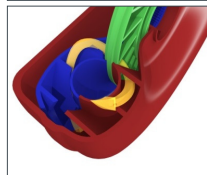
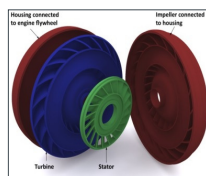
Remove heat efficiently

Resist oxidation

Deliver specialized friction requirements



Automatic Transmission Torque Converter



Torque Converter Lock-Up Clutch

Torque Converter Clutch

- Large energy loss without clutch
- Clutches added in 1970s to improve fuel economy
- Full lock-up at highway speeds
- Lock-up clutch evolved for improved comfort and additional fuel economy benefits
- Slipping clutch at low speeds

ATF requirements

Act as a Hydraulic Fluid

Large operating range (-40C to 175C)

Deliver specialized friction requirements



Torque Converter Clutch Friction Deterioration → Shudder

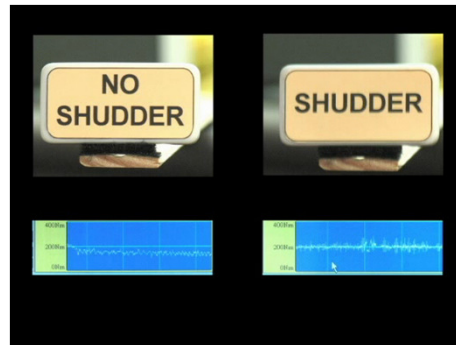


Sh-h-h-udder Occurs!

Self-Excited Driveline Vibration

ATF must:

Deliver specialized friction requirements



ATF Performance Requirements

Act as a Hydraulic Fluid

Corrosion protection

Provide Anti-wear performance

Antifoam properties

Remove heat efficiently

Large operating range
(-40°C to 175°C)

Ensure transmission seal performance

Resist oxidation

Shear Stability

Deliver specialized friction requirements



Stepped Automatic Transmission Summary

The automatic transmission has 4 major components:

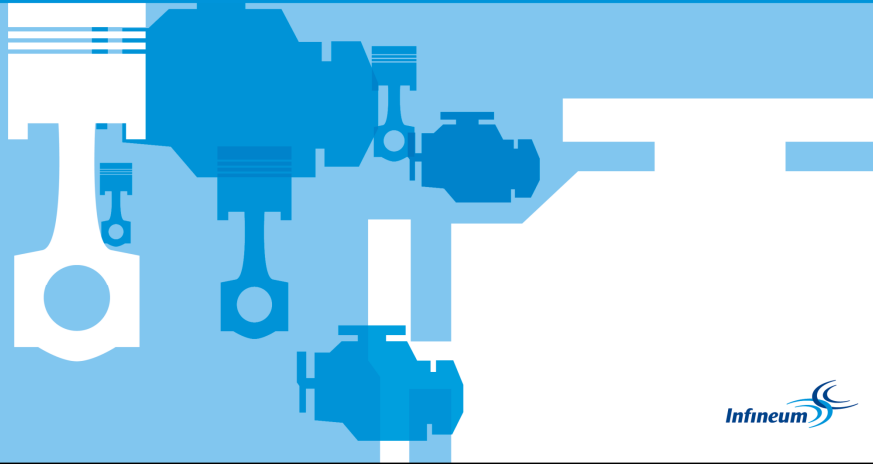
1. Torque Converter – transfer power from engine to transmission
2. Planetary Gear Set – changes output speed
3. Valve Body – the “brain” of the transmission
4. Clutches (plate or band) – changes gear ratios

The fluid needs to do the following:

1. Act as a hydraulic fluid
2. Protect the Gear Set (Anti-Wear)
3. Remove heat efficiently
4. Ensure seal performance
5. Resist oxidation
6. Protect against corrosion
7. Deliver specialized Friction Characteristics



Fluid Trends and Testing Automatic Transmission Fluids



25

Key Performance Tests for ATF

Viscometrics

Kinematic viscosity @ 100°C
(KV100)

Brookfield viscosity @ -40°C
(BF-40)

Shear stability 20hrs KRL
(KV100 and apparent viscosity),
Sonic Shear

Performance

Lubrication of transmission
parts at high temperature

Transmission operability at cold
temperatures - *cold morning
start*

Ensures aged ATF adequately
lubricates transmission parts



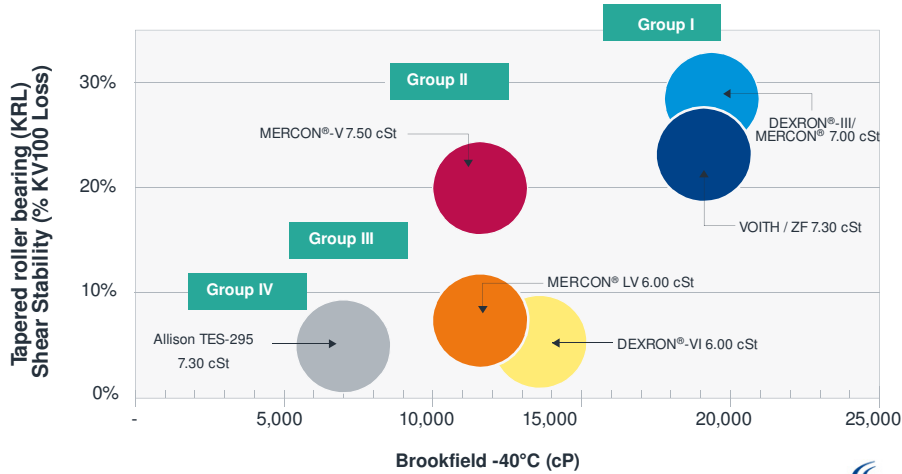
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Viscometric Trends

Performance you can rely on.

ATF Shear Stability vs. Low Temperature Viscosity



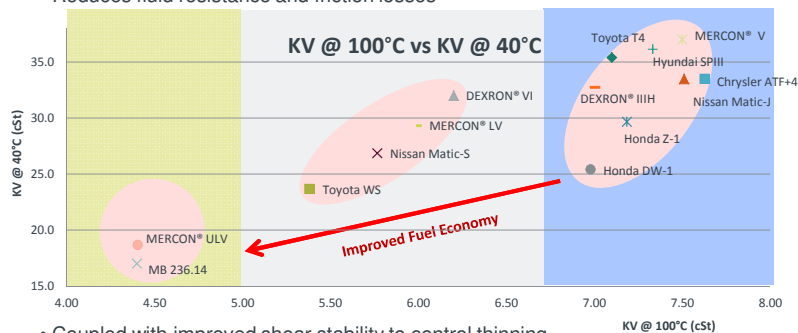
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New Generation ATFs Lower Viscosity for Fuel Economy

Performance you can rely on.

