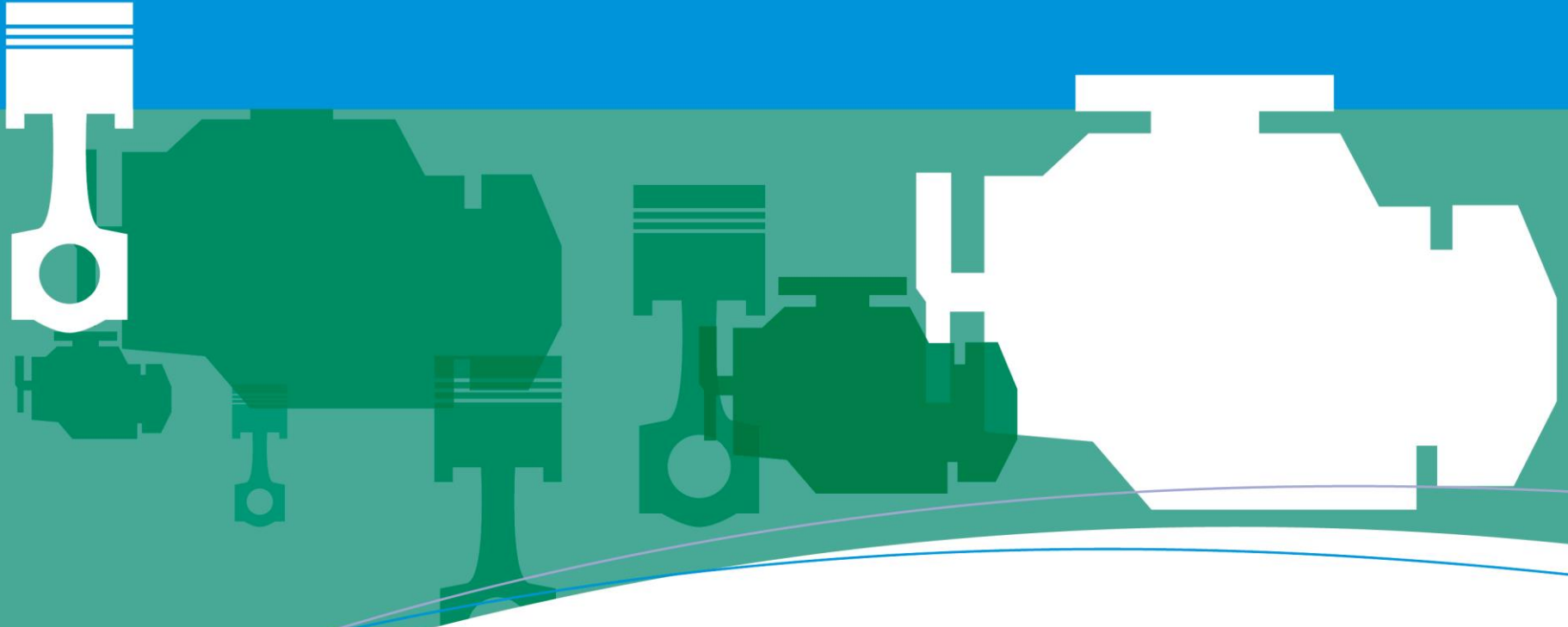


Performance you can rely on.

Power transmission fluids



InfineumInsight.com/Learn



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

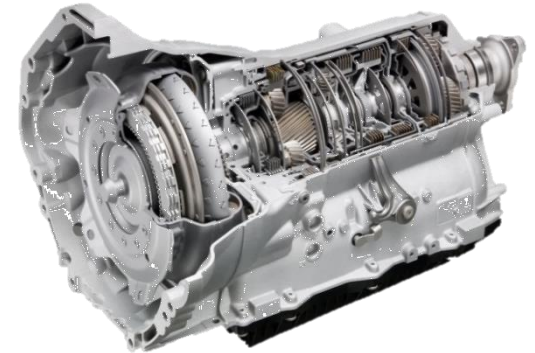


What does a transmission do?

- 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)** describe fluids necessary for proper operation of automatic transmissions including: stepped automatic transmissions, dual clutch transmission, continuously variable transmission, etc.
- **Automatic Transmission Fluids (ATF)**, generally refer 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
- **Dedicated Hybrid Transmission (DHT)**
 - Combines stepped automatic transmission with electric motor (e.g. Toyota's Hybrid Synergy Drive)
- **Reduction Transmission (Electric)**
 - Transmissions used by purely electric vehicles to increase torque output from electric motors (Nissan Leaf)
- **Manual Transmission (MT)**



Automatic transmissions

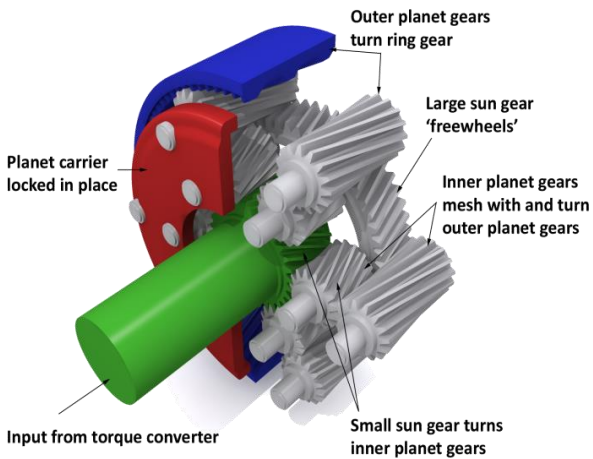
Stepped Automatic

↑ 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



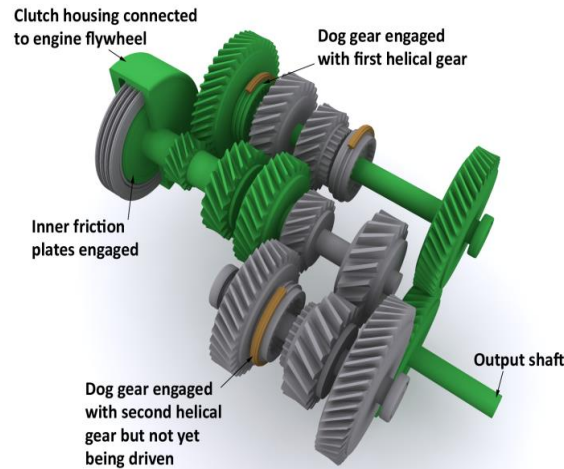
Dual Clutch

↑ DCT PROS

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

↓ DCT CONS

- Launch feel not as smooth as stepped AT



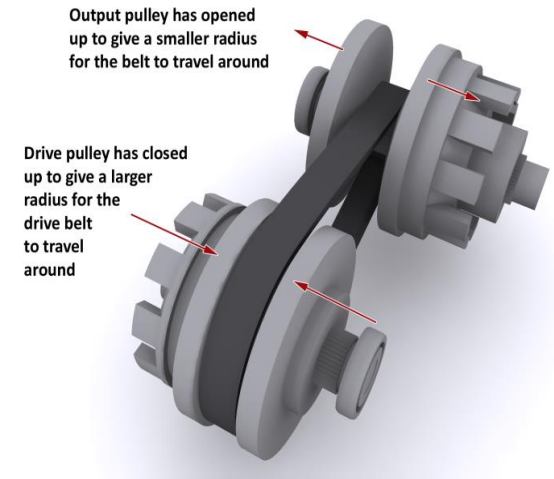
Continuously Variable

↑ CVT PROS

- + Comfort due to no shifting
- + Acceleration
- + Fuel Efficiency

↓ CVT CONS

- Torque Capacity
- Cannot utilize existing stepped AT manufacturing sites



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 installations

Passenger Car And Light Duty Truck Transmission Installations

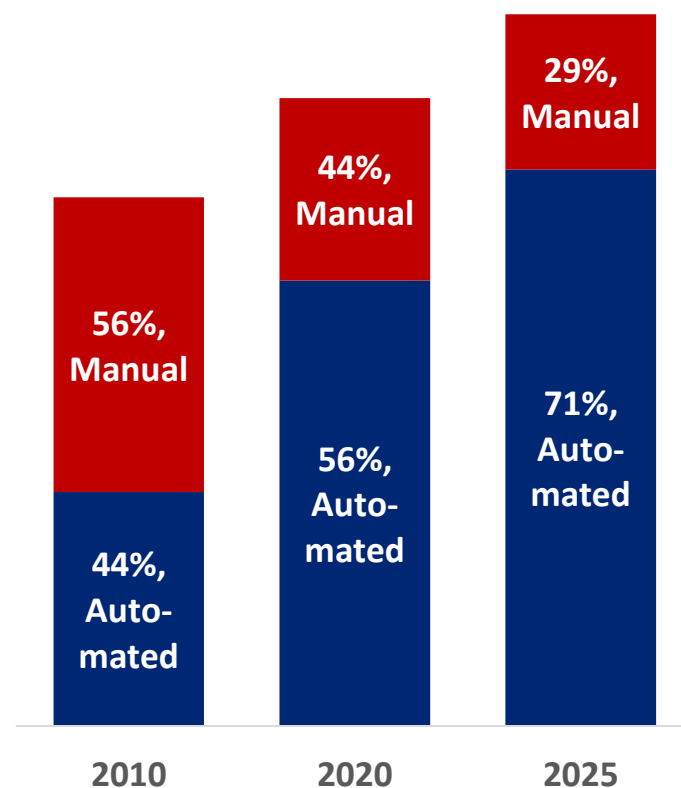
Manual

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

Automated

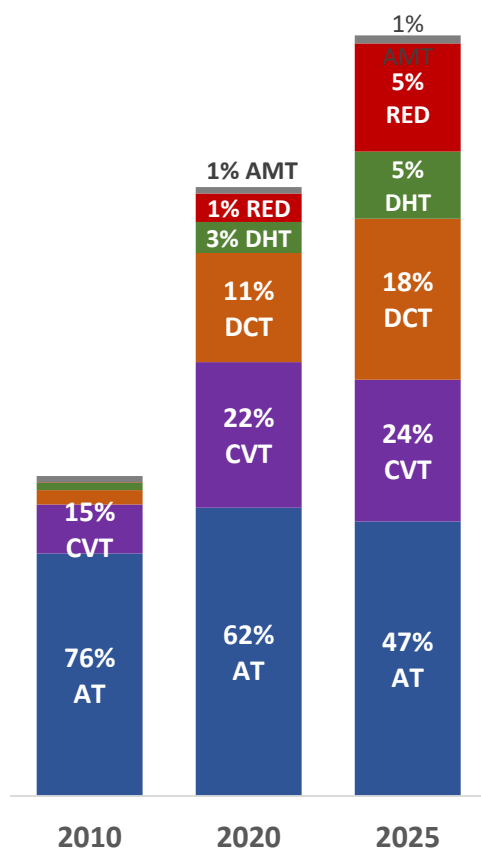
Market share increasing with fuel economy now better than manual. Increasing diversity in design.

Global Light Duty Transmission Installations



Data Source: IHS Automotive, Feb '20

Global automated transmission installations



Data Source: IHS Automotive, Feb '20

Automated Manual Transmission (AMT)

Some production increase, market share low and declining

Reduction Transmission (Electric)

Large electric vehicle increase, market gaining momentum

Dedicated Hybrid Transmissions (DHT)

Large hybrid vehicle increase, continuing market share growth

Dual Clutch Transmission (DCT)

Large increase, with market share gain in China and Europe

Continuously Variable Transmission (CVT)

Increase in production now peaking with electrification

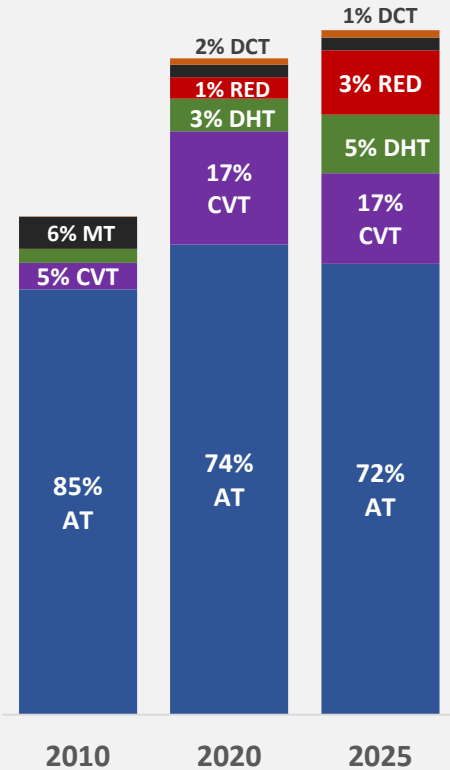
Stepped Automatic Transmission (AT)

