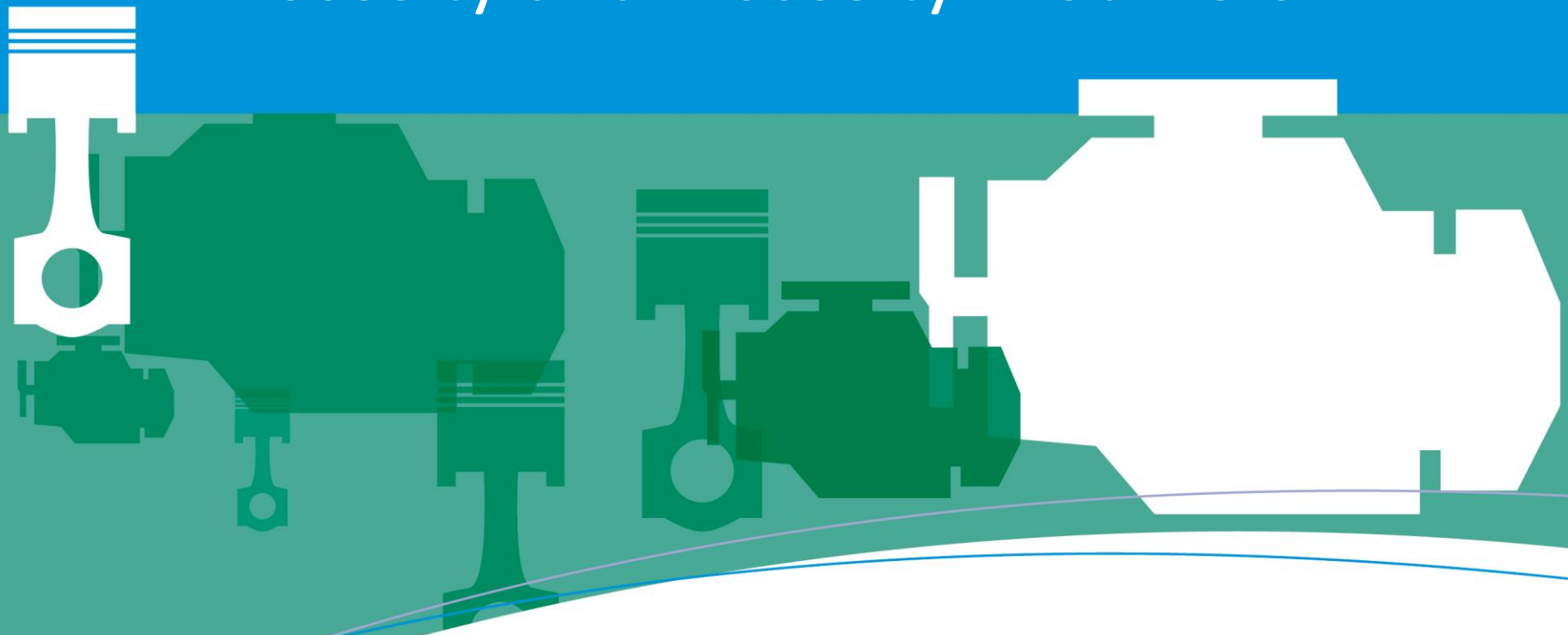
Performance you can rely on.

Viscosity and Viscosity Modifiers



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Balance of Additives, VM and Base Oil

Lubricant

Commercially available product

'Finished Oil'

Base Oil	60-90%
Viscosity Modifier & flow improver	5-15%
Additive Package	5-25%

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Why do we need Viscosity Modifiers?

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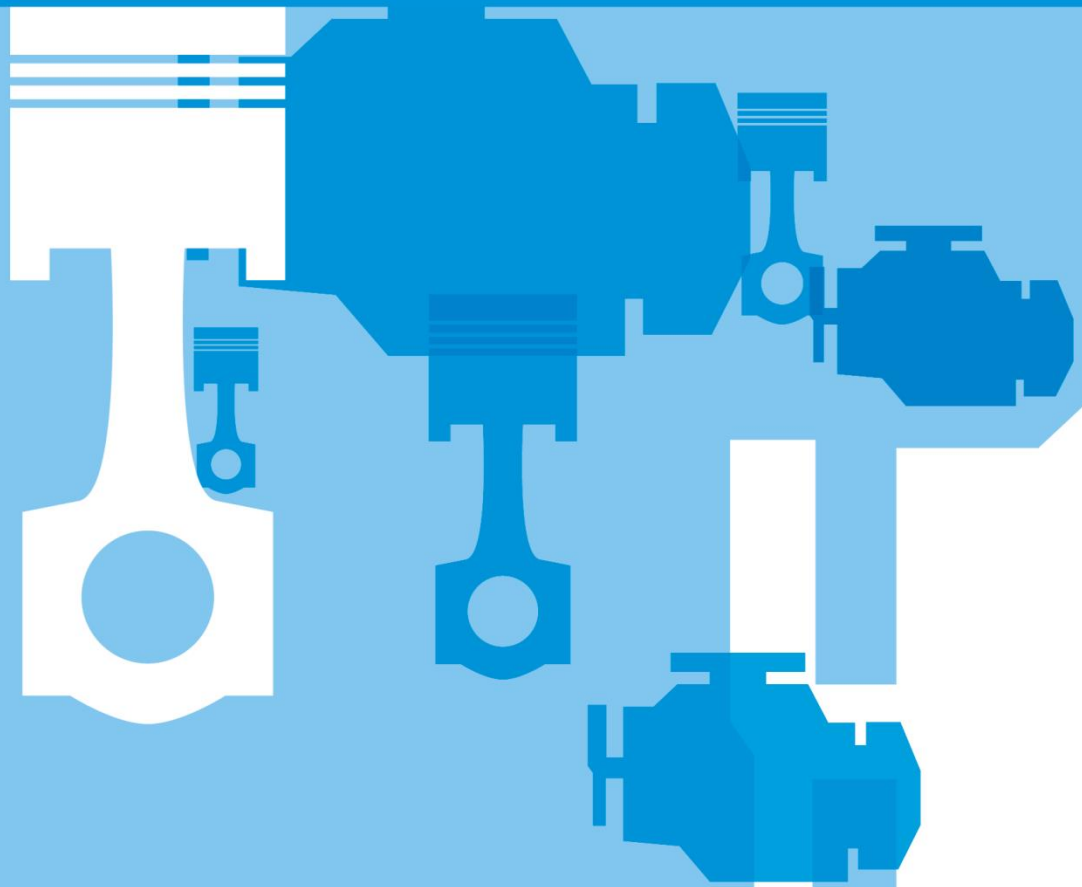
Agenda

01 | **Origins** of viscosity

02 | Understand why we use **viscosity modifiers** and how they work

03 | Learn how oils are classified as multigrade under **SAE J300**

Viscosity



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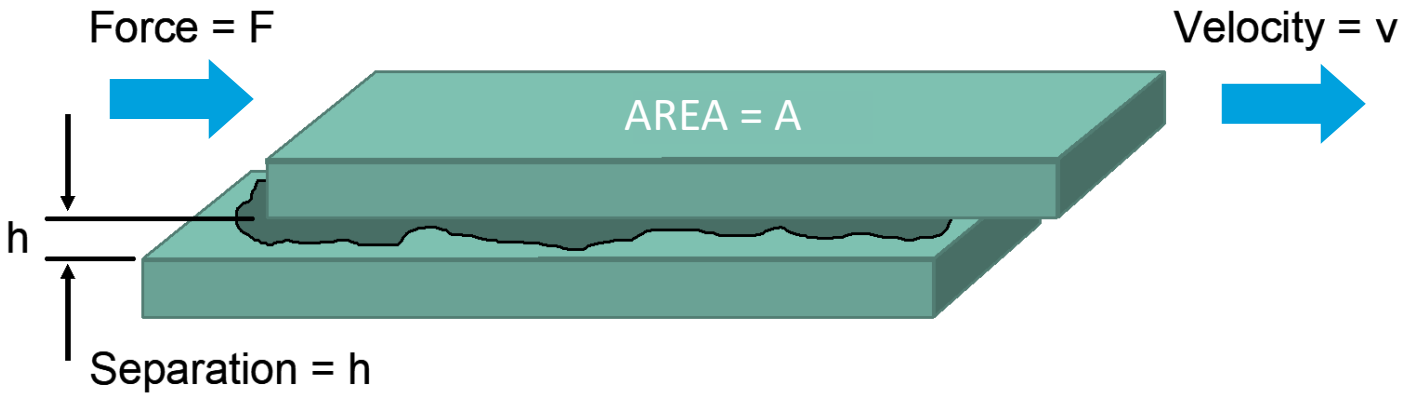
What is Viscosity?

- **'Thickness'** of a fluid
- **Temperature** dependent
- **Resistance** to flow of a fluid
- **Viscosity** = $\frac{\text{shear stress}}{\text{shear rate}}$ (Newton's Law)



What is Viscosity?

