Power Transmission Fluids
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
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

**Stepped Automatic**

- **Pro**: + Torque Capacity
  - Fuel Efficiency in 6-speed + applications
  - + Launch Feel

- **Con**: - Fuel Efficiency in applications with less than 5-speeds
  - - Packaging Size

**Dual Clutch**

- **Pro**: + Torque Capacity
  - + Fuel Efficiency
  - + Shift Feel
  - + Can use existing MT manufacturing sites

- **Con**: - Launch feel not as smooth as stepped AT
  - - Can use existing stepped AT sites

**Continuously Variable**

- **Pro**: + Comfort due to no shifting
  - + Acceleration
  - + Fuel Efficiency

- **Con**: - Torque Capacity
  - - Cannot utilize existing stepped AT manufacturing sites

*Performance you can rely on.*
Transmission Trend Drivers

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
Global Transmission Production

Global Transmission Production by Transmission Type

2015

2020

MANUAL

AUTOMATIC

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

- **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

**Source:** IHS
Transmission Hardware Trends
North America Installations – CAFE Impacts

Conventional ATs Being Replaced

Rapid increase in AT forward speeds

Growing foreign AT influence

DATA SOURCE: IHS
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]

- CVT
- DEXRON®-VI
- MERCON® LV
- MERCON® SP
- IMPORT LOW
- IMPORT HIGH
- ATF+4
- MERCON® V
- DIII/M

2012
2020
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

**Pros**

- Torque Capacity
- Fuel Efficiency in 6-speed applications
- Packaging Size
- Launch Feel

**Cons**

- Fuel Efficiency in applications with less than 5-speeds
Automatic Transmission Hardware

Photo source: BMWBLOG.COM

Torque Convertor

Clutches

Planetary Gear

Valve Body

Performance you can rely on.
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
Automatic Transmission Gear Reduction

Planetary Gear

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

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

ATF requirements

- Remove heat efficiently
- Resist oxidation
- Deliver specialized friction requirements
Automatic Transmission Torque Converter

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 (-40°C to 175°C)
- Deliver specialized friction requirements

Torque Converter Lock-Up Clutch
Torque Converter Clutch Friction Deterioration → Shudder

Self-Excited Driveline Vibration

Intermittent Shudder

Continuous Shudder

No Shudder
Sh-h-h-udder Occurs!

Self-Excited Driveline Vibration

ATF must:

Deliver specialized friction requirements
ATF Performance Requirements

- Act as a Hydraulic Fluid
- Provide Anti-wear performance
- Remove heat efficiently
- Ensure transmission seal performance
- Shear Stability
- Corrosion protection
- Antifoam properties
- Large operating range (-40°C to 175°C)
- Resist oxidation
- 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
### Key Performance Tests for ATF

<table>
<thead>
<tr>
<th><strong>Viscometrics</strong></th>
<th><strong>Performance</strong></th>
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<tbody>
<tr>
<td>Kinematic viscosity @ 100°C (KV100)</td>
<td>Lubrication of transmission parts at high temperature</td>
</tr>
<tr>
<td>Brookfield viscosity @ -40°C (BF-40)</td>
<td>Transmission operability at cold temperatures - cold morning start</td>
</tr>
<tr>
<td>Shear stability 20hrs KRL (KV100 and apparent viscosity), Sonic Shear</td>
<td>Ensures aged ATF adequately lubricates transmission parts</td>
</tr>
</tbody>
</table>

Performance you can rely on.
Viscometric Trends

ATF Shear Stability vs. Low Temperature Viscosity

- Group I
  - DEXRON®-III/ MERCON® 7.00 cSt
  - VOITH / ZF 7.30 cSt

- Group II
  - MERCON®-V 7.50 cSt

- Group III
  - MERCON® LV 6.00 cSt

- Group IV
  - Allison TES-295 7.30 cSt
  - DEXRON®-VI 6.00 cSt

Tapered roller bearing (KRL) Shear Stability (% KV100 Loss)

Brookfield -40°C (cP)
New Generation ATFs
Lower Viscosity for Fuel Economy

Latest 6+speed transmissions use lower viscosity ATF

- Reduces fluid resistance and friction losses

KV @ 100°C vs KV @ 40°C

• 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
**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