Production slowly declining, with growing diversity of designs

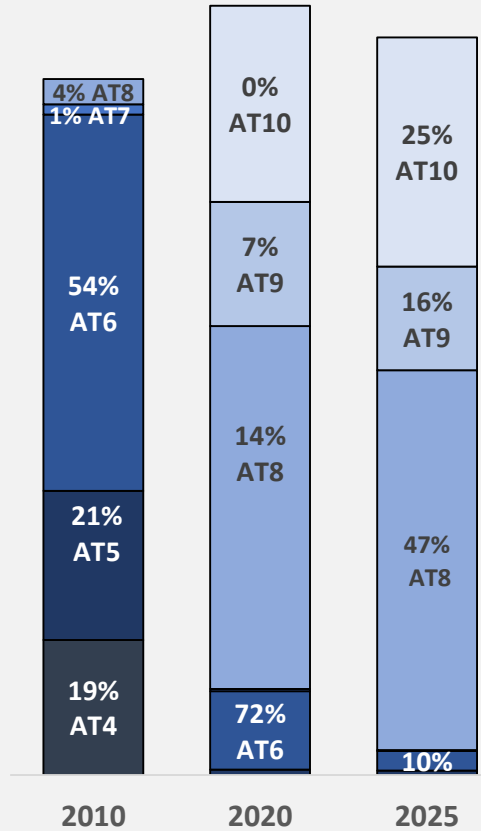
Transmission hardware trends

North America installations – CAFE impacts

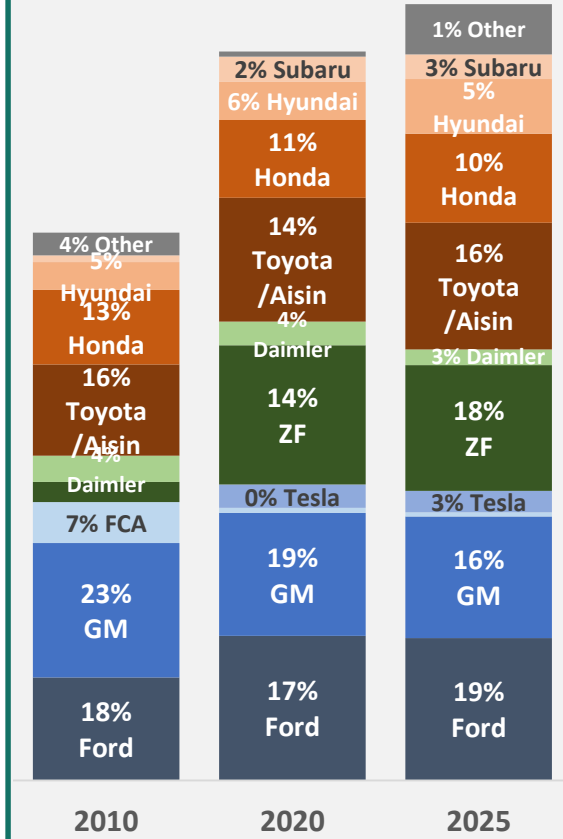
Growth in Non-Conventional Designs



Rapid Increase in AT Forward Speeds



Growing Foreign Influence



Data Source: IHS Automotive, Feb '20

ATF Market review

low-viscosity ATF growth

Type F: true vehicle requirement <0.1%

- low cost, hard shift, other applications

DIII/M: declining to <20%

- low cost also keeping market afloat

MERCON® V: also declining to <20%

- all out of warranty period

ATF+4®: stable at ~10%

- still used by Chrysler

Import Multi-Vehicle; growing to >25%

- greater, if also for GM and Ford licensed applications

DEXRON®-VI/MERCON® LV: increasing, >10%

- Fords now reaching 150,000 mile ODI

Ultra Low Viscosity [ULV] – negligible demand

- Recently introduced, also with long ODI

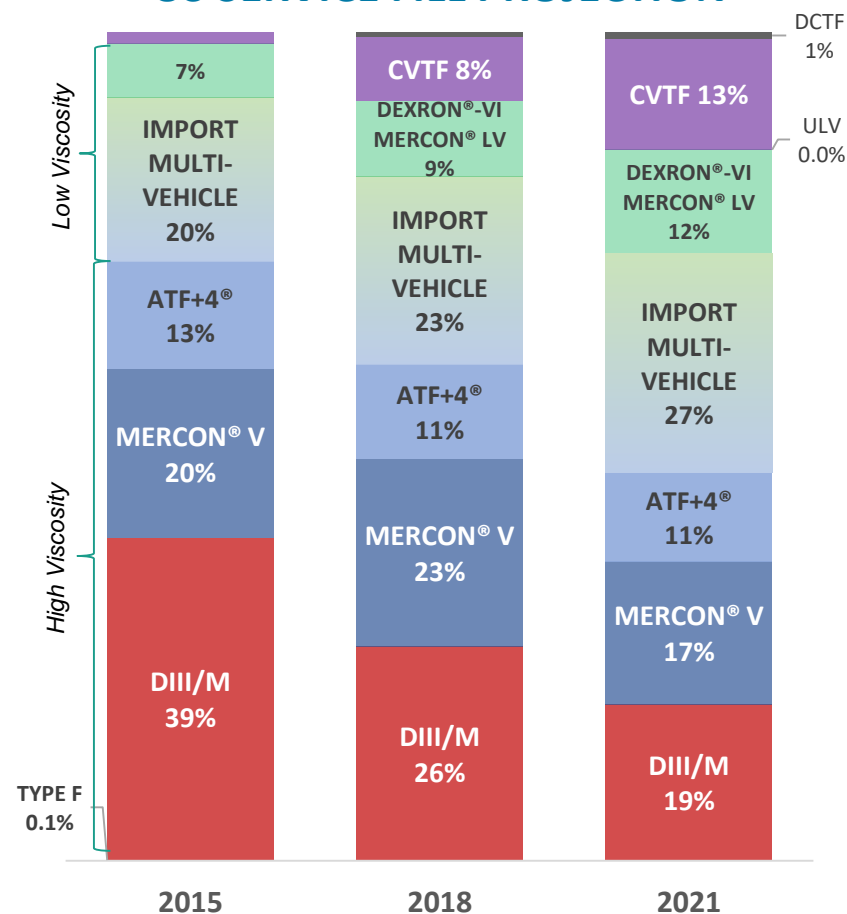
CVTF: growing to >10% demand

- CVT installations up, with relatively short ODIs

DCTF: less than 1% demand

- few DCT installations in US

US SERVICE FILL PROJECTION

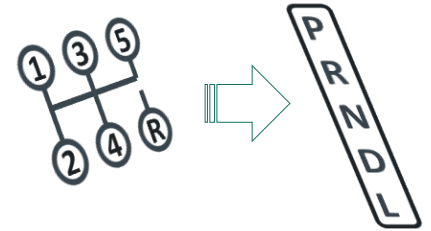


Data Source: Infineum database

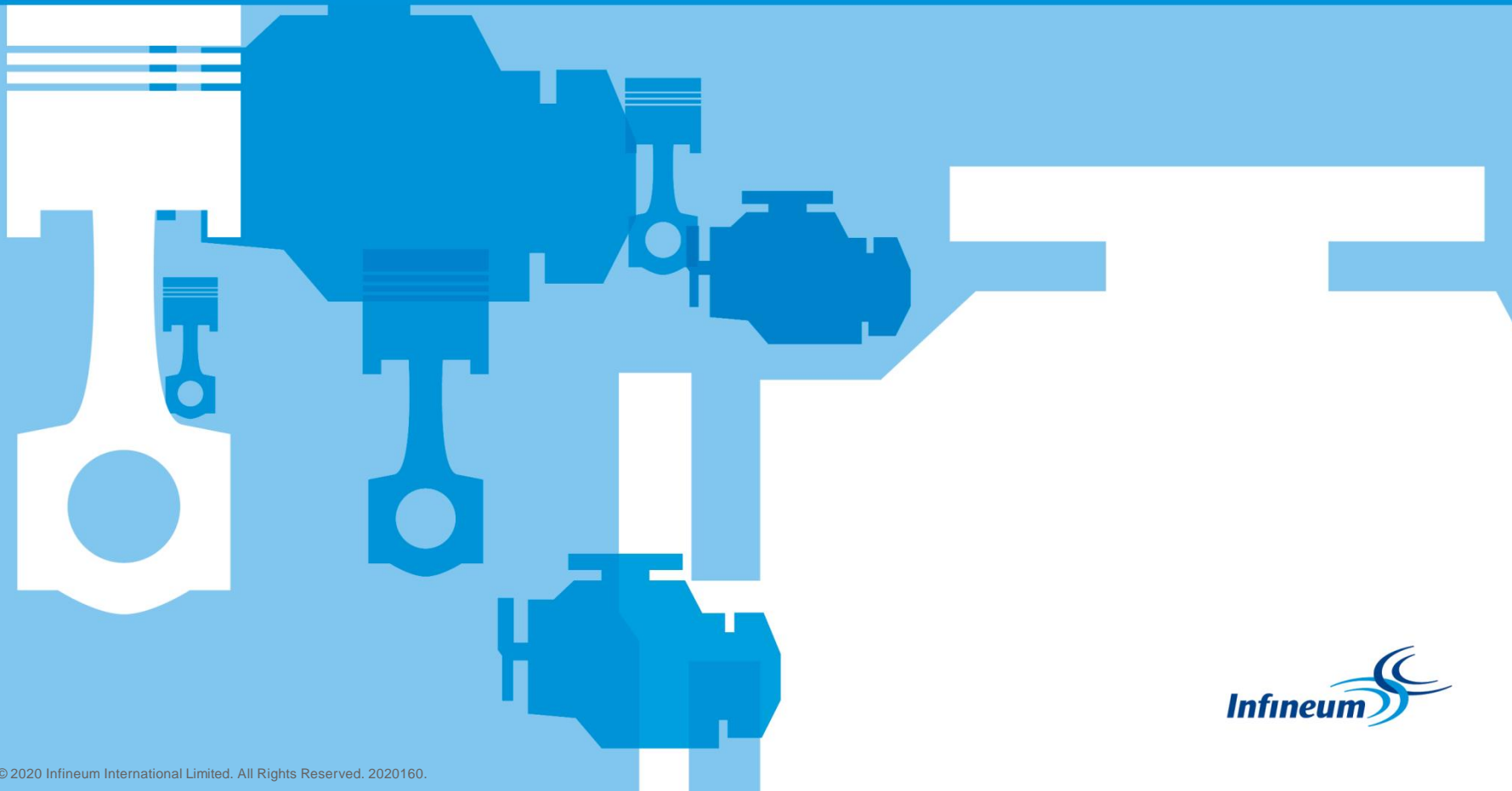


Market summary

- **Growing use of automated transmissions.**
 - Now providing better fuel economy than manuals.
 - Manual production is now lower than automatics.
- **Stepped Automatics are still the majority**
 - Gaining more gears – most now >8-speeds.
 - Major manufacturers are Ford, GM, ZF and Toyota.
 - CVTs and DCTs are gaining market share.
 - Increasing use of hybrid and reduction gear boxes for electric motors.
- **Most automatic transmission fluids are now lower viscosity.**
 - Less churning loss leads to better fuel economy.
 - Import multi-vehicle ATFs gaining market share, often with GM and Ford approvals.
 - CVT fluid demand increasing, with short drain intervals



AT Hardware and ATF performance requirements



Stepped planetary automatic transmission

Hardware

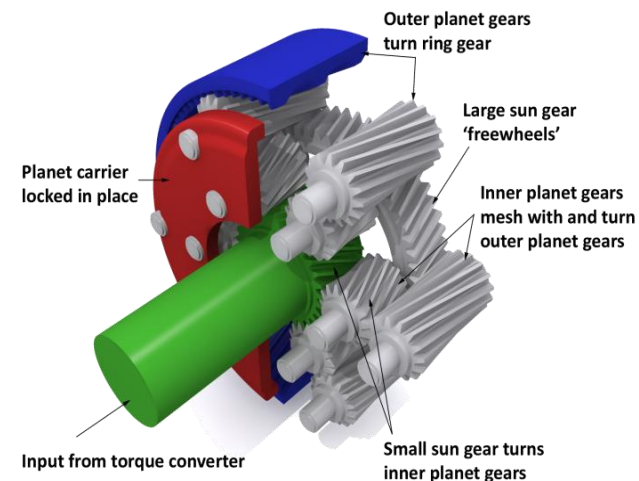
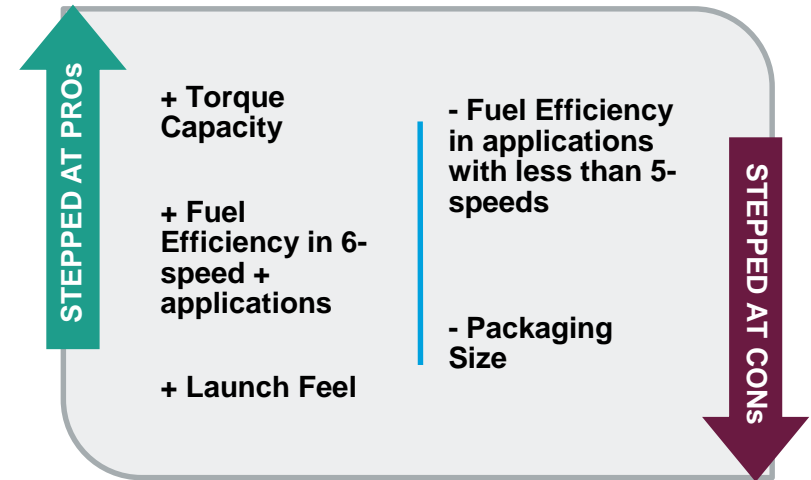
- **Planetary Gearset** – gear ratio control
- **Torque Converter** – fluid-coupling to transfer power from engine to transmission
- **Clutch Packs**
- **Valve-Body**

Market

- Most common global transmission type

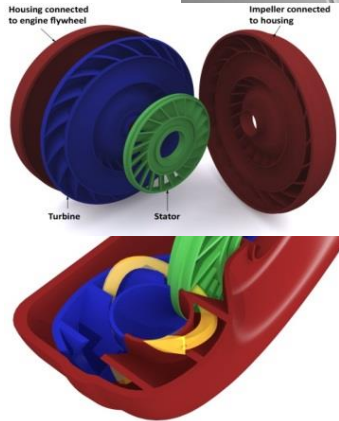
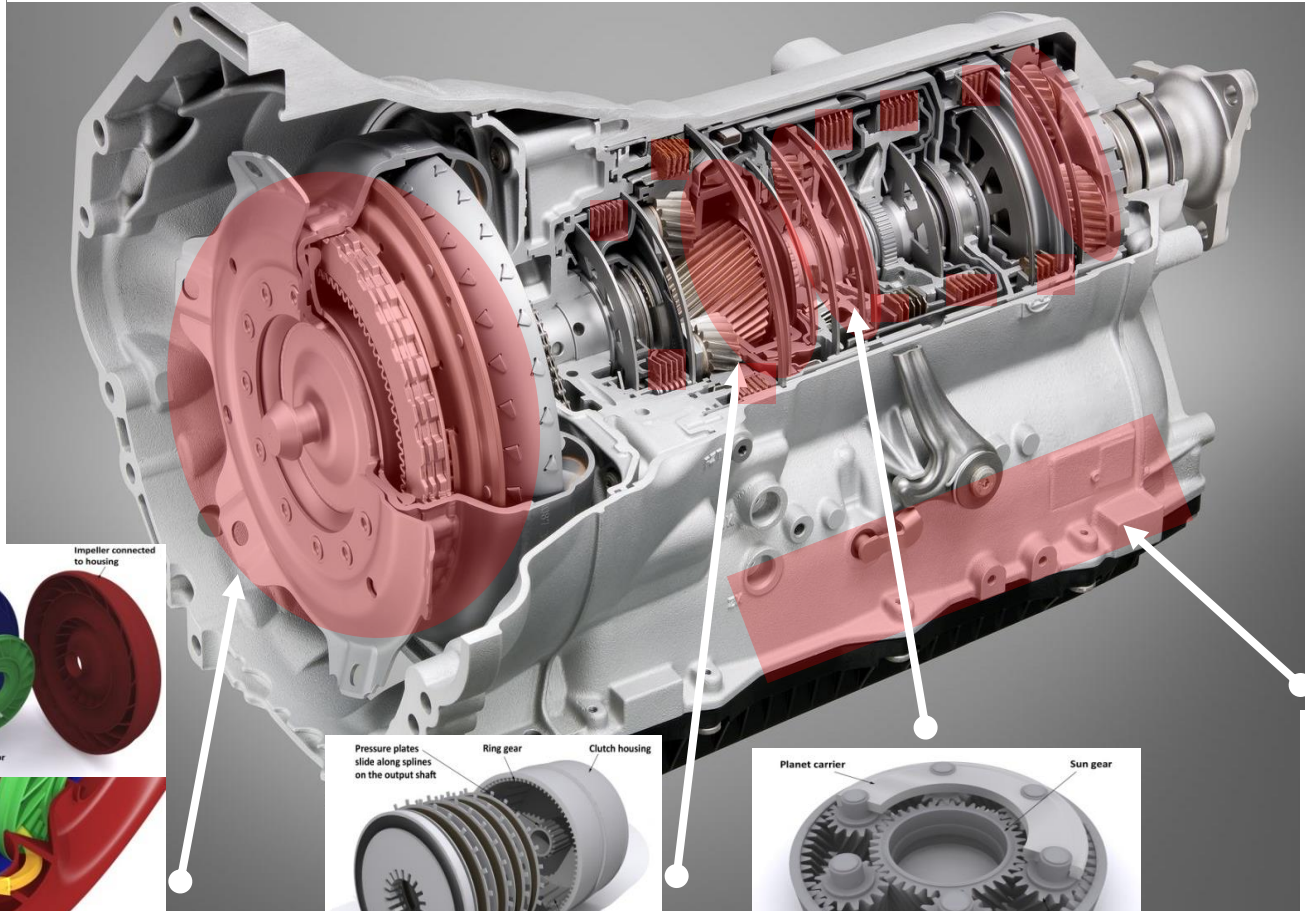
Manufacture

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

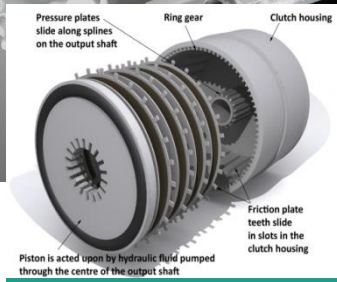


Automatic transmission hardware

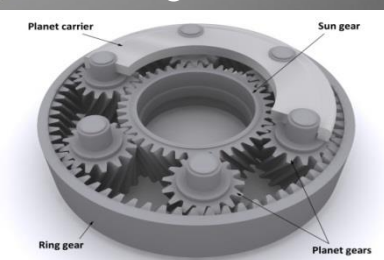
Photo source: BMWBLOG.COM



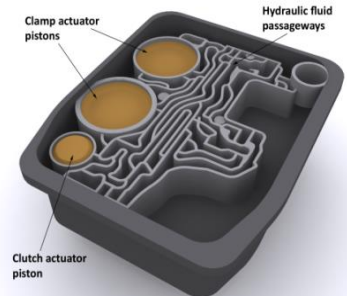
Torque Converter



Clutches



Planetary Gear

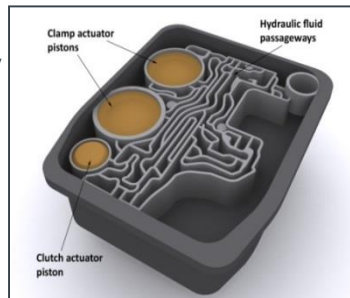


Valve Body

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

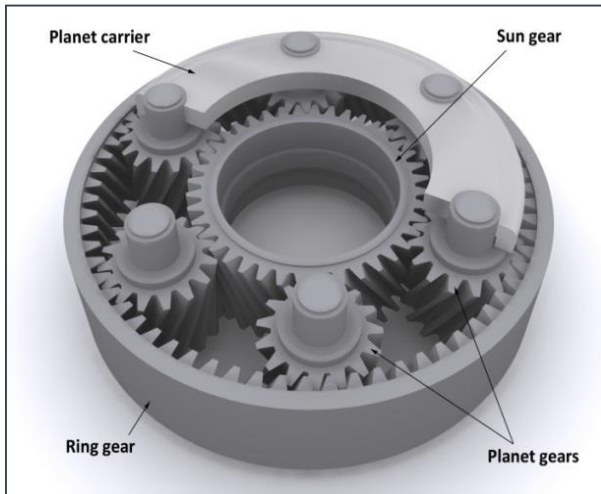
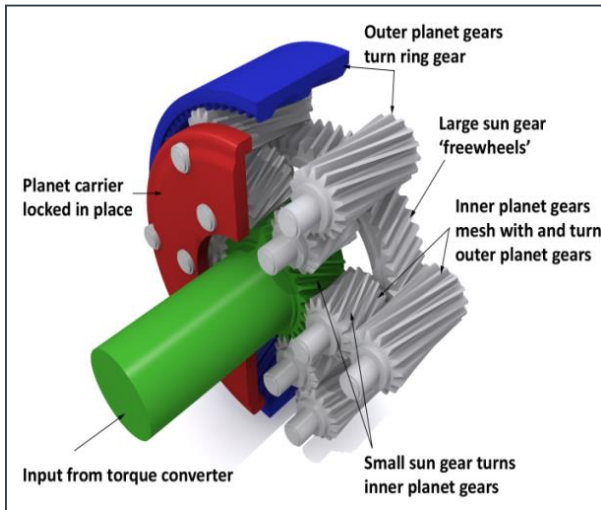
Large operating range
(-40C to 175C)

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

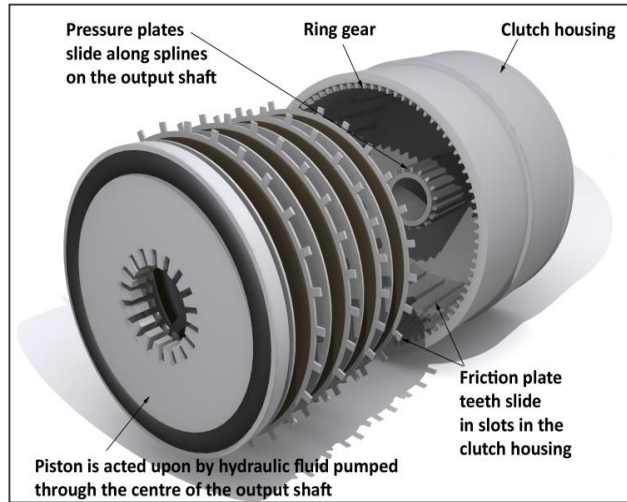
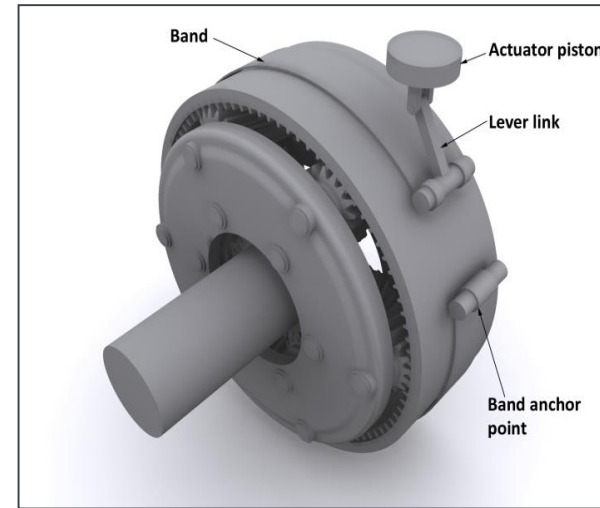


Plate Clutch



Band Clutch

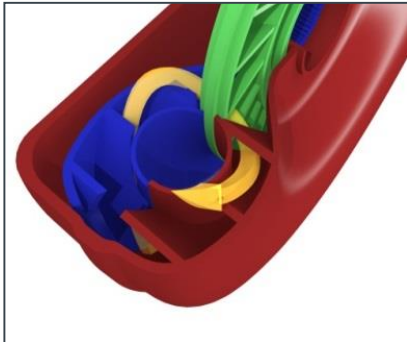
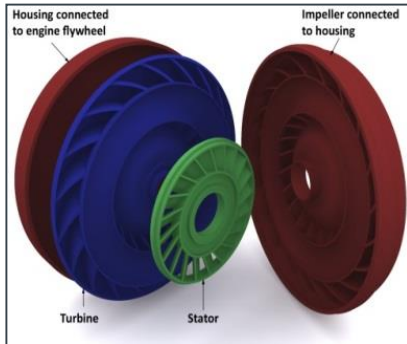
ATF requirements