Two key types of viscosity:

Dynamic viscosity

- Measured under high shear environments
- mPa·s or cP

Kinematic viscosity

- Measured under low shear i.e. gravity
- mm^2/s or cSt

Viscosity of Materials

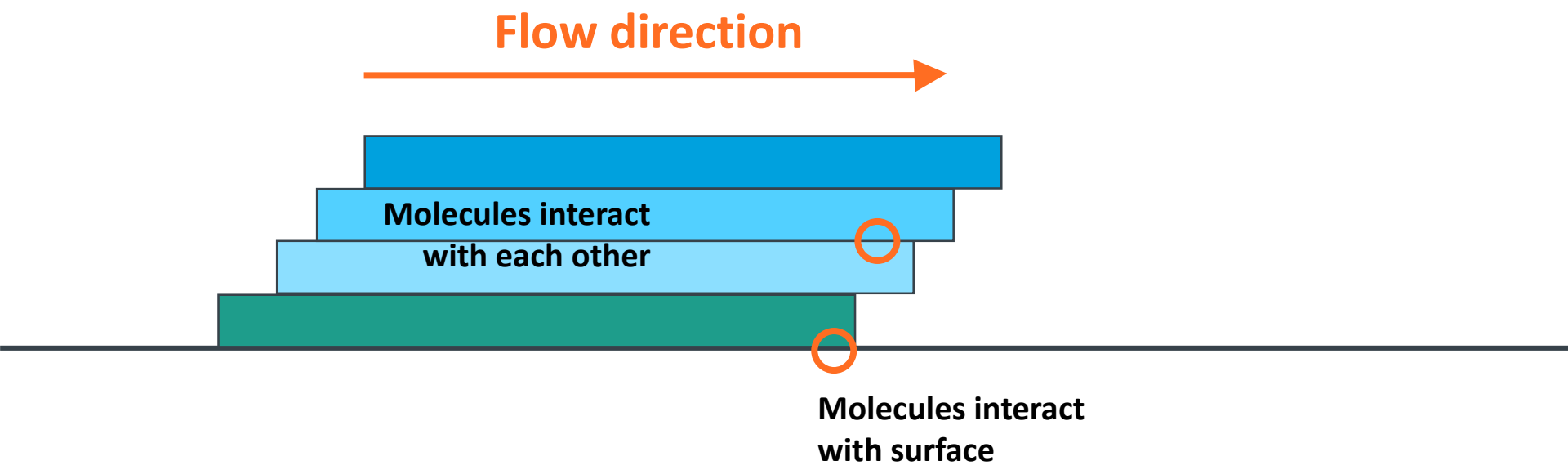
100 000 cP

1 cP

0.5 cP

Different materials have different viscosities

Molecular Origins of Viscosity



The interacting forces between the layers of molecules creates resistance to flow, giving rise to viscosity

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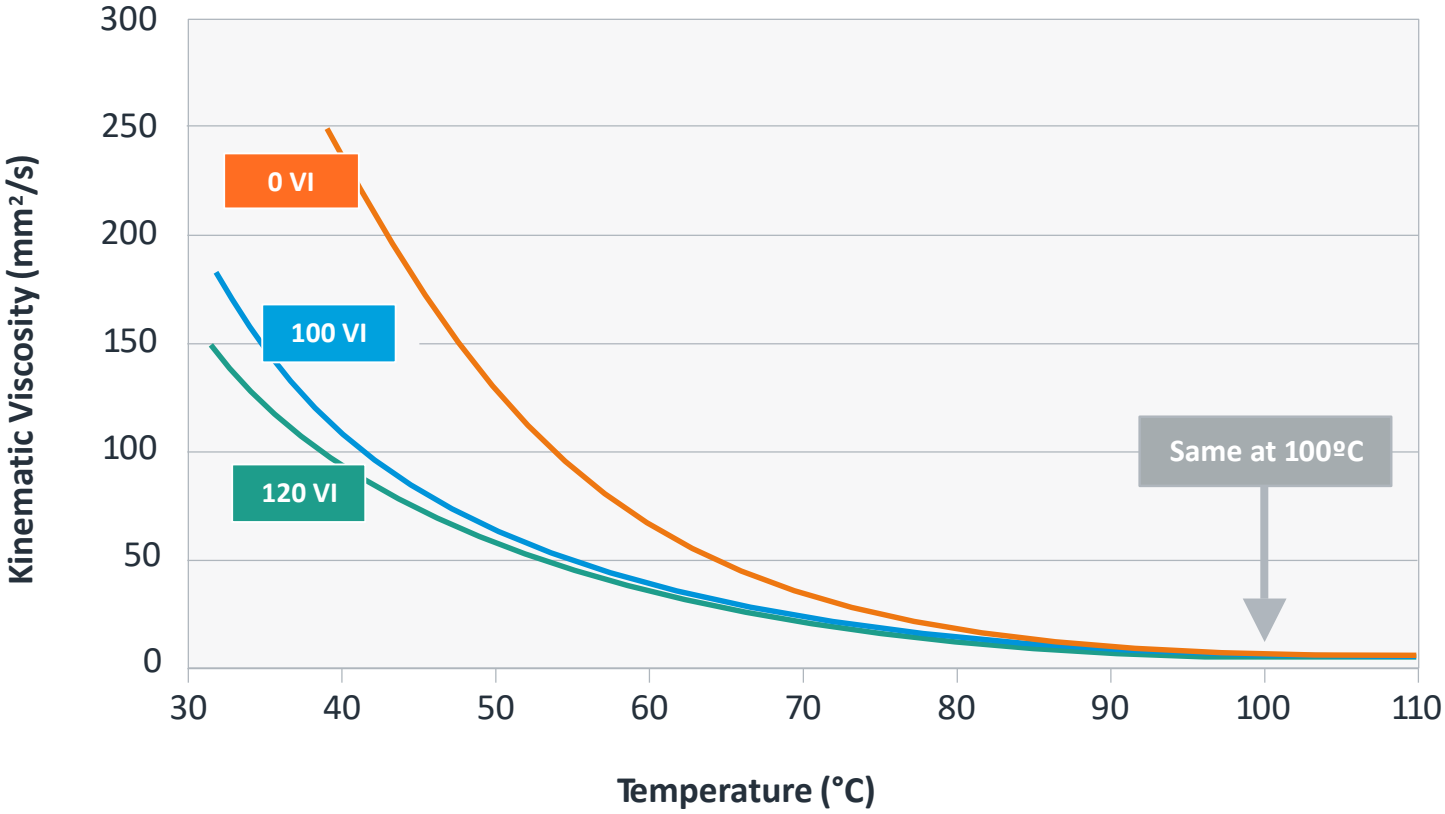
Viscosity Index



Viscosity Index (VI) defines the viscosity relationship with temperature:

- Low VI oils viscosity change significantly with temperature
- High VI oils viscosity changes much less with temperature

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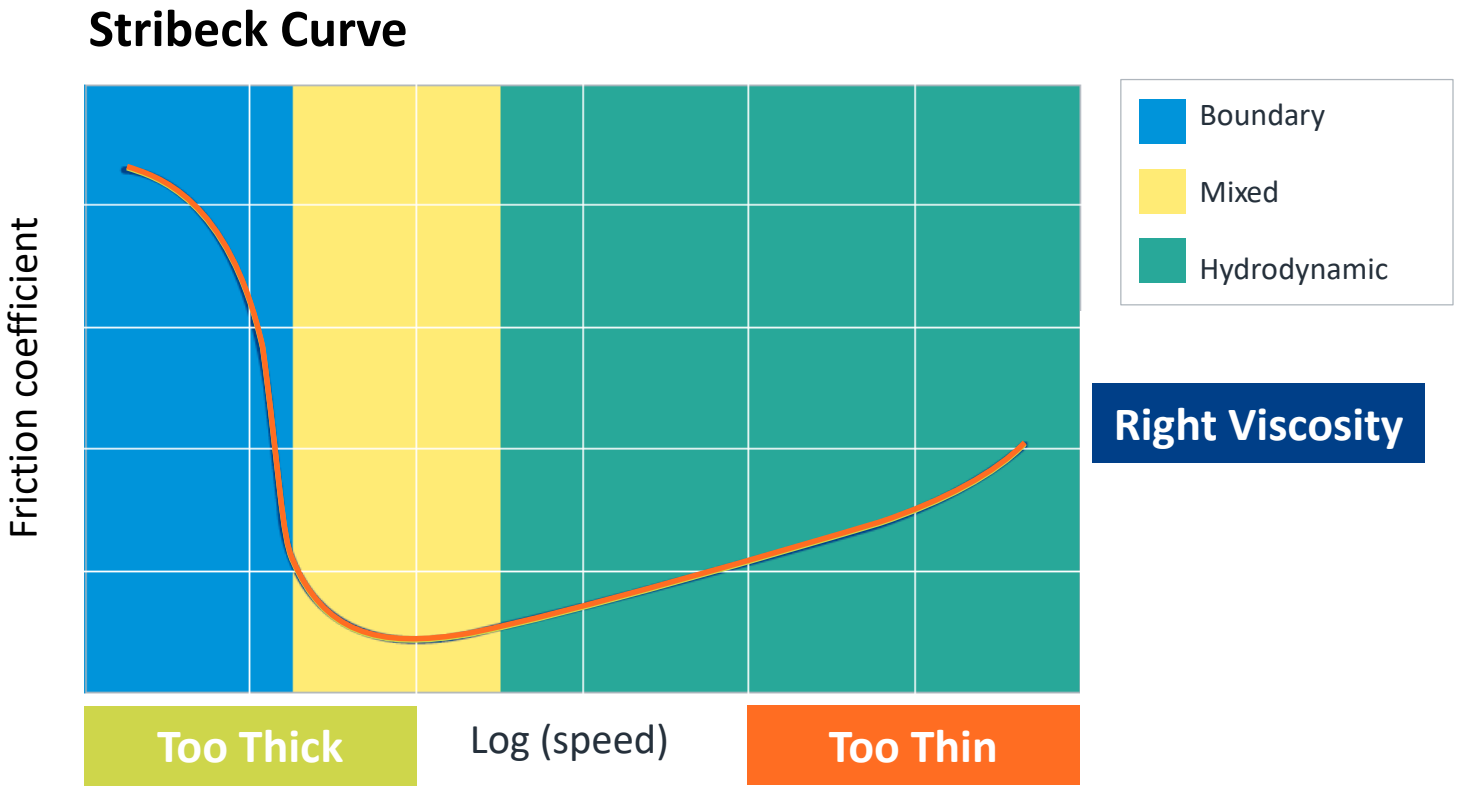
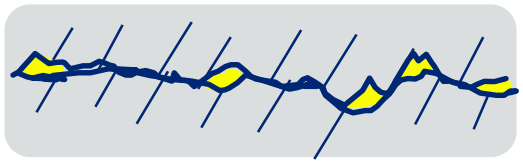
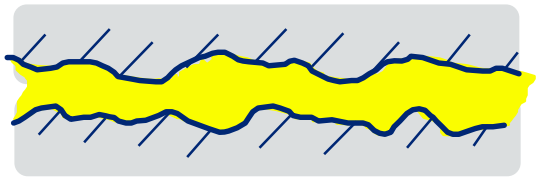
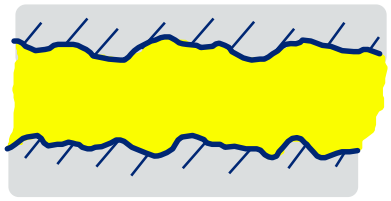
What is the Optimal Viscosity?