Latest 6+speed transmissions use lower viscosity ATF

- Reduces fluid resistance and friction losses



- Coupled with improved shear stability to control thinning

Some OEMs replacing high-vis ATF with low-vis ATF

- Others maintain two specs – notably Ford, Hyundai and Toyota

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Key Performance Tests for ATF

Oxidation

Aluminum Beaker Oxidation Test (ABOT) - Ford

Turbo Hydra-Matic Oxidation Test* (THOT) - GM

Indiana Stirring Oxidation Test (ISOT) - Asia Pacific OEMs

CEC L-48-A-00 (A), DKA Oxidation Test – European OEMs

Performance

Chain scission → Loss of lubrication

Viscosity increase → Sluggish operation

Sludge formation → Clogged valve body

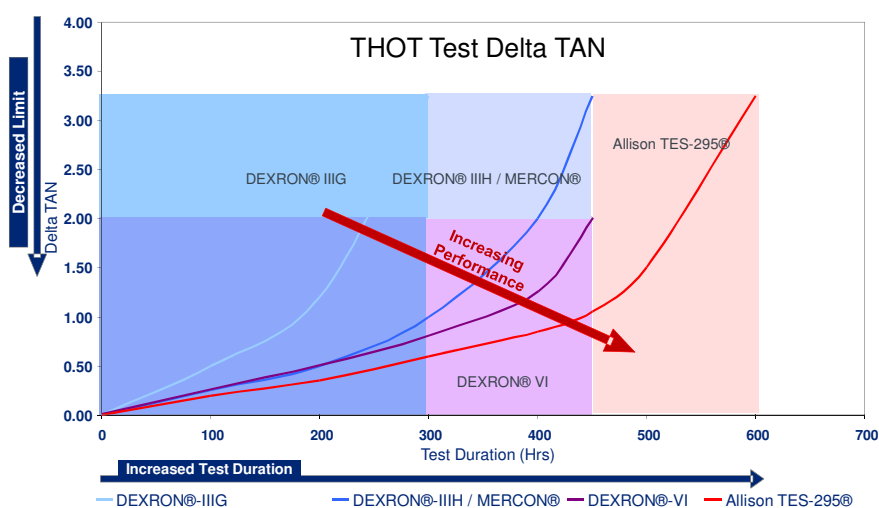
Acid formation → Corrosion

Friction Modifier attack → Poor shifting

*GM THOT has been made obsolete



Trends in Oxidation Performance



Key Performance Tests for ATF

Clutch Friction

Shifting Clutch

- SAE#2 Friction and Anti-Shudder Durability (ASD) rig – US and Asia Pacific OEMs
- Band Friction test – GM
- Plate Friction test – GM and Ford
- Cycling test – GM

Torque Converter Clutch

- Low Velocity Friction Apparatus (LVFA) for ASD – Asia Pacific OEMs

Performance

Shifting Clutch

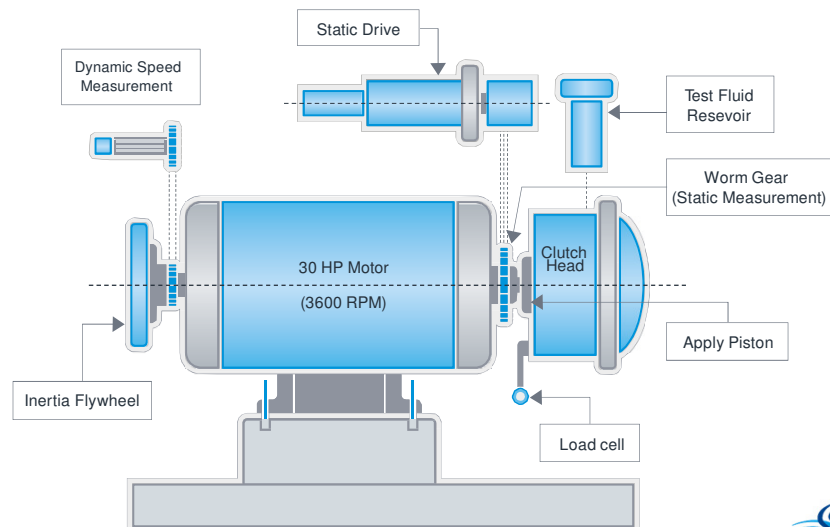
- Abrupt, harsh shift
- Elongated shift and potential slippage
- Gives clutches good holding power, high transmission capacity