Remove heat
efficiently

Resist oxidation

Deliver specialized
friction
requirements

Automatic transmission torque converter



Torque Converter Clutch

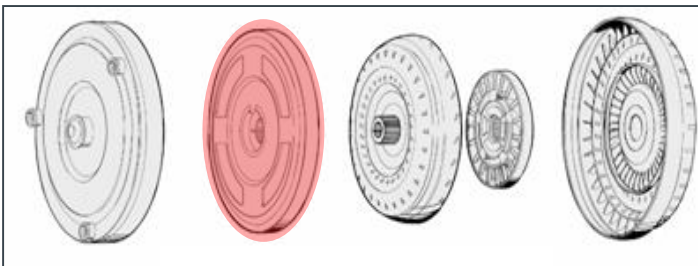
- Large energy loss without clutch
- Clutches added in 1970s to improve fuel economy
 - Full lock-up at highway speeds
- Lock-up clutch evolved for improved comfort and additional fuel economy benefits
 - Slipping clutch at low speeds

ATF requirements

Act as a Hydraulic Fluid

Large operating range (-40C to 175C)

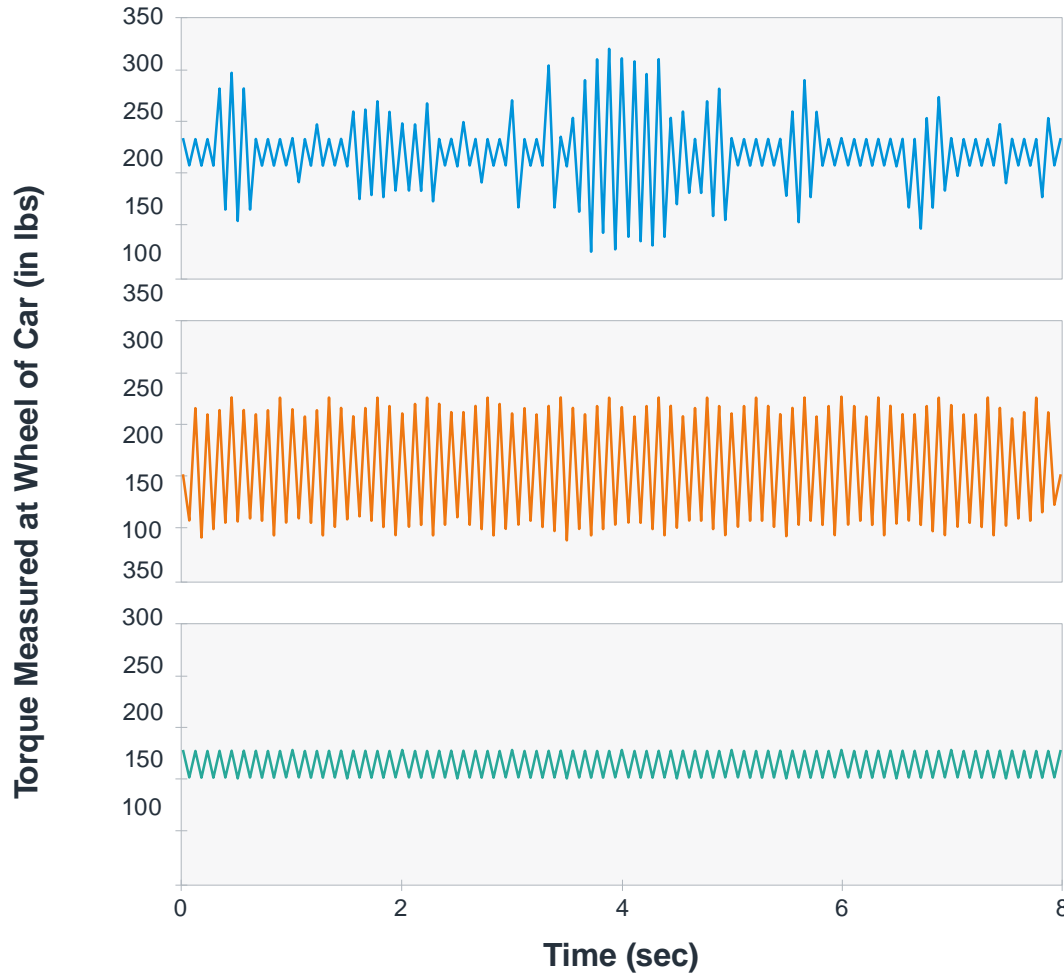
Deliver specialized friction requirements



Torque Converter Lock-Up Clutch

Torque converter clutch friction deterioration → shudder

Self-Excited Driveline Vibration



Intermittent Shudder

Continuous Shudder

No Shudder

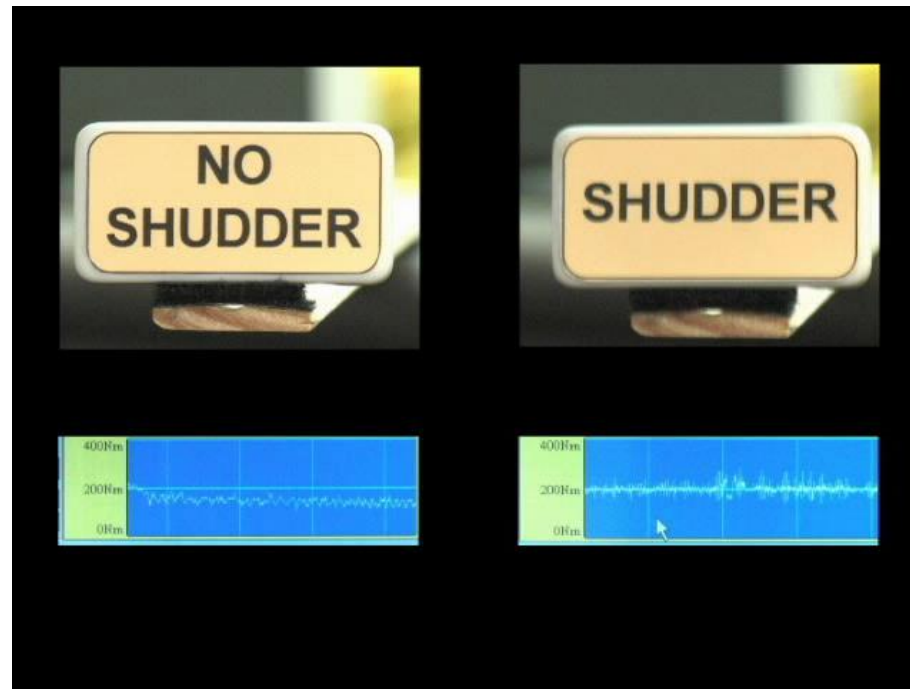


Sh-h-h-udder occurs!

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

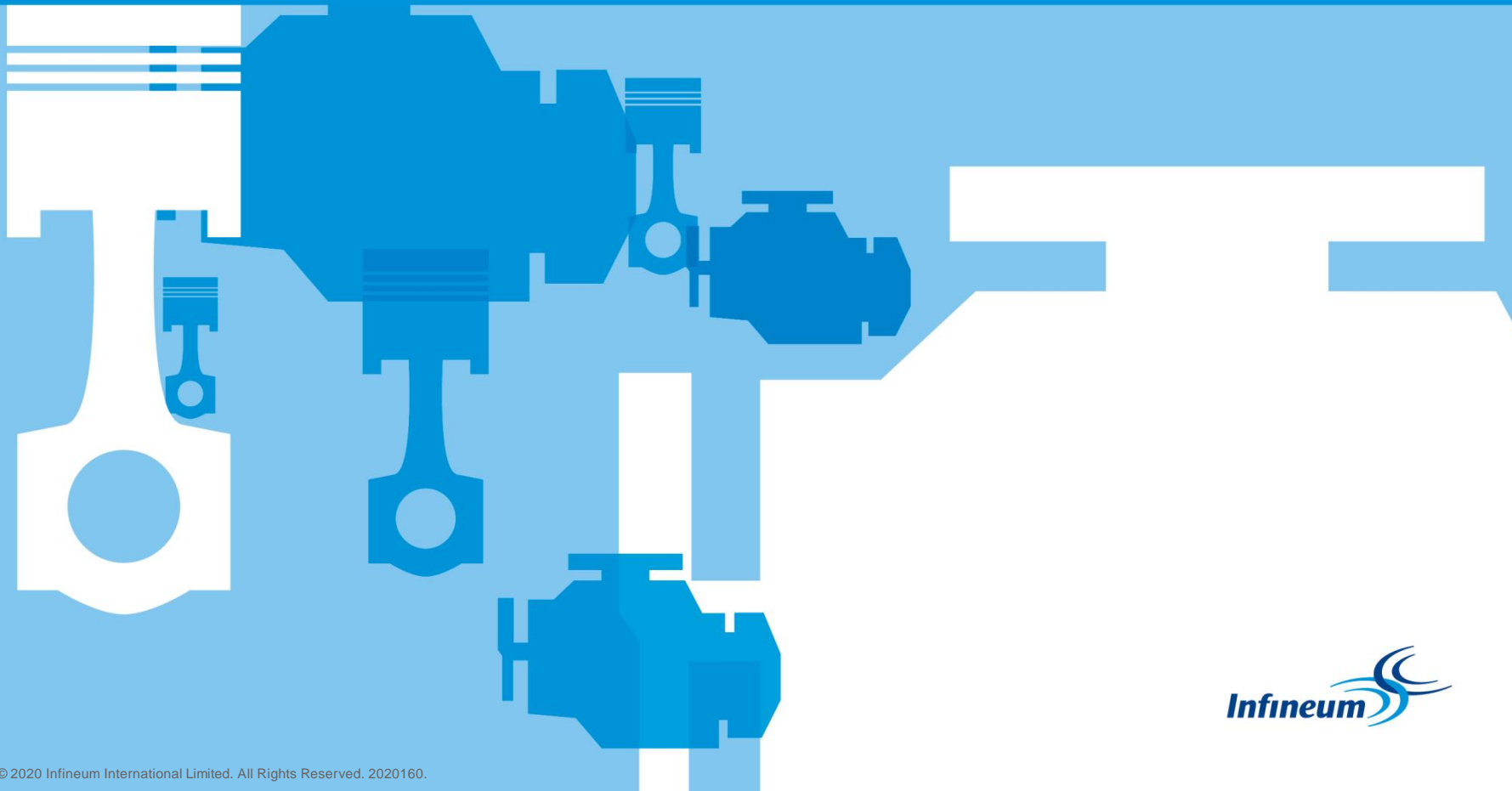
The automatic transmission has 4 major components:

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

Viscometrics

Kinematic viscosity @ 100°C
(KV100)

Brookfield viscosity @ -40°C
(BF-40)

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

Performance

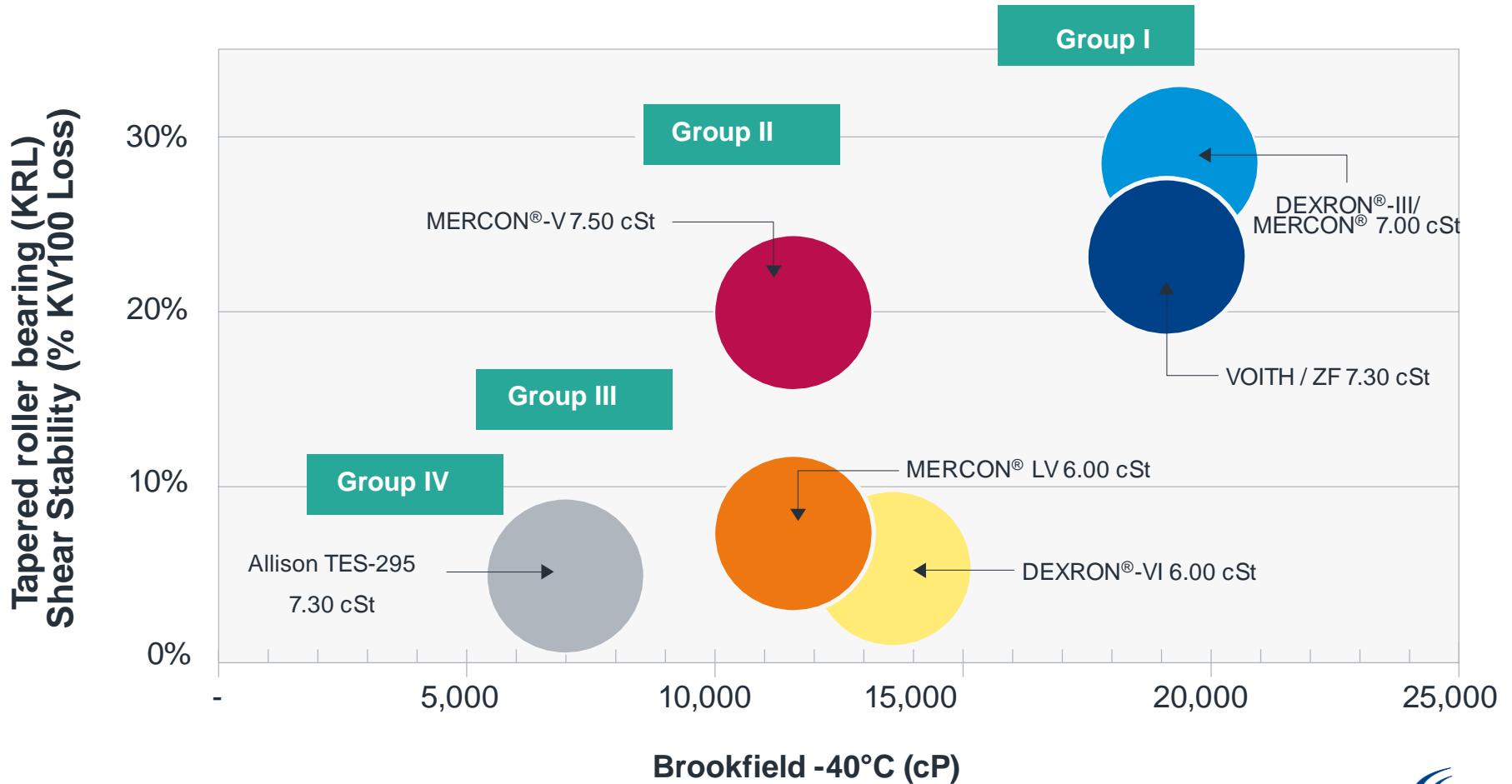
Lubrication of transmission
parts at high temperature

Transmission operability at cold
temperatures - *cold morning
start*

Ensures aged ATF adequately
lubricates transmission parts

Viscometric trends

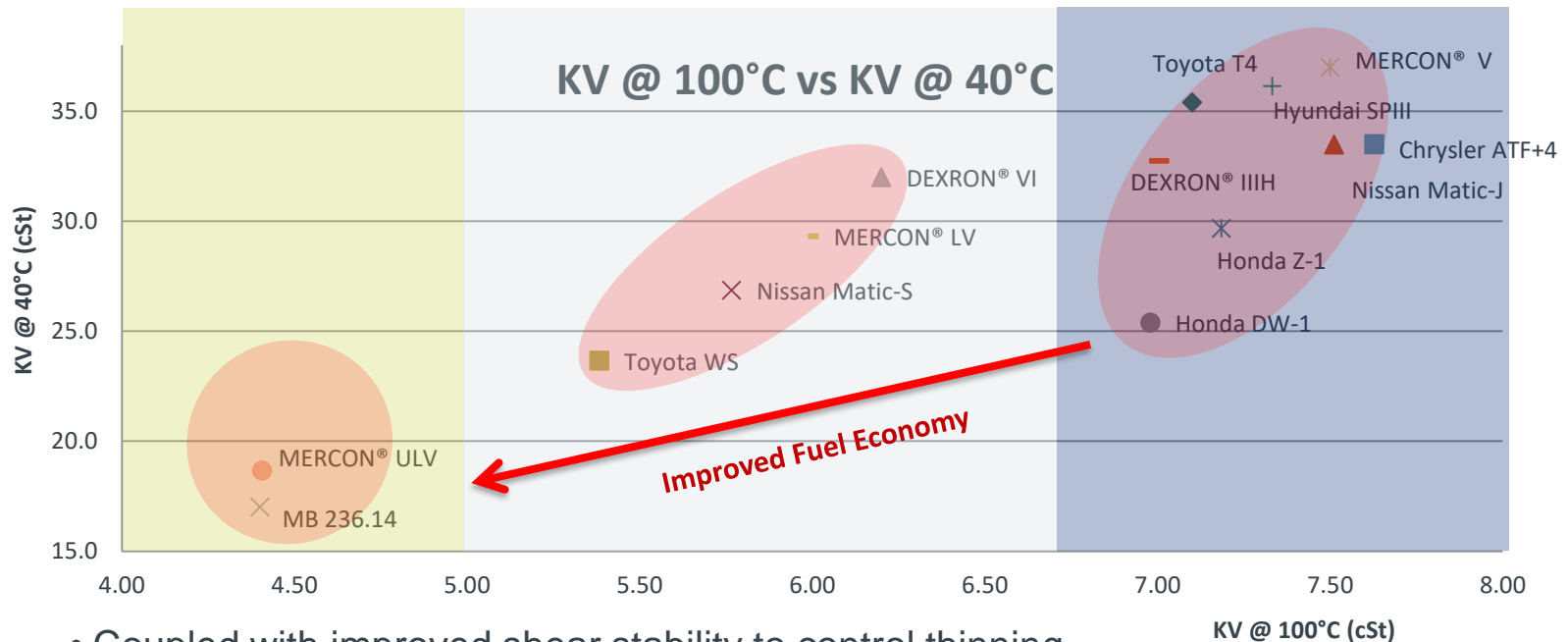
ATF Shear Stability vs. Low Temperature Viscosity