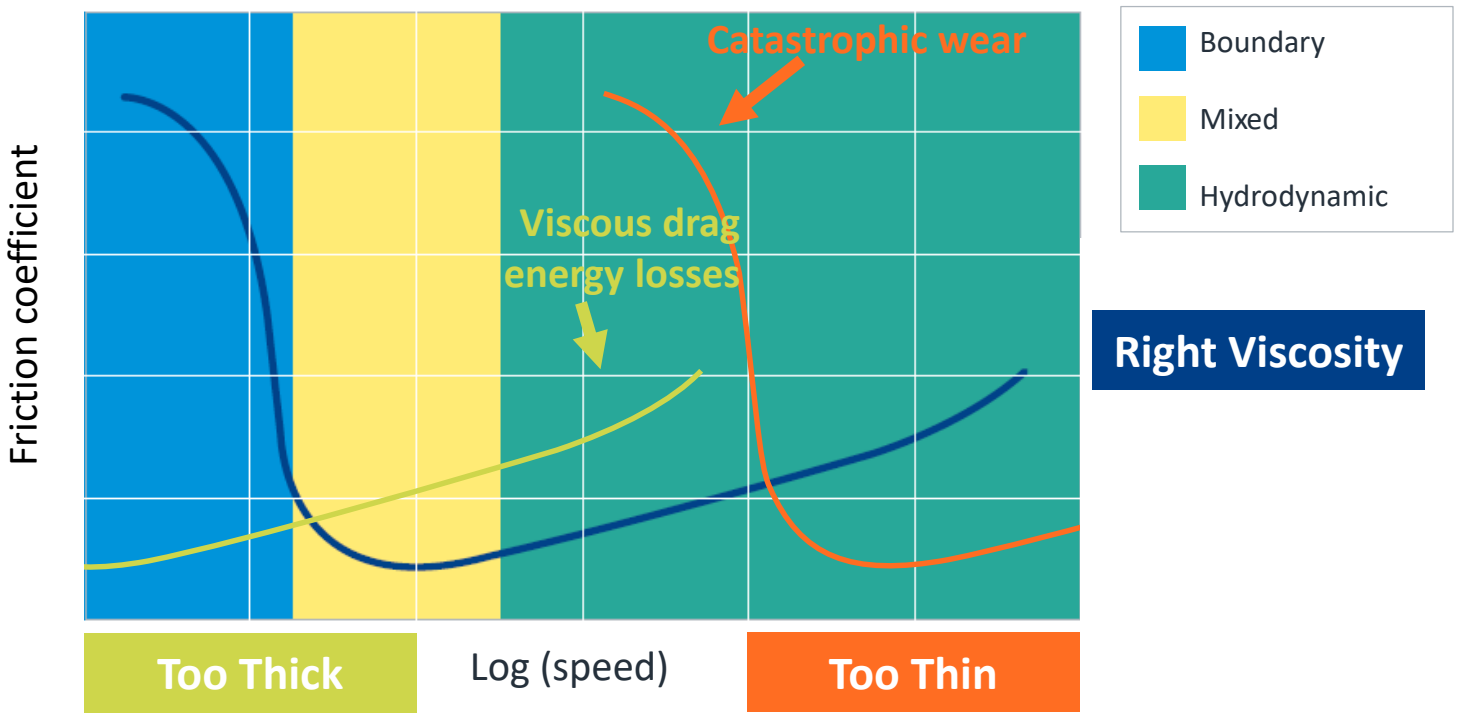

Boundary


Mixed

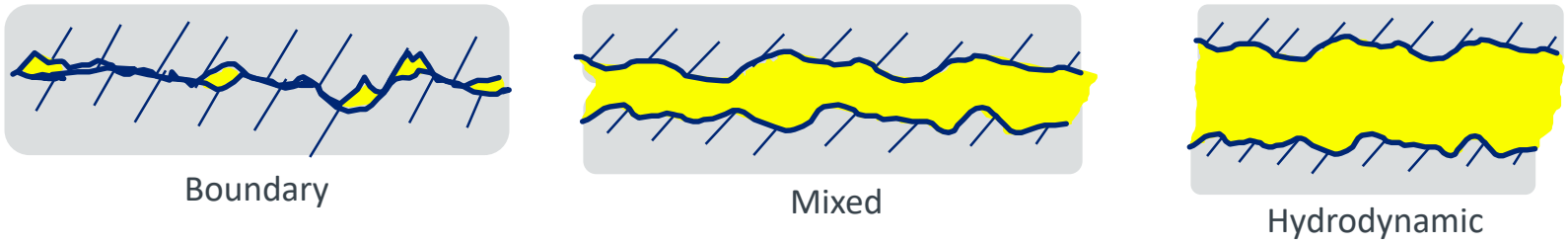

Hydrodynamic

What is the Optimal Viscosity?

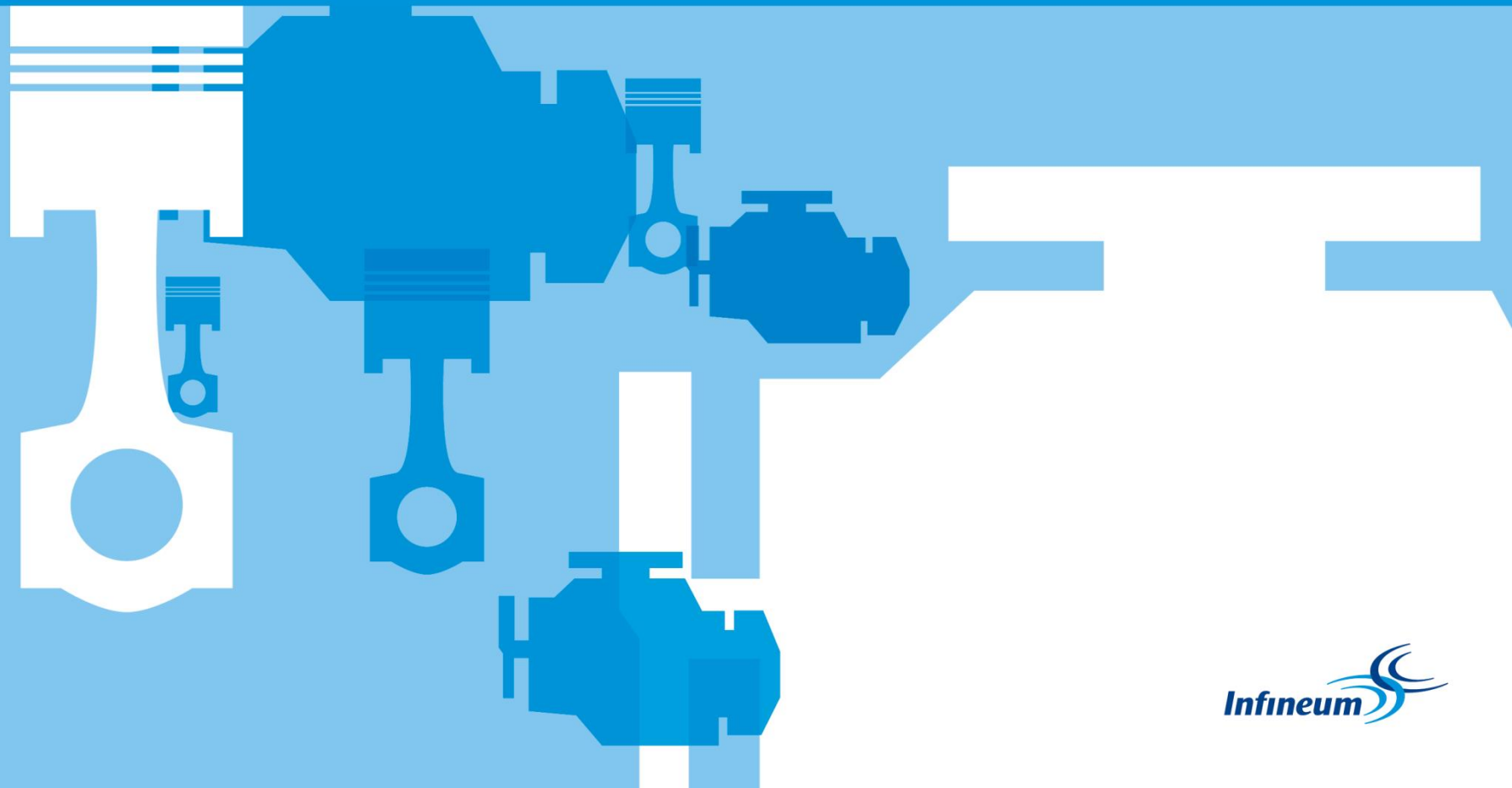
Stribeck Curve



Right Viscosity



Viscosity Modifiers



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Viscosity Modifiers

Viscosity Modifiers (VM) are used to reduce influence of temperature on the viscosity of lubricants