Torque Converter Clutch

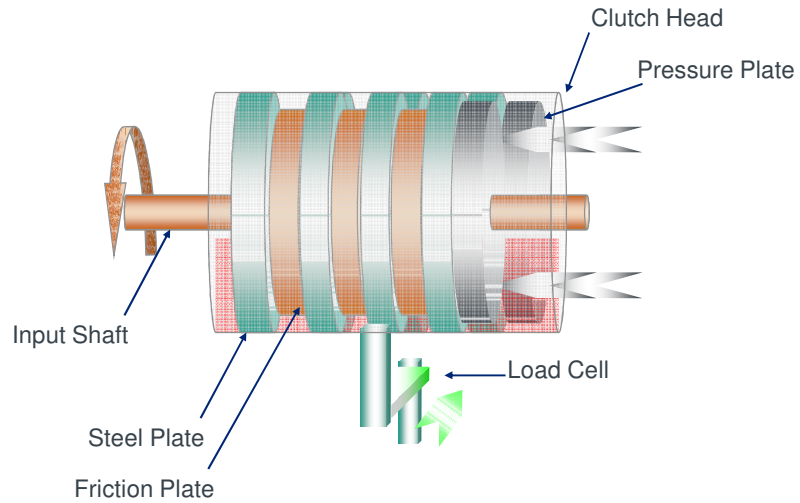
- Anti-Shudder durability



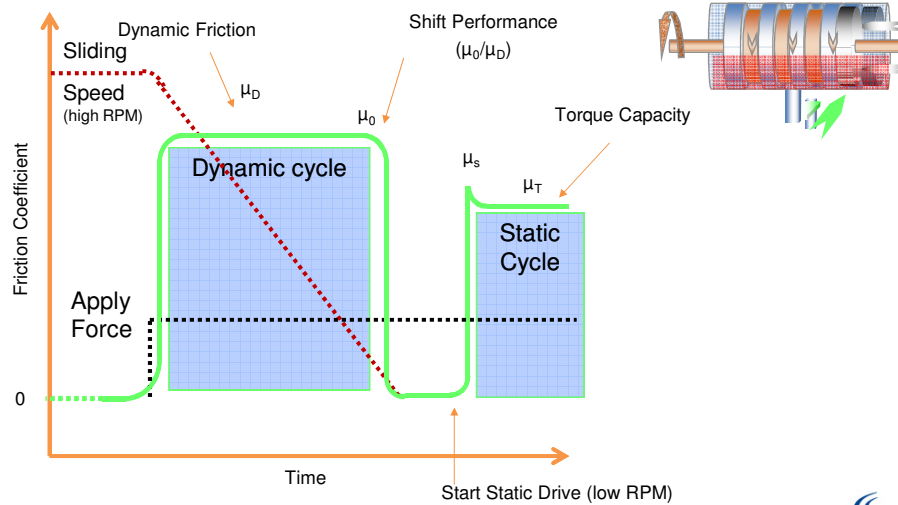
SAE No. 2 Friction Test Machine



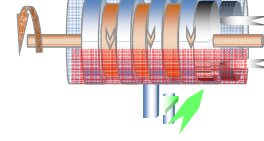
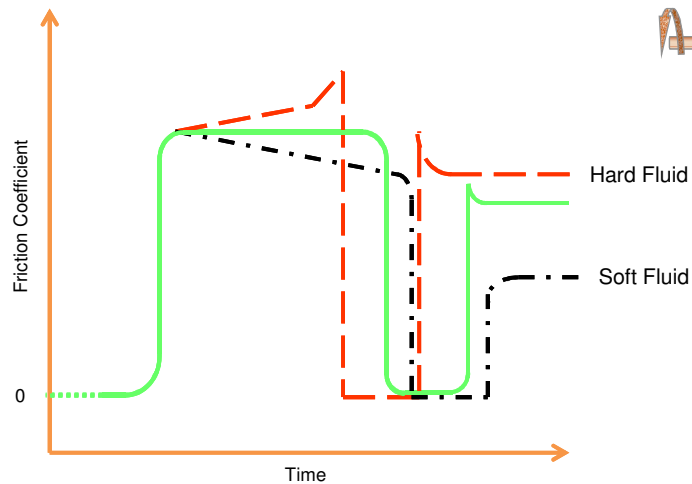
SAE No. 2 Friction Test Machine Clutch Head



Output From SAE No. 2 Friction Test Machine



Output From SAE No. 2 Friction Test Machine



Desirable Clutch Friction Fluid Performance

Dynamic friction (μ_D) → high, flat

- Short shift minimizes energy transfer to fluid

Low speed friction (μ_0) → slight decrease

- High value - abrupt, harsh shift
- Low value - elongated shift and potential slippage

Static friction (μ_T) → high

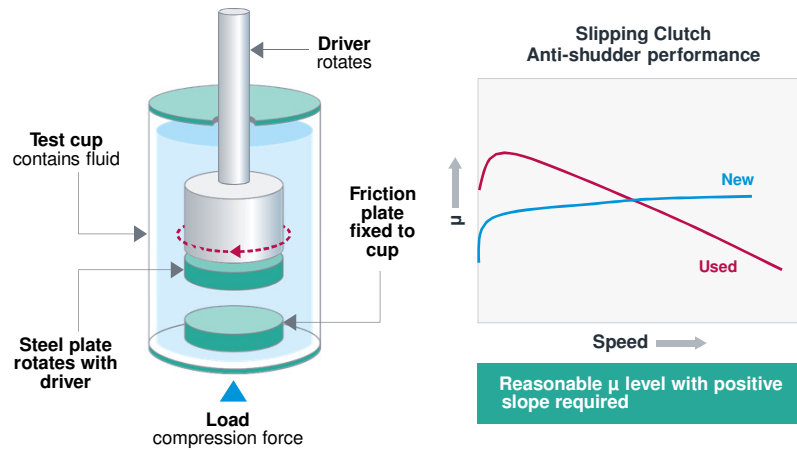
- Gives clutches good holding power, high transmission capacity

Trend

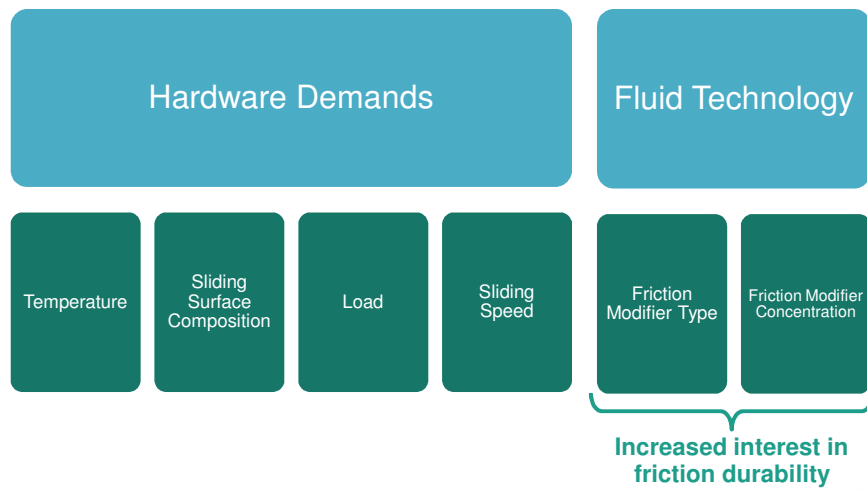
- Increase friction durability



Low Velocity Friction Apparatus (LVFA)



What Affects Friction?



ATF Performance Summary

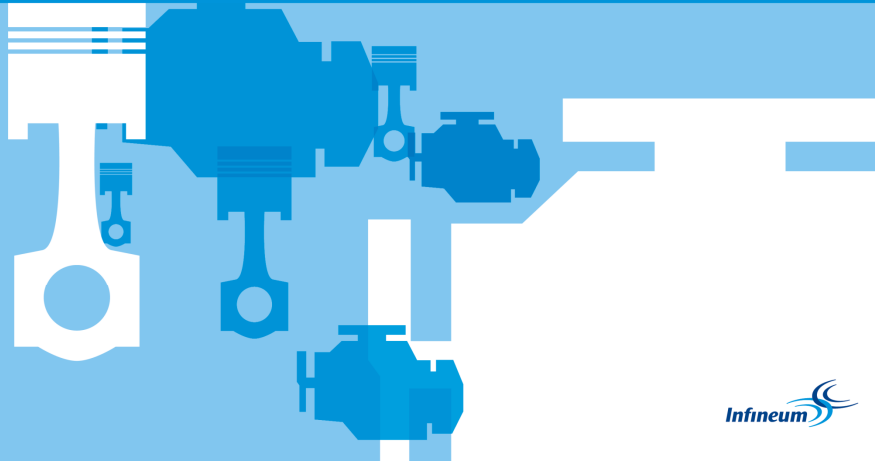
ATF must meet exacting requirements for a variety of parameters

Key Performance Attributes










- Viscometrics
- Oxidation resistance
- Friction stability and durability



ATF Service-Fill Specifications



Passenger Car ATF Specifications

	OEM	High Viscosity	Low Viscosity	Ultra Low Viscosity
North American OEMs		MERCON® MERCON® V	MERCON® LV	MERCON® ULV
		ATF +3® ATF +4®	948TE	-
		DEXRON® II DEXRON® III	DEXRON® VI DEXRON® HP	-
European OEMs		MB 236.10	MB 236.12	MB 236.14
		Lifeguard 5	Lifeguard 8	-
Asia Pacific OEMs		Toyota T-IV	Toyota WS	-
		Matic J/K	Matic S	-
		Honda Z-1	Honda DW-1	-
		Hyundai SP-III	Hyundai SP-IV	-

*Bolted specifications are open to licensing

Key JAMA Requirements

As many ATF specifications are not available for public licensing, many OEMs recognize JASO testing requirements for ATFs.