THOT Test Delta TAN

- DEXRON® IIIG
- DEXRON® IIIH / MERCON®
- DEXRON® VI
- Allison TES-295®

Test Duration (Hrs)

Delta TAN

Increased Test Duration

Increased Performance

Decreased Limit

Decrease Spec. Limit

Increased Test Duration
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

- Dynamic Speed Measurement
- Static Drive
- Test Fluid Reservoir
- Worm Gear (Static Measurement)
- Inertia Flywheel
- 30 HP Motor (3600 RPM)
- Clutch Head
- Apply Piston
- Load cell
SAE No. 2 Friction Test Machine
Clutch Head

Input Shaft
Steel Plate
Friction Plate

Clutch Head
Pressure Plate
Load Cell
Output From SAE No. 2 Friction Test Machine

Dynamic Friction

Shift Performance ($\mu_0/\mu_D$)

Torque Capacity

Apply Force

Dynamic cycle

Static Cycle

Time

Friction Coefficient

Start Static Drive (low RPM)

$\mu_D$

$\mu_0$

$\mu_s$

$\mu_T$
Output From SAE No. 2 Friction Test Machine

- **Friction Coefficient** vs. **Time**
- **Hard Fluid**
- **Soft Fluid**

- Performance you can rely on.
Desirable Clutch Friction Fluid Performance

**Dynamic friction** ($\mu_D$) → high, flat
- Short shift minimizes energy transfer to fluid

**Low speed friction** ($\mu_0$) → slight decrease
- High value - abrupt, harsh shift
- Low value - elongated shift and potential slippage

**Static friction** ($\mu_T$) → high
- Gives clutches good holding power, high transmission capacity

**Trend**
- Increase friction durability
Low Velocity Friction Apparatus (LVFA)

Driver rotates

Test cup contains fluid

Steel plate rotates with driver

Friction plate fixed to cup

Load compression force

Slipping Clutch Anti-shudder performance

Reasonable $\mu$ level with positive slope required
What Affects Friction?

Hardware Demands

- Temperature
- Sliding Surface Composition
- Load
- Sliding Speed

Fluid Technology

- Friction Modifier Type
- Friction Modifier Concentration

Increased interest in friction durability
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

<table>
<thead>
<tr>
<th>OEM</th>
<th>High Viscosity</th>
<th>Low Viscosity</th>
<th>Ultra Low Viscosity</th>
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<tr>
<td>North American OEMs</td>
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<td><strong>MERCON® V</strong>&lt;br&gt;<strong>MERCON® LV</strong>&lt;br&gt;<strong>MERCON® ULV</strong>&lt;br&gt;<strong>ATF +3®</strong>&lt;br&gt;<strong>ATF +4®</strong>&lt;br&gt;<strong>948TE</strong>&lt;br&gt;-&lt;br&gt;-</td>
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<td>European OEMs</td>
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<tr>
<td>Asia Pacific OEMs</td>
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</table>

*Bolded 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-A 13 – Standard JASO ATF specification
- JASO 1-A 13-LV – Low Viscosity (6.5 cSt max)
- JASO 2-A 13 – JASO 1-A 13 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 Convertor Clutch)**
- Method: JASO M349 LVFA (D-0600-02)
- Requirements: Durability of positive m-V slope

Slipping Clutch
Anti-shudder performance

Reasonable $\mu$ level with positive slope required

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Performance you can rely on.
# Heavy-duty ATF Specifications

<table>
<thead>
<tr>
<th>OEM</th>
<th>Region / Type</th>
<th>Standard Drain Interval</th>
<th>Intermediate Drain Interval</th>
<th>Long / Extended Drain Interval</th>
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<td>H 40 EP™</td>
<td>-</td>
<td>-</td>
<td>Allison TES-468™</td>
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<td>Allison TES-468™</td>
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<td>5000, 6000, 8000, and 9000 Series</td>
<td>Allison TES-439™</td>
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<td>Allison TES-353™</td>
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<td>VOITH</td>
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<td>Service Bulletin 13 &amp; 118 Long Drain (72K mi)</td>
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<td>G607 – H55.6335xx Standard - 60,000 km</td>
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<td>EcoMat</td>
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<td>ZF TE-ML 14B 60,000 km</td>
<td>ZF TE-ML 14C 120,000 km</td>
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<td>EcoLife</td>
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<td>-</td>
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<td>339 Type Z2/Z11</td>
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<td>STD 1273,40 – Trucks STD 1273,41 – VCE</td>
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<td>STD 1273,42 – VCE</td>
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<tr>
<td>All</td>
<td>All</td>
<td>MB 236.7</td>
<td>MB 236.9</td>
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</tbody>
</table>
ATF Formulations
Typical ATF Additives