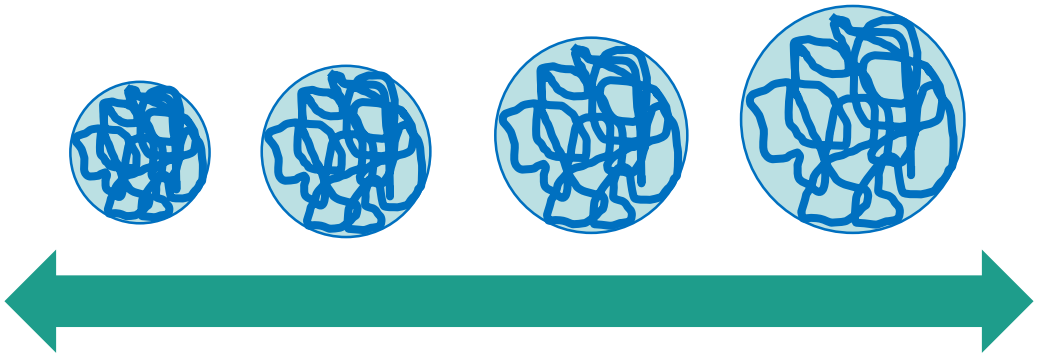
- Also known as **Viscosity Index Improvers**

Used in majority of **engine oils** and many **transmission oils**

Viscosity Modifiers

- **Polymeric** in structure
- Occupy **large volumes in solution**

- **Increase viscosity proportionally** to the volume that the polymer occupies
- **Volume of Viscosity Modifier** in solution is dependent on **medium** it is in, **temperature** and **pressure**



Many factors will affect how much volume the polymer occupies in space, and therefore how much viscosity it adds

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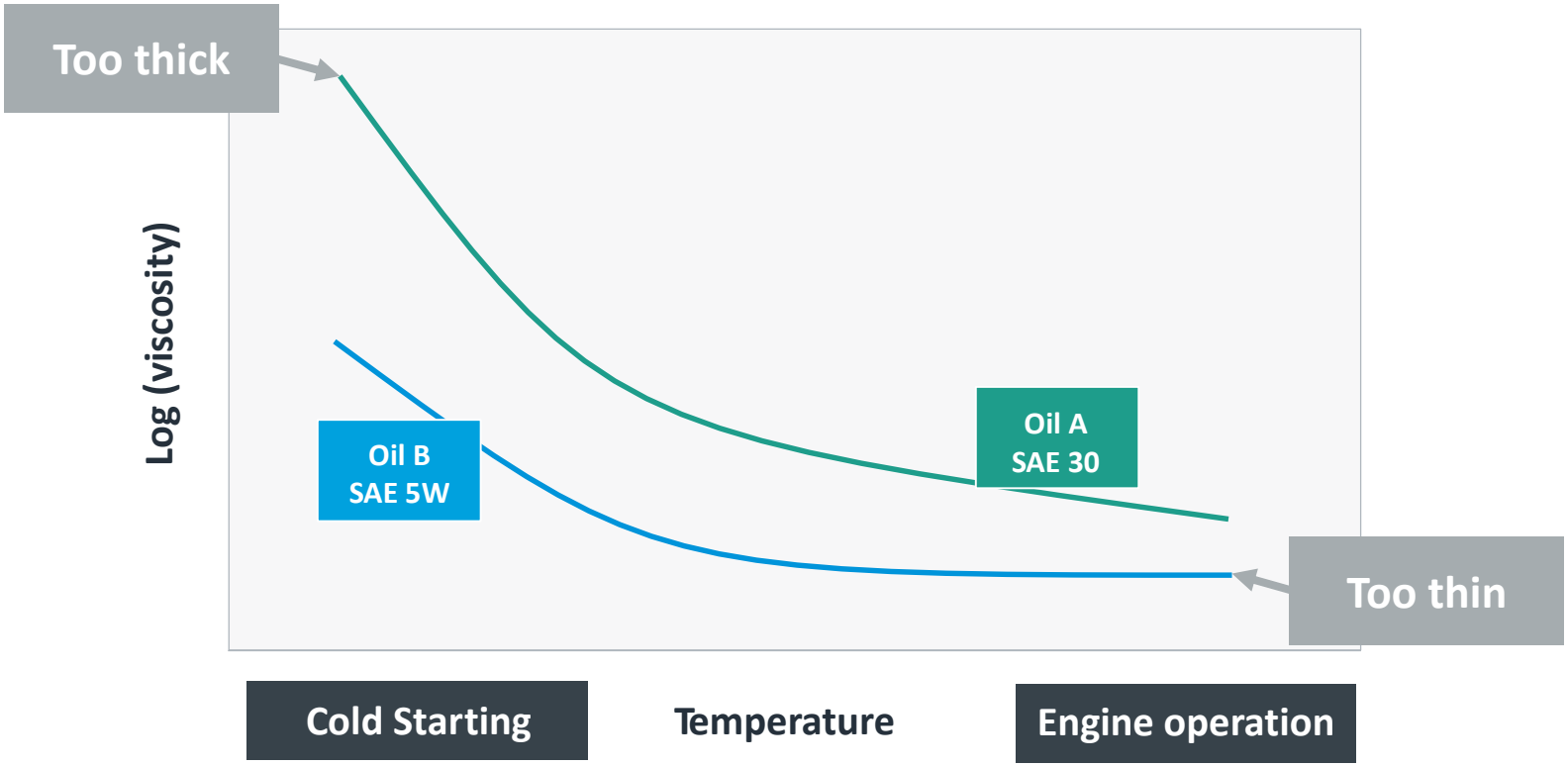
Function of Viscosity Modifiers



Base oil viscosity has strong temperature dependence

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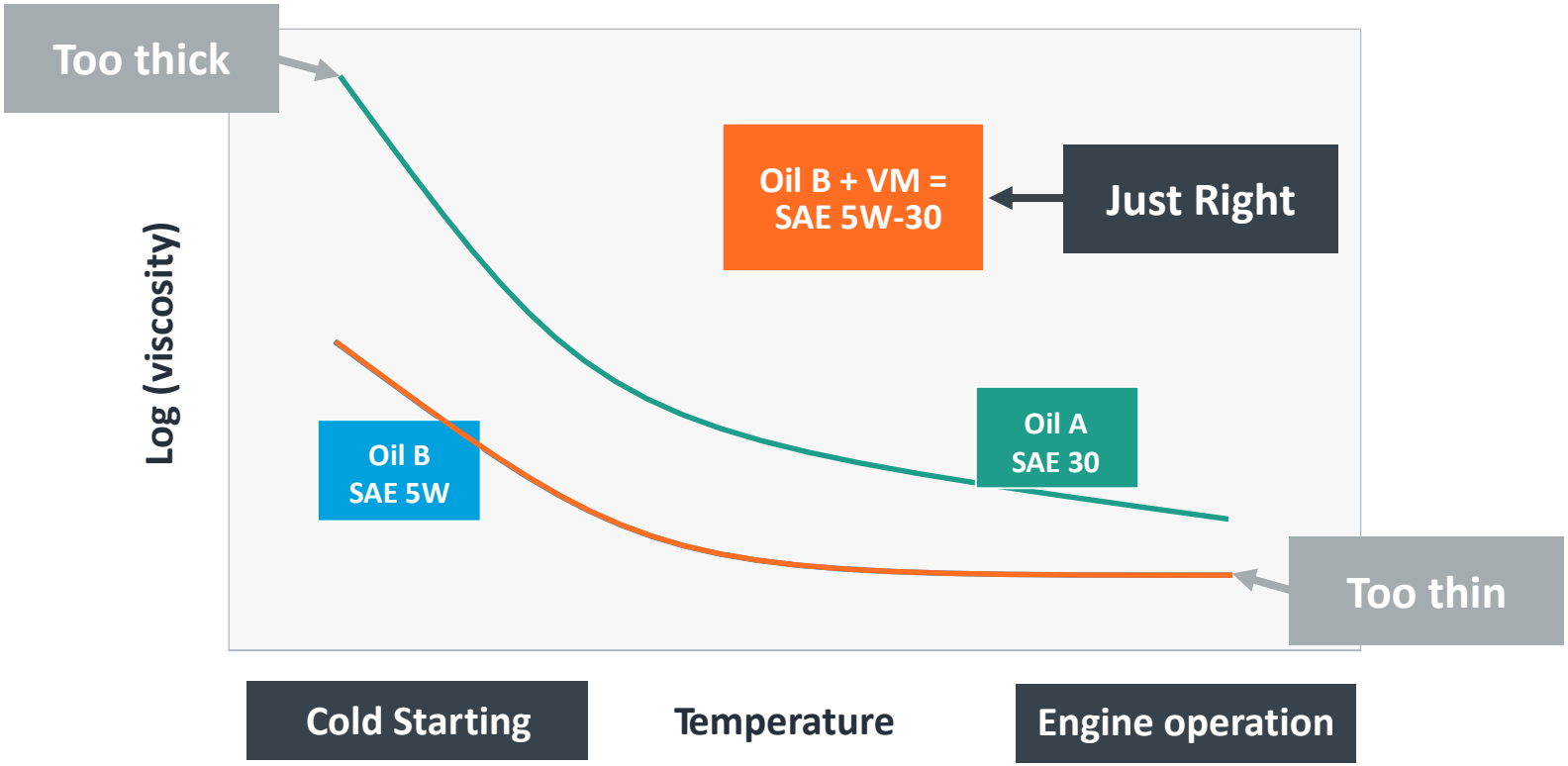
Function of Viscosity Modifiers



Adding VM reduces temperature dependence, giving protection at higher temperatures, whilst being pumpable at lower temperatures