JASO Specifications

- JASO 1-A₁₃ – Standard JASO ATF specification
- JASO 1-A₁₃-LV – Low Viscosity (6.5 cSt max)
- JASO 2-A₁₃ – JASO 1-A₁₃ without ASD Performance

Shear Stability

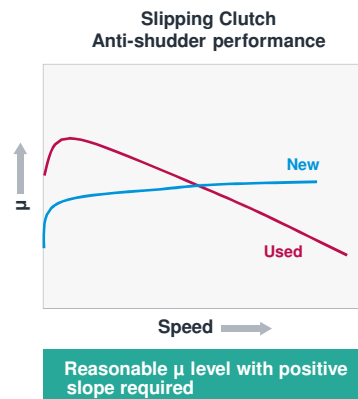
- Method: JASO M347
- Requirements: KV100 after shear 5.2 min

Friction Characteristics (Shifting Clutch)






- Method: JASO M348 SAE#2 (NW-461E)
- Requirements: Torque capacity, Dynamic friction stability, and shift performance

Anti-Shudder Performance (Torque Converter Clutch)

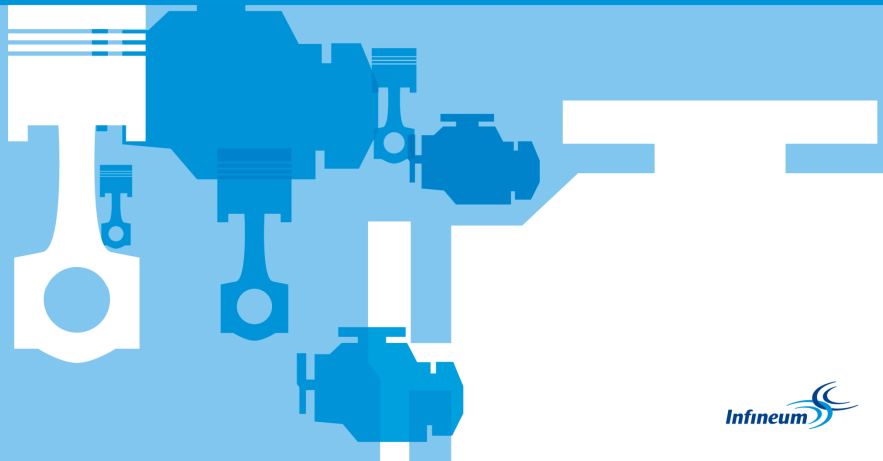
- Method: JASO M349 LVFA (D-0600-02)
- Requirements: Durability of positive m-V slope



Heavy-duty ATF Specifications

OEM	Region / Type	Standard Drain Interval	Intermediate Drain Interval	Long / Extended Drain Interval
	1000/2000, 3000, and 4000 Series	Allison TES-389™	-	Allison TES-295® Allison TES-468™
	H 40 EP™ H 50 EP™	-	-	Allison TES-468™
	5000, 6000, 8000, and 9000 Series	Allison TES-439™	-	Allison TES-353™
VOITH	North America	Service Bulletin 13 & 118 Standard Drain (36K mi)	-	Service Bulletin 13 & 118 Long Drain (72K mi)
	Europe	G607 – H55.6335xx Standard - 60,000 km	-	G1363 – H55.6336xx Long - 120,000 km
	EcoMat	ZF TE-ML 14A 30,000 km	ZF TE-ML 14B 60,000 km	ZF TE-ML 14C 120,000 km
	EcoLife	ZF TE-ML 20B 60,000 km	-	ZF TE-ML 20C 120,000 km
	All	339 Type V1/Z1	339 Type Z2/Z11	339 Type V2/Z3/Z12
	All	STD 1273,40 – Trucks STD 1273,41 – VCE	-	STD 1273,42 – VCE
	All	MB 236.7 MB 236.9	-	-

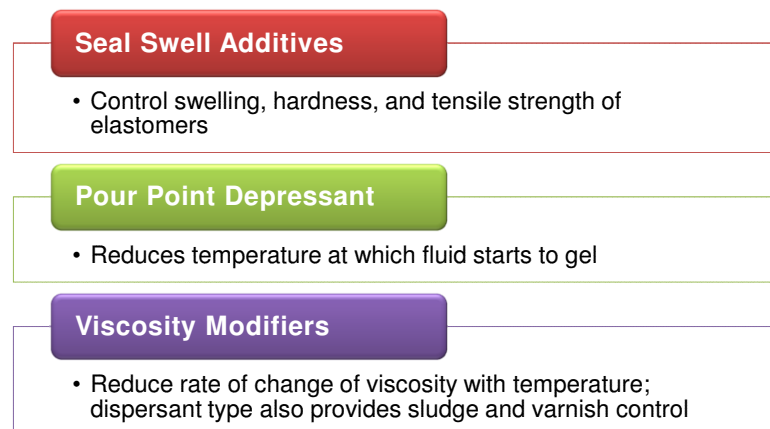
ATF Formulations



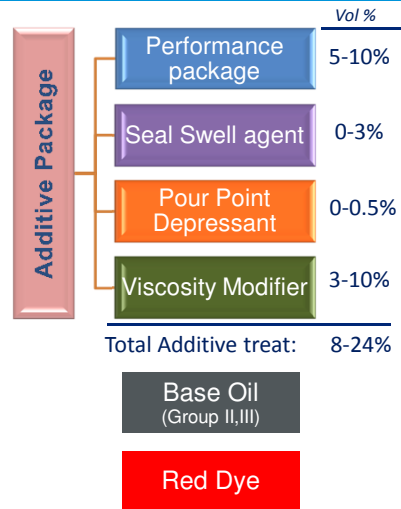
Typical ATF Additives



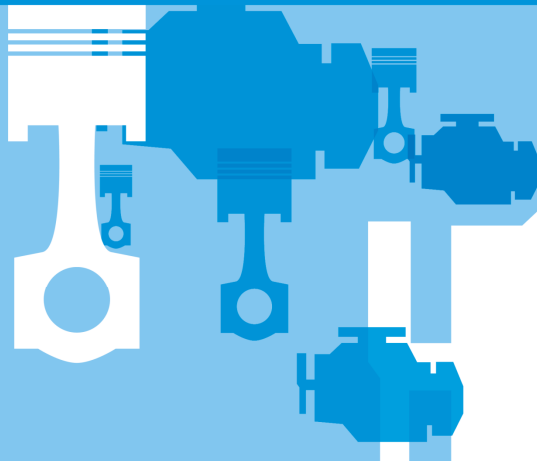
Typical ATF Additives



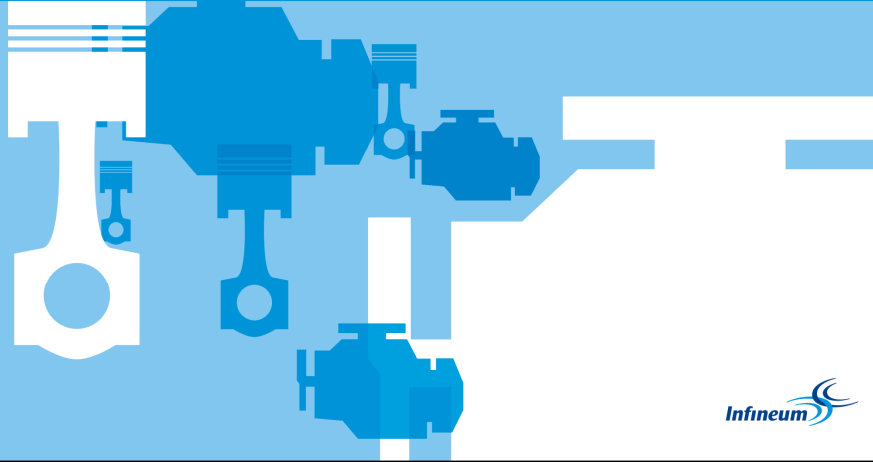
Typical ATF Additive Treat Levels



Other Automatic Transmissions



Dual Clutch Transmissions (DCT)