New generation ATFs lower viscosity for fuel economy

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

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

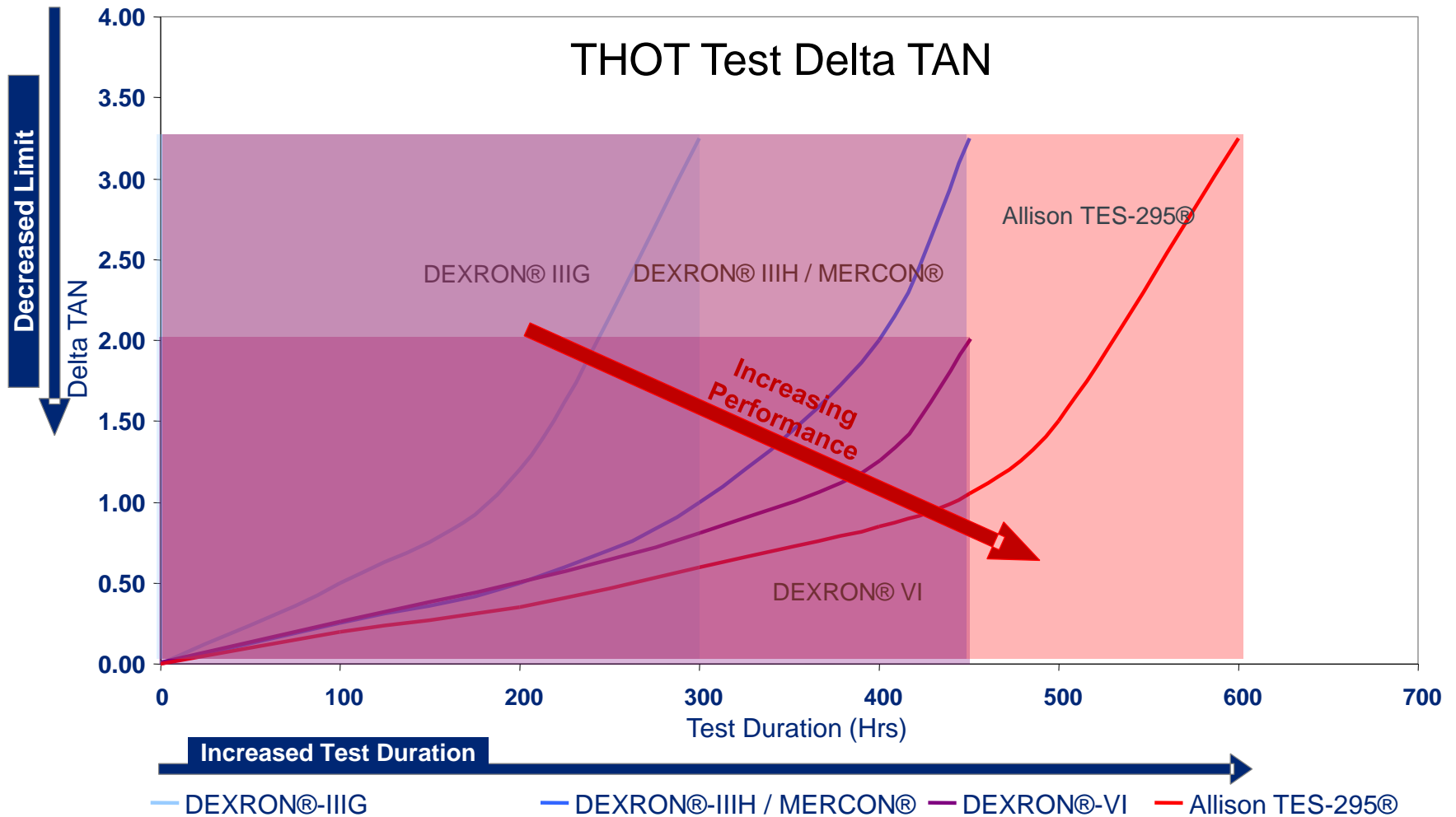
Sludge formation → Clogged
valve body

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

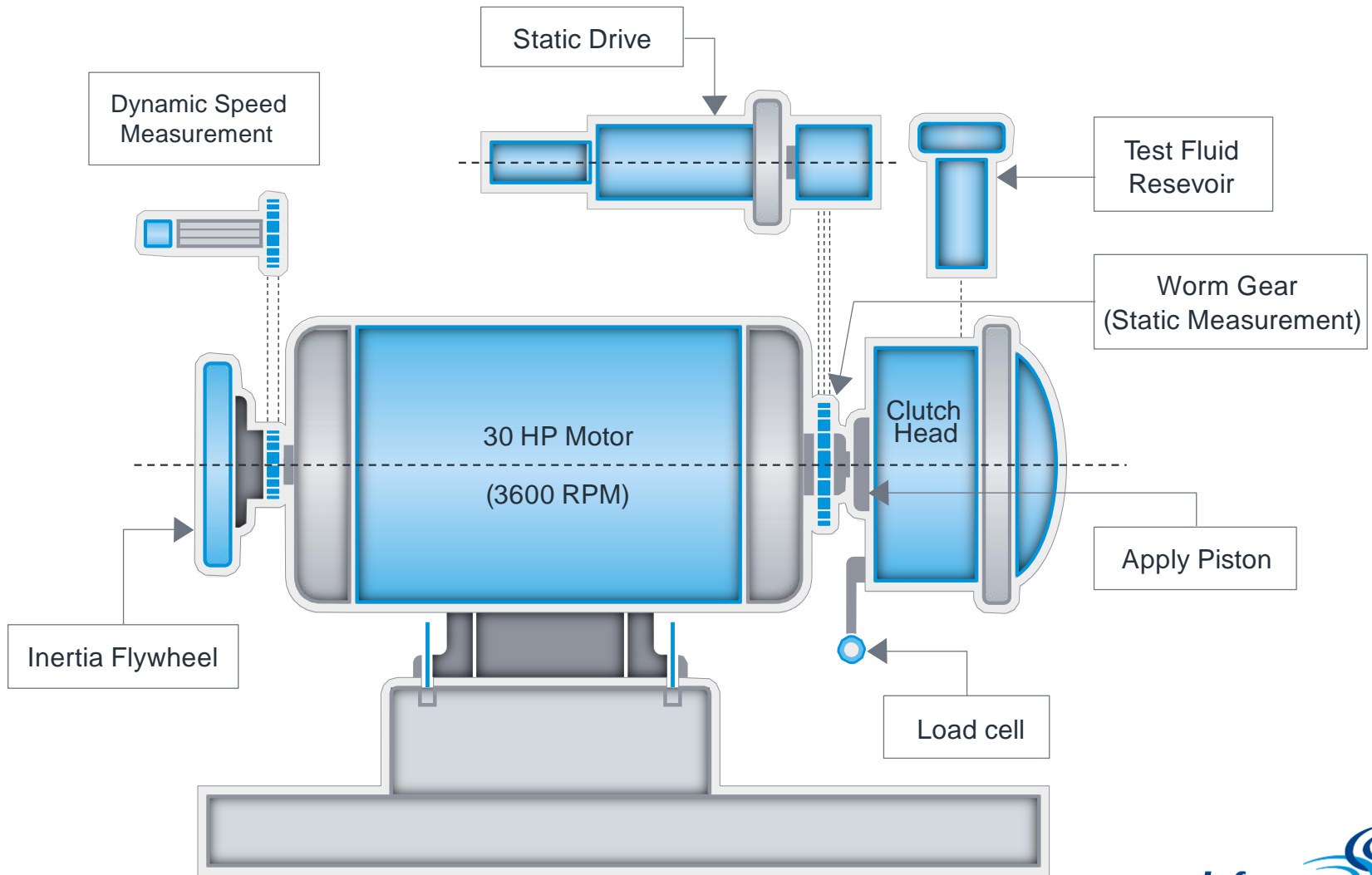
Shifting Clutch

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

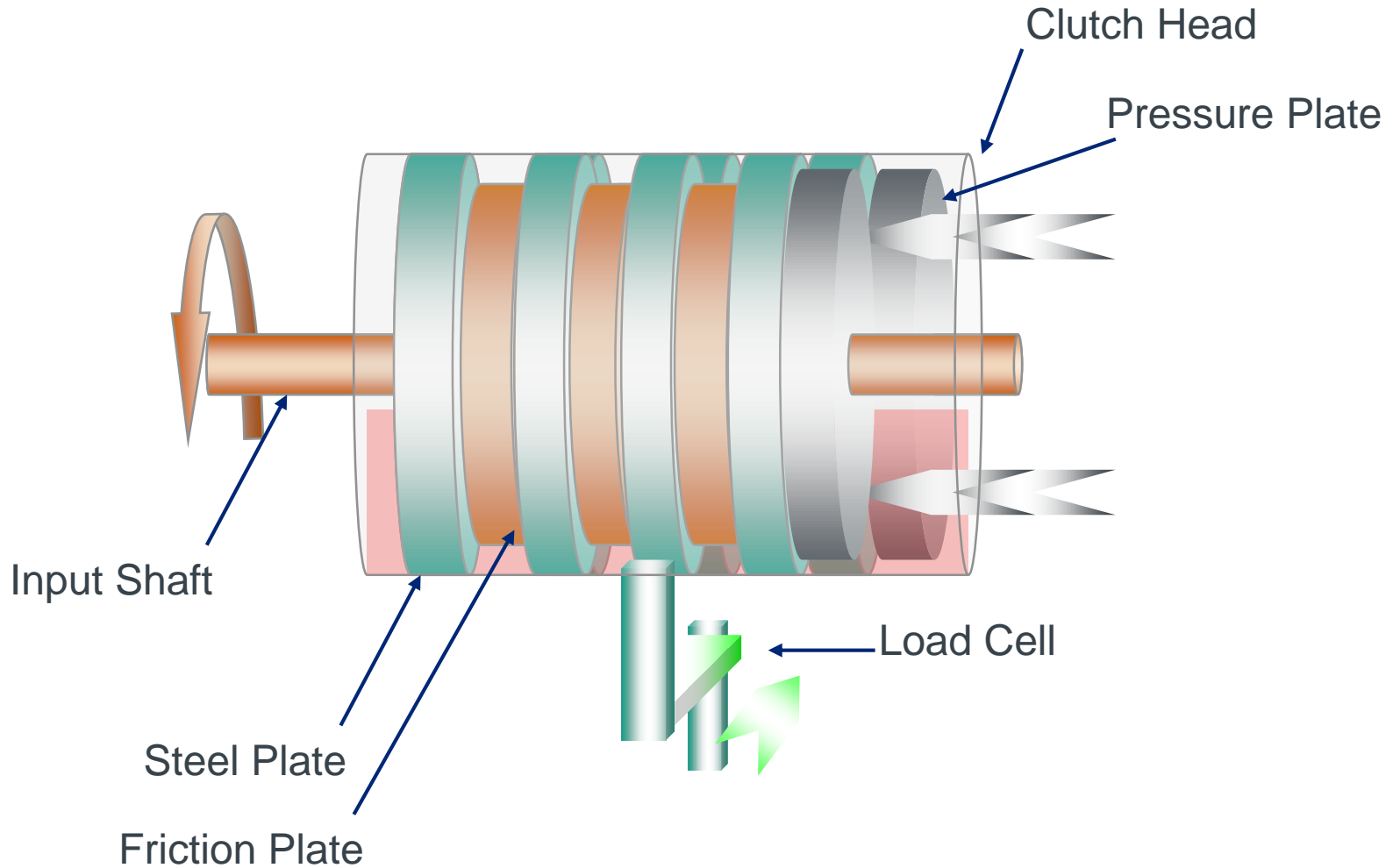
Torque Converter Clutch

- Anti-Shudder durability

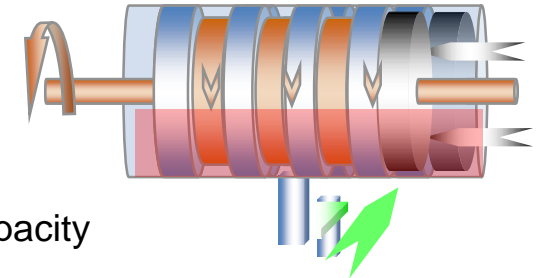
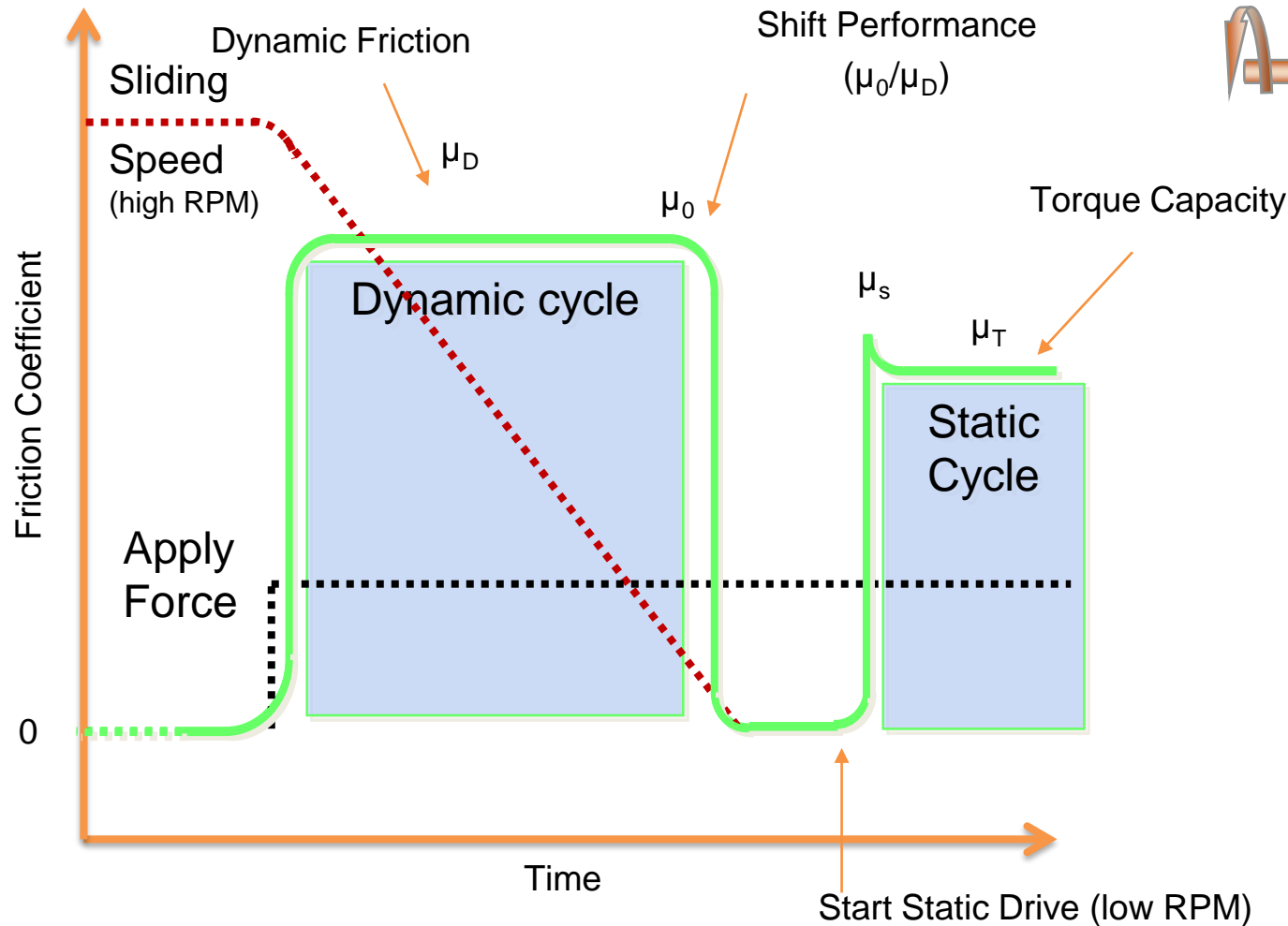
SAE No. 2 Friction test machine



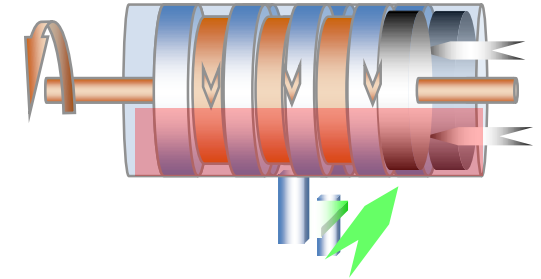
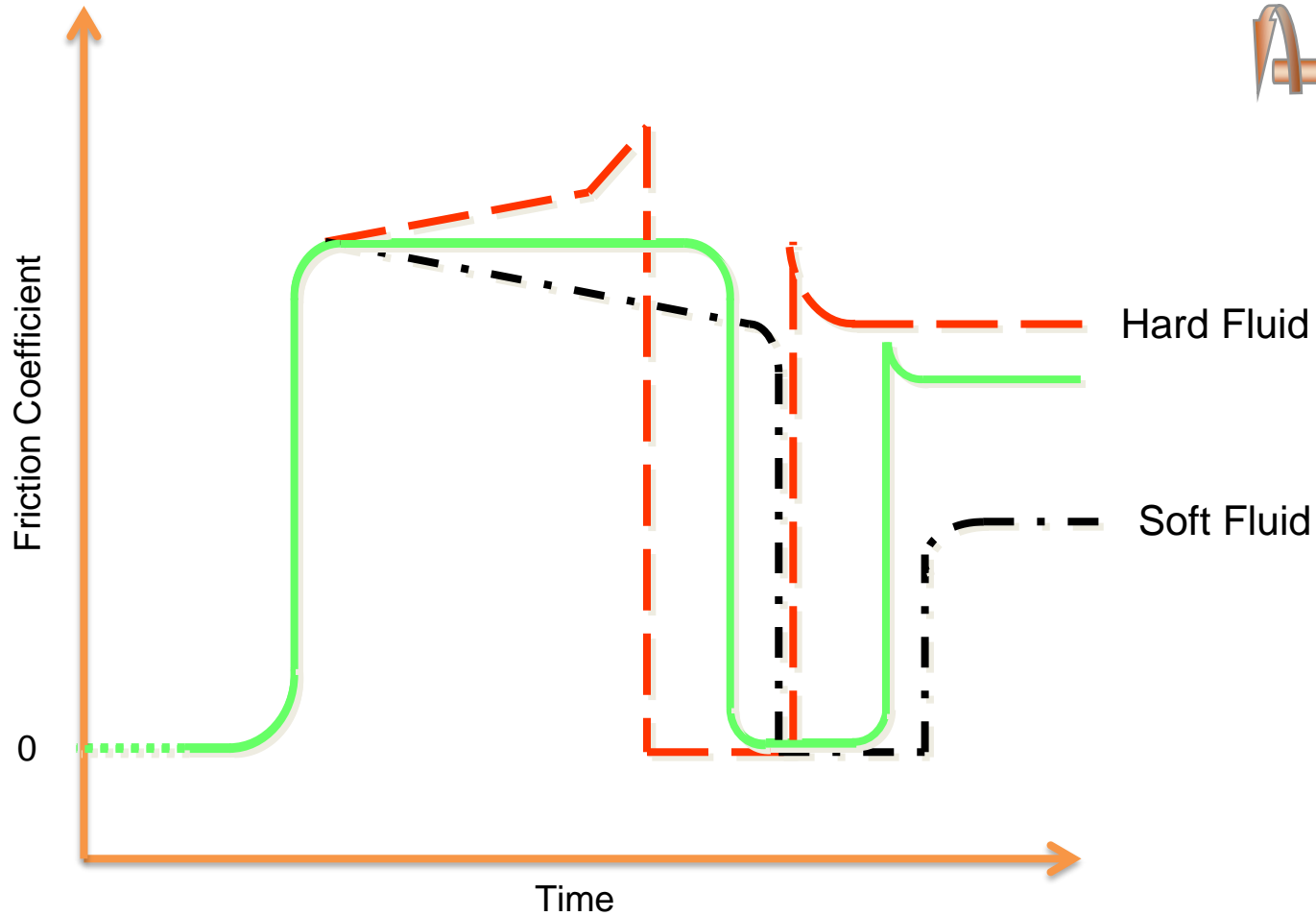
SAE No. 2 Friction test machine clutch head