- **Dispersants**
  - Sludge and varnish control

- **Antioxidants**
  - Oxidation control

- **Anti-wear Agents**
  - Planetary gear, bushing, thrust washer, sprag and pump wear control

- **Friction Modifiers**
  - Control clutch plate and band friction
  - Shift feel
  - Control torque converter and clutch friction
  - Prevent shudder

- **Corrosion Inhibitors**
  - Prevent corrosion of bushing and thrust washers
Typical ATF Additives

**Seal Swell Additives**
- Control swelling, hardness, and tensile strength of elastomers

**Pour Point Depressant**
- Reduces temperature at which fluid starts to gel

**Viscosity Modifiers**
- Reduce rate of change of viscosity with temperature; dispersant type also provides sludge and varnish control
Typical ATF Additive Treat Levels

- **Performance package**: 5-10%
- **Seal Swell agent**: 0-3%
- **Pour Point Depressant**: 0-0.5%
- **Viscosity Modifier**: 3-10%

Total Additive treat: 8-24%

- **Base Oil (Group II, III)**
- **Red Dye**
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

Youtube DCT Video - https://www.youtube.com/watch?v=cd10wif87Qk
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

**Dry-DCT PROs**
- Simplicity
- Use only gear oil
- Higher efficiency
- Heat & Friction losses
- Drivability
- Torque Limitation (250Nm)

**Dry-DCT CONs**
- Higher Torque Capacity
- Requires special DCT Fluid
- Shorter oil drain interval (i.e. ~40K mi for VW)
- Faster shifts
- Cost

**Wet-DCT PROs**
- Improved friction, controllability and heat dissipation

**Wet-DCT CONs**
- Used in medium segment car market
- Torque limitation of 250Nm
Performance you can rely on.

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)
SAE CVT Video

Performance you can rely on.
Continuous 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

Engine Efficiency

RPM

4-speed
6-speed
CVT
Continuously Variable Transmissions
Variator System

Metal ‘V-belt’ and Conical Pulley System

• Gear reduction ratio = Ro / Ri
  • 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

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CVT Fluid Technology
Typical Properties – Commercially Available Fluids

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

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

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

<table>
<thead>
<tr>
<th>OEM Requirements</th>
<th>CVTF</th>
<th>DCTF</th>
<th>ATF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel on Steel Friction</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Wear Protection</td>
<td>✓</td>
<td>✓</td>
<td>□/✓</td>
</tr>
<tr>
<td>Paper on Steel Friction</td>
<td>□/✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shear Stability</td>
<td>✓</td>
<td>□/✓</td>
<td>□/✓</td>
</tr>
<tr>
<td>Oxidation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Air-release</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gear Protection</td>
<td>□</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓: 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
ATF specifications: US OEMs
Fluid improvement trend

Base stock requirement

Grp III

Anti-Shudder Durability

Oxidation Stability

Grp II

Friction Durability

Grp I

High Shear Stability

Lower KV @ 100°C

Lower Brookfield @-40°C

MERCON®

MERCON® V

MERCON® LV
Fluid improvement trend

- Base stock requirement
- Anti-Shudder Durability
- Oxidation Stability
- Friction Durability
- High Shear Stability
- Lower KV @ 100°C
- Lower Brookfield @ -40°C

Colors:
- DEXRON®-IIIH
- DEXRON®-IV
- ALLISON TES-295
- ATF+4®
### ATF specifications – HD European OEMs