GETRAG DCT Video



Dual Clutch Transmissions Technology Update

Hardware

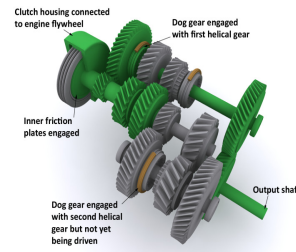
- Combines elements of both manual and automatic transmissions

Market

- DCT currently attracting great interest
- Especially in Europe where market share projections approach 20% by 2020

Manufacture

- First commercial transmission introduced by VW
- Driven by fuel efficiency and driver comfort



DCT Pros

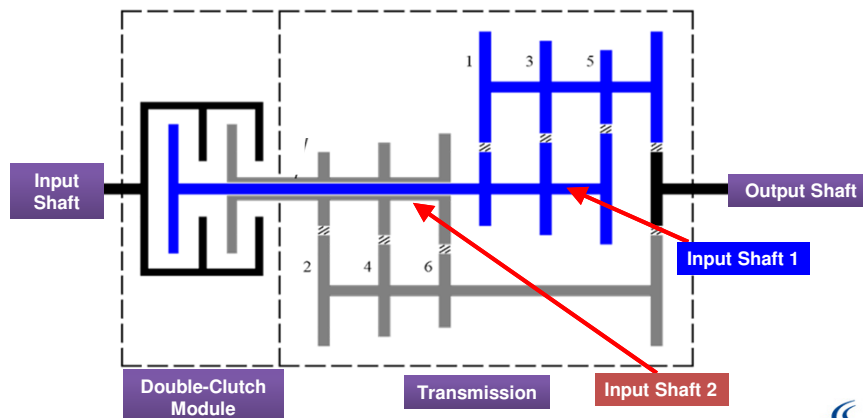
- + Fuel Efficiency
- + Shift Feel
- + MT manufacturing (EU)

DCT Cons

- Launch feel may be not as smooth as stepped AT

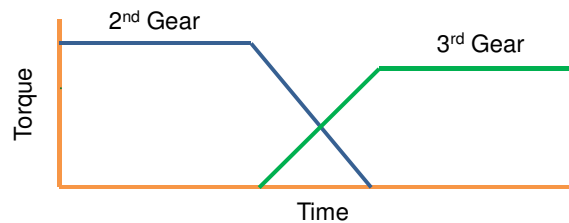
Dual Clutch Transmissions How They Work

- 2 input shafts are connected to two different clutches
 - 1,3,5 gears are connected to one
 - 2,4,6 gears are connected to the other



Dual Clutch Transmissions How They Work

- Consecutive gears can be “synchronized,” but only one gear is connected to engine via active clutch
 - e.g; While 2nd gear is synchronized and engaged, 3rd is “synchronized” and disengaged.
- To change from 2nd gear to 3rd gear, the secondary clutch opens (disengages) while the primary clutch closes (engages)
 - Shortest shift time of any production transmission type



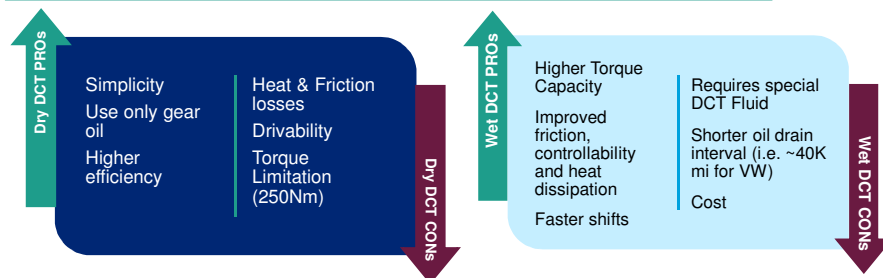
Dual Clutch Transmission Technology Trends Wet and Dry Clutch Systems

Dry-DCT Applications

- Used in medium segment car market
- Torque limitation of 250Nm

Wet-DCT Applications

- Used in high torque demanding vehicles to improve heat dissipation and friction performance.
- Also finds application with very small engines, where heat dissipation is critical



DCT Fluid Requirements

Dry-DCT Fluid Requirements

- Gear Pitting protection
- Friction and wear control for synchronizers
- Corrosion resistance
- Material compatibility
- Oxidation control
- **Manual Transmission Fluids can typically meet dry clutch DCT needs**

Wet-DCT Fluid Requirements

- Same as for Dry DCT, but adding / balancing Clutch Friction control and Anti-Shudder Durability



DCT Summary

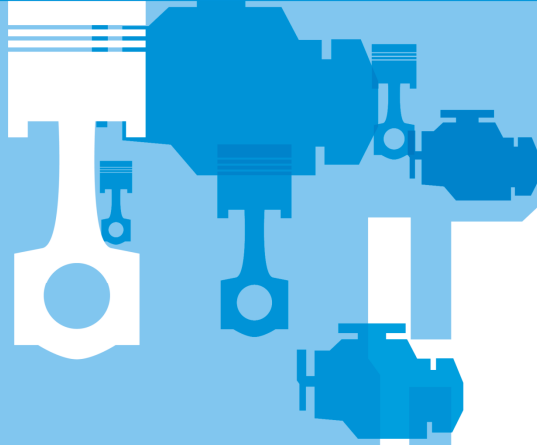
Dual Clutch Transmissions are essentially manual transmissions that can shift automatically

DCT Fluids need to have the following properties

1. Gear Pitting protection
2. Friction and wear control for synchronizers
3. Corrosion resistance
4. Material compatibility
5. Oxidation control
6. Adding / balancing Clutch Friction Control
7. Anti-Shudder Durability

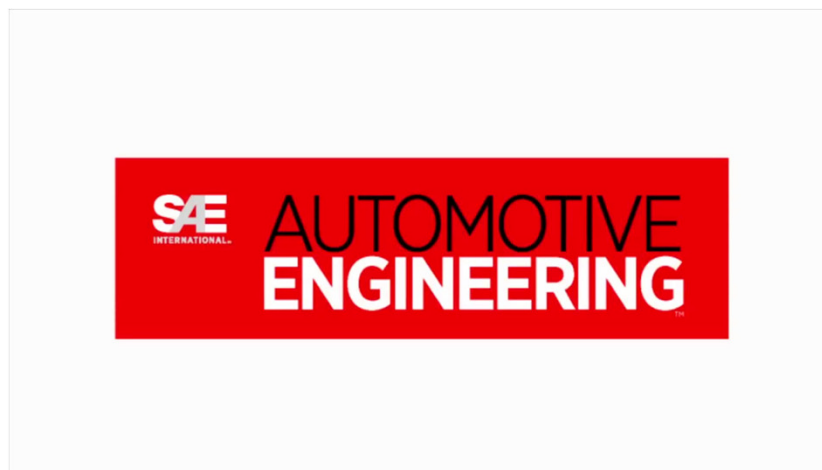


Continuously Variable Transmissions (CVT)



