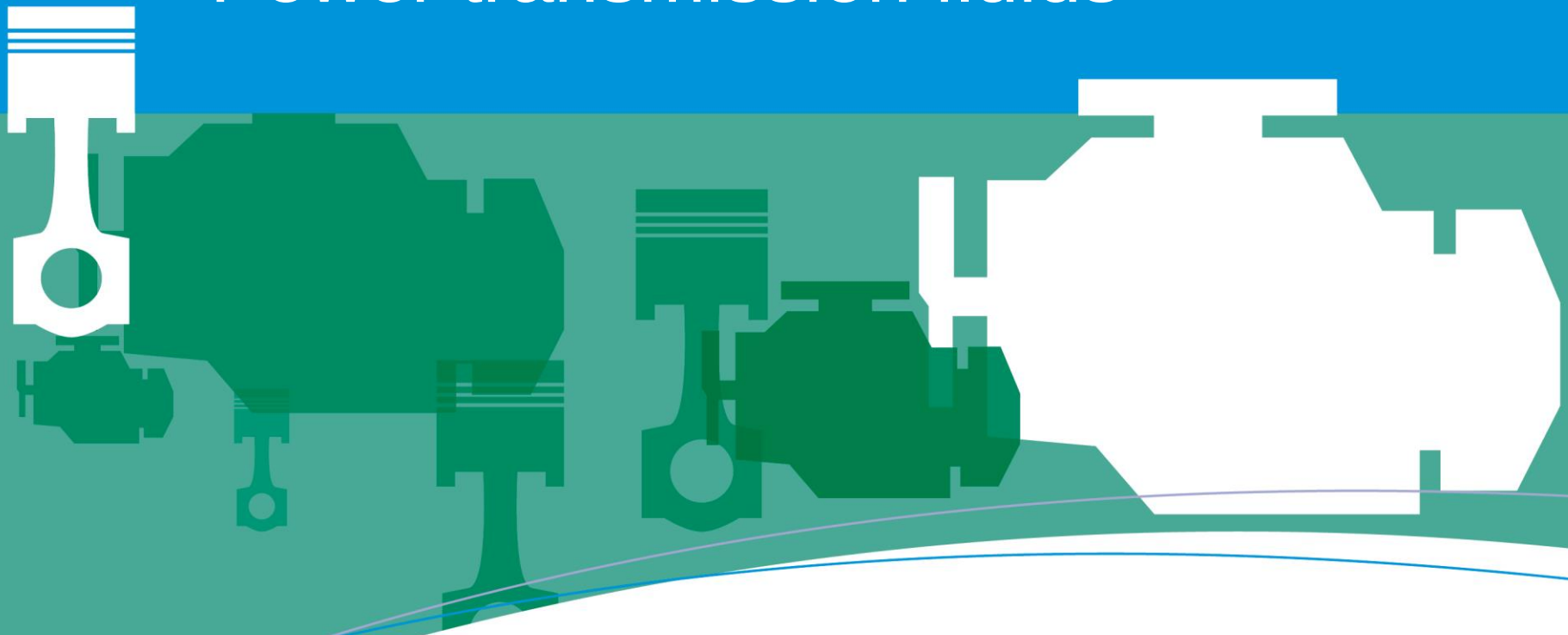
Performance you can rely on.

Power transmission fluids



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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?

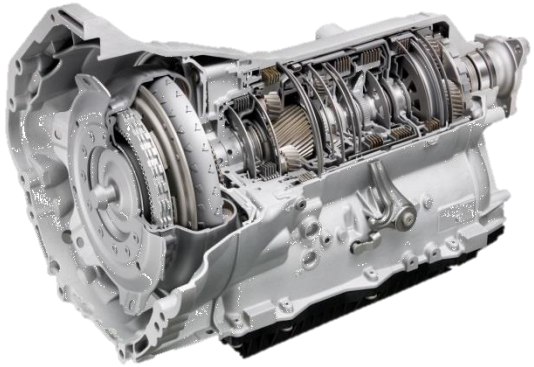
- A transmission adapts the output of the internal combustion engine to the drive wheels
  - Important element in the “feel” of driving for consumers

- ***Power transmission fluids*** *(PTF)* relates 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 relates 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)**



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Automatic Transmissions Hardware

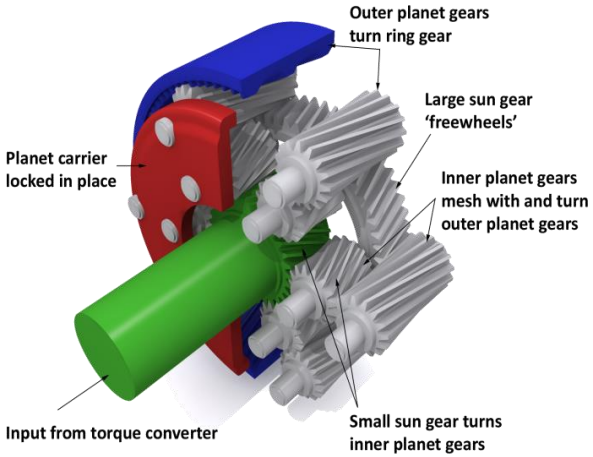
Stepped Automatic

STEPPED AT PROs

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

STEPPED AT CONs

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



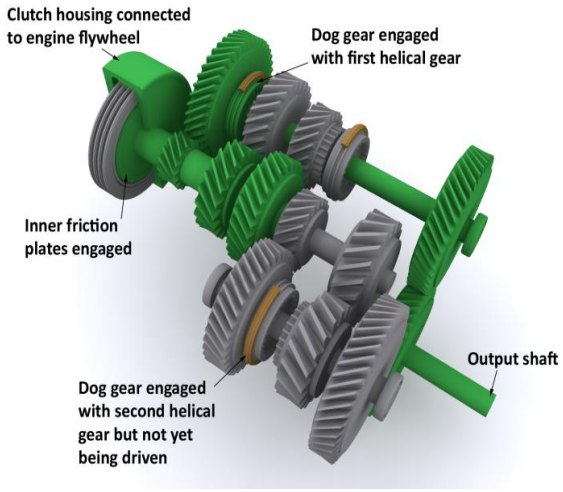
Dual Clutch

DCT Pros

+ Torque Capacity
+ Fuel Efficiency
+ Shift Feel
+ Can use existing MT manufacturing sites

DCT Cons

- Launch feel not as smooth as stepped AT



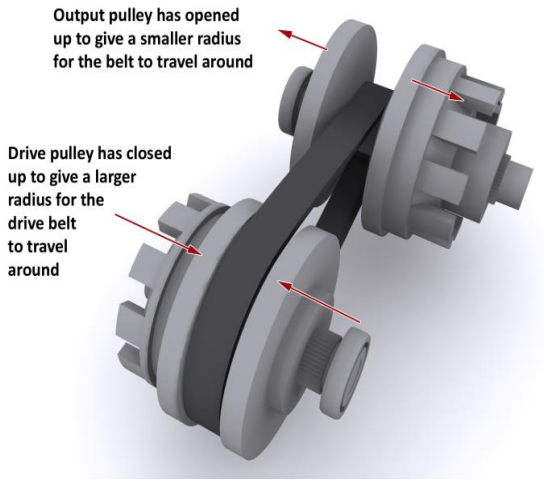
Continuously Variable

CVT Pros

+ Comfort due to no shifting
+ Acceleration
+ Fuel Efficiency

CVT Cons

- Torque Capacity
- Cannot utilize existing stepped AT manufacturing sites



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Drivers for Transmission Development

Fuel Economy And Emissions

- Development of CVT, DCT and higher gear ratio spread
- 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, sporting, dynamic driving style, Adapts to suit your individual driving style

Compact Size And Reduced Weight

- Increased Torque Density
- Smaller Transmissions – less fluid

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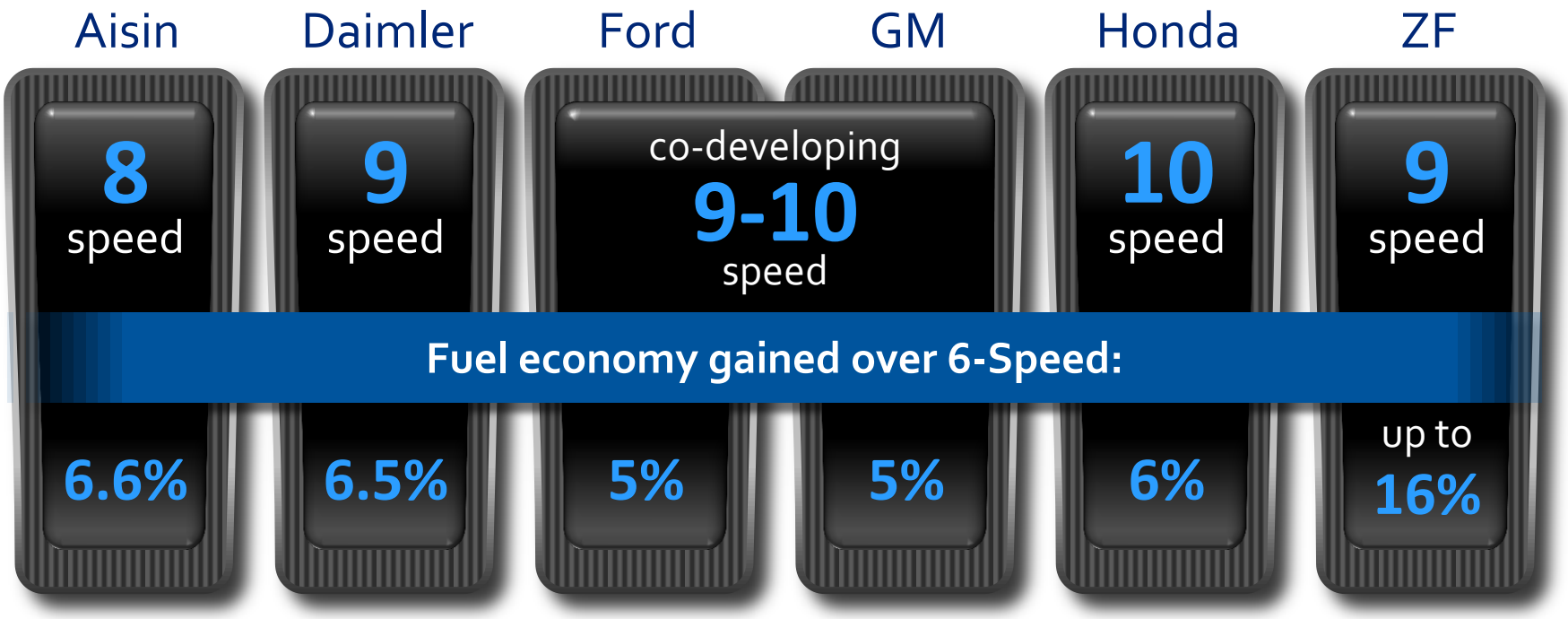
Automatic Transmission Trends

Stepped Automatic Hardware Trends



- Expanded gear ratios
- Quicker shifts
- More frequent shifts

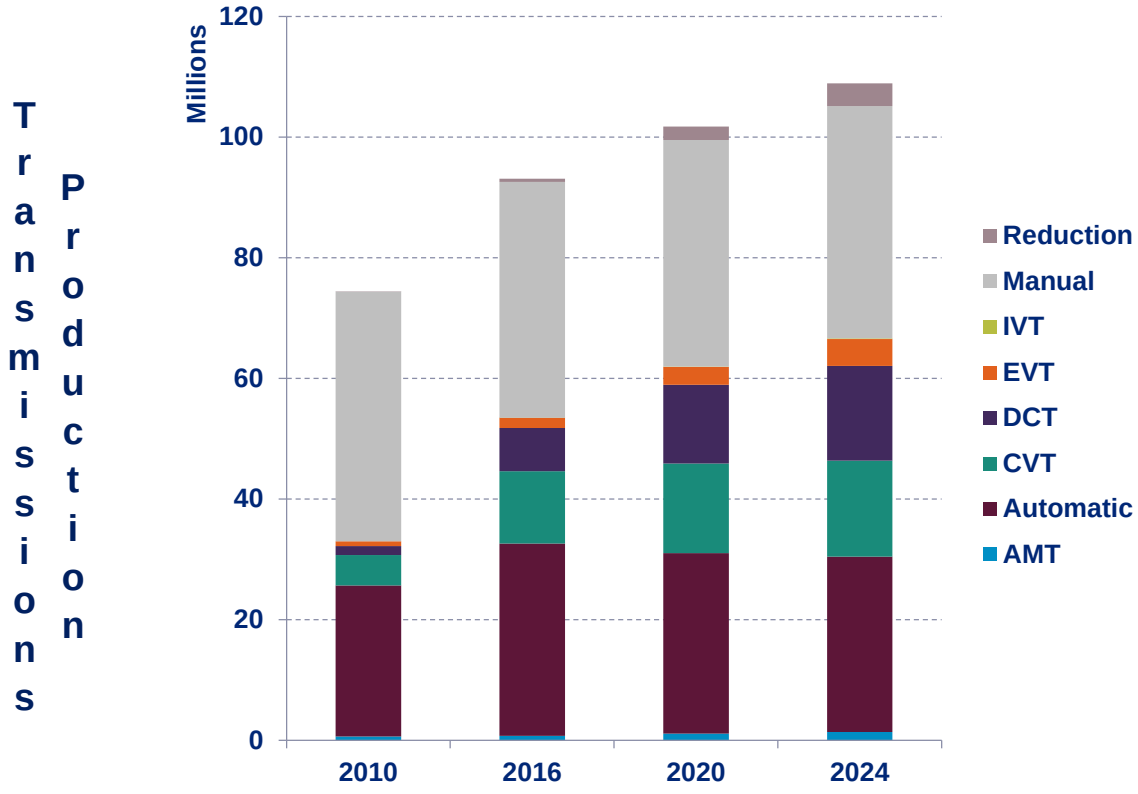
- Higher temperatures
- Smaller ATF capacity
- Lower oil pressure