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

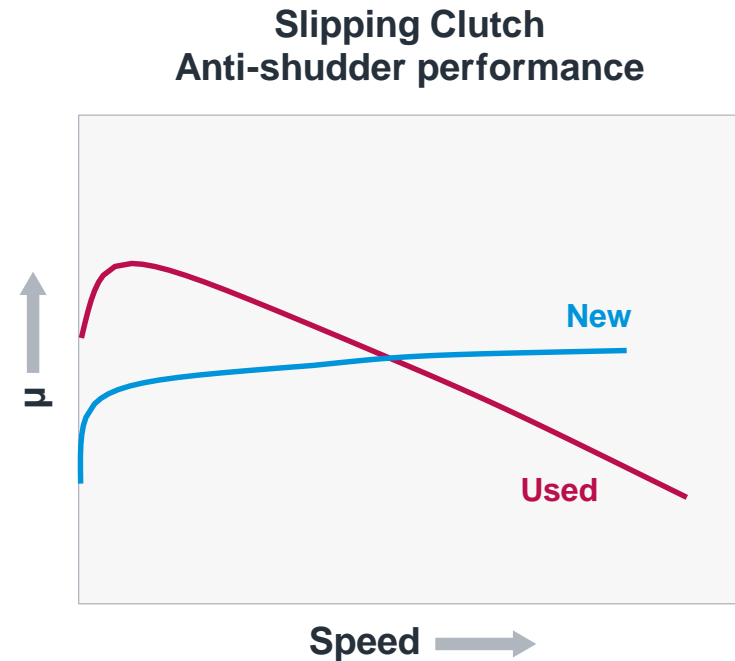
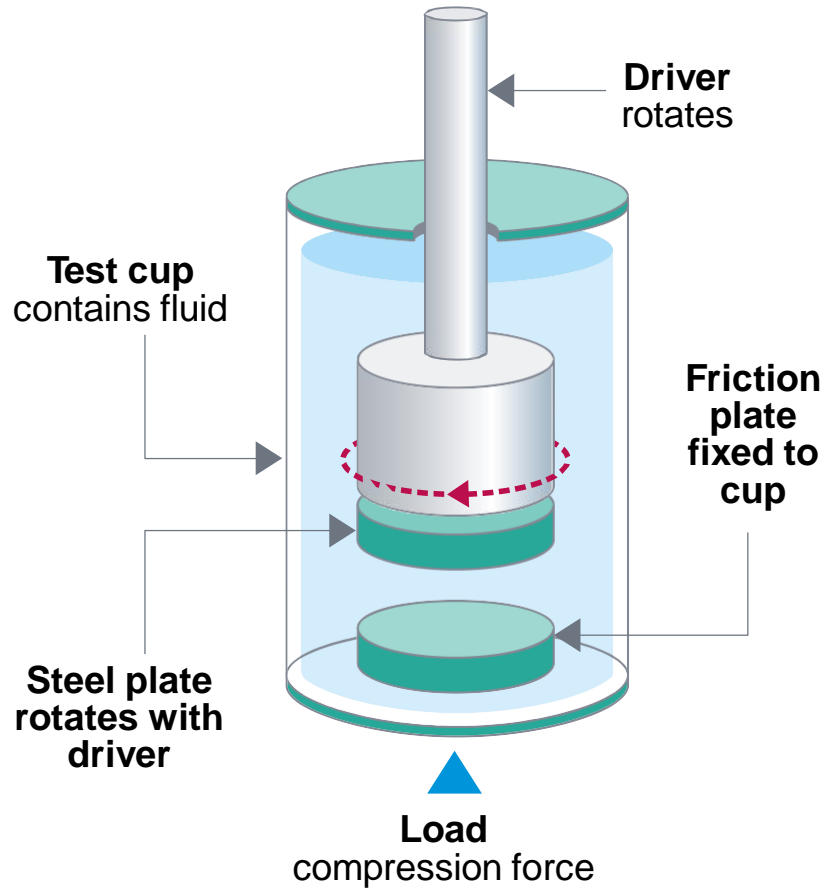
Static friction (μ_T) → high

- Gives clutches good holding power, high torque capacity

Trend

- Increase friction durability

Low velocity friction apparatus (LVFA)



Reasonable μ level with positive slope required

What affects friction?

Hardware Demands

Fluid Technology

Temperature

Sliding
Surface
Composition

Load

Sliding
Speed

Friction
Modifier Type

Friction Modifier
Concentration

Increased interest in
friction durability



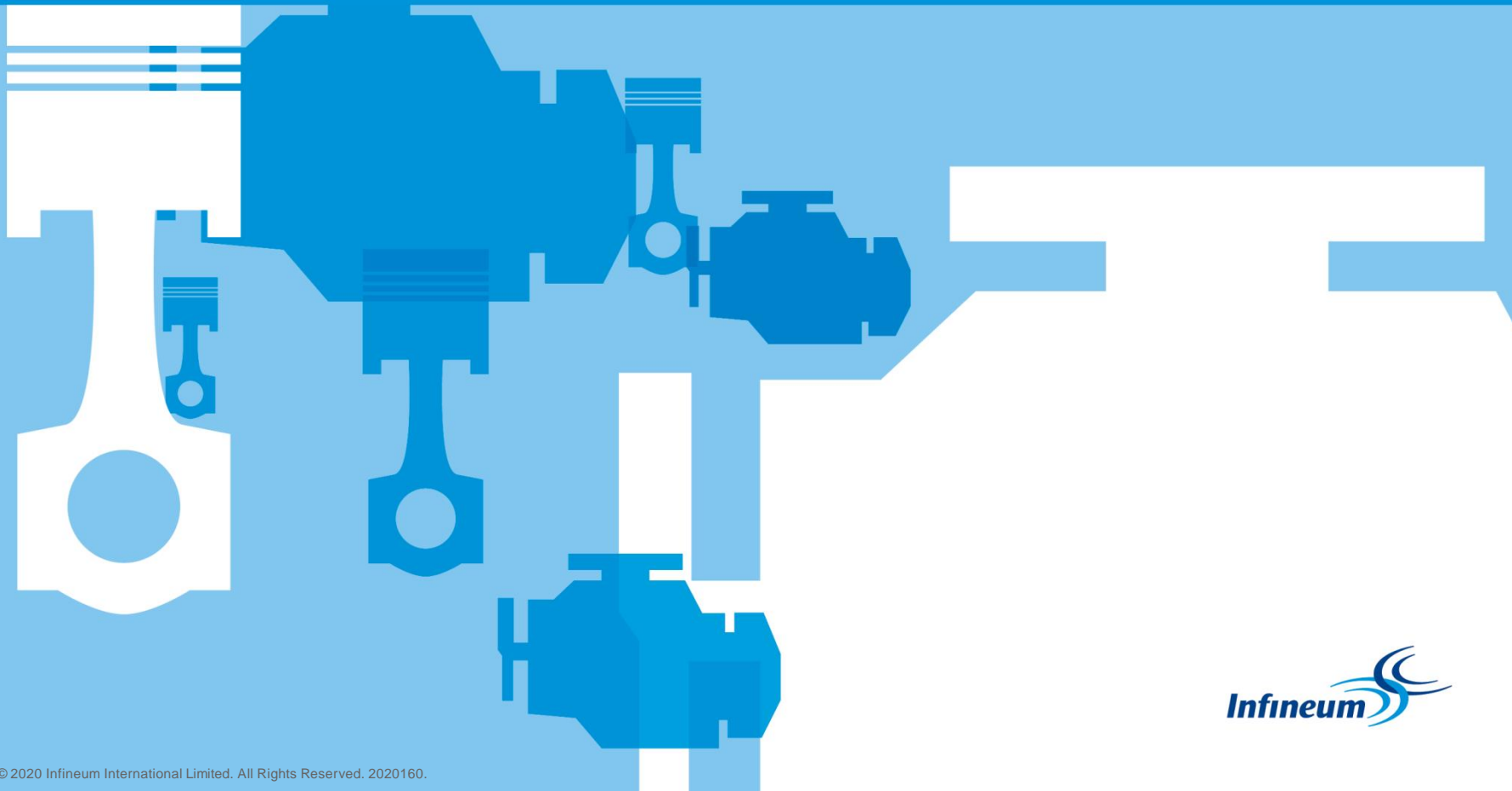
ATF performance summary

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

	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	DEXRON® ULV
European OEMs	 Mercedes-Benz	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	-

***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-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

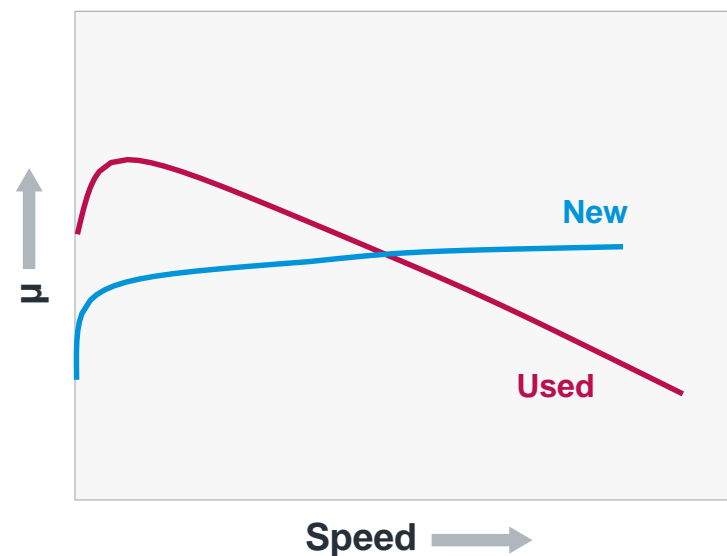
Friction Characteristics (Shifting Clutch)

- 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

Slipping Clutch Anti-shudder performance

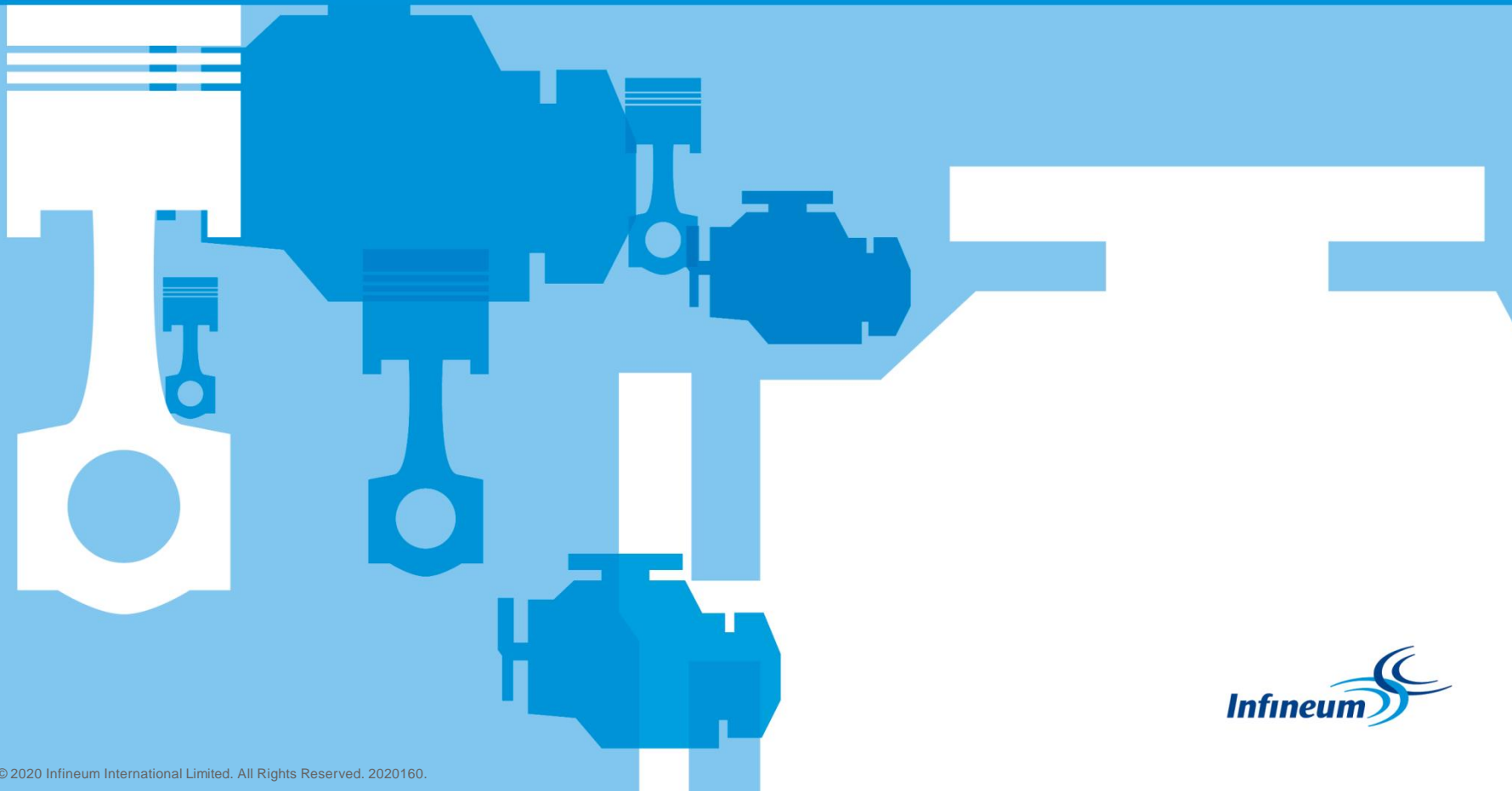


Reasonable μ level with positive slope required

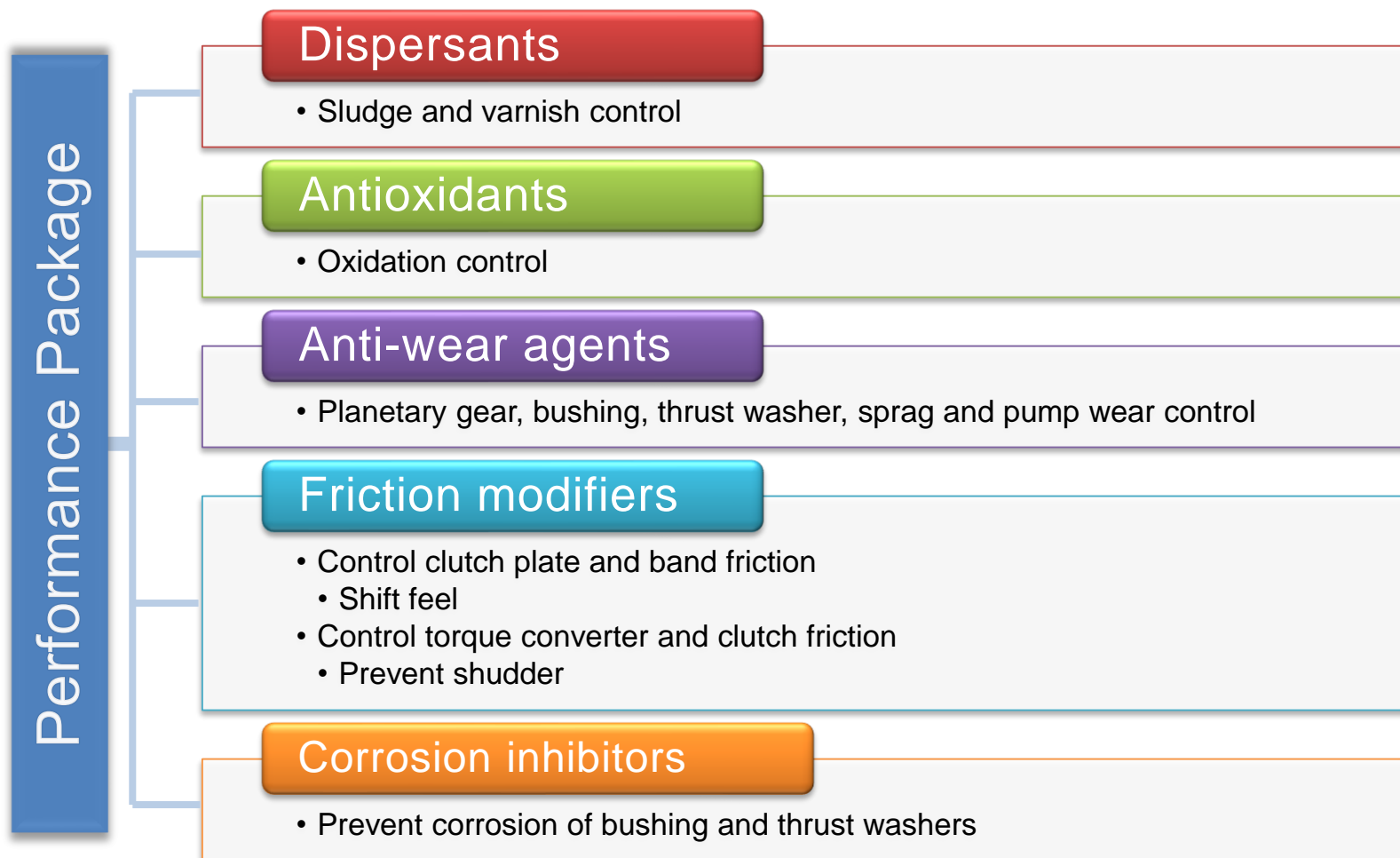
Heavy-duty ATF specifications

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™
	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
 Mercedes-Benz	All	MB 236.7 MB 236.9	-	-