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SAE CVT Video



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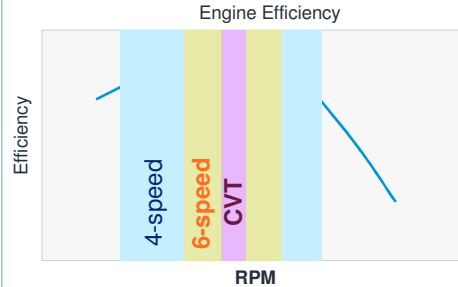
Continuously Variable Transmissions Hardware

Variator

- Key component allowing continuous step-less change in gear ratio
 - Engine run at optimum efficiency
 - Fuel economy and performance
- Smooth power delivery, no 'shift shock'
- Driving performance – minimum power loss during ratio changes

Types

- Steel belt – push or pull belt types
- Toroidal – traction drive
- Hydromechanical – combination of hydraulic and mechanical



OEMs Using CVTs Today

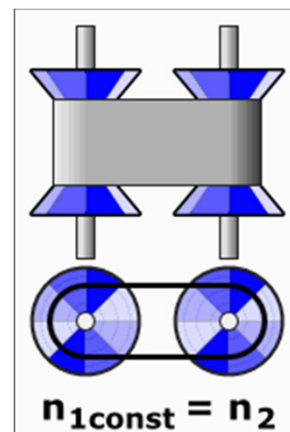
- Nissan
- Subaru
- Honda
- Toyota
- Audi
- Ford
- GM



Continuously Variable Transmissions Variator System

Metal 'V-belt' and Conical Pulley System

- Gear reduction ratio = R_o / R_i
 - Defined by radius of belt travel on pulley
- High clamping forces prevent belt from slipping
- Radius of belt travel controlled by width of pulley



Nissan CVT Video

<http://youtu.be/GLNqzn7WgDQ?t=31s>

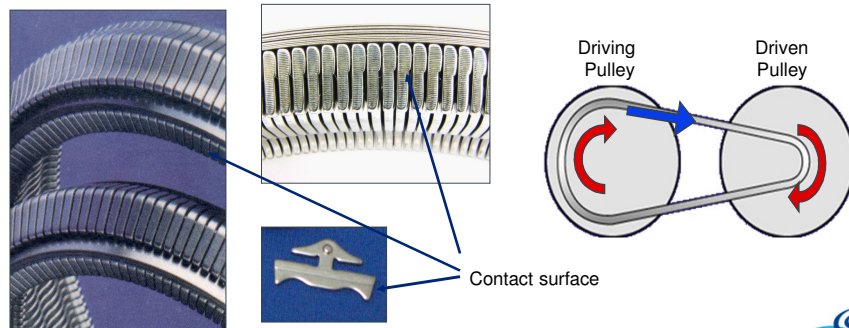
<http://www.nissanusa.com/content/dam/nissan/vehicles/2013/pathfinder/colors-photos/videos/cvt.mp4>



Continuously Variable Transmissions

VDT – Push Belt

- Developed by Van Doorne Transmissie (VDT)
- Push belt consists of ~300 steel blocks connected by flexible steel rings
- Force transmitted from pulley to pulley via compressional forces between belt elements



Continuously Variable Transmissions

LuK chain – Pull Belt

- Chain links joined by rocker pins
 - Pulley clamping force acts on rocker pin ends
- Force transmitted by tension on chain links



Subaru Chain CVT Transmission Video:
<http://www.subaru.com/engineering/transmission.html>



Continuously Variable Transmissions Fluid Requirements

Steel-on-Steel Friction

- Wear control
- Fatigue and sliding wear control

Shear Stability

- High pressure pumps shear fluids aggressively

Oxidation Stability

- CVTs run hot
- Fill for life application

Paper-on-Steel Friction

- Starting clutch, torque converter clutch, forward-reverse clutch

All other conventional ATF properties

- Hydraulic performance, antifoaming, transmission coolant, seal compatibility, non-corrosive



CVT Fluid Technology Typical Properties – Commercially Available Fluids

- No public specifications exist for CVT Fluids
- Typical properties of commercially available CVT Fluids for VDT:

Properties	Typical Values
Kinematic Viscosity at 100°C	~ 7.00 cSt
Viscosity Index	~200
Brookfield at -40°C	<9,000 cP
Shear Stability	<10% shear Loss KV100
Typical Elements	B, P, Ca (high level), some have Zn or Mg
Cu Corrosion	1b
Oxidation Stability	Exceed JASO 1A
4 Ball Extreme Pressure	Welding Load ~160 kg; Load Wear Index ~30
JASO Anti-Shudder Durability	Durability less than 100 hours
JASO Clutch Friction M348	MuD Change: ~10% Max. Mu0/MuD: 0.91 – 1.12 Min MuT: ~0.11
Steel on Steel (SOS) Friction	0.11 – 0.13 for NS-2, TC, HCF-2, Audi CVTF, ZF CVTF 0.09 – 0.11 for HMMF

VDT: Van Doorne Transmissions

CVT Summary

- A CVT has few parts compared to other automatic transmission types
 - Uses two variator pulleys and a belt or chain instead of a planetary gear set
 - Has a continuum of gear ratios rather than discrete steps of ratio
- CVTs allow for a smoother power delivery
 - Power can be optimized for acceleration or fuel economy
- CVTs cannot handle higher torque applications
- CVT Fluid needs to do everything a normal ATF does, but with steel-on-steel friction performance as well



Fluid Requirements Comparison CVTF vs DCTF vs ATF

OEM Requirements	CVTF	DCTF	ATF
Steel on Steel Friction	✓	✗	✗
Wear Protection	✓	✓	□/✓
Paper on Steel Friction	□/✓	✓	✓
Shear Stability	✓	□	□
Oxidation	✓	✓	✓
Air-release	✓	✓	✓
Gear Protection	□	✓	✓

✓ : Major □ : Minor ✗ : Not Required



Automatic Transmission Fluids Summary

Transmission Trends

- Stepped planetary transmissions remain predominant
 - Increase in gear ratios to improve fuel economy
 - Reduced size and weight
 - Aggressive slipping clutch
- Nonconventional transmissions gain market share
 - CVT growth in Asia and North America
 - DCT growth in Europe