- Lighter materials
- New friction plate materials
- Lower friction bearings

By 2020, 65% of the Stepped Automatic will be 7 speed or higher

Global Transmission Production

- Global Transmission Production is forecasted to grow to **100+ million units in 2020**



Source: IHS 2017 Transmission Production Forecast

Global Transmission Production by Type

Stepped Automatic Transmission (AT) production share will slowly decrease to 30% in 2020 from 34% in 2010

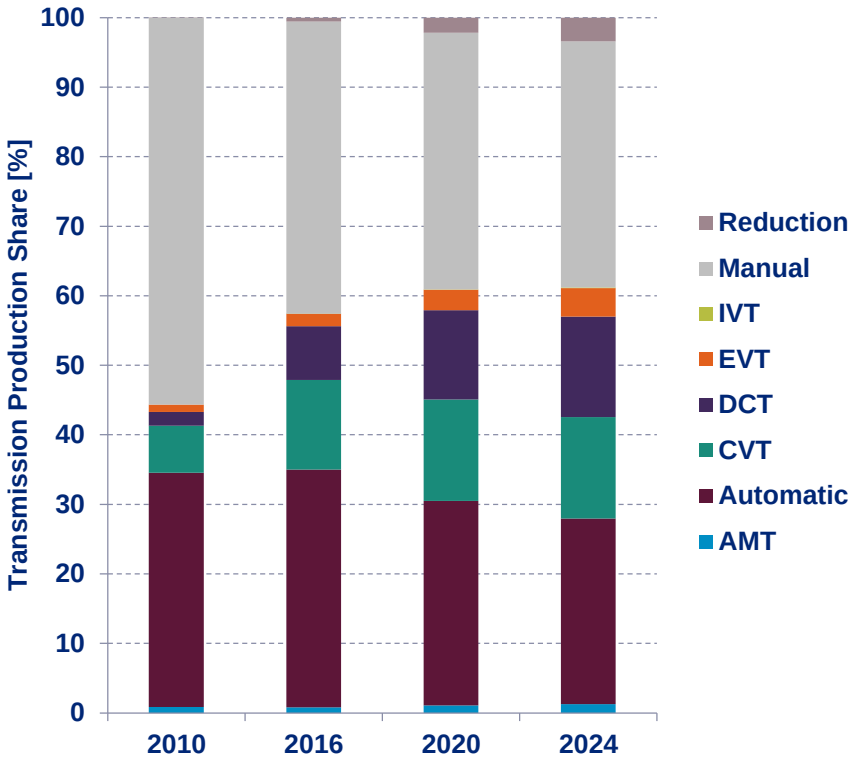
Continuously Variable Transmission (CVT) production share will increase to 13% in 2020 from 7% in 2010

Dual Clutch transmission (DCT) production share will increase to 11% in 2020 from 2% in 2010

Electrically Variable Transmission (EVT) production share will remain low, at 3% by 2020

Electric Vehicle Transmission (Reduction) production share will remain very low, at 1% by 2020

Manual transmission (MT) production share will decline by 15% from 2010 to 2020



Source: IHS 2017 Transmission Production Forecast

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Summary

- Automatic transmission products will grow steadily towards 2020
- FE continues to drive hardware changes
- More speeds added, 8-10 speed stepped automatics and DCTs
- Different regional and OEM strategies

Stepped Automatic

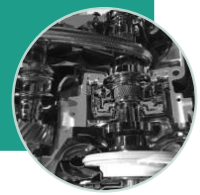
- Increase in the number of speeds, including 10 & 11 speeds
- Favoured mainly by NA OEMs

DCTs

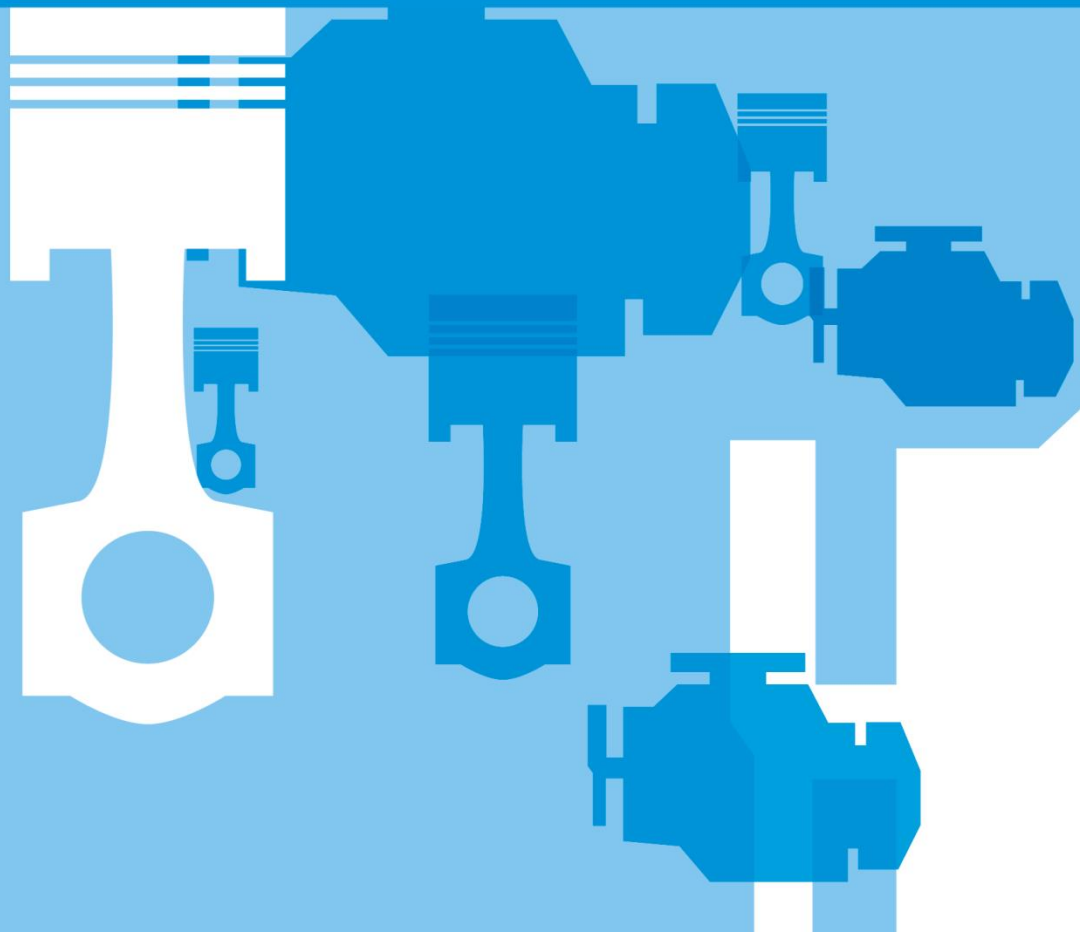
- Over 10 million units in 2020 with ~60% Wet clutch DCT
- Favoured by European OEMs

CVTs

- Strong Growth over 13 million units in 2020
- Favoured mainly by Japanese OEMs



ATF hardware and performance requirements



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Stepped Planetary Automatic

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

STEPPED AT PROs

+ Torque Capacity

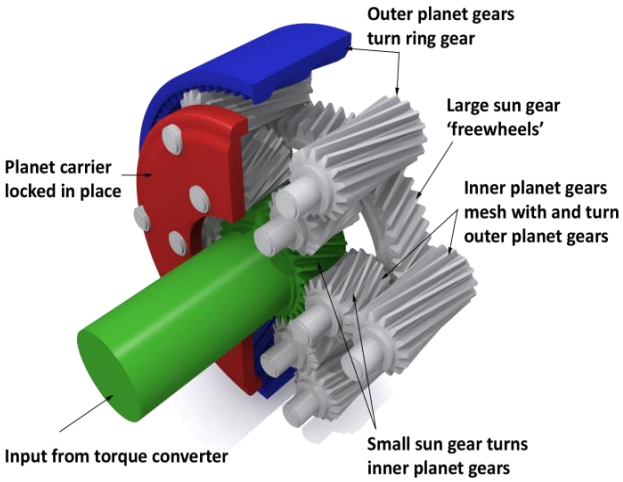
+ Fuel Efficiency in 6+ speed applications

+ Launch Feel

- Fuel Efficiency in applications with less than 5-speeds

- Packaging Size

STEPPED AT CONs



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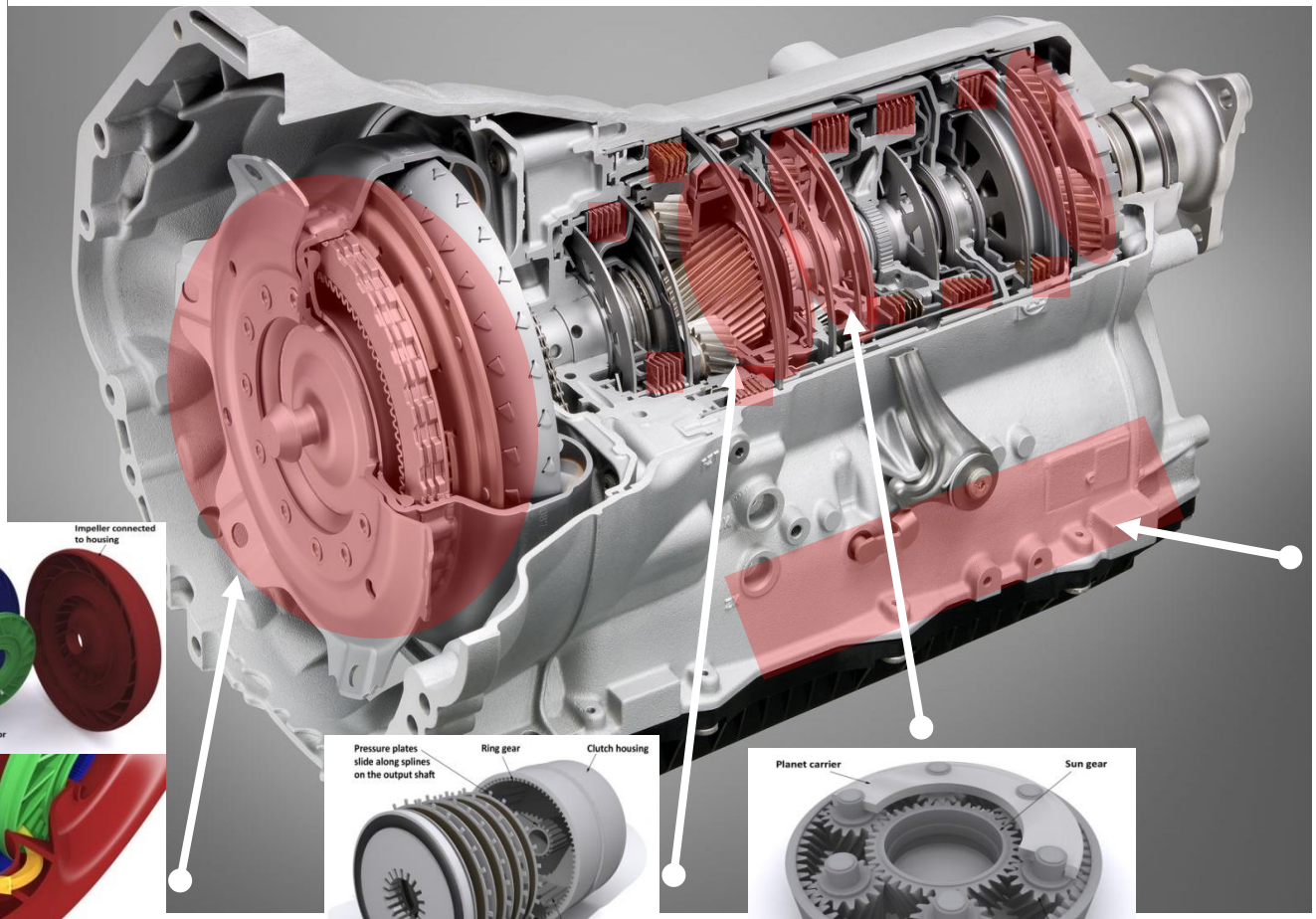
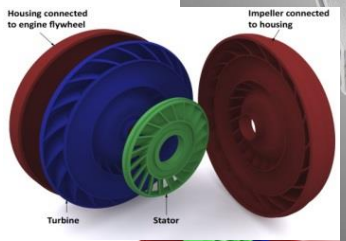
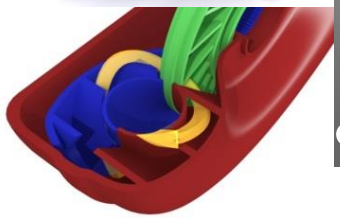
Stepped Automatic Transmission