ATF formulations



Typical ATF additives



Typical ATF additives

Seal swell additives

- Control swelling, hardness, and tensile strength of elastomers

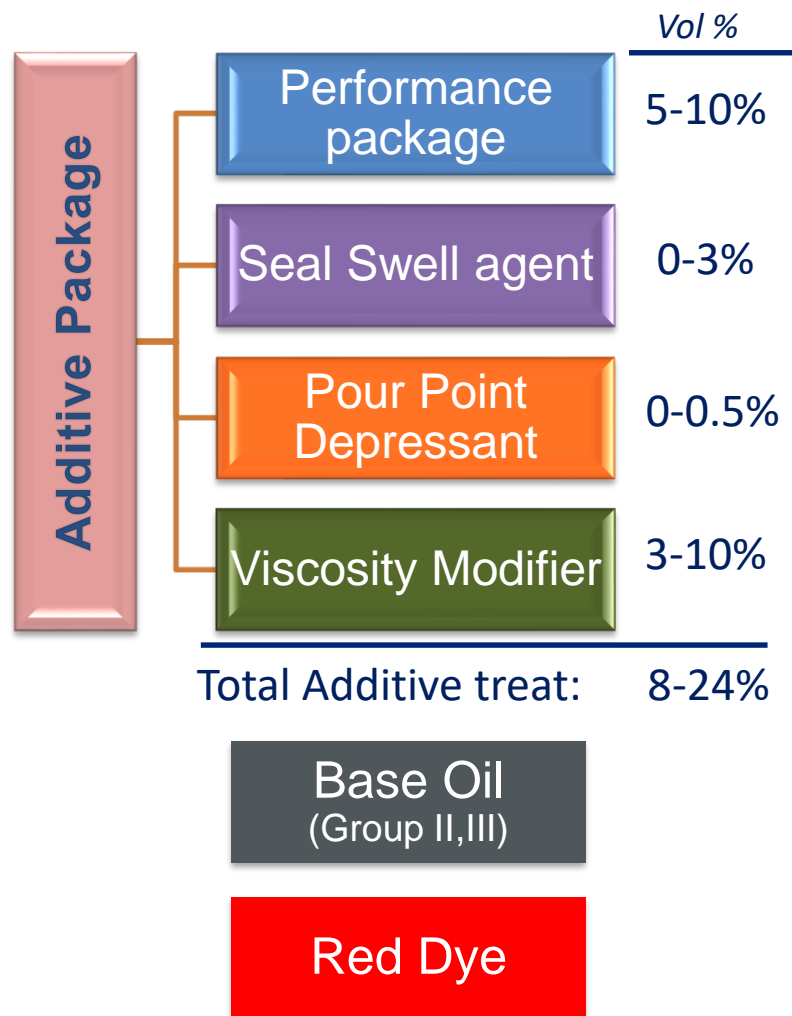
Pour point depressant

- Reduces temperature at which fluid starts to gel

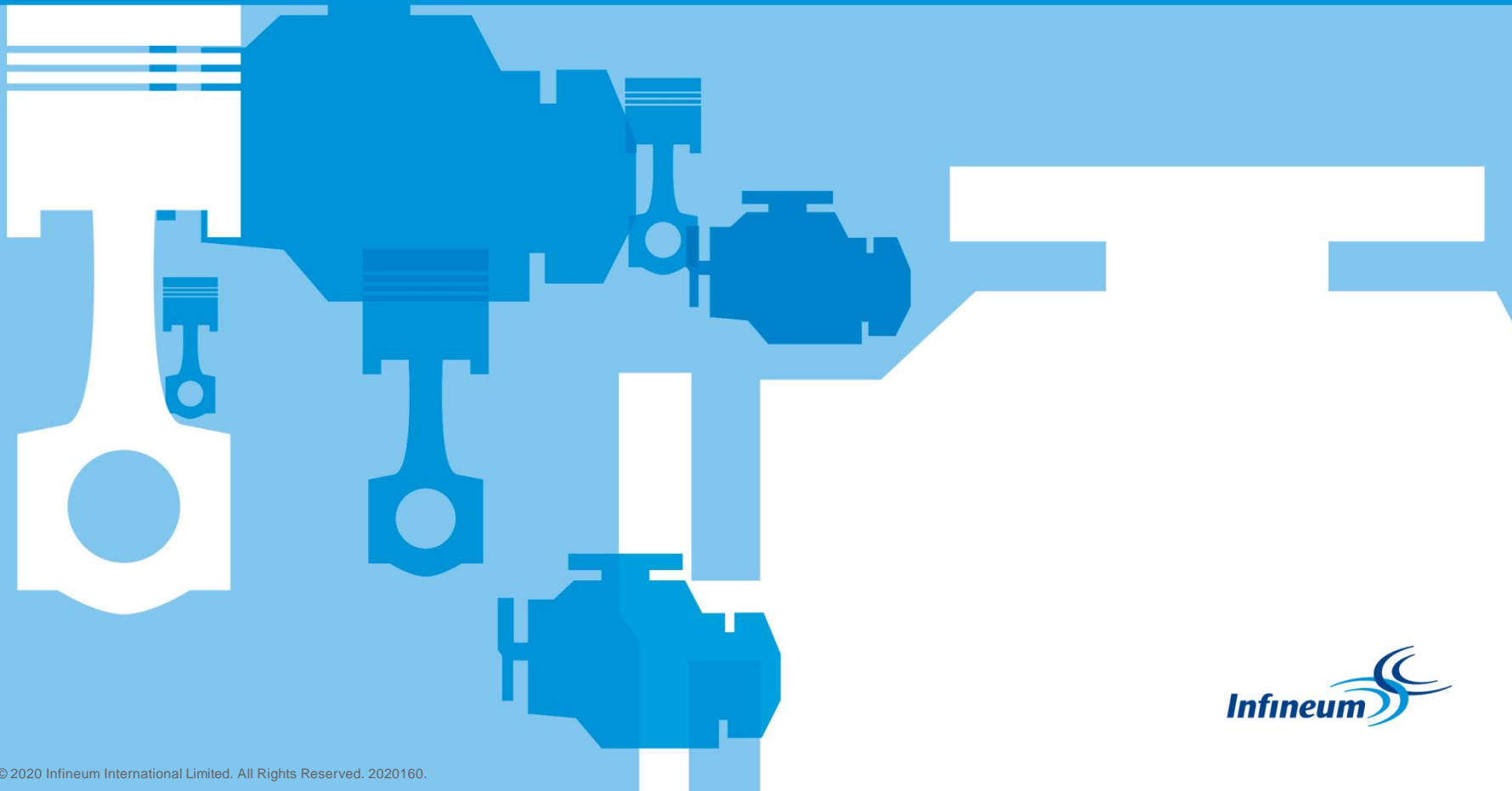
Viscosity modifiers

- Reduce rate of change of viscosity with temperature; dispersant type also provides sludge and varnish control

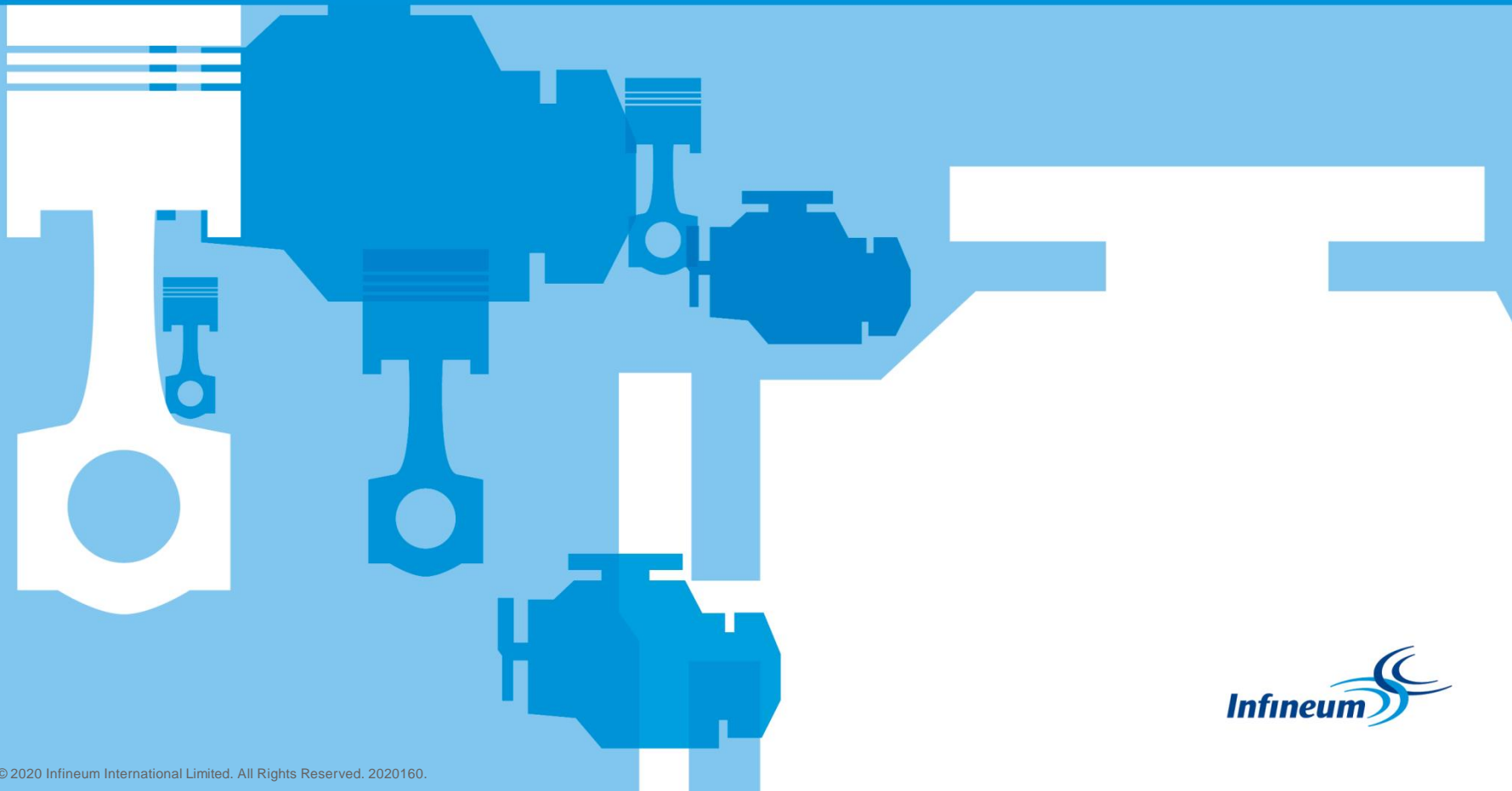
Typical ATF additive treat levels



Other automatic transmissions



Dual clutch transmissions (DCT)



GETRAG DCT Video



Dual clutch transmissions technology update

Hardware

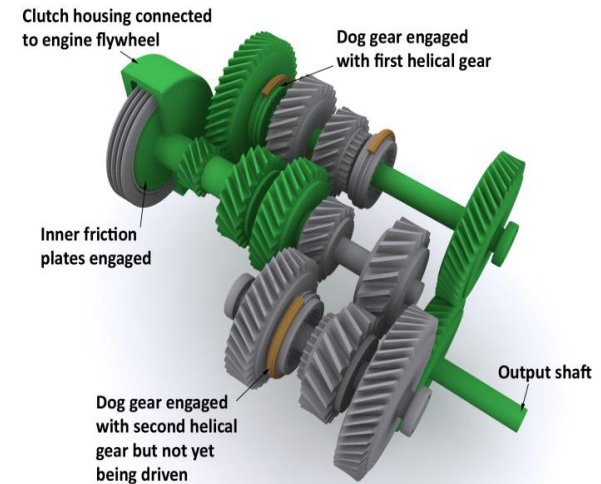
- Combines elements of both manual and automatic transmissions

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)

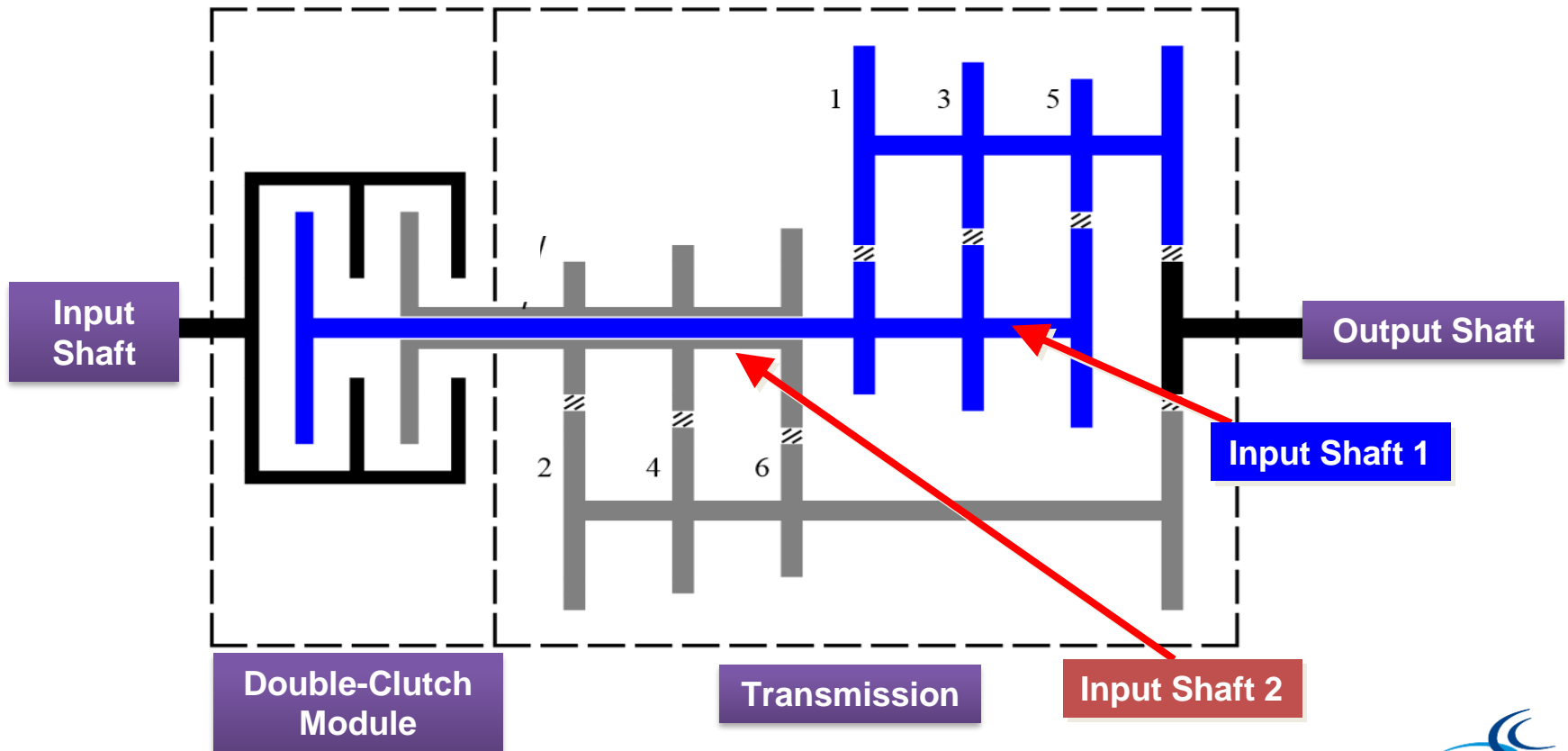
- Launch feel may be not as smooth as stepped AT

DCT Cons

Dual clutch transmissions

how they work

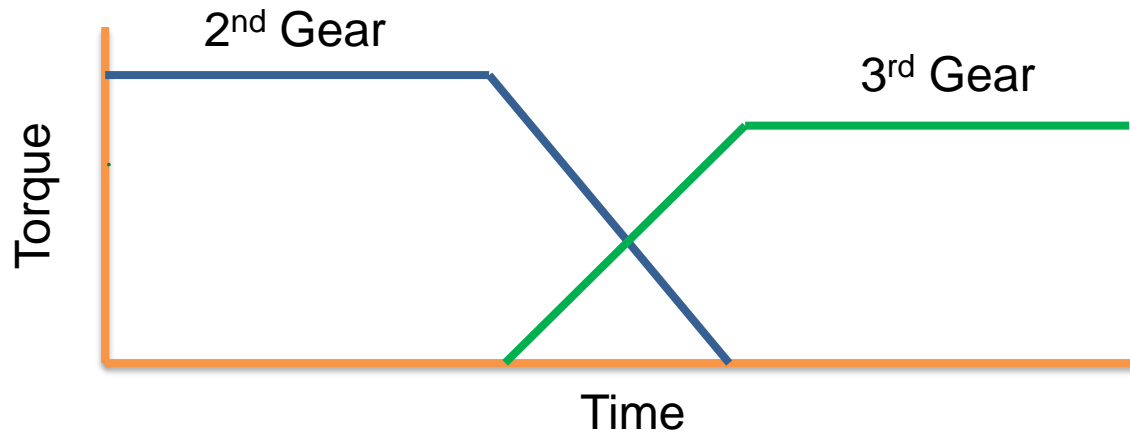
- 2 input shafts are connected to two different clutches
 - 1,3,5 gears are connected to one
 - 2,4,6 gears are connected to the other



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



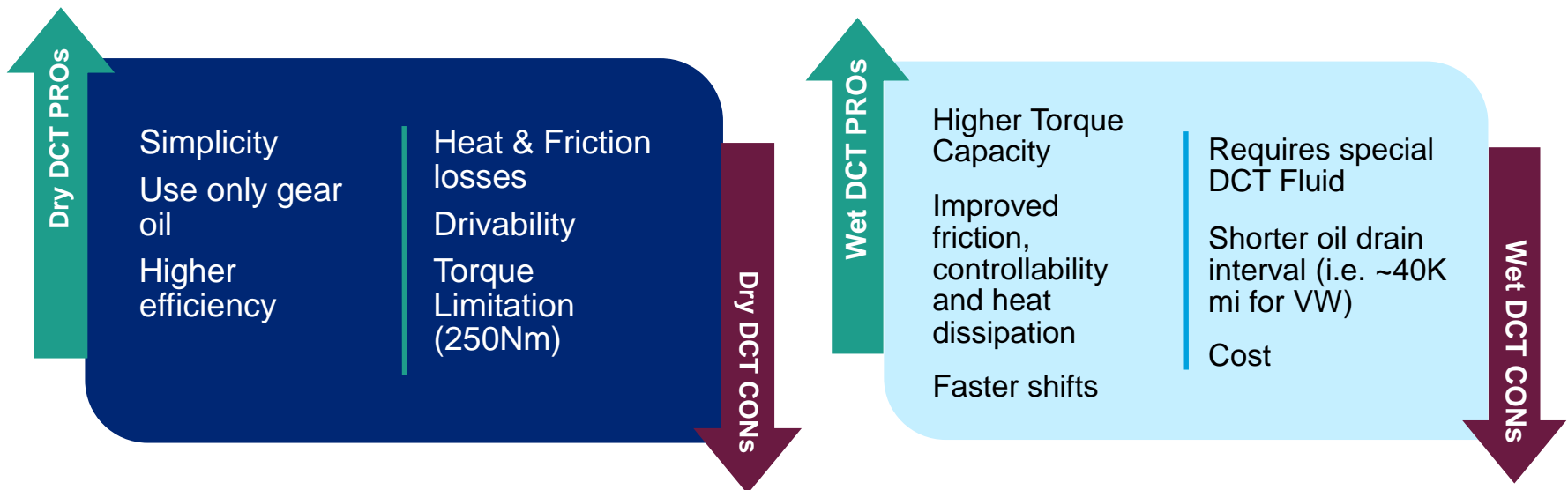
Dual clutch transmission technology trends wet and dry clutch systems