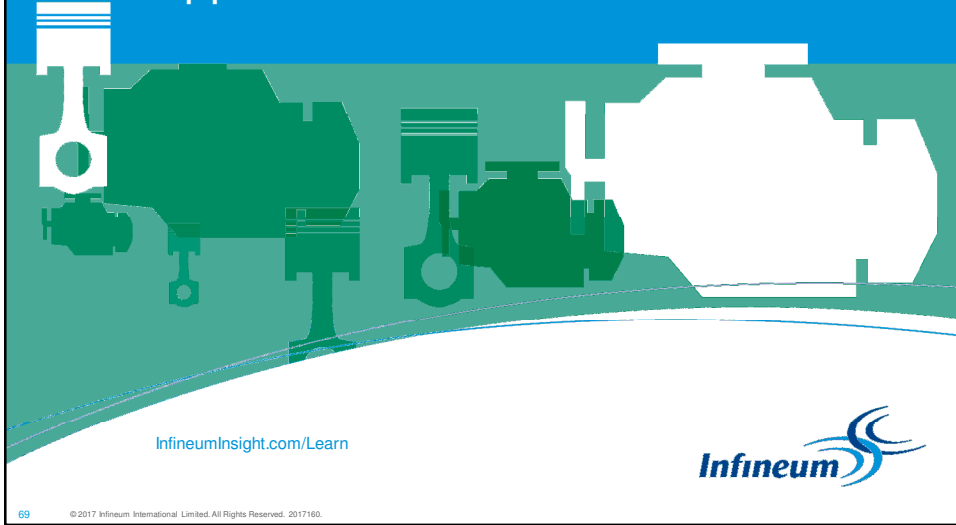
Automatic Transmission Fluids Summary

Fluid Trends

- OEMs specify ATF with:
 - Exact friction requirements
 - Anti-shudder durability
 - Friction Durability
 - Specific viscosity and shear stability requirements
 - Better oxidation performance for longer drain intervals
- Low Viscosity ATF becoming more predominant
 - Improved fuel economy
 - Longer oil drain intervals
- Service-Fill market preference towards Multi-Vehicle ATF
- CVTs and DCTs require genuine OEM fluids

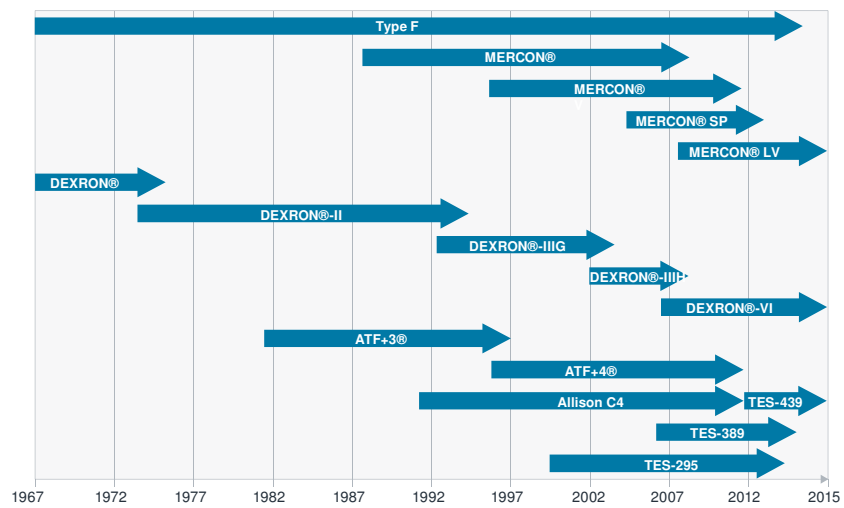


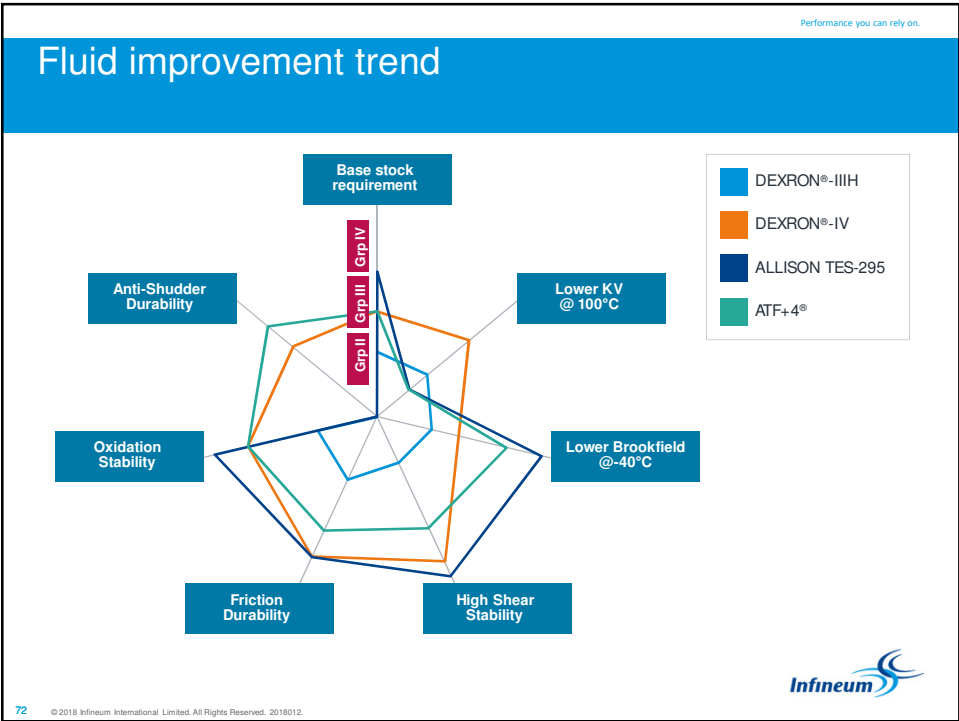
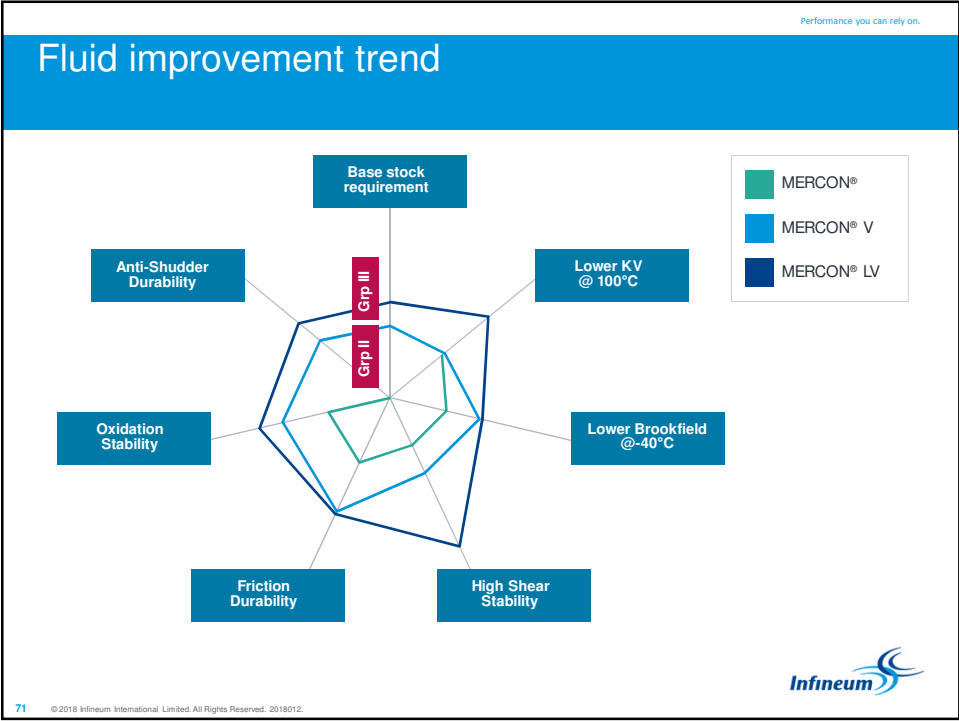
Appendix