Automatic Transmission Hardware

Photo source: BMWBLOG.COM



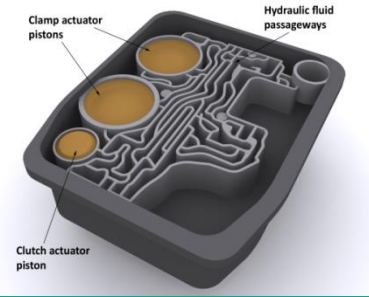




Torque Convertor

Clutches

Planetary Gear

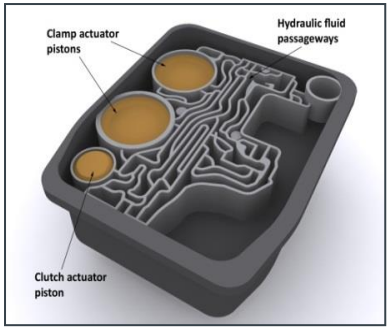


Valve Body

Automatic Transmission Hydraulics

Hydraulic System

- Components
  - Valve body
  - Pump
  - Filter
  - Cooler

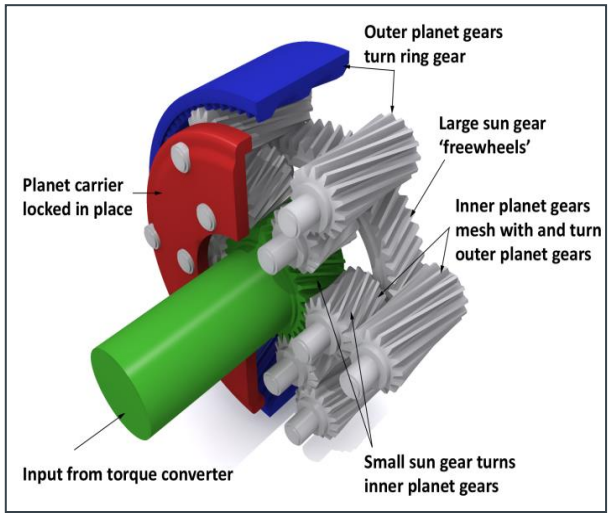


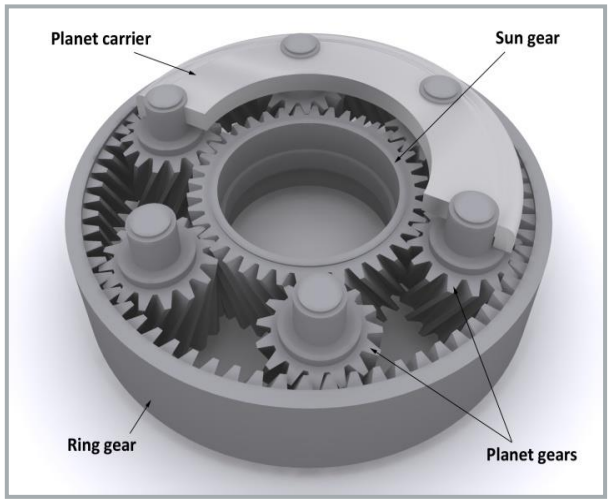
- Used to pressurize piston plate for clutches
- Used to move band-activation pistons up and down

ATF requirements

- Act as a Hydraulic Fluid
- Antifoam properties
- Large operating range (-40°C to 175°C)
- 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 – plate and band clutches

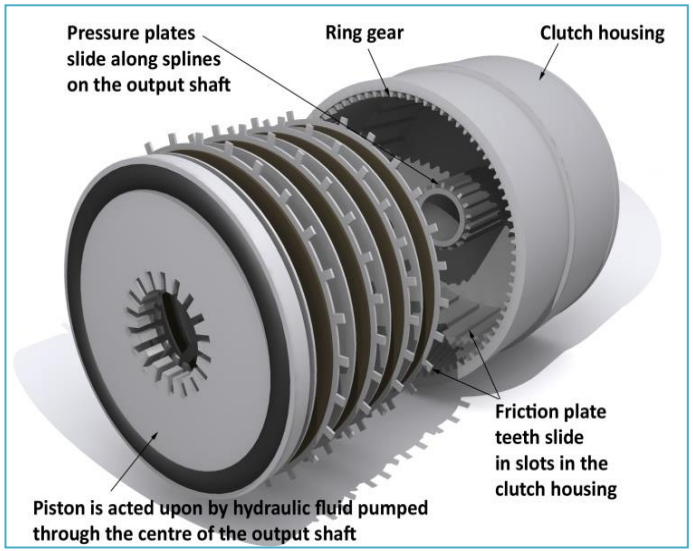
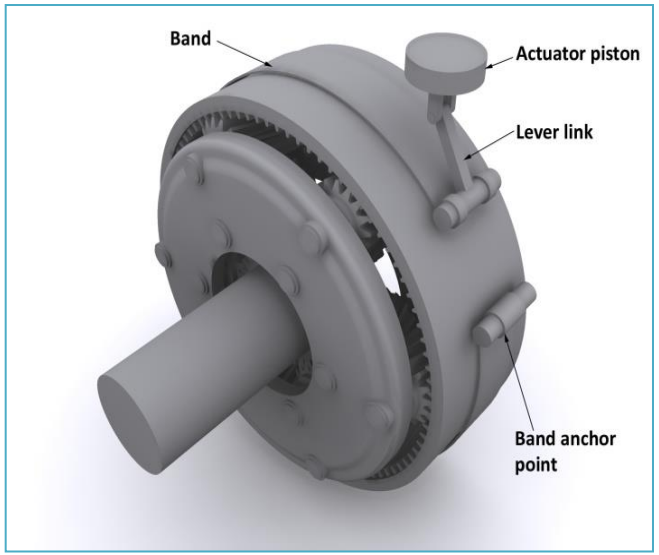


Plate Clutch

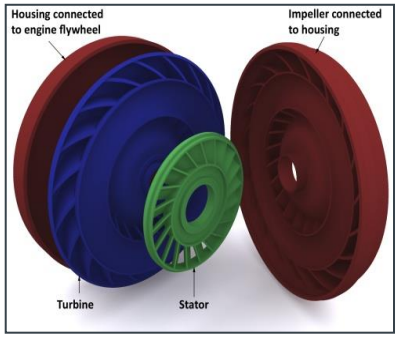
Band Clutch

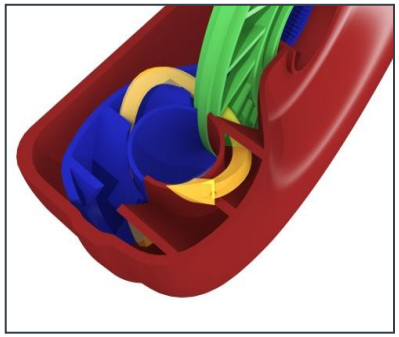


ATF requirements

- Remove heat efficiently
- Resist oxidation
- Deliver specialized friction requirements

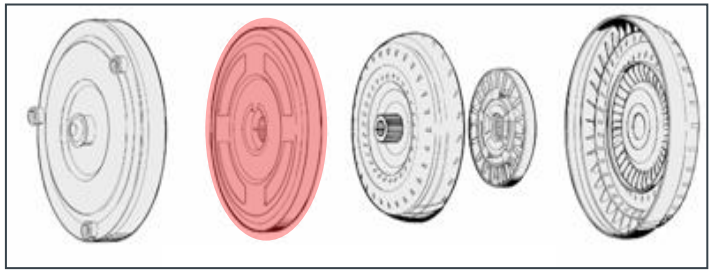
Automatic transmission – torque converter





Torque Converter 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

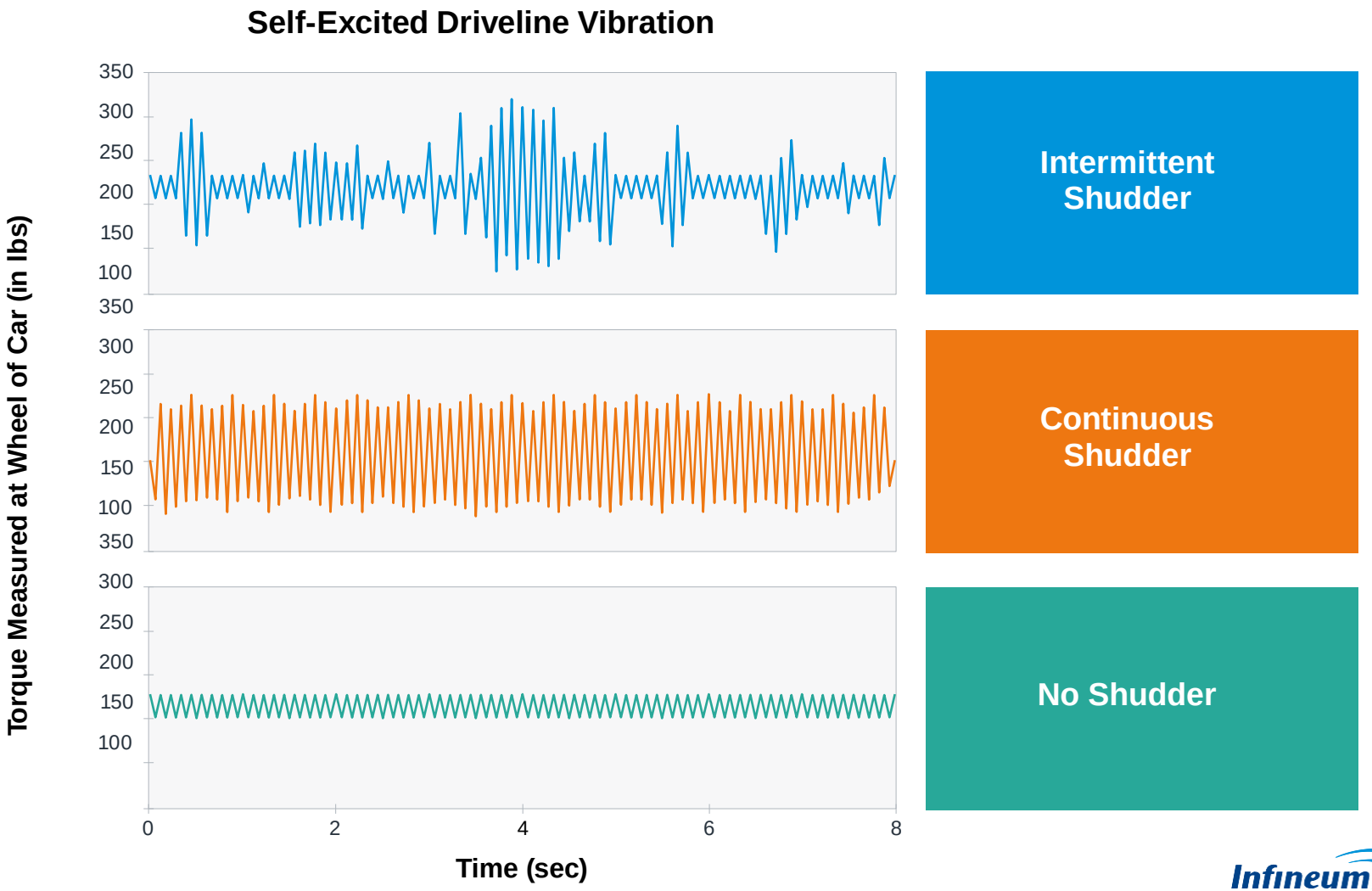


Torque Converter Lock-Up Clutch

ATF requirements

- Act as a Hydraulic fluid
- Large operating range (-40°C to 175°C)
- Deliver specialized friction requirements