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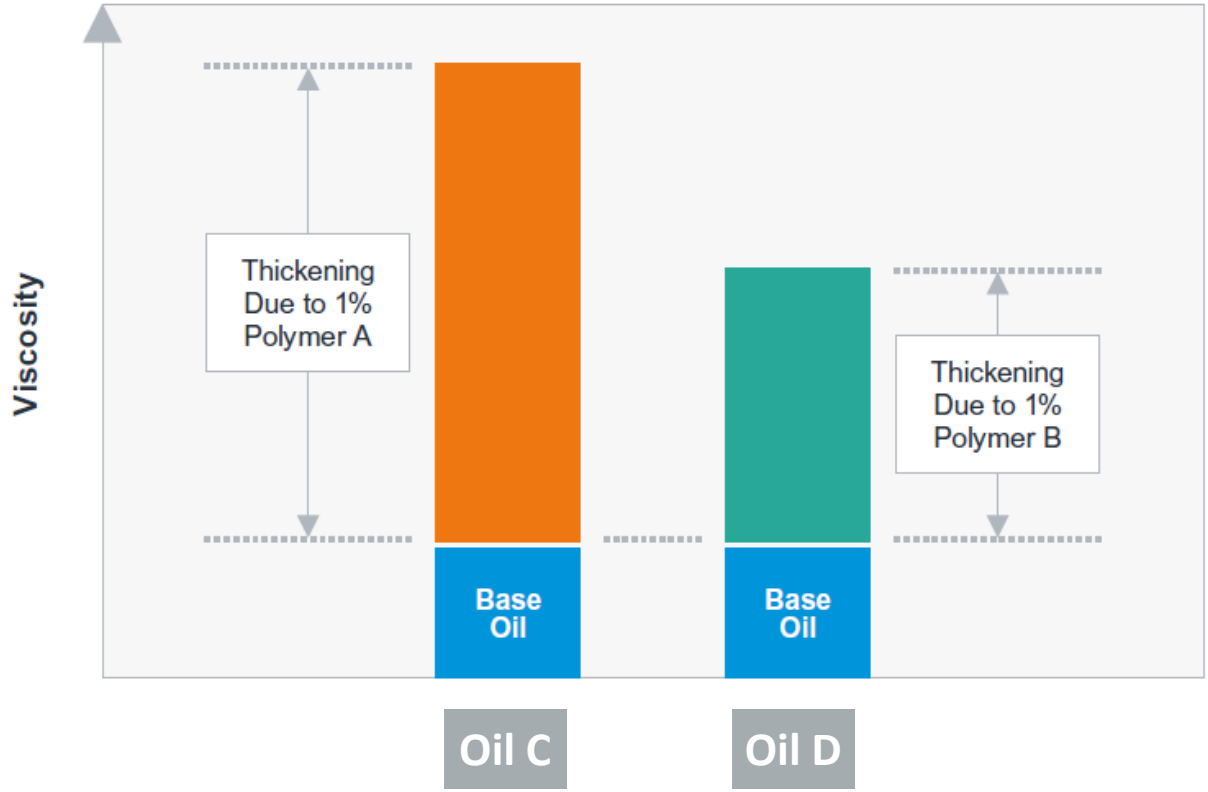
Key Terms

- Thickening Efficiency
- Shear Stability Index

Thickening Efficiency



Thickening Efficiency (TE) is amount of viscosity increase per 1% polymer

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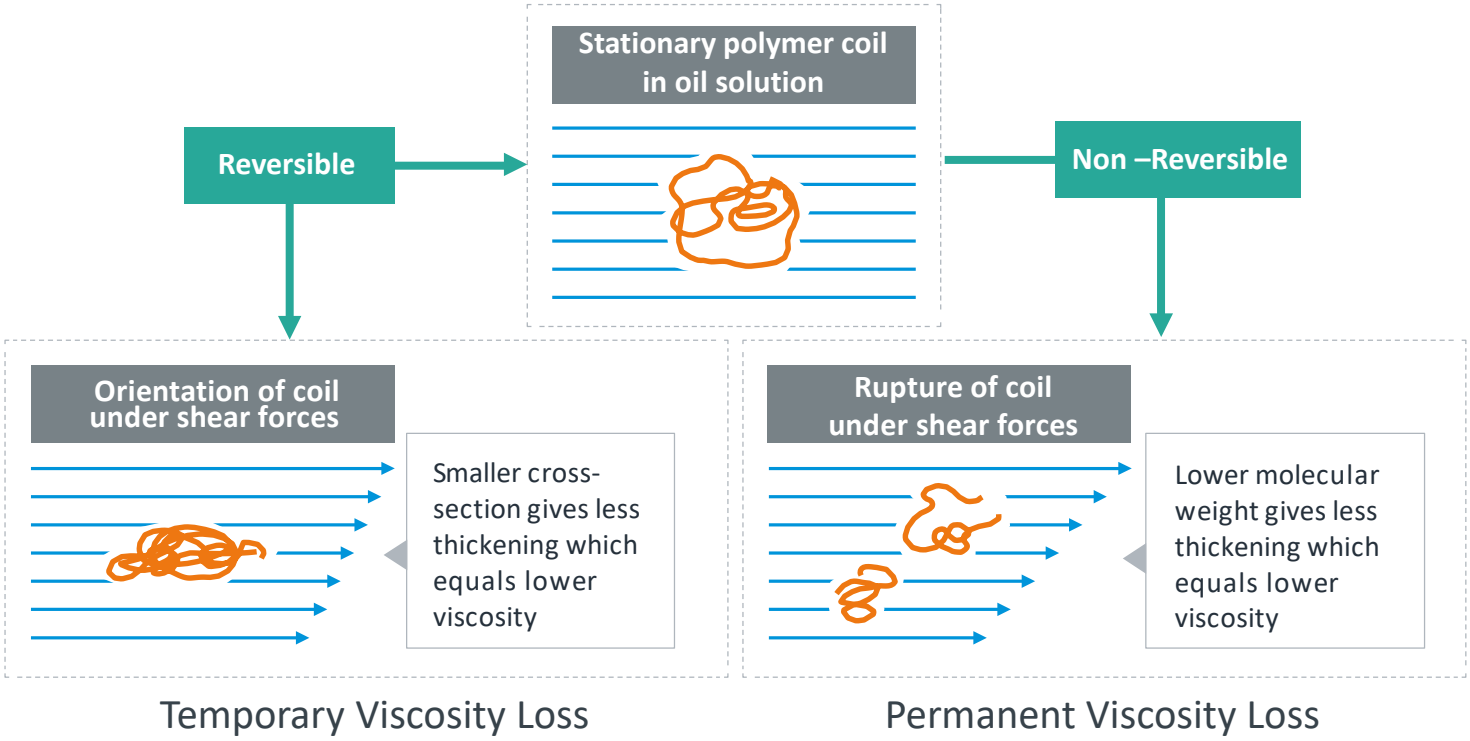
Shear-Thinning

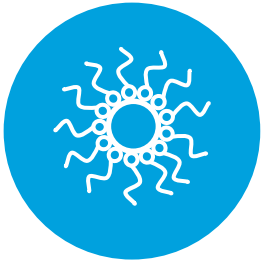
Temporary & Permanent Viscosity Loss



Shear Stability Index (SSI)

Shear Stability Index (SSI) measure of permanent loss of viscosity due to added polymer

- 30 cycles in Kurt Orbahn shear test
- SSI usually measured in a reference oil that represents polymer behavior in SAE 15W-40 grade



The higher the SSI the more permanent viscosity loss upon oil shearing

SSI depends on polymer chemistry, molecular geometry and molecular weight

- Larger polymers have a greater chance of experiencing permanent viscosity loss

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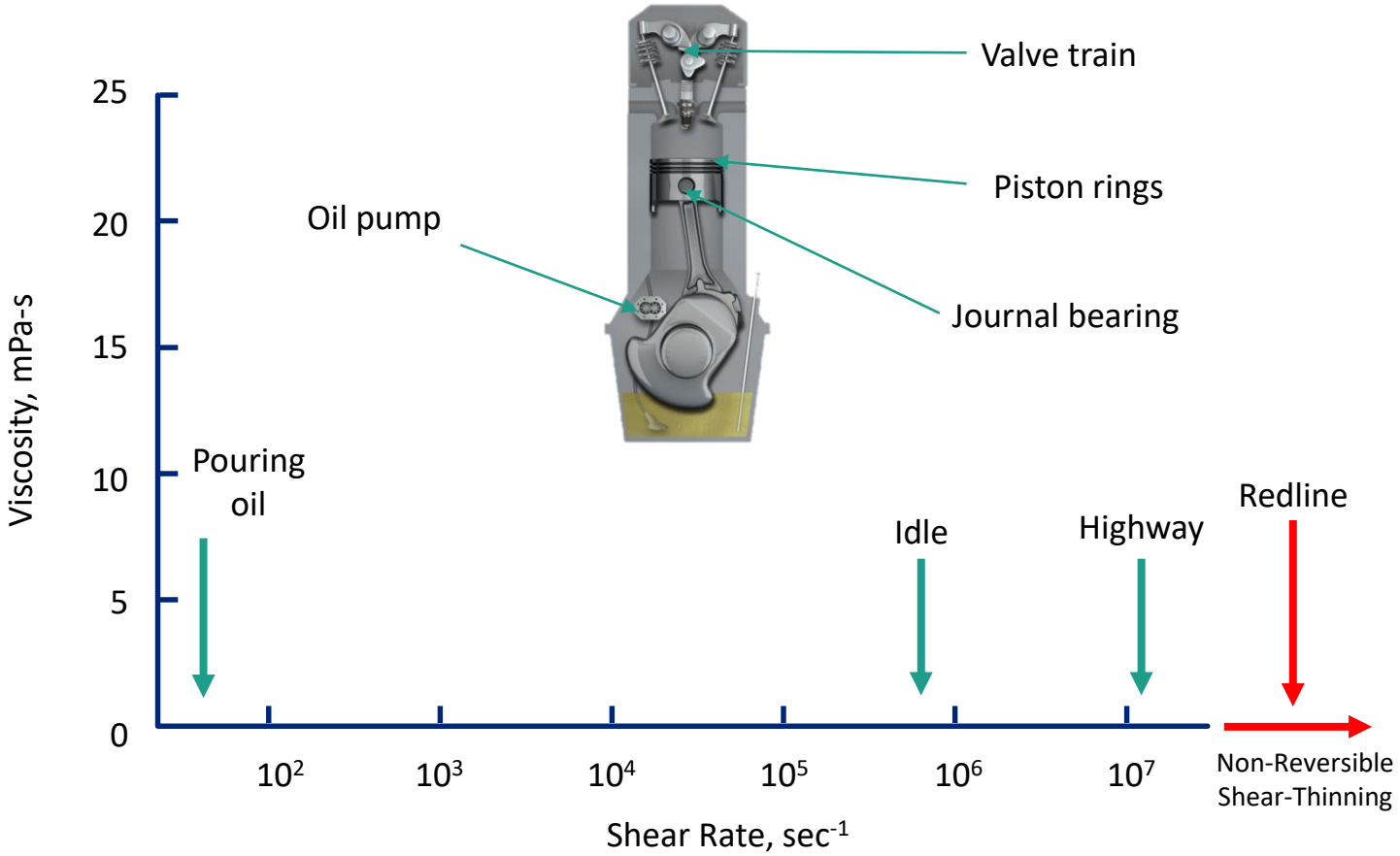
Typical Shear Rates