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ATF specifications: US OEMs







ATF specifications – Asia Pacific OEMs

- No OEM specifications available to public
 - Hardware designs and fluid requirements confidential
 - Common requirements can be seen through industry activities: JASO

OEM	JASO 1A	Minimum Performance
Toyota	Type T-III Type T-IV Type WS	Good ASD Long ASD Long ASD, Low Vis 6-spd
Nissan	MATIC D MATIC J MATIC K MATIC S	No ASD 4-spd Long ASD Long ASD FWD 5-spd Long ASD, Low Vis, RWD 5,7-spd
Honda	ATF-Z1 DW-1	AT High VI ATF
Hyundai / Kia	SP-III SP-IV	Long ASD Long ASD, Low Vis 6-spd



Key JAMA requirements

Shear Stability

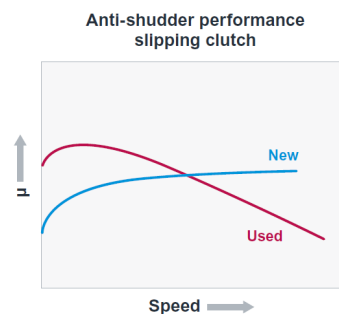
- Method: JASO M349-95 Sonic
- Requirements: KV100 after shear 5.7 minimum
 - ~20% max vis. loss when fresh fluid KV100 is 7.1

Friction Characteristics (Shifting Clutch)

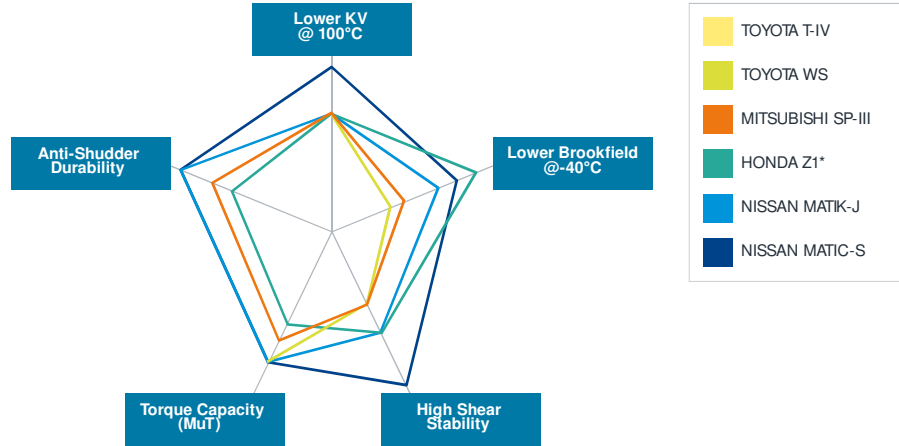
- Method: JASO M348-2002 SAE#2 (NW-461E)
- Requirements: Torque capacity, Dynamic friction stability, and shift performance

Anti-Shudder Performance (Torque Converter Clutch)

- Method: JASO M349-2001 LVFA (D-0512)
- Requirements: Durability of positive m-V slope



Fluid improvement trend



*Honda Z1 performance suggests hardware uniqueness



Oxidation test in ATF – ABOT

- Aluminum Beaker Oxidation Test (ABOT) is a bench test required for official Ford MERCON® and MERCON® V ATF qualification
 - Immersed in beaker circulates and shears test fluid
 - External heaters maintain fluid temperature of 155°C (311°F)
 - External air pumped into gear pump
 - Metal catalysts submerged in fluid to evaluate fluid's tendencies to attack metals, such as lead, copper, and aluminum.
 - Fluid samples drawn at intervals throughout test and at end of test, and analyzed for
 - Pentane insolubles, 300 hours max %
 - Differential IR carbonyl absorbance, 300 hours max per cm
 - Total acid number change, 300 hours max
 - Viscosity change, 300 hours max %



Oxidation test in ATF – THOT (or GMOT)

- Turbo Hydra-matic Oxidation Test is designed to evaluate an automatic transmission fluid's oxidation resistance, thermal stability and material compatibility characteristics; required for official GM DEXRON® ATF qualification
 - 7.5 kW electric motor and GM 4L60E Electronic Transmission
 - 450 hours steady state
 - Test fluid temperatures maintained at 163°C (325°F)
 - External air pumped into transmission
 - Fluid samples drawn at intervals throughout test and at end of test, and analyzed for
 - Products of oxidation
 - TAN increase
 - Differential IR
 - Viscosity increase
 - Wear metals
 - End of test evaluation includes used fluid analysis and transmission component rating for sludge accumulation



Oxidation test in ATF – DKA

- DKA (or CEC L-48-A-95 method) is mostly used in Europe
 - Test tube 100 ml of fluid sample
 - Air flow 5L/hr
 - Test fluid temperatures maintained at 150°C – 170°C
 - Test duration: 192 hrs
 - Fluid samples drawn at intervals throughout test and at end of test and analyzed for
 - Change in KV40°C and KV100°C
 - TAN increase
 - Differential IR
 - Insoluble content and varnish deposit



Oxidation test in ATF – ISOT

- Indiana Stirring Oxidation Test is designed to evaluate an automatic transmission fluid's oxidation resistance, thermal stability, and material compatibility characteristics; mostly used in Japan
 - Test tube 250 ml of fluid sample
 - Temperature can vary (150-165°C); SOP is 165.5°C (+/-0.5°C)
 - Test duration can range from 48 hrs to 500 hrs; SOP is 96 hrs
 - Stirrer RPM at 1300 rpm (+/- 15)
 - Steel and copper catalyst ring added to sample during testing
 - Change in KV100°C, KV Ratio
 - TAN increase
 - Differential IR, @carbonyl (1725 cm⁻¹)
 - Copper corrosion
 - Varnish stick rating



Ford and GM specification comparison

	100°C Viscosity	-40°C Brookfield	Shear stability	Oxidation	Friction durability	Anti-shudder durability ◇
MERCON® V	6.8 cSt MIN	13,000 cP MAX	6.0 cSt MIN (20hr KRL)	+	++	+
MERCON® LV*	6.2 cSt MIN	13,000 cP MAX	5.5 cSt MIN (20hr KRL)	++	+++	++
DEXRON® - VI	6.4 cSt MAX	15,000 cP MAX	5.5 cSt MIN (40hr KRL)	+++	+++	+

* Predicted since spec not released
 ◇ Material specific



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