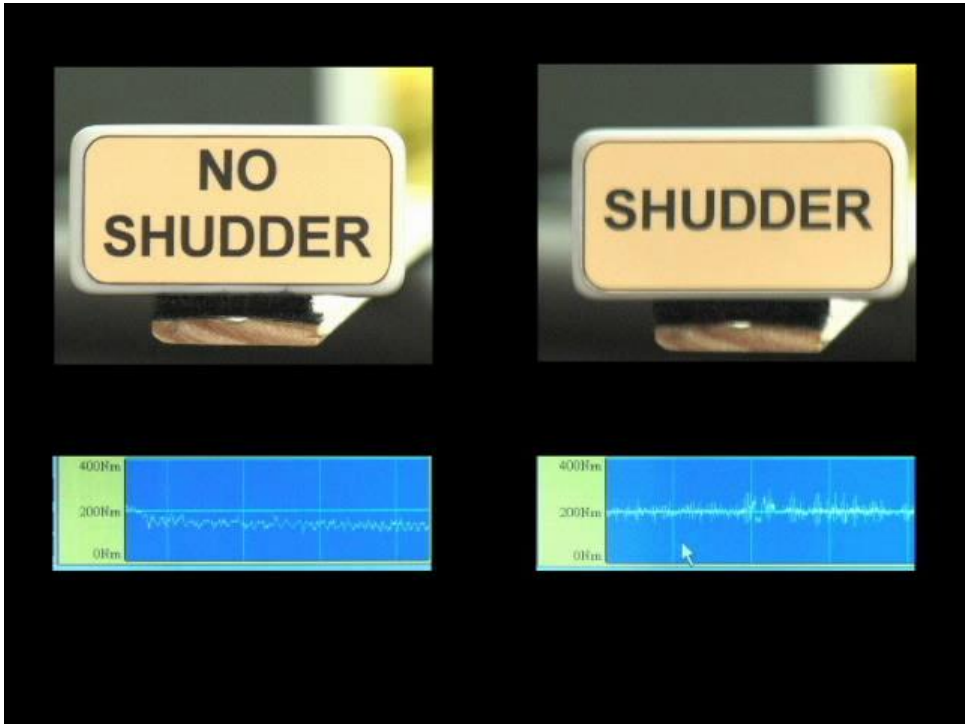
Torque converter clutch
Friction deterioration → shudder



Sh-h-h-udder occurs!

Self-Excited Driveline Vibration

ATF must deliver specialised friction requirements



Stepped Automatic Transmission Hardware 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

Stepped Automatic Transmission Fluid Summary

The fluid needs to do the following:

- 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

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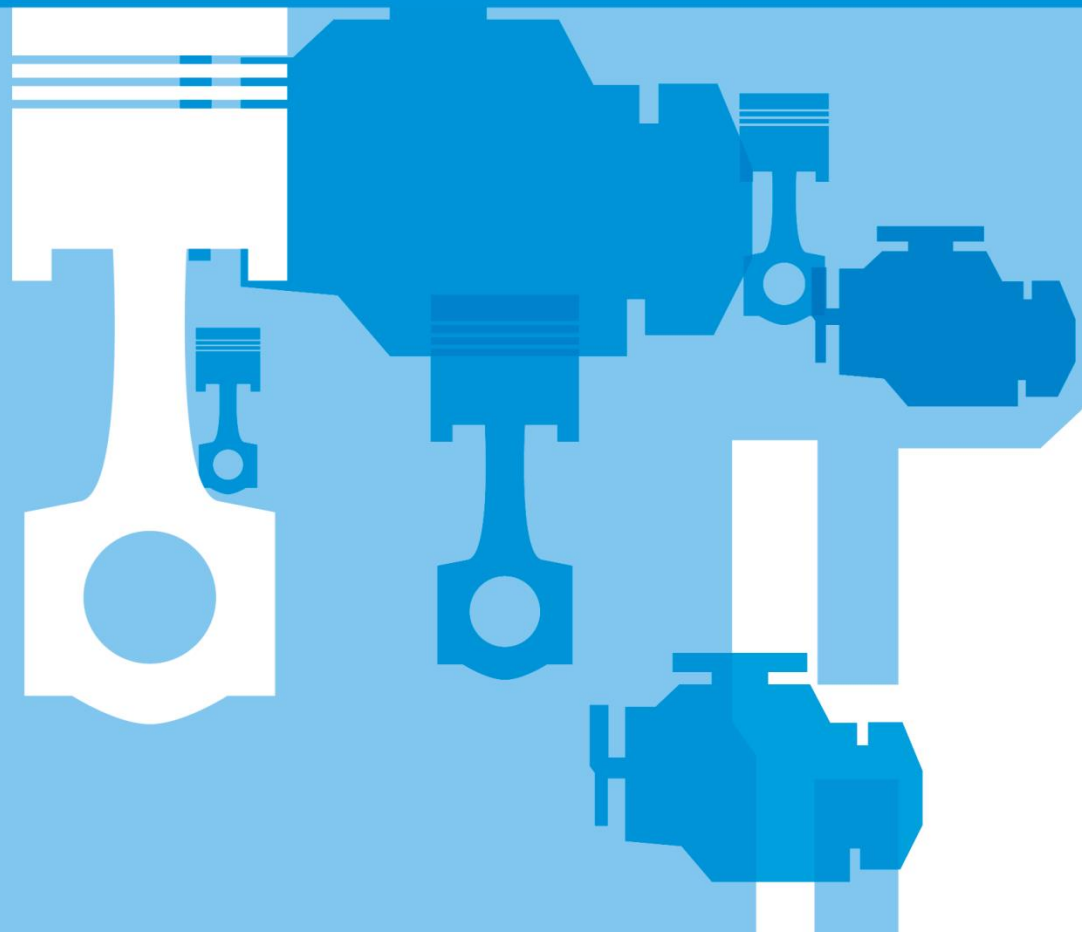
Performance you can rely on.

Trends and Testing of Automatic Transmission Fluids



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Key performance tests for ATF

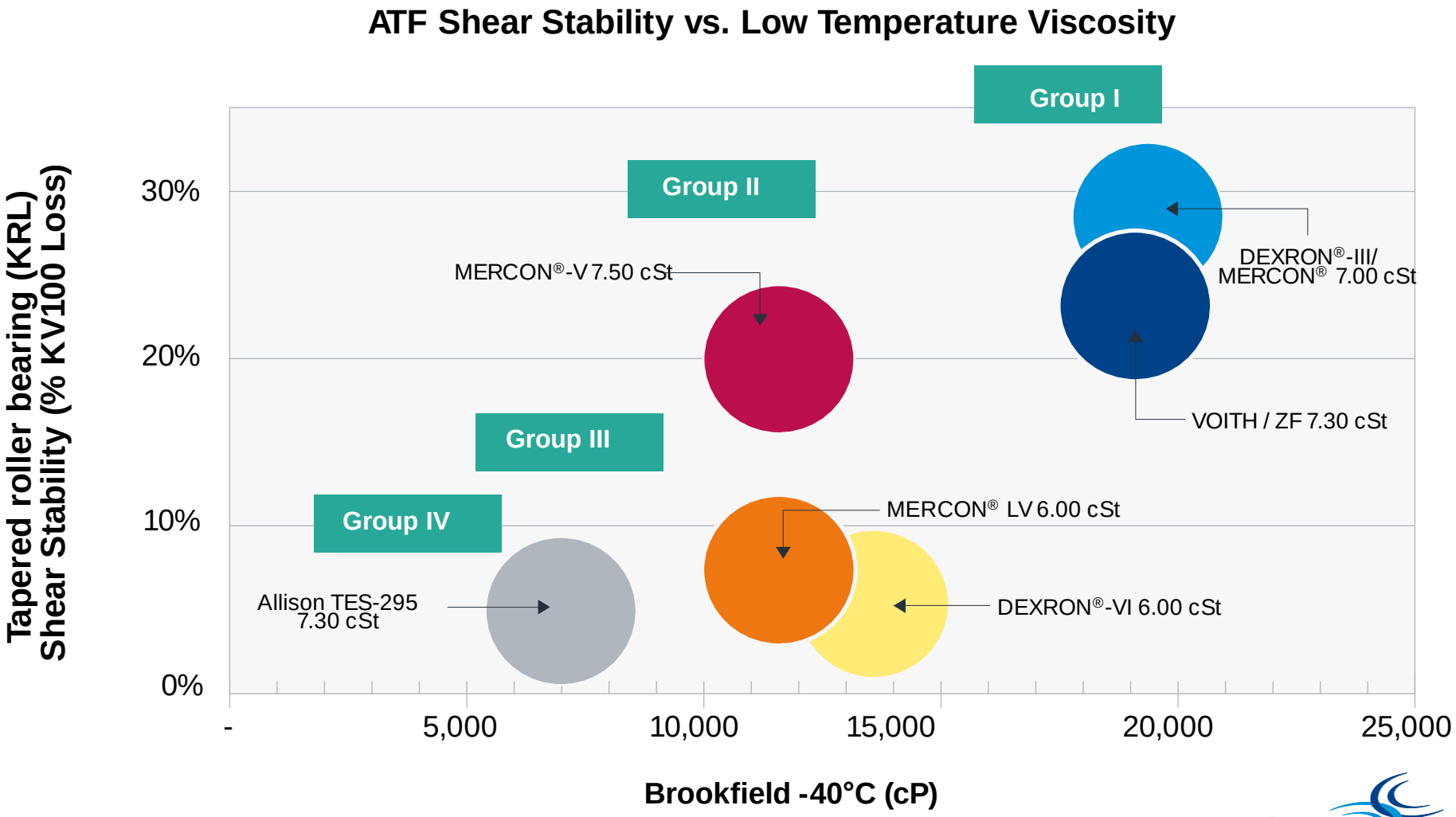
Viscometrics

- Kinematic viscosity @ 100^{0}C (KV100)
- Brookfield viscosity @ -40^{0}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

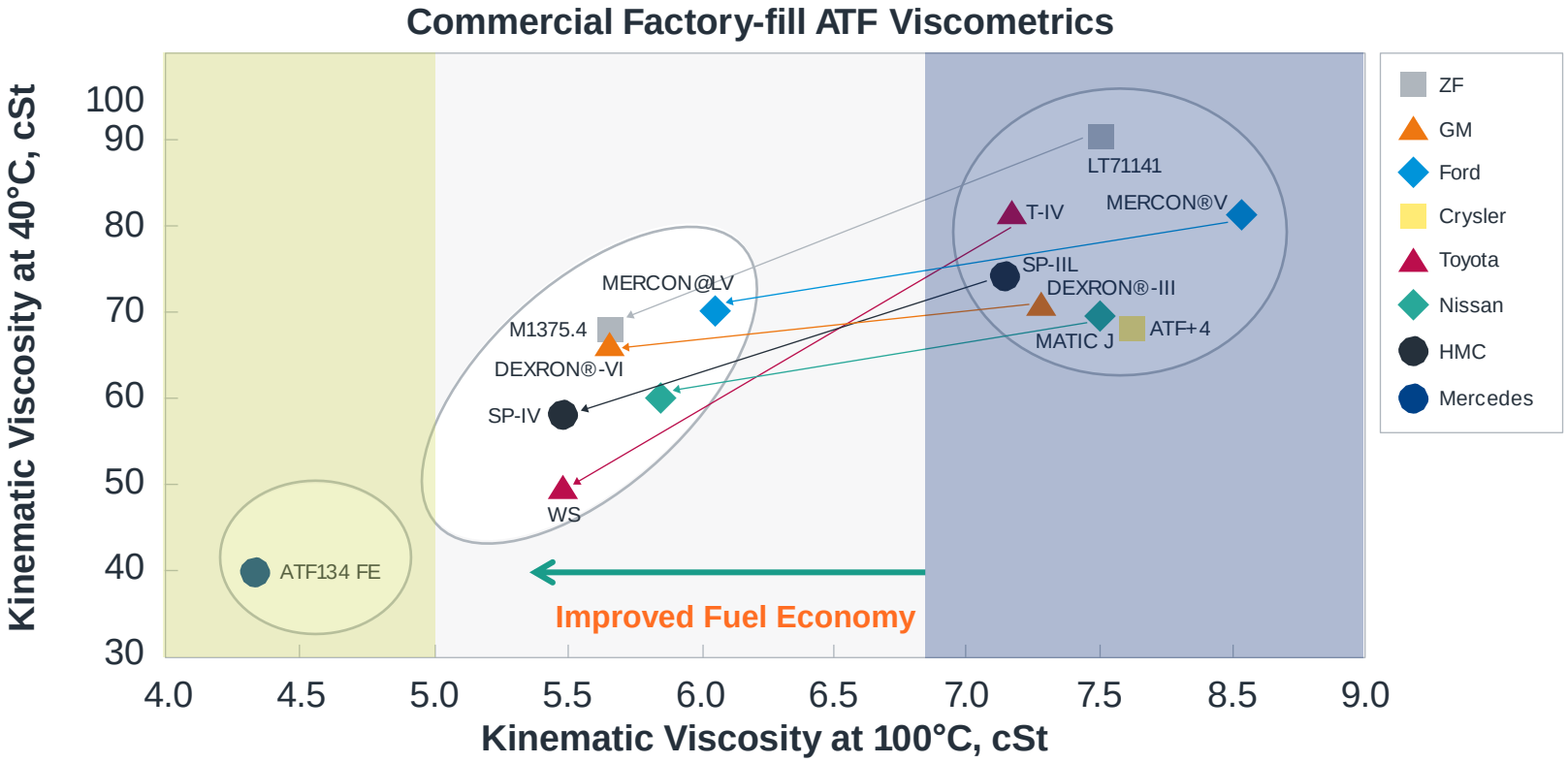
Viscometric trends



New Generation ATFs
Lower viscosity for fuel economy

Latest 6+ speed transmissions use lower viscosity ATFs

- Reduce fluid resistance and friction losses
- Provide improved shear stability to control thinning