There are different shear environments within the engine

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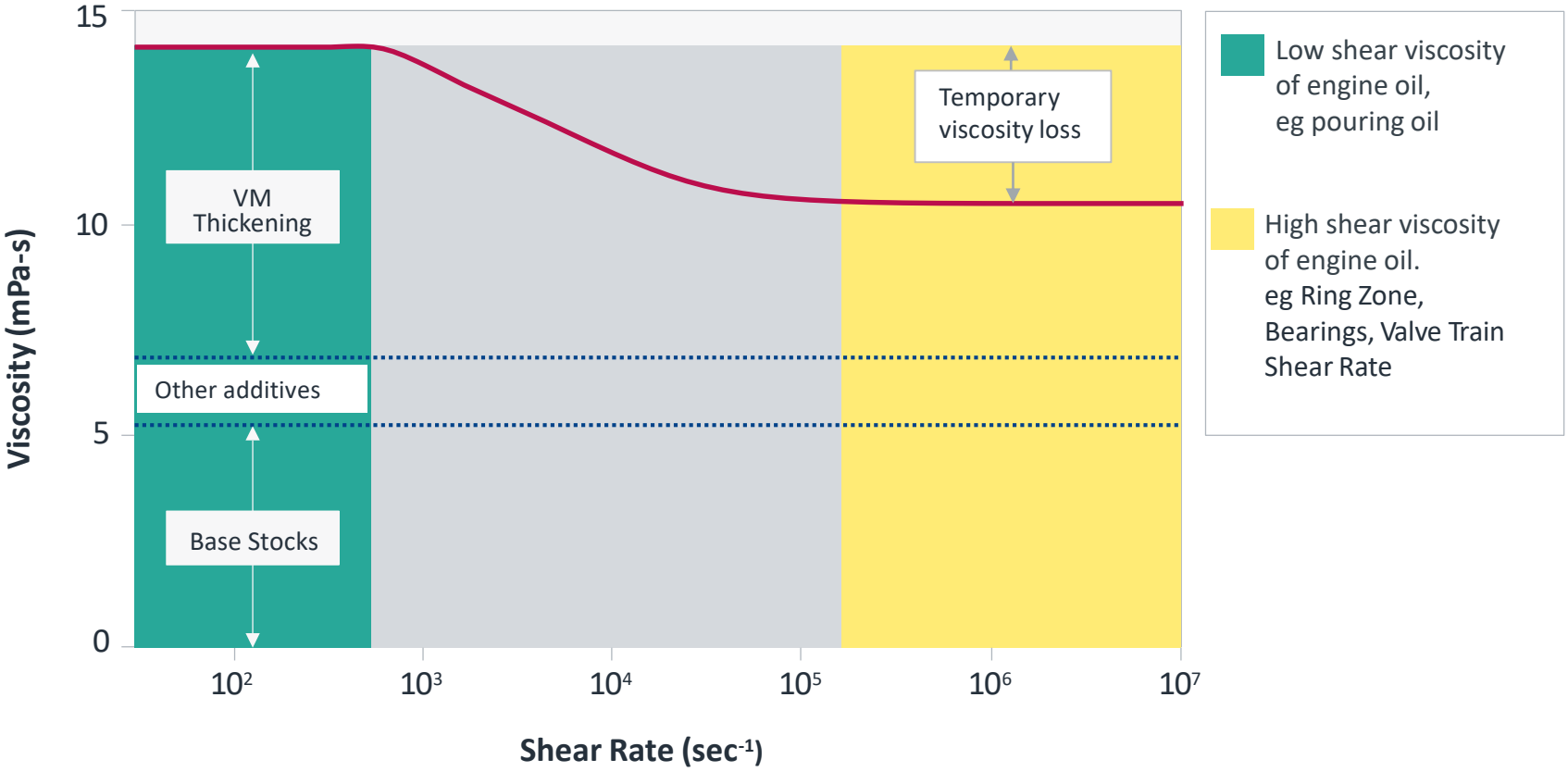
Shear Rate and Shear-thinning



Every VM experiences temporary viscosity loss in the oil

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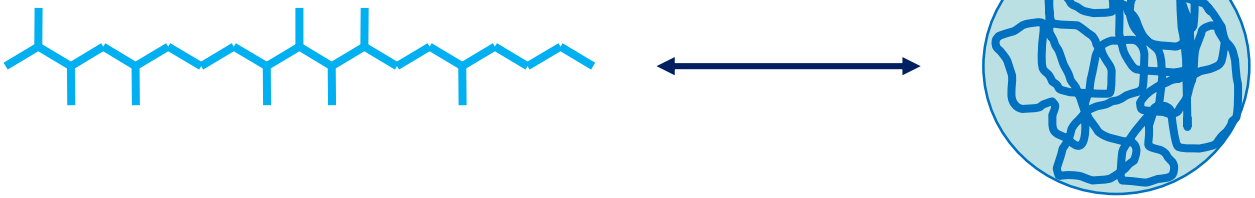
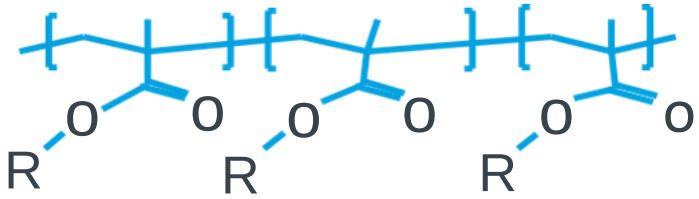
Viscosity Modifier Chemistry

Ethylene-Propylene Co-polymer (OCP)



Polymethacrylate: (PMA)

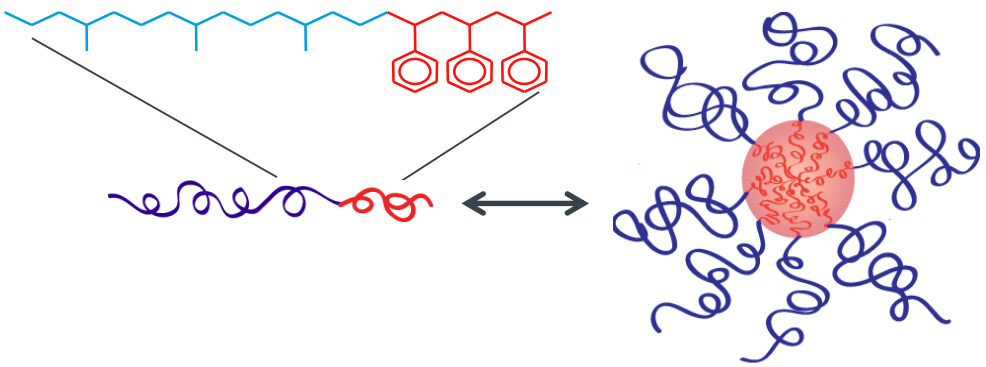


PMA

VM polymers can have different chemistries

Viscosity Modifier Chemistry

Hydrogenated Styrene-Diene:
Linear Polymer



Hydrogenated Styrene-Diene:
Star Polymer

HSD linear polymers form flexible micelles in solution, whereas star polymers are permanent micelles