<table>
<thead>
<tr>
<th>OEM</th>
<th>SPECIFICATION / OIL DRAIN INTERVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZF TE-ML 14 – Ecomat</td>
<td>A. 30,000 km</td>
</tr>
<tr>
<td>(Trucks, Buses)</td>
<td>B. 60,000 km</td>
</tr>
<tr>
<td></td>
<td>C. 120,000 km</td>
</tr>
<tr>
<td>ZF TE-ML 20 – EcoLife</td>
<td>B. 60,000 km</td>
</tr>
<tr>
<td>(Trucks, Buses)</td>
<td>C. 120,000 km</td>
</tr>
<tr>
<td>Voith (EU)</td>
<td>G607 – H55.6335xx: Standard - 60,000 km</td>
</tr>
<tr>
<td></td>
<td>G1363 – H55.6336xx: Long - 120,000 km</td>
</tr>
<tr>
<td>Voith (NA)</td>
<td>Service Bulletin 13: Standard - 36,000 mi</td>
</tr>
<tr>
<td></td>
<td>Service Bulletin 13: Long - 72,000 mi</td>
</tr>
<tr>
<td>MAN 339</td>
<td>Type V1/Z1: Standard</td>
</tr>
<tr>
<td></td>
<td>Type Z2/Z11: Intermediate</td>
</tr>
<tr>
<td></td>
<td>Type V2/Z3/Z12: Long</td>
</tr>
<tr>
<td>Mercedes Benz</td>
<td>Genuine Oil – MB 236.7, MB 236.9</td>
</tr>
<tr>
<td>Volvo</td>
<td>STD 1273,40 – Trucks – Standard Drain</td>
</tr>
<tr>
<td></td>
<td>STD 1273,41 – VCE : 2000 hrs</td>
</tr>
<tr>
<td></td>
<td>STD 1273,42 – VCE : 4000 hrs – Trucks – Extended Drain</td>
</tr>
</tbody>
</table>
ATF specifications: Japanese OEMs

- TOYOTA T-III
- TOYOTA T-IV
- NISSAN
- MITSUBISHI
- HONDA ATP-II
- HYUNDAI SP-III
- MITSUBISHI SP-IV
- HONDA ATP-Z1
- HONDA ATF-
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

<table>
<thead>
<tr>
<th>OEM</th>
<th>JASO 1A</th>
<th>Minimum Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota</td>
<td>Type T-III</td>
<td>Good ASD</td>
</tr>
<tr>
<td></td>
<td>Type T-IV</td>
<td>Long ASD</td>
</tr>
<tr>
<td></td>
<td>Type WS</td>
<td>Long ASD, Low Vis 6-spd</td>
</tr>
<tr>
<td>Nissan</td>
<td>MATIC D</td>
<td>No ASD 4-spd</td>
</tr>
<tr>
<td></td>
<td>MATIC J</td>
<td>Long ASD</td>
</tr>
<tr>
<td></td>
<td>MATIC K</td>
<td>Long ASD FWD 5-spd</td>
</tr>
<tr>
<td></td>
<td>MATIC S</td>
<td>Long ASD, Low Vis, RWD 5,7-spd</td>
</tr>
<tr>
<td>Honda</td>
<td>ATF-Z1</td>
<td>AT</td>
</tr>
<tr>
<td></td>
<td>DW-1</td>
<td>High VI ATF</td>
</tr>
<tr>
<td>Hyundai / Kia</td>
<td>SP-III</td>
<td>Long ASD</td>
</tr>
<tr>
<td></td>
<td>SP-IV</td>
<td>Long ASD, Low Vis 6-spd</td>
</tr>
</tbody>
</table>
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 Convertor Clutch)**
- Method: JASO M349-2001 LVFA (D-0512)
- Requirements: Durability of positive m-V slope
Fluid improvement trend

- **Lower KV @ 100°C**
- **Lower Brookfield @-40°C**
- **Anti-Shudder Durability**
- **Torque Capacity (MuT)**
- **High Shear Stability**

*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

<table>
<thead>
<tr>
<th></th>
<th>100°C Viscosity</th>
<th>-40°C Brookfield</th>
<th>Shear stability</th>
<th>Oxidation</th>
<th>Friction durability</th>
<th>Anti-shudder durability&lt;br&gt;◊</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERCON® V</td>
<td>6.8 cSt MIN</td>
<td>13,000 cP MAX</td>
<td>6.0 cSt MIN (20hr KRL)</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>MERCON® LV*</td>
<td>6.2 cSt MIN</td>
<td>13,000 cP MAX</td>
<td>5.5 cSt MIN (20hr KRL)</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>DEXRON® - VI</td>
<td>6.4 cSt MAX</td>
<td>15,000 cP MAX</td>
<td>5.5 cSt MIN (40hr KRL)</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>

* Predicted since spec not released
◊ Material specific
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