Some OEMs are 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

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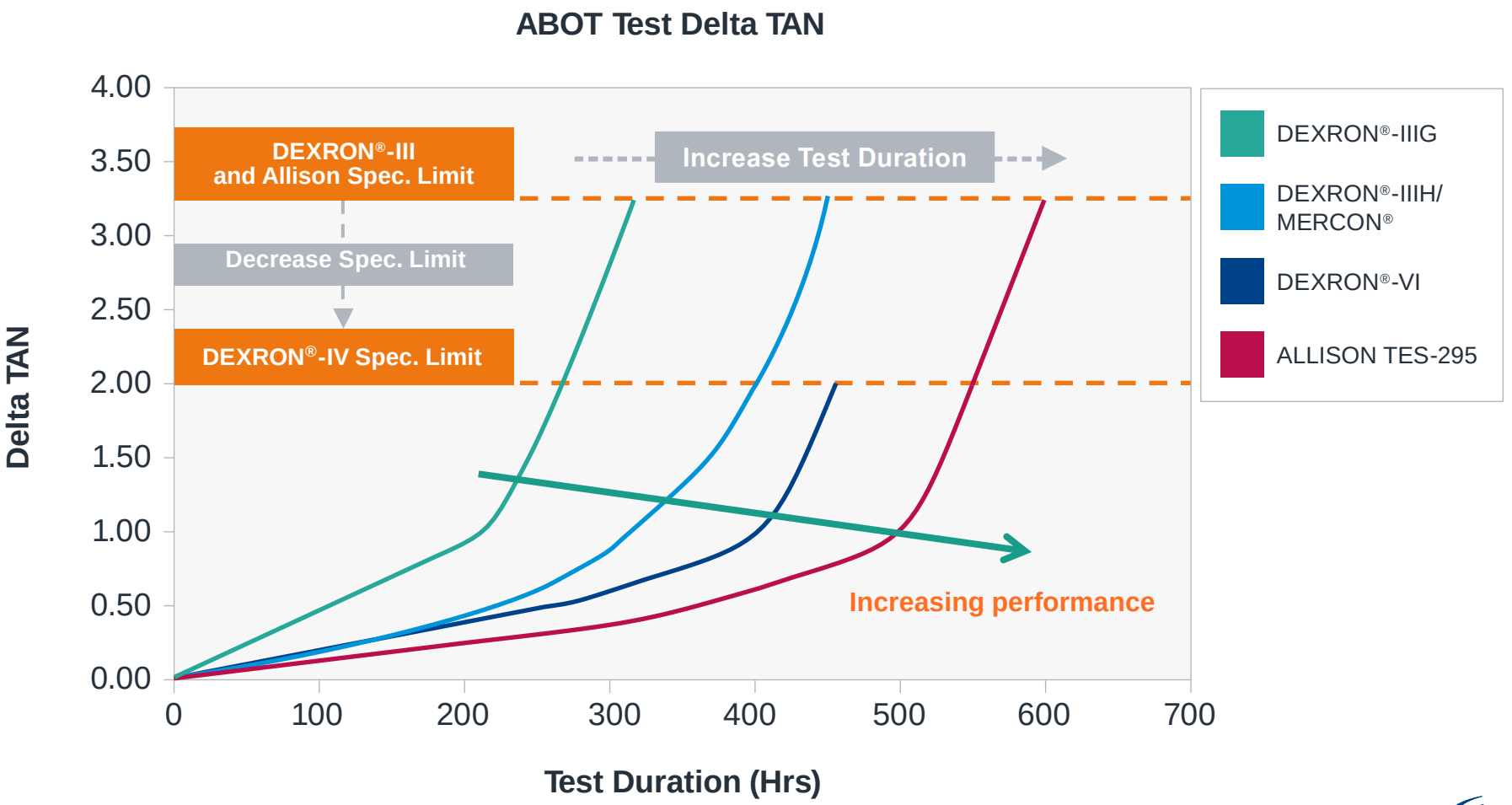
Trends in oxidation performance



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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

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What affects friction?

Impacts on Friction

Hardware Demands

- Temperature
- Sliding Surface Composition
- Load
- Sliding Speed

Fluid Technology

- Friction Modifier Type
- Friction Modifier Concentration

Increased interest in friction durability

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ATF performance summary

ATF must meet exact requirements for a variety of parameters

Key performance attributes

- **Viscometrics**
  - Shift towards lower viscosity fluids for fuel economy benefits
- **Oxidation resistance**
  - Increasing requirements for durability and performance as hardware changes
- **Friction stability and durability**
  - Specific to each application and OEM

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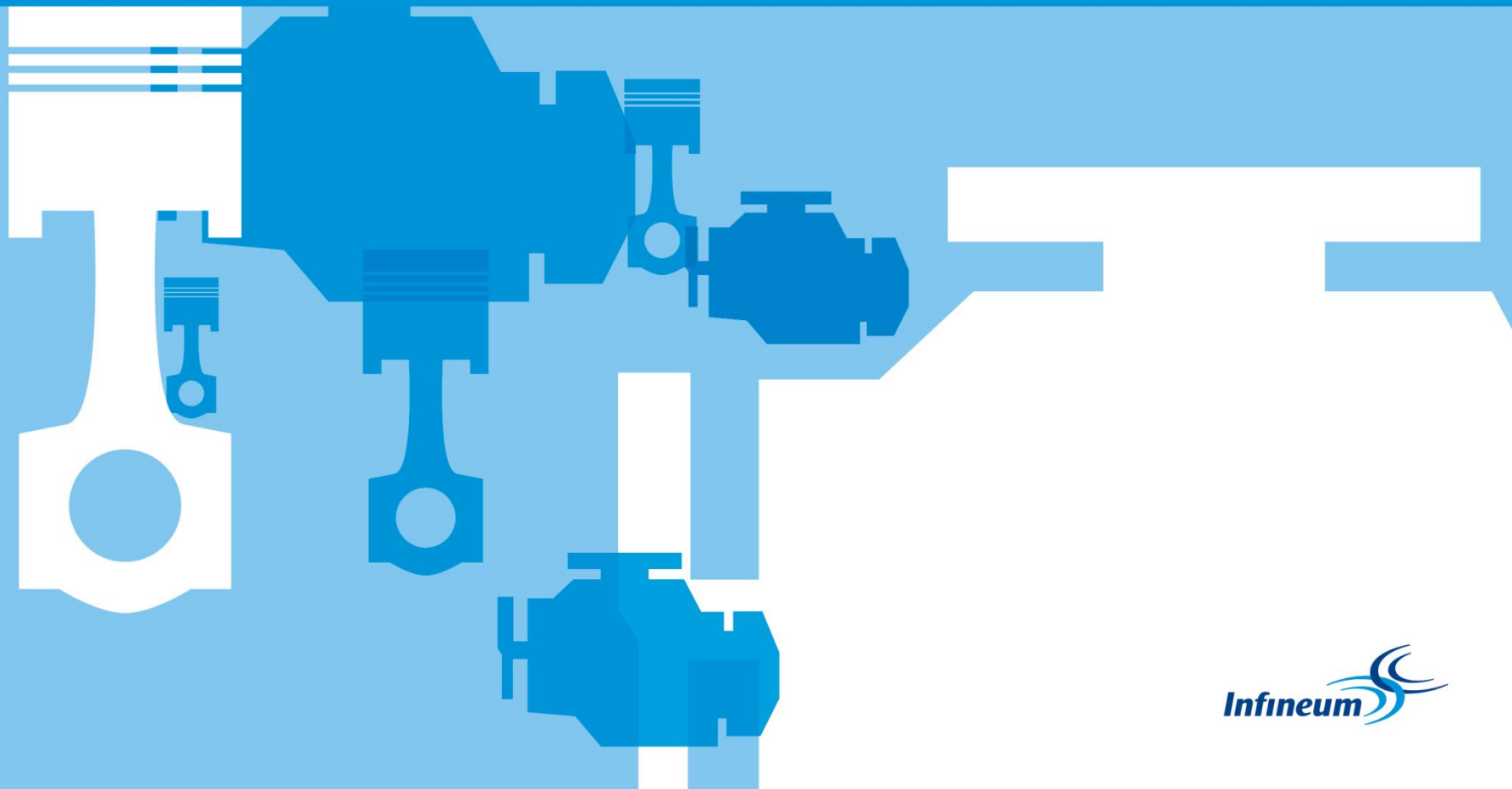
Performance you can rely on.

ATF service-fill specifications



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Passenger car ATF specifications

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

***Bolded specifications are open to licensing**

Key JAMA requirements

As many ATF specifications are not available for public licensing, many OEMs recognize JASO 1A 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

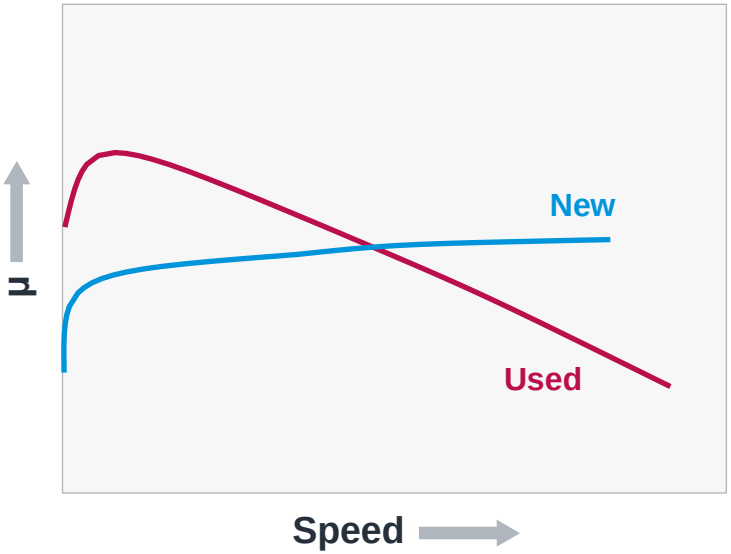
Friction Characteristics (Shifting Clutch)