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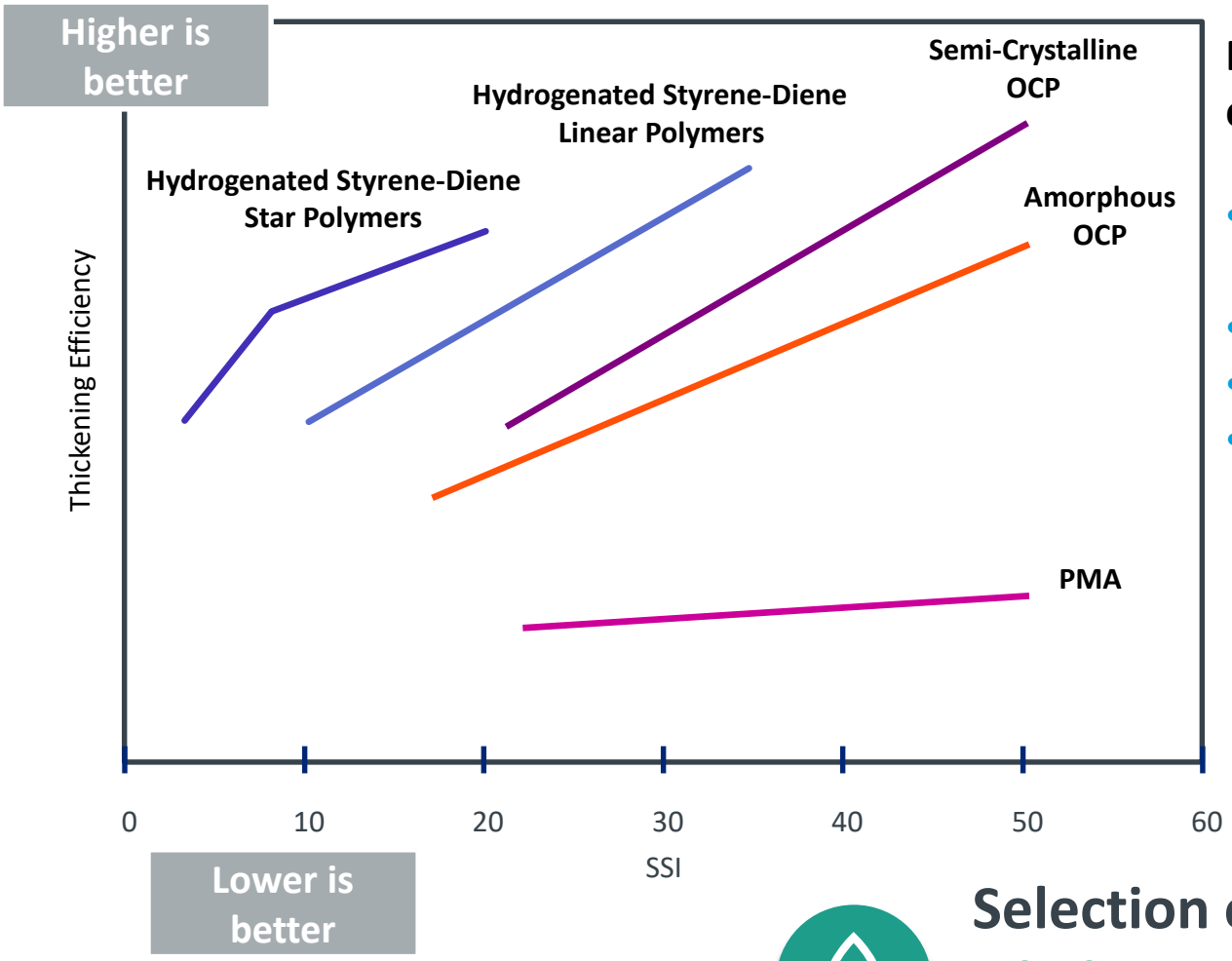
Performance Comparison TE vs SSI

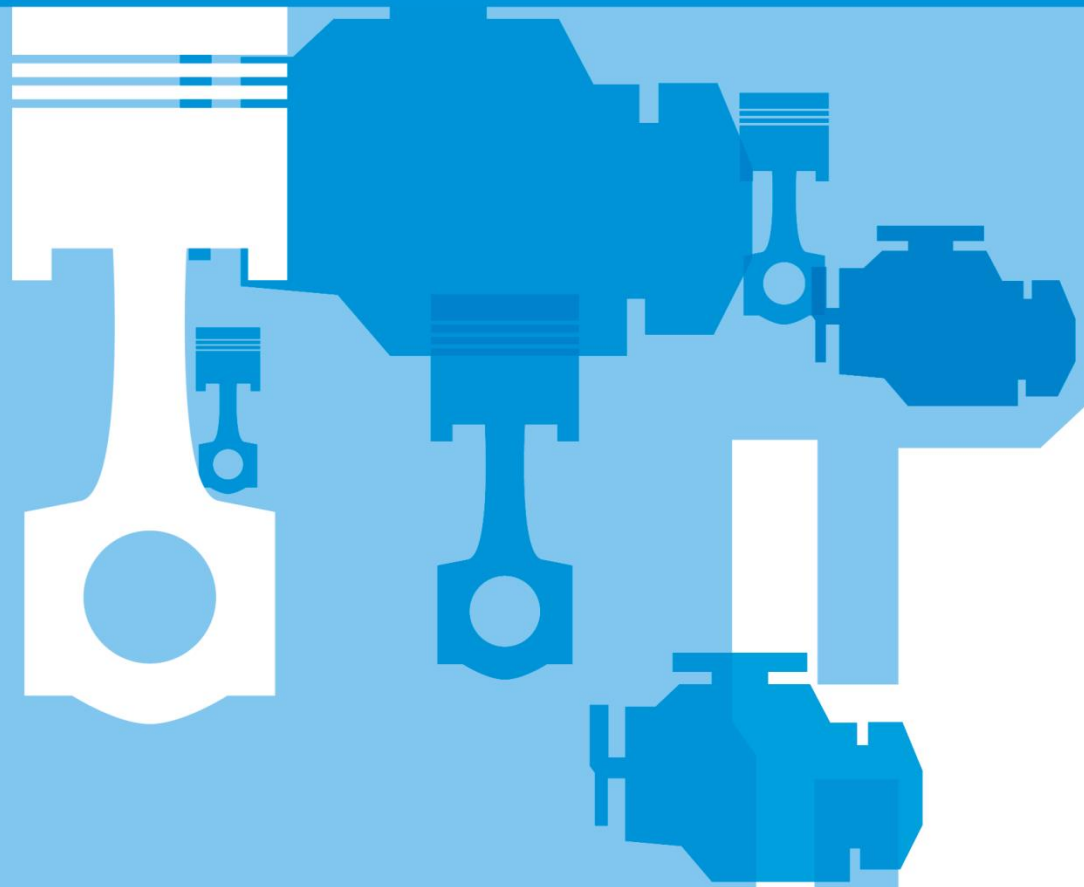


Factors that need to be considered when selecting VM:

- Cost to achieve required thickening (Cost vs. TE)
- Shear Thinning Properties
- Low Temperature Properties
- Other performance harms/credits
  - Soot handling
  - Deposit control
  - Oxidative stability

Selection of appropriate VM is a balance of TE and SSI for your application

Pour Point Depressants



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Pour Point Depressants

Pour Point Depressants

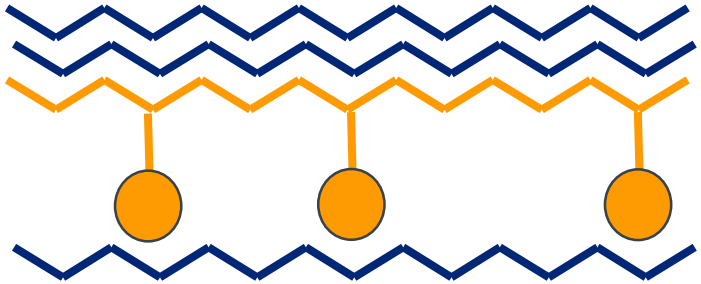
- Commonly referred to as PPDs
- Also know as Lube Oil Flow Improvers (LOFIs)

Break up regularity of wax crystals

- Prevent large crystal sheets from forming
- Encourage small crystals - easier flow
- Minimize low-temperature viscosity

Types:

- Polymethacrylates (**PMA**)
- Fumarate Vinyl Acetates (**FVA**)



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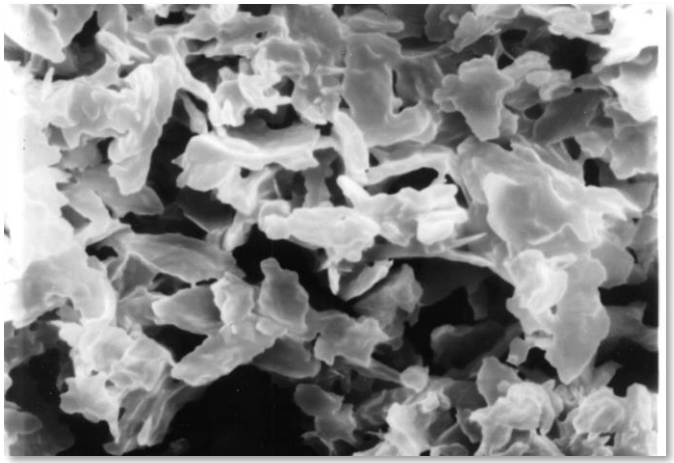
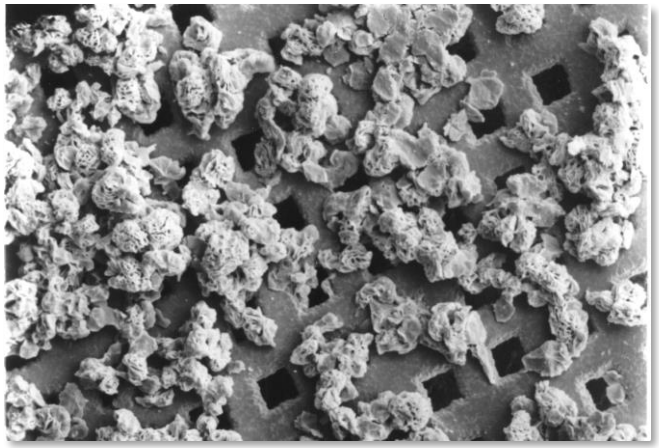
Wax crystal modification by PPD



+ PPD



- **Wax crystals** can cause most serious type of engine problem
- Engines can start but **oil does not flow**, leading to catastrophic engine failure