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

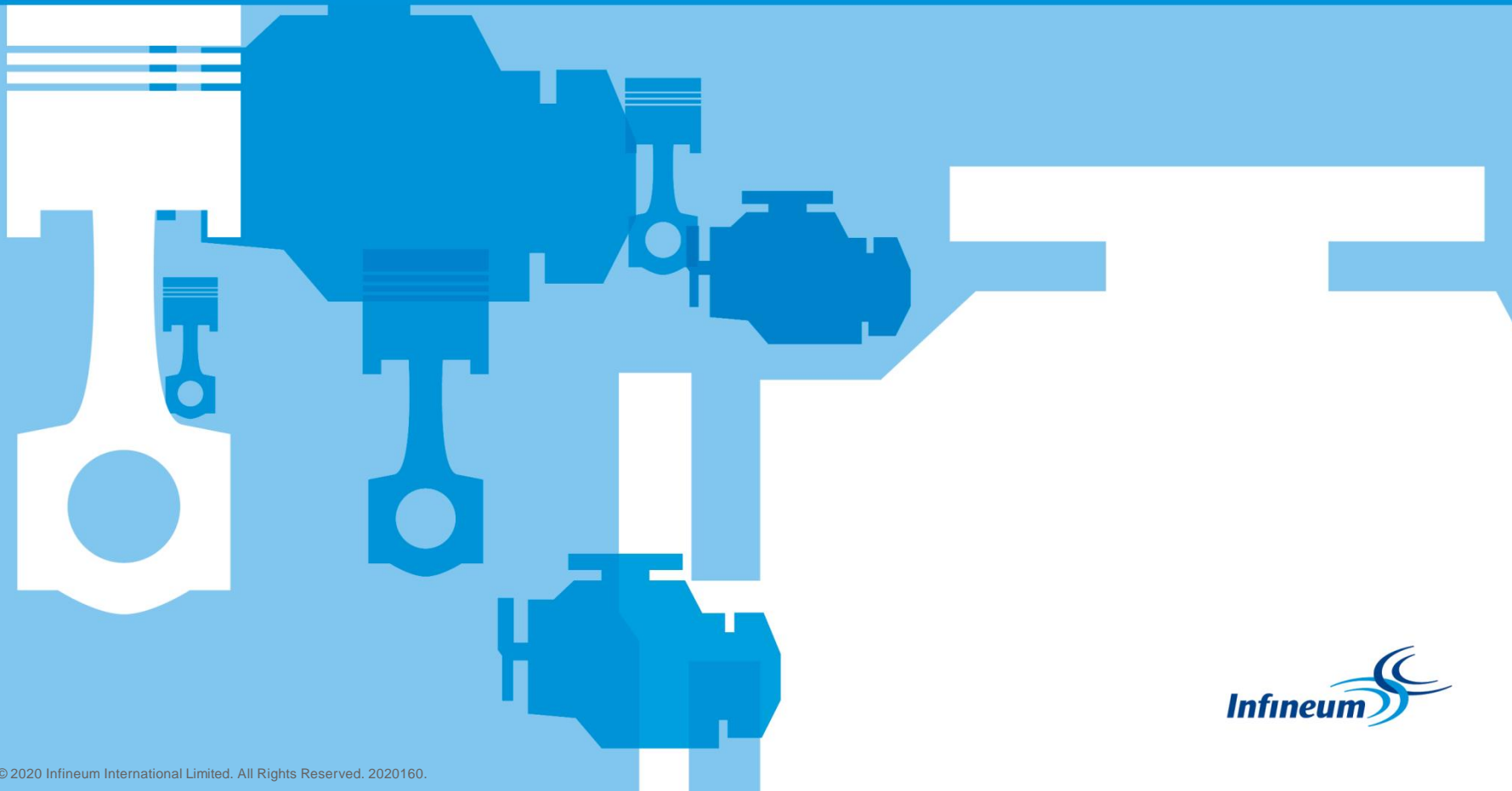
DCT Summary

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)



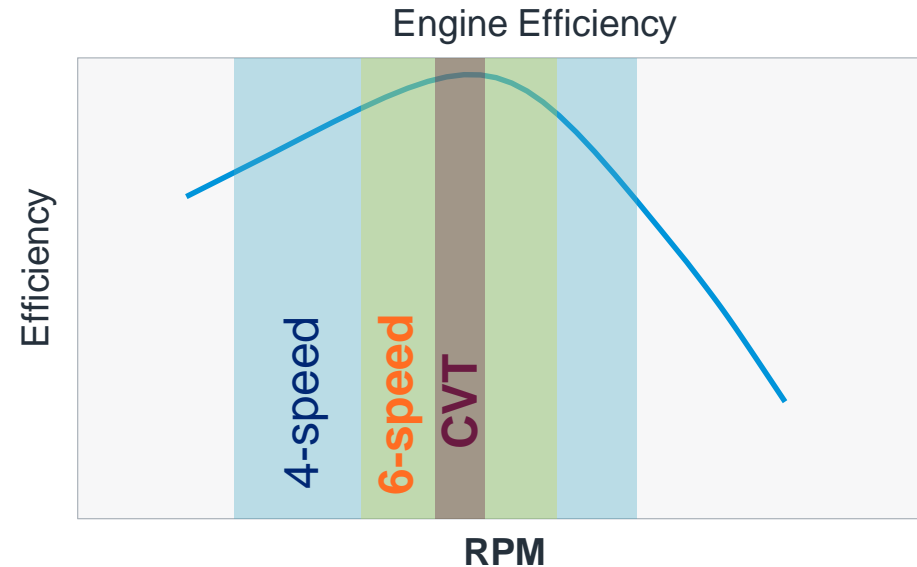
Continuously variable transmissions hardware

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



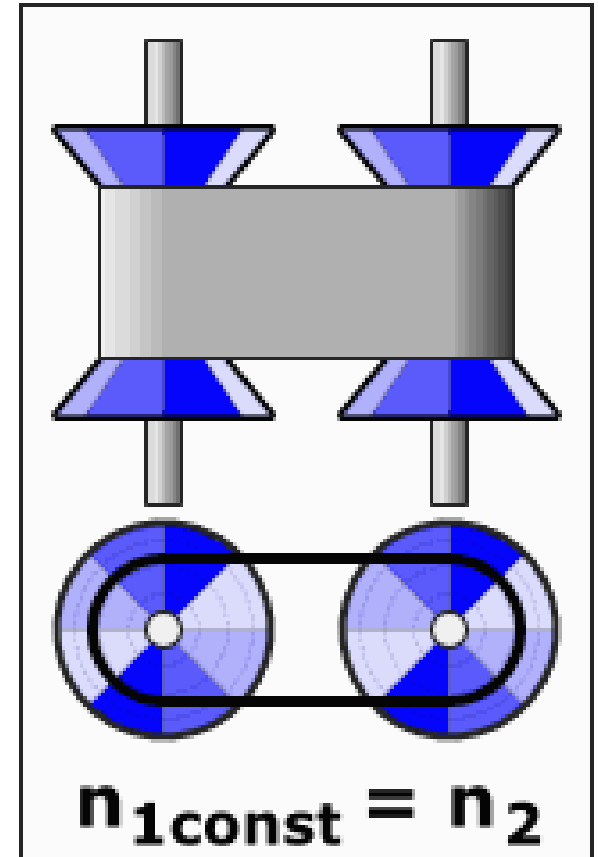
OEMs Using CVTs Today

- 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)

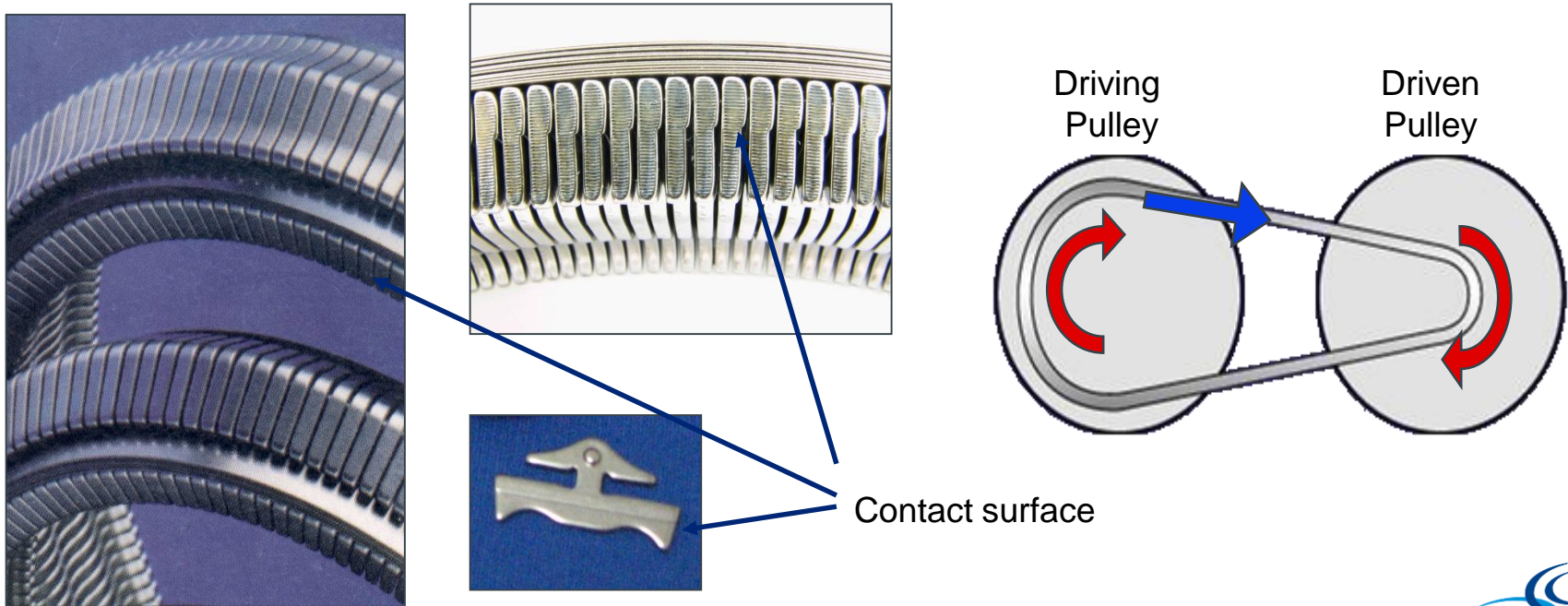
<http://youtu.be/GLNqzn7WgDQ?t=31s>

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

Continuously variable transmissions

VDT – push belt

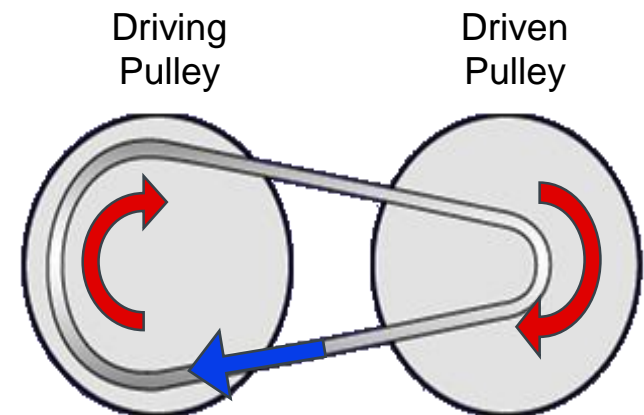
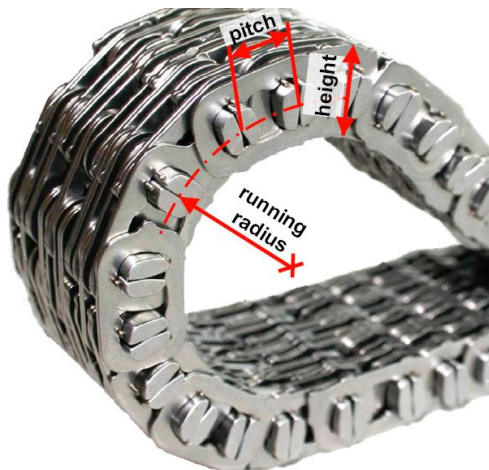
- Developed by Van Doorne Transmissie (VDT)
- Push belt consists of ~300 steel blocks connected by flexible steel rings
- Force transmitted from pulley to pulley via compressional forces between belt elements



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

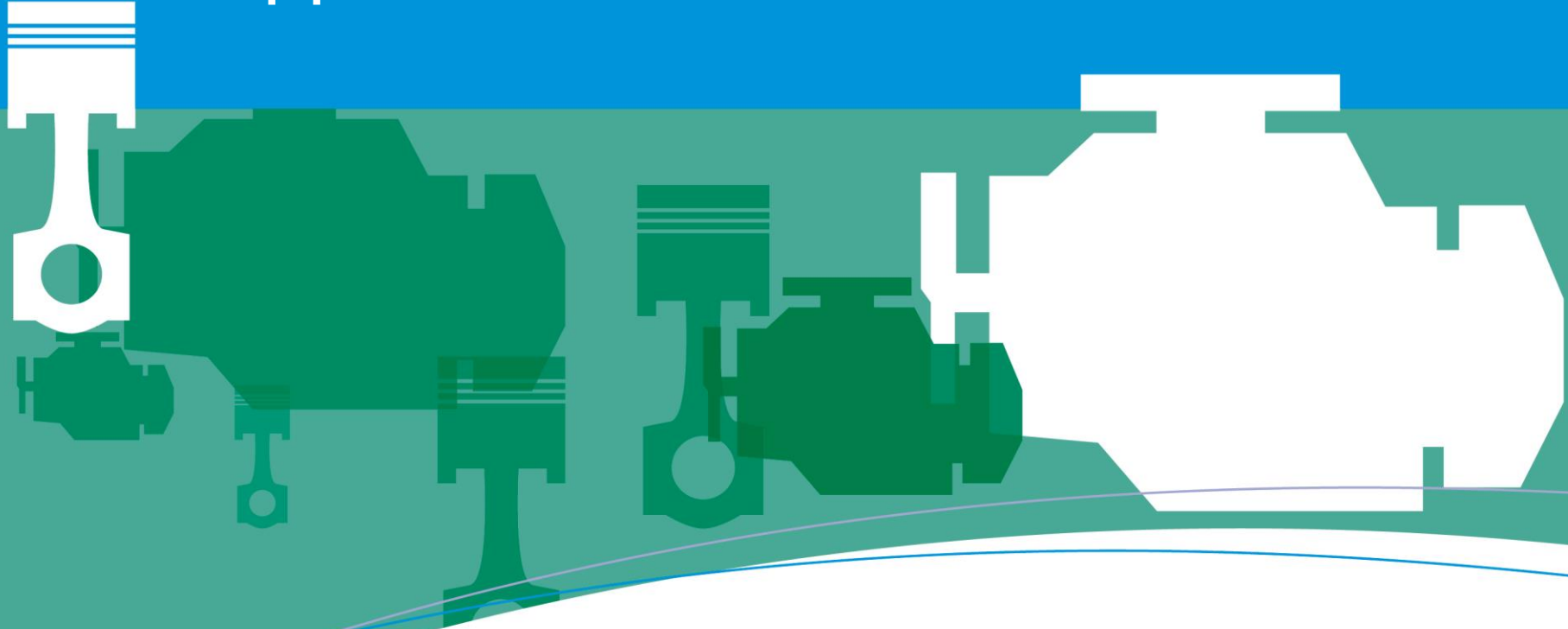
- Stepped planetary transmissions remain predominant
 - Increase in gear ratios to improve fuel economy
 - Reduced size and weight
 - Aggressive slipping clutch
- Nonconventional transmissions gain market share
 - CVT growth in Asia and North America
 - DCT growth in Europe