- 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

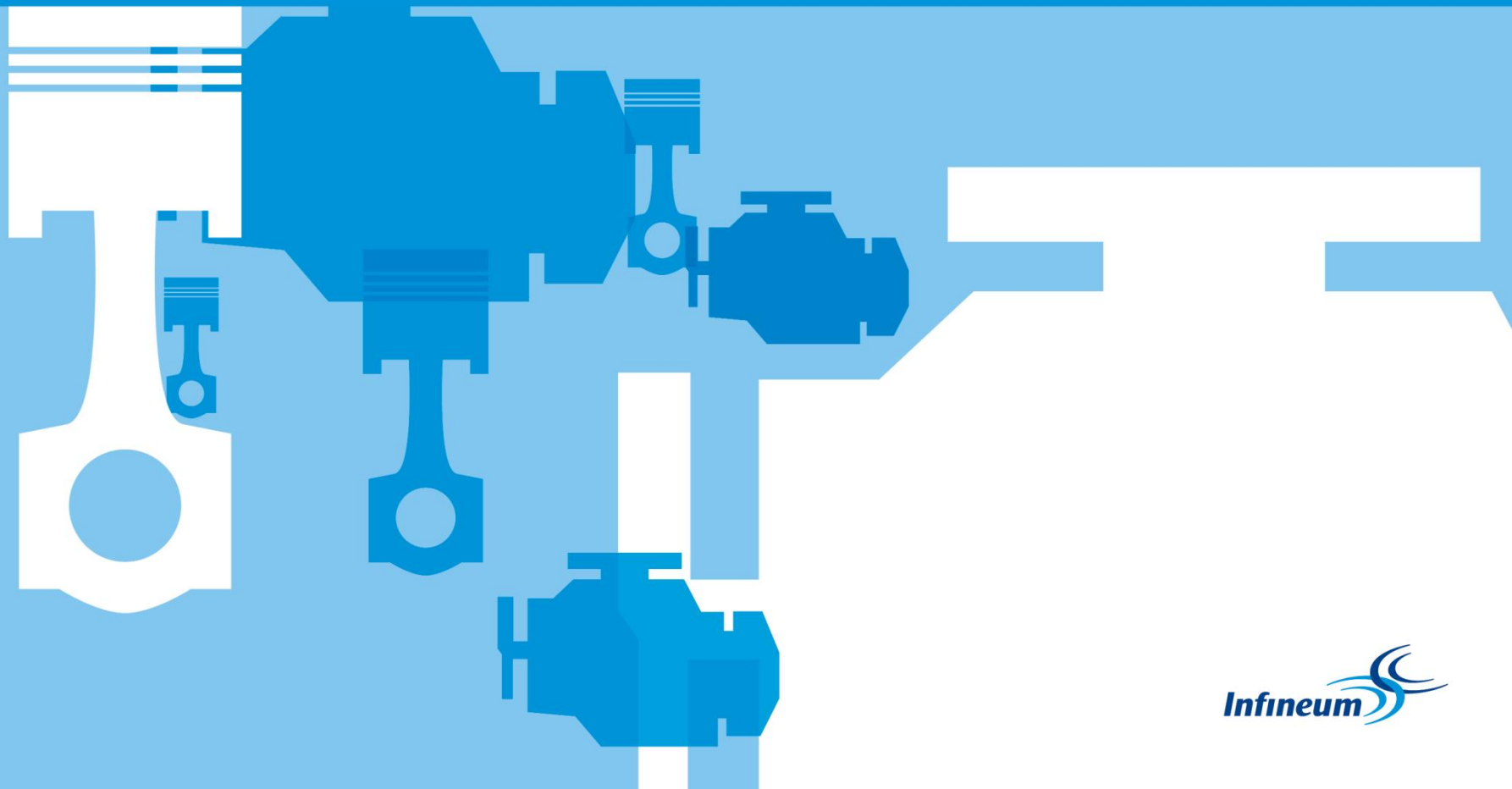


Reasonable μ level with positive slope required

Heavy duty ATF specifications

OEM	Region / Type	Standard ODI	Intermediate ODI	Long ODI	Extra-Long ODI
Allison Transmissions	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 – 60K km	-	G1363 – H55.6336xx Long – 120K km	Voith 150.014524.xx Extra Long – 180K km
ZF	EcoMat	ZF TE-ML 14A 30K km	ZF TE-ML 14B 60K km	ZF TE-ML 14C 120K km	
	EcoLife	-	ZF TE-ML 20B 60K km	ZF TE-ML 20C 120K km	
MAN	All	339 Type V1/Z1	339 Type Z2/Z11	339 Type V2/Z3/Z12	
Volvo	All	STD 1273,40 – Trucks STD 1273,41 – VCE	-	STD 1273,42 – VCE	
Mercedes-Benz	All	MB 236.7 MB 236.9	-	-	

ATF formulations



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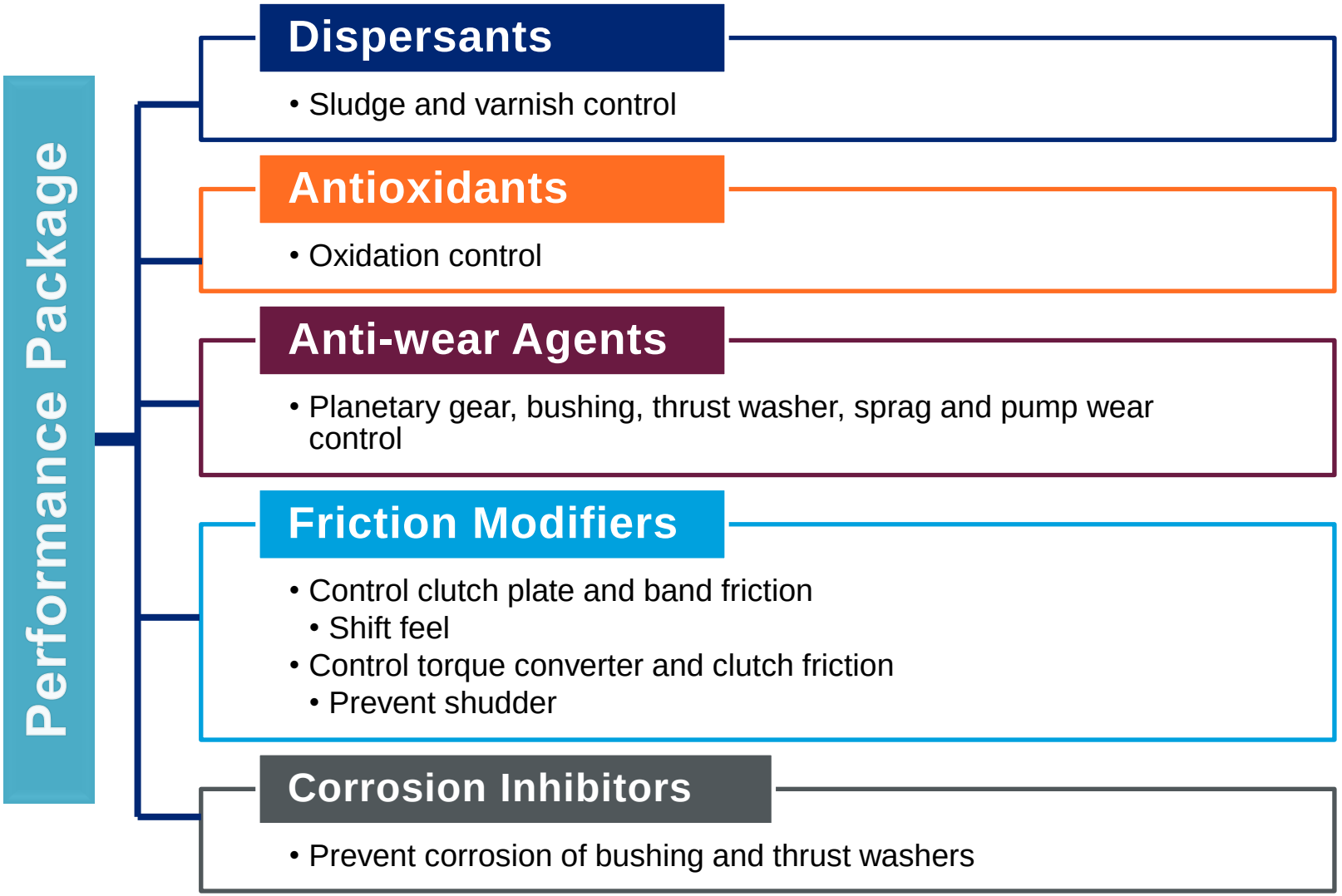
Typical ATF additives



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

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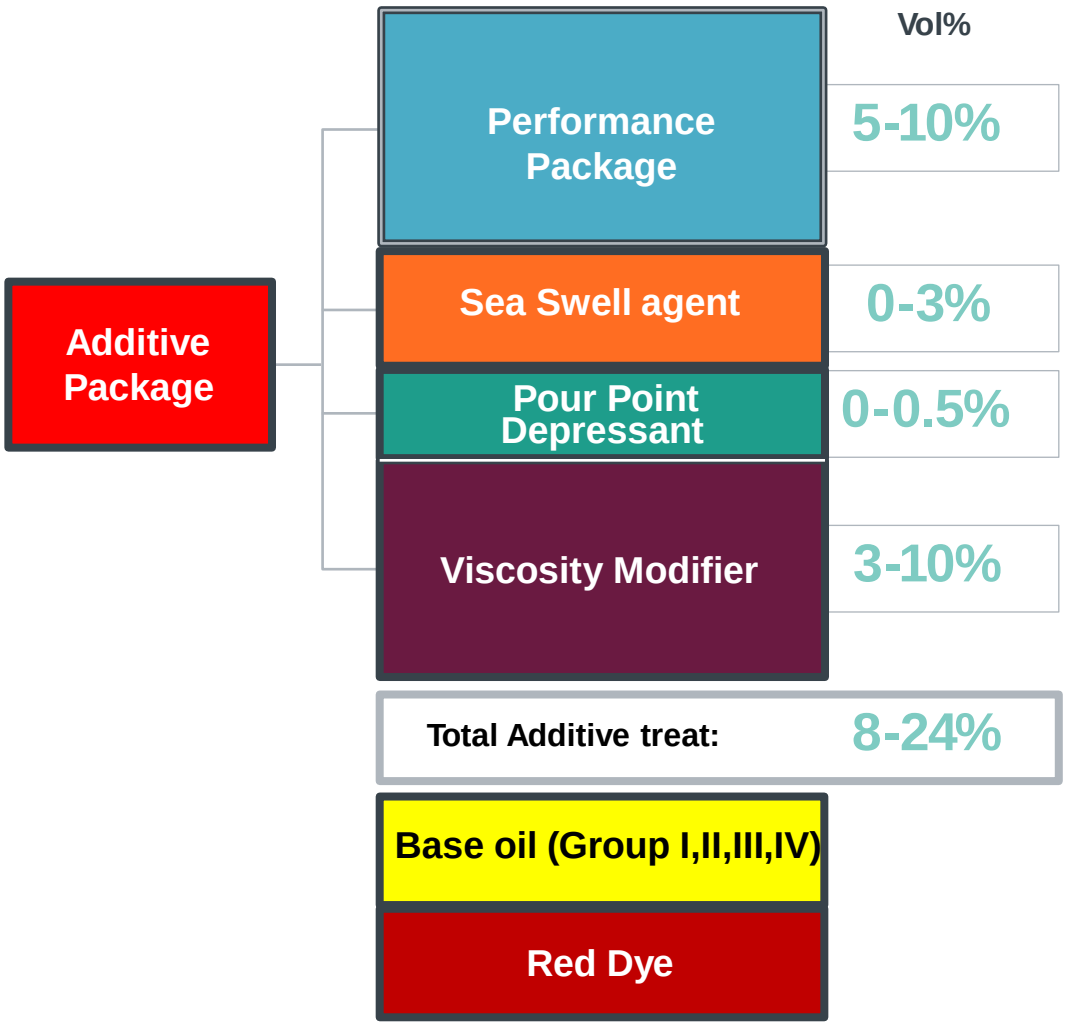
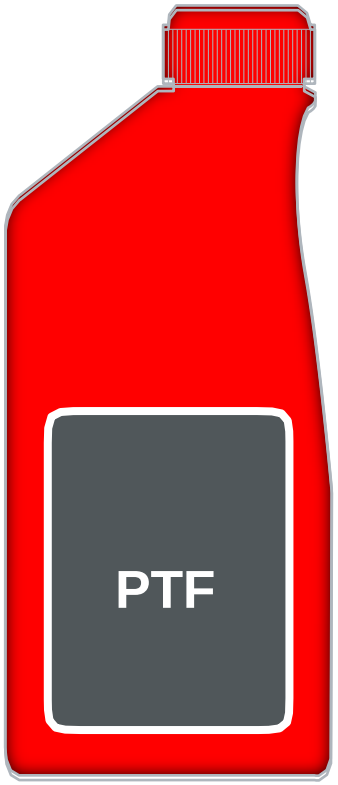
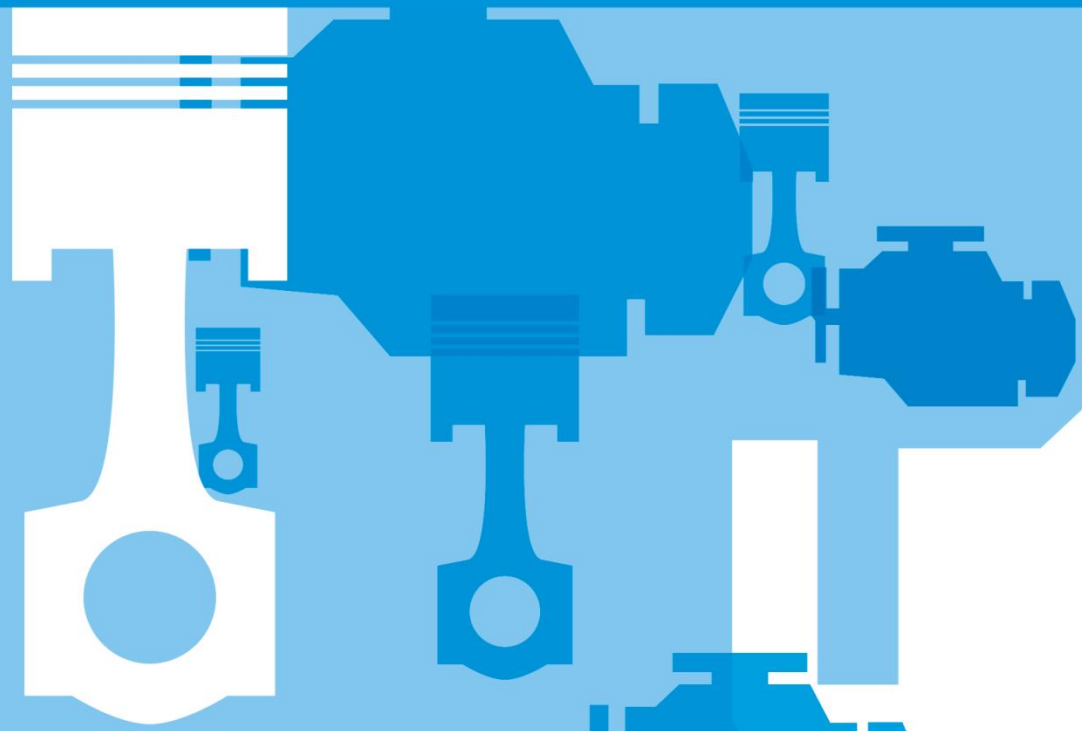
Typical ATF additive treat levels