PPDs are needed to stop wax crystals forming at low temperatures

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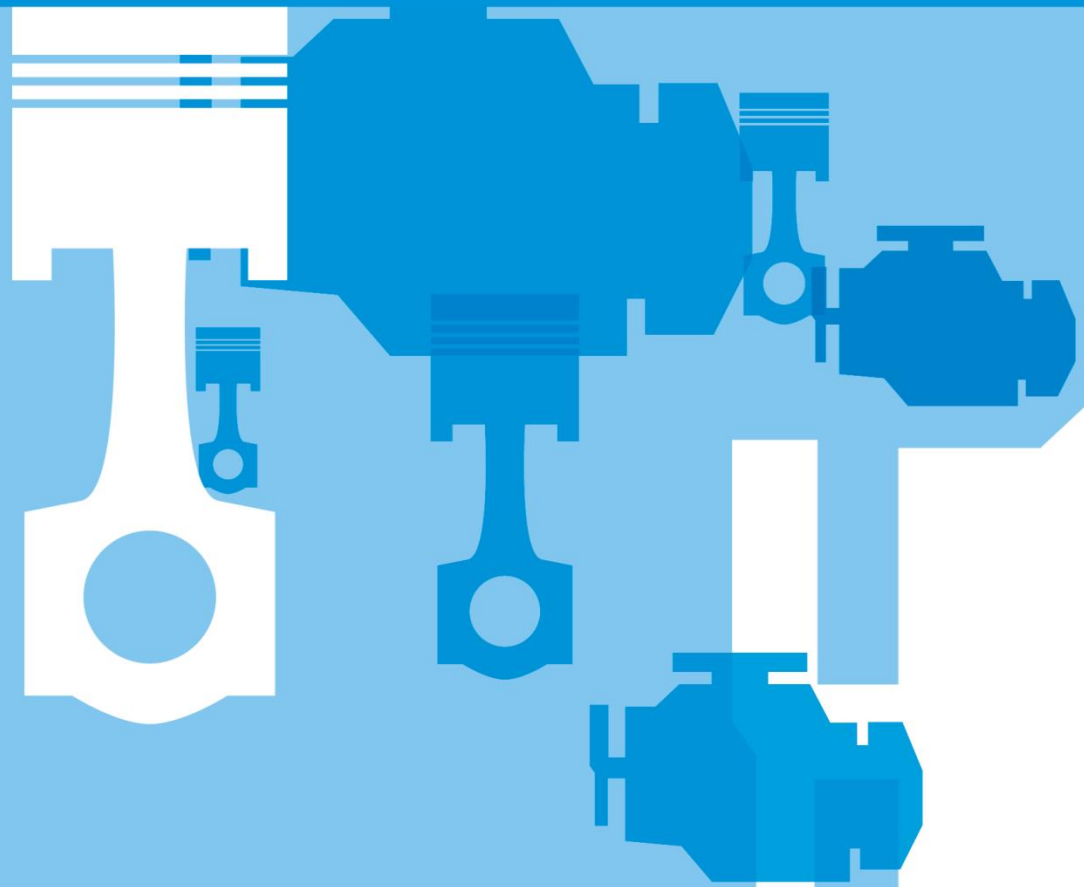
SAE Viscosity Grades



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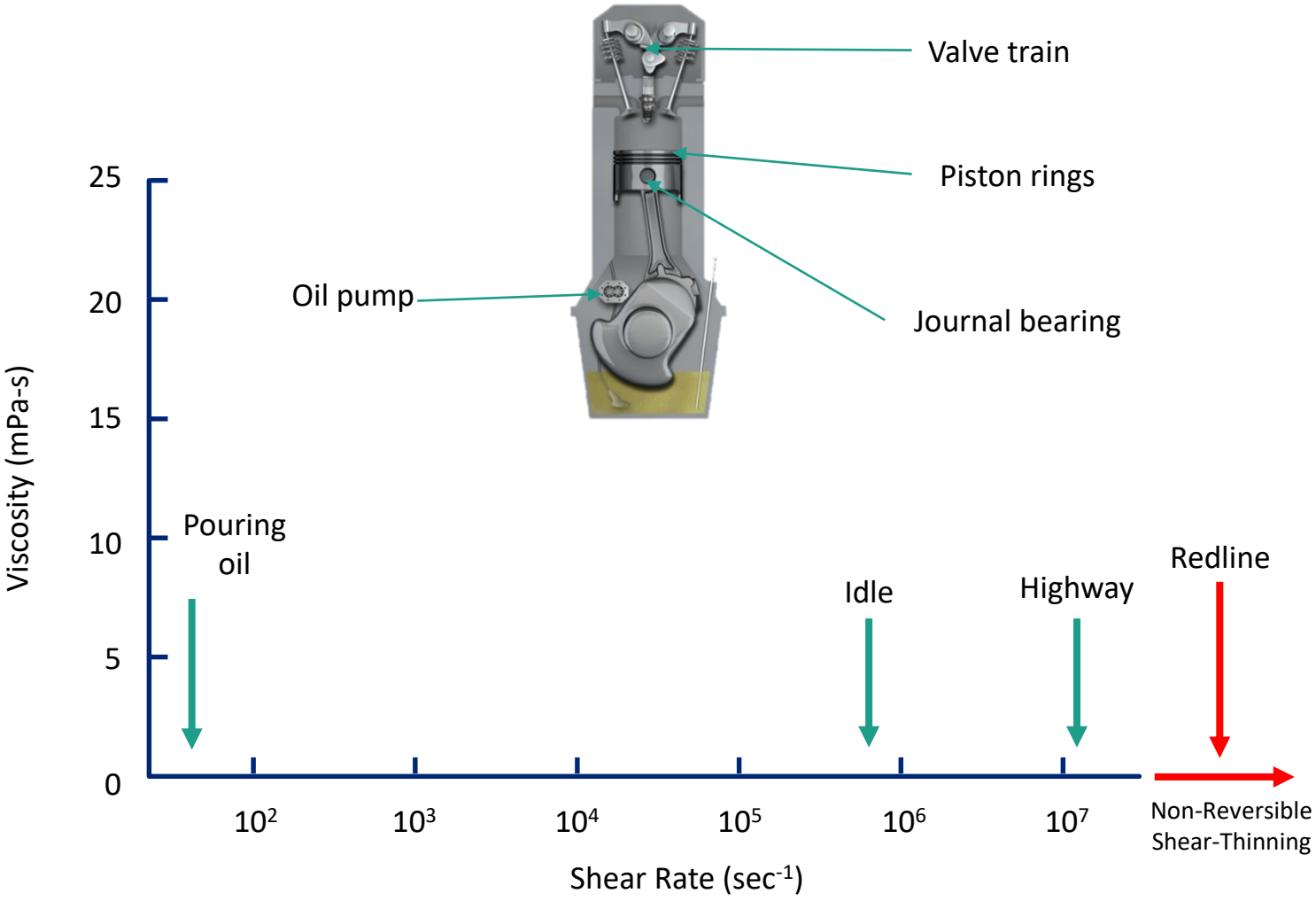
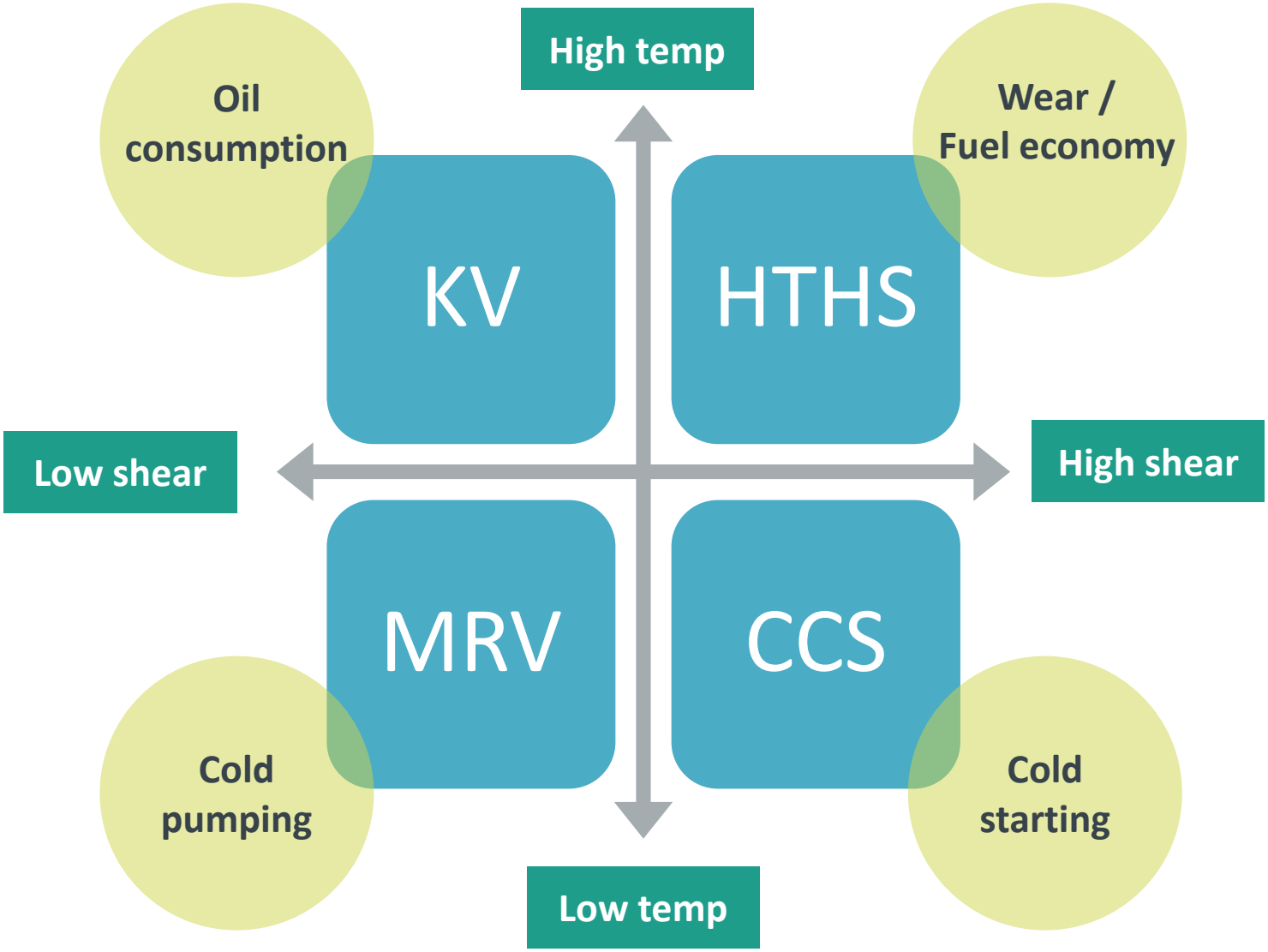
Typical Shear Rates



Viscosity Measurement Methods



SAE J300 Engine Oil Viscosity Grades

SAE Grade	CCS mPa-s