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

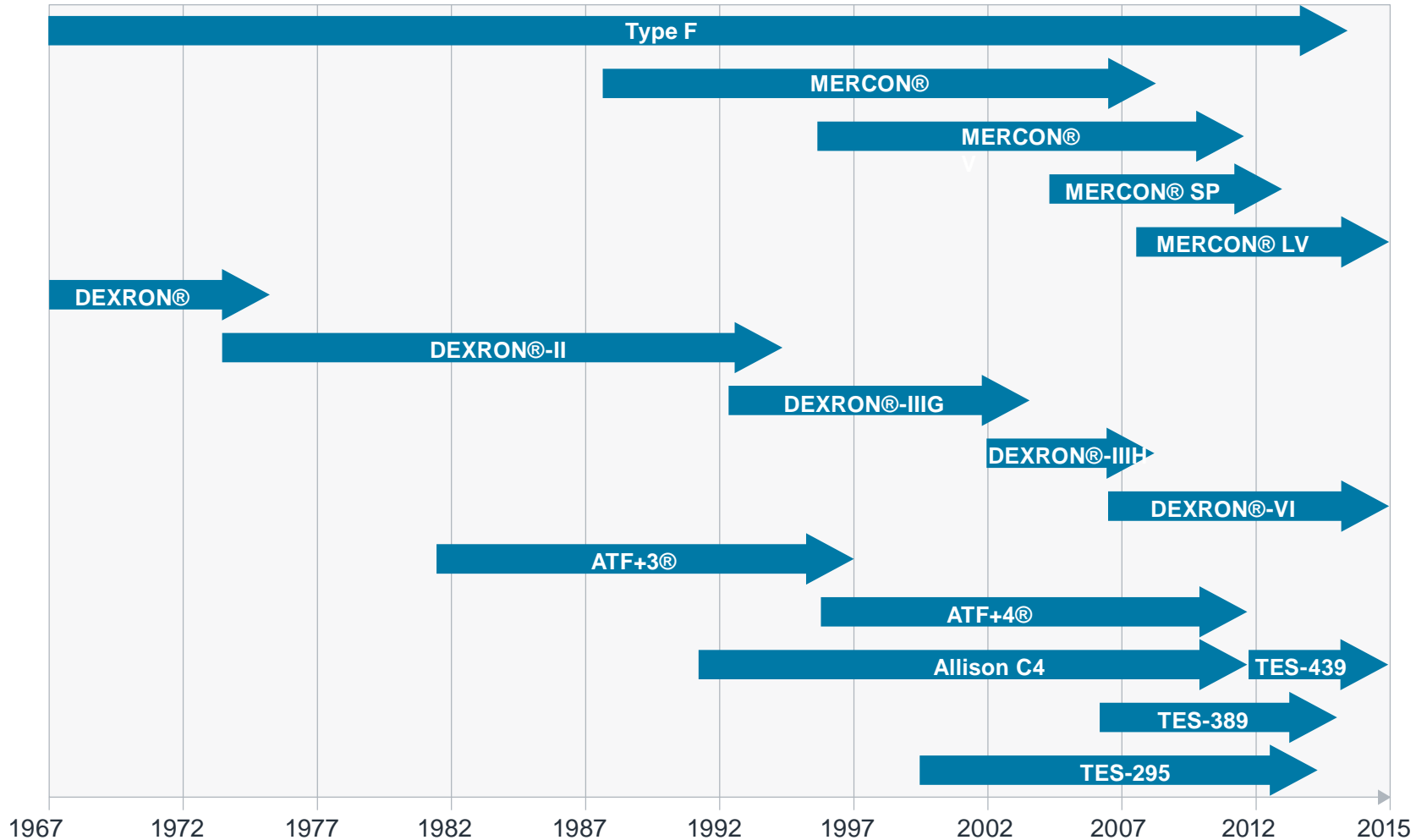
Appendix



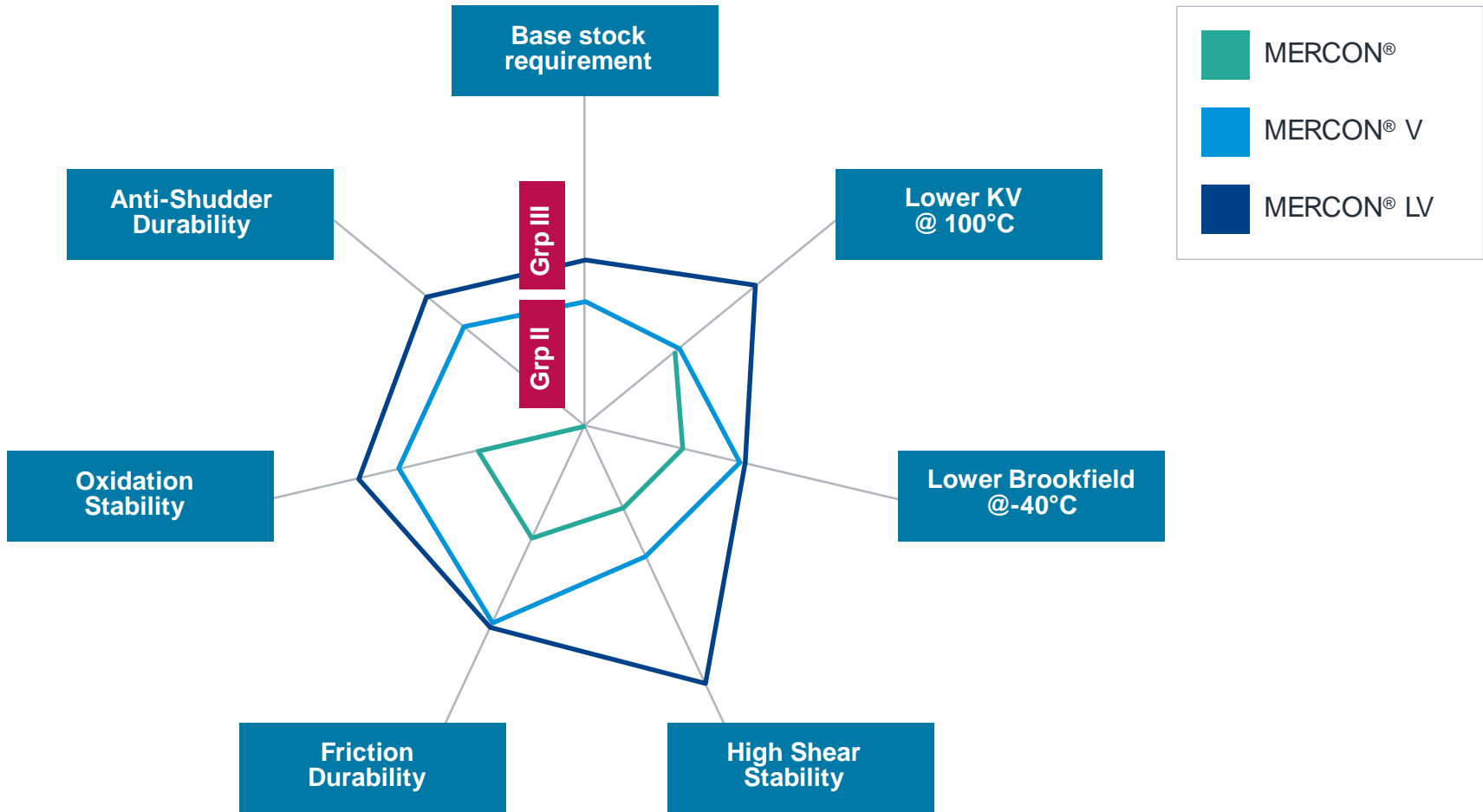
InfineumInsight.com/Learn



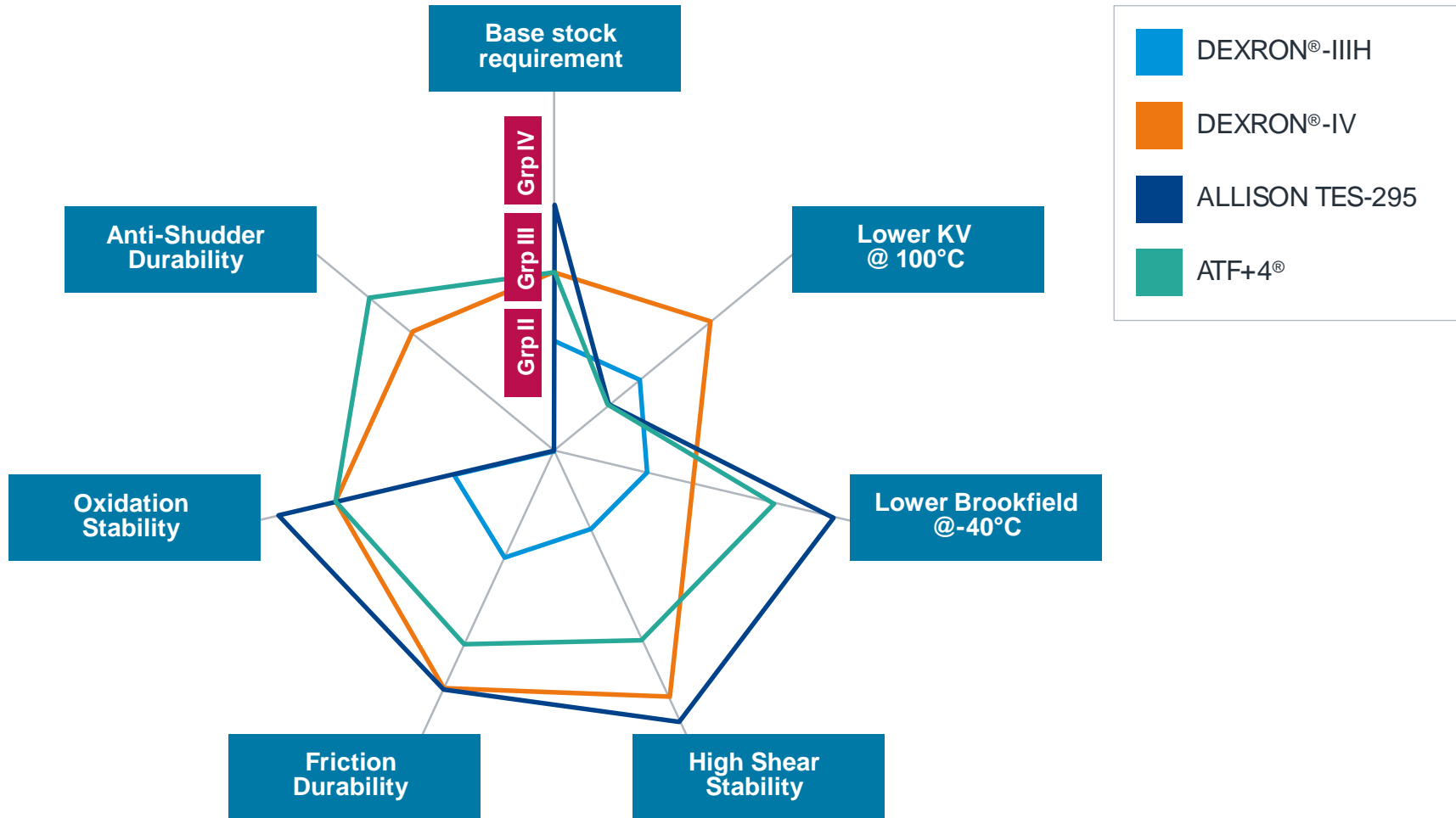
ATF specifications: US OEMs



Fluid improvement trend



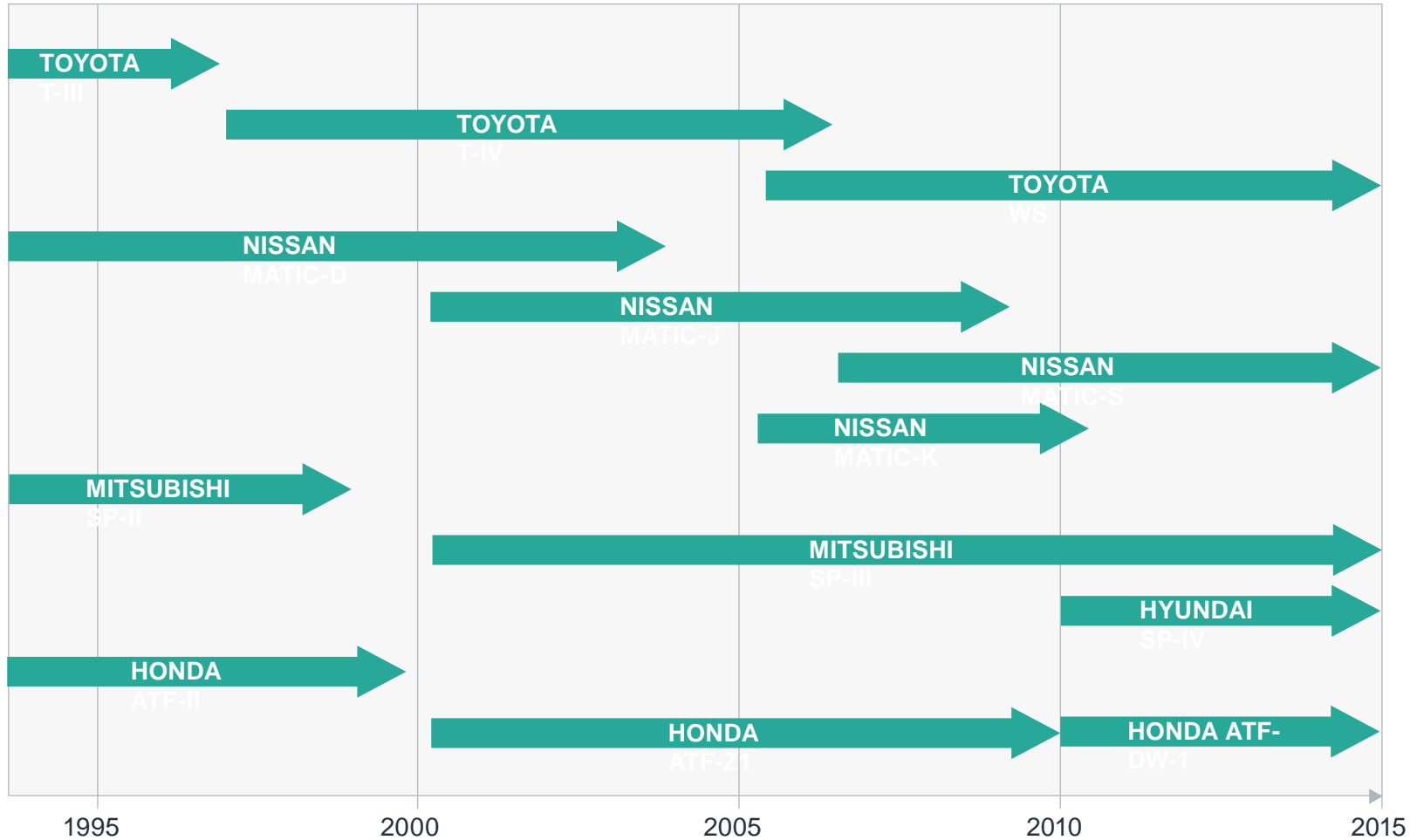
Fluid improvement trend



ATF specifications – HD European OEMs

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

ATF specifications: Japanese 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

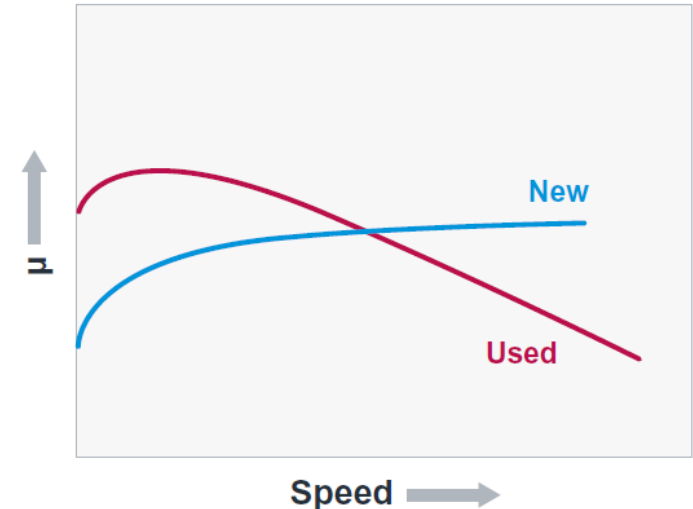
Friction Characteristics (Shifting Clutch)

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

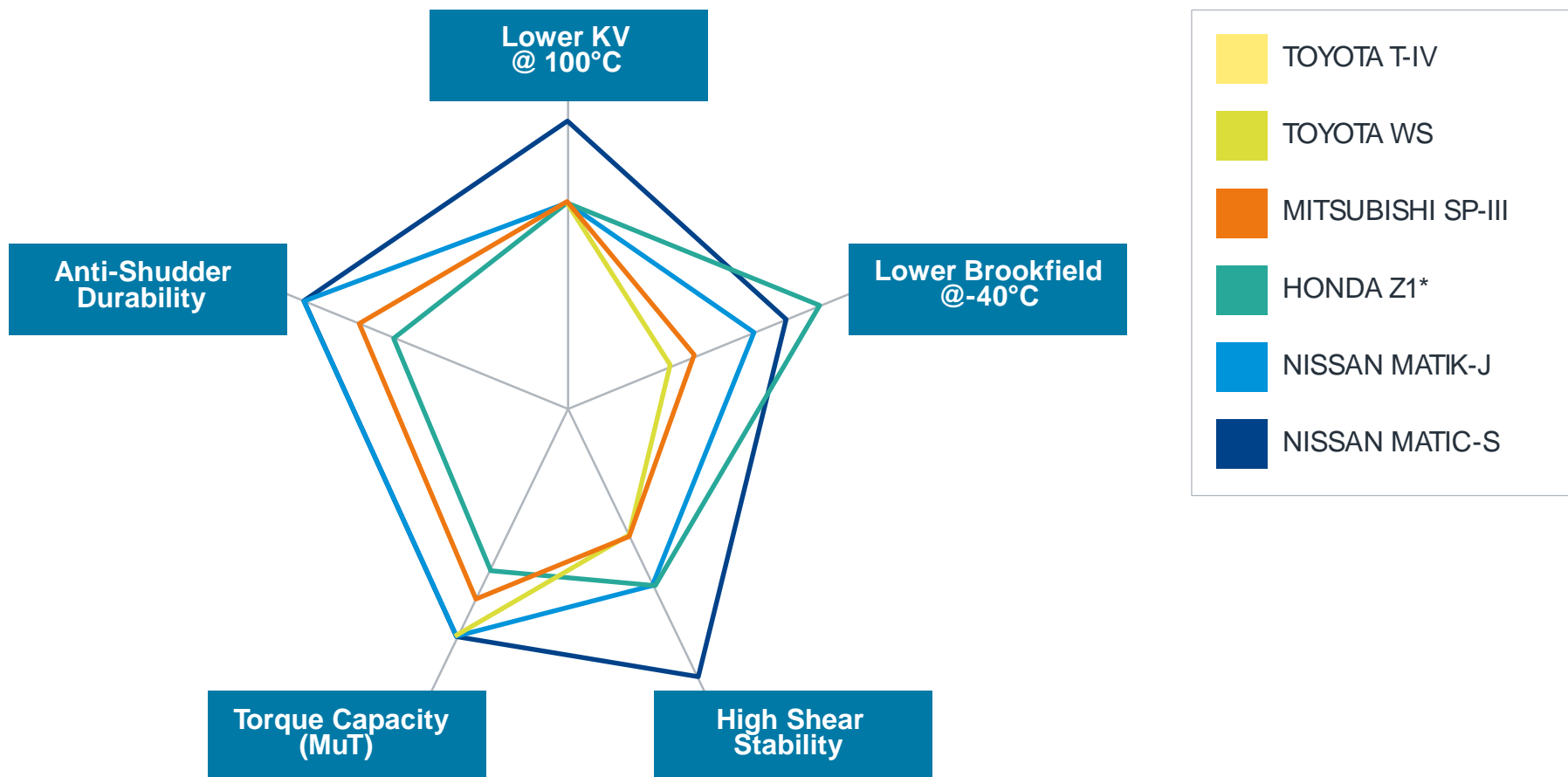
Anti-Shudder Performance (Torque Converter Clutch)

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

Anti-shudder performance slipping clutch



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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