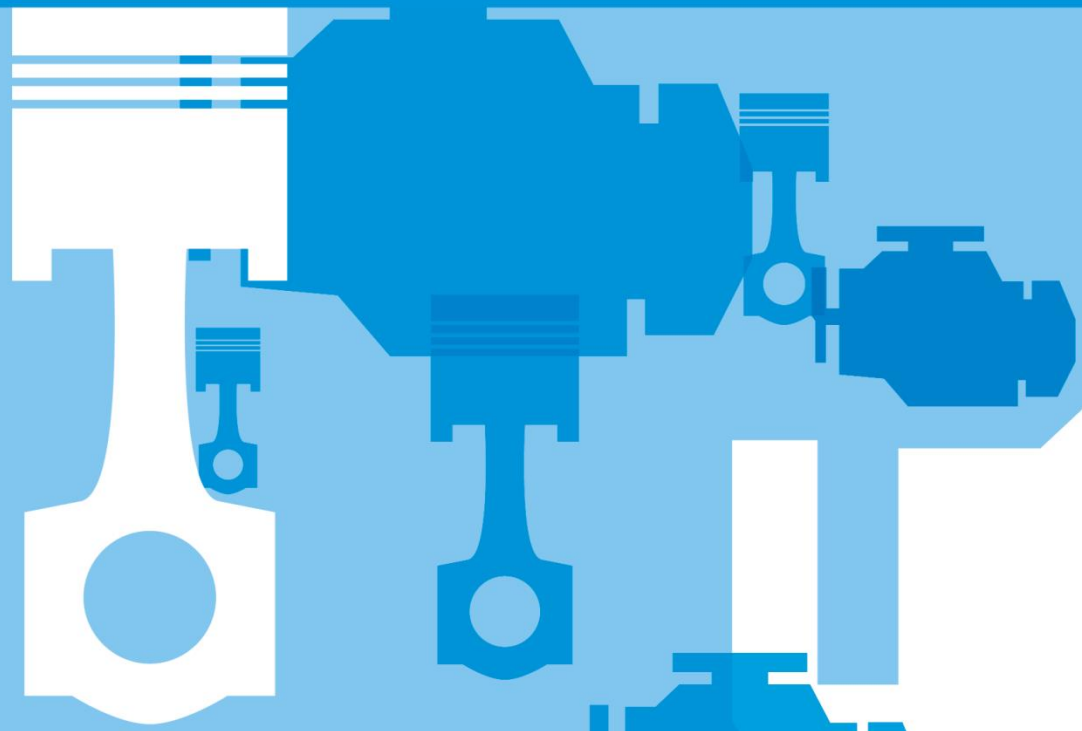




Other automatic transmissions



Dual Clutch Transmissions (DCT)



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DCT: technology update

Hardware

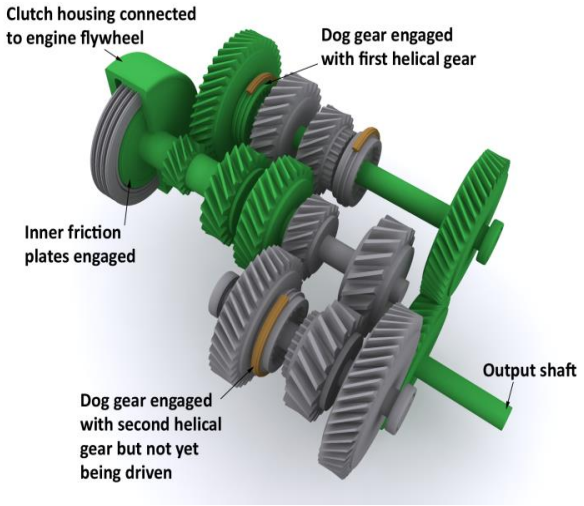
- Combines elements of both manual and automatic transmissions

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

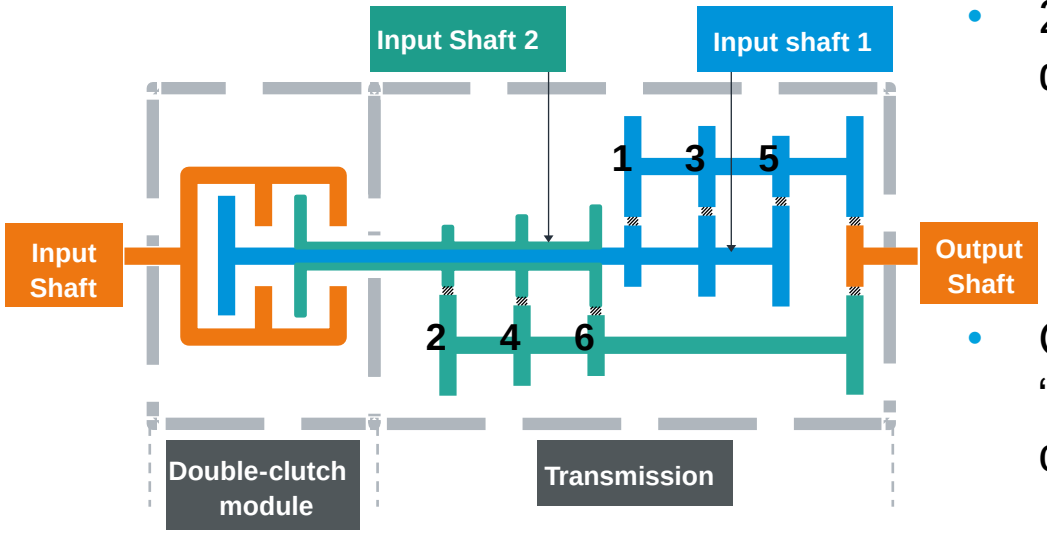
+ Shift Feel

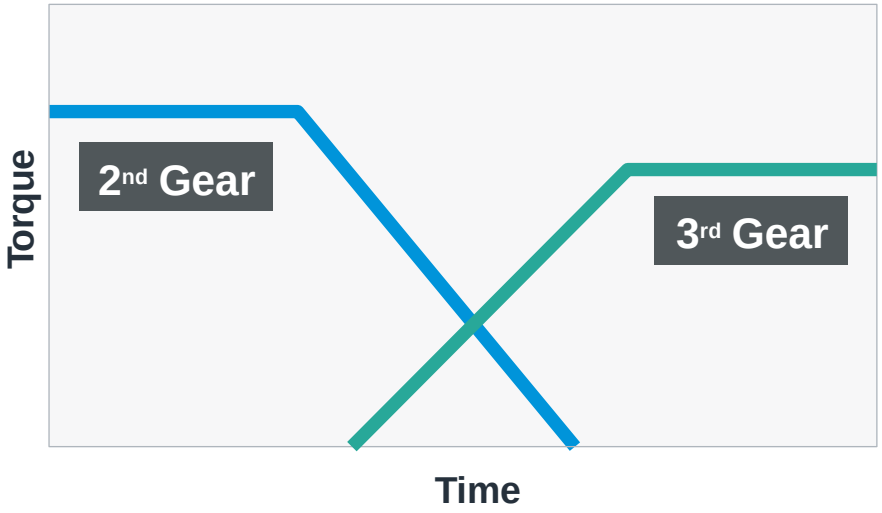
+ MT manufacturing (EU)

DCT Cons

- Launch feel not as smooth as stepped AT

DCT: how it works





- 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
- 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)
  - Result: shorter shift time

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DCT: technology trends – wet or dry clutch?

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

Dry DCT CONs

- Heat & Friction losses
- Drivability
- Torque Limitation (250Nm)

Wet DCT PROs

- Higher Torque Capacity
- Improved friction, controllability and heat dissipation
- Faster shifts

Wet DCT CONs

- Requires special DCT Fluid
- Shorter oil drain interval (i.e. ~40K mi for VW)
- Cost

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, with additional requirements:
  - Adding / balancing Clutch Friction Control
  - Anti-Shudder Durability

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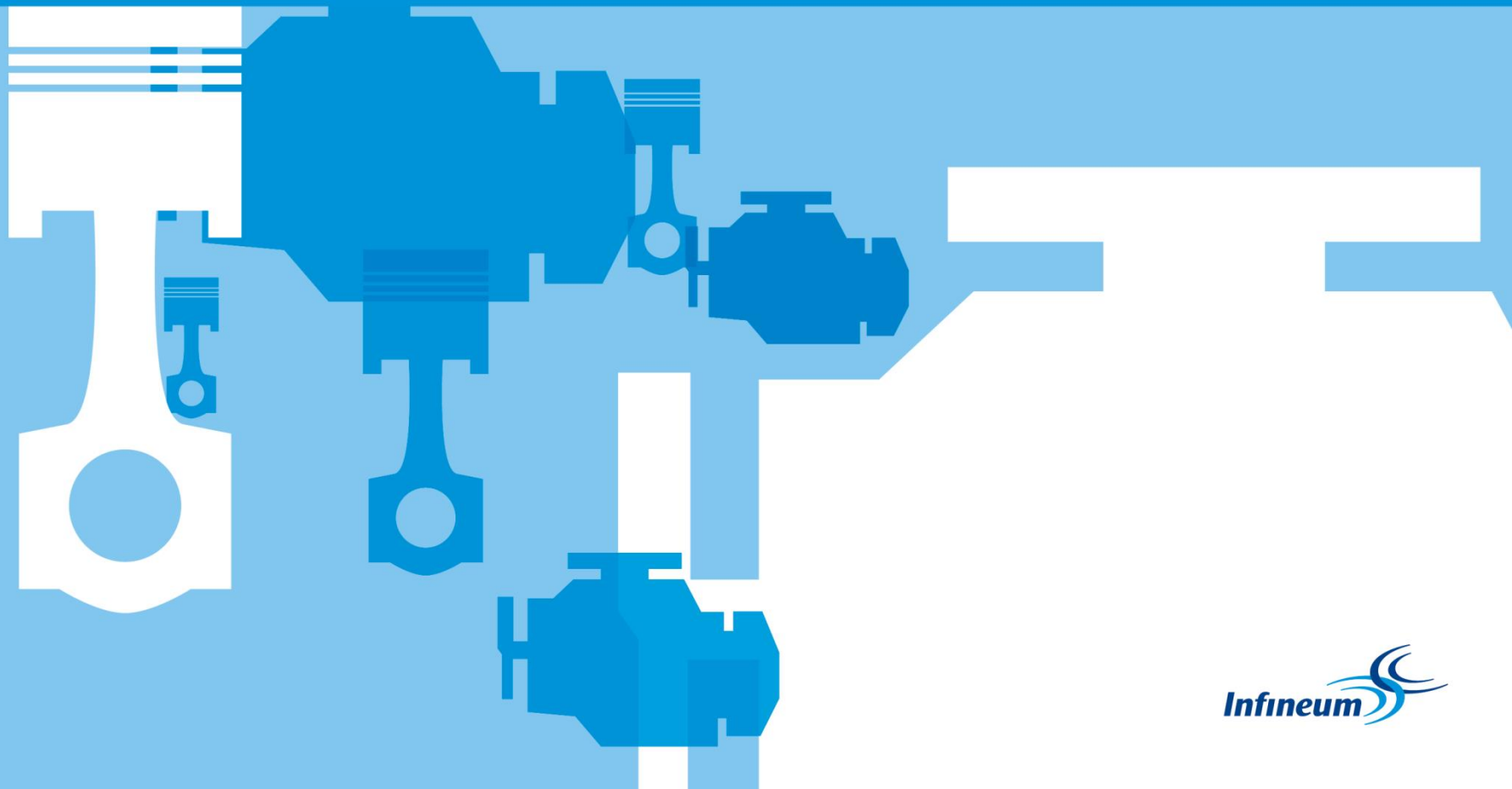
DCT Summary

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

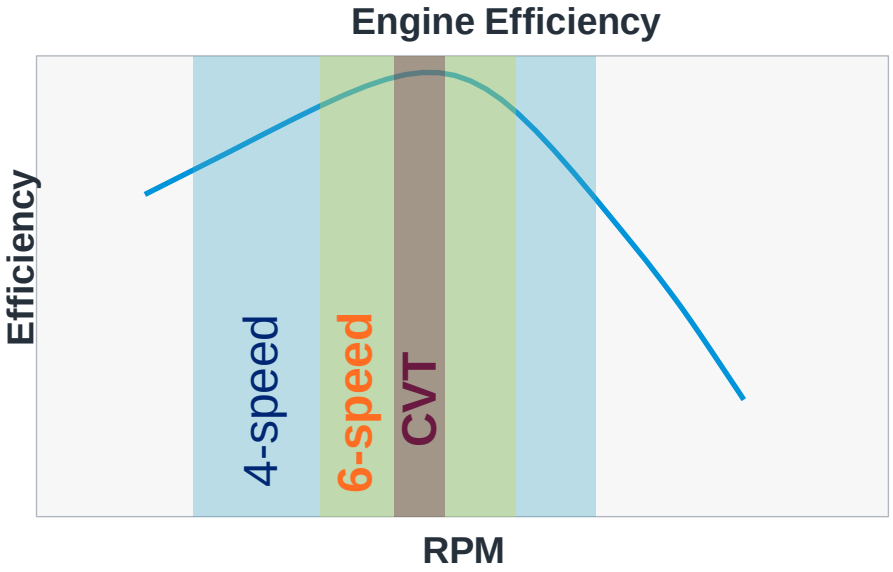
CVT - hardware

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



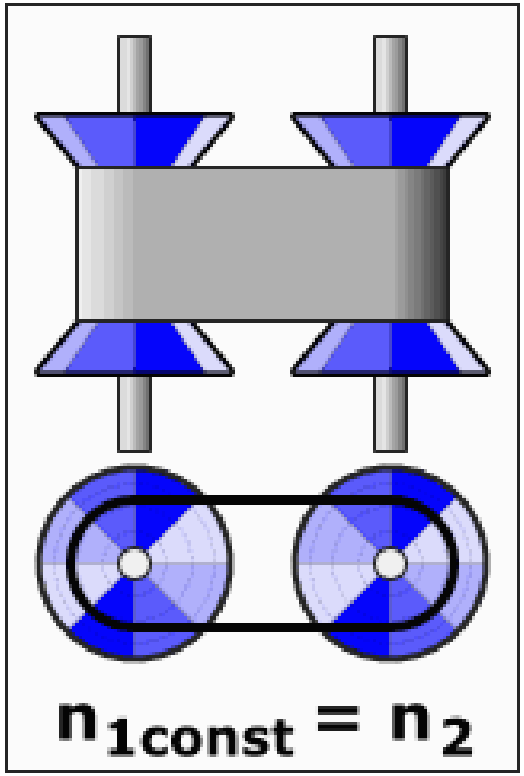
OEMS Using CVTs Today

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

CVT variator

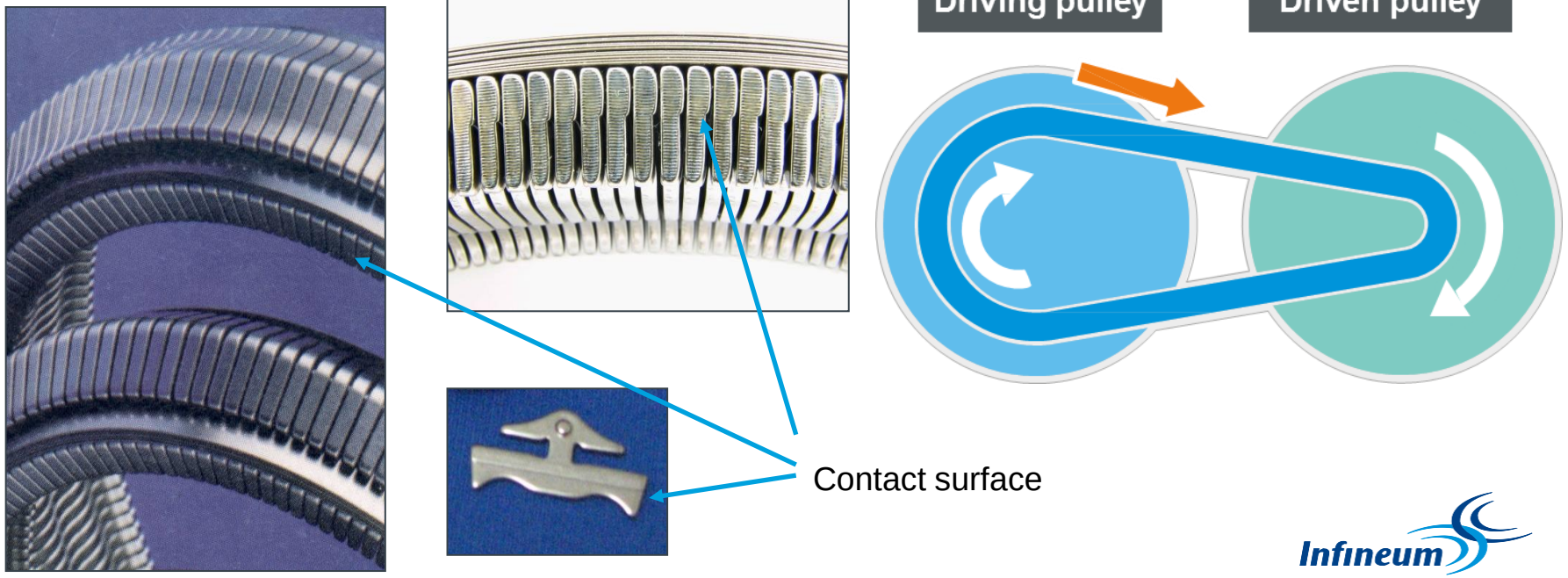
Metal “V-belt” and conical pulley system

- 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



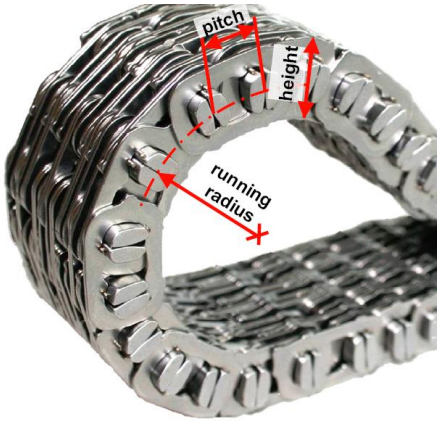
VDT – push belt

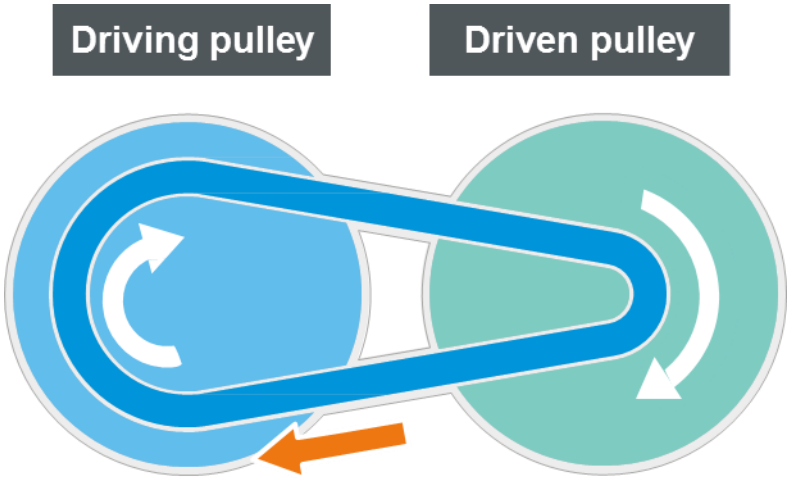
- Developed by Van Doorne Transmissie (VDT)
- Push belt consists of ~300 steel blocks connected by flexible steel rings
- Force transmitted from pulley to pulley via compressional forces between belt elements



CVT 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





CVT 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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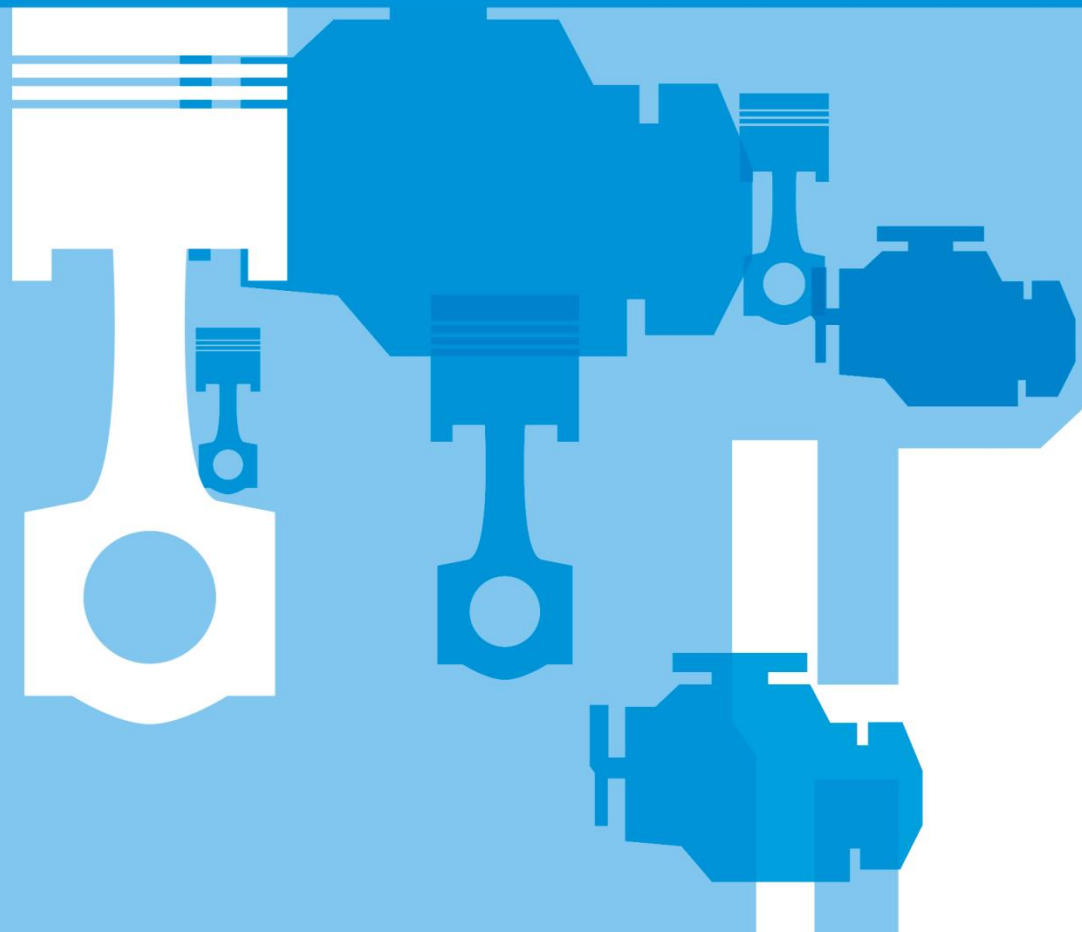
CVT summary

- 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

Summary



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Automatic transmission 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
  - DCT growth predominantly in Europe
  - CVT growth predominantly in North America
  - Asia gives a mixed picture, with China favouring DCT and Japanese OEM preferring CVT

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Automatic transmission fluids summary

Fluid Trends

- OEMs specify ATF with:
  - Exact friction requirements (e.g. friction and anti-shudder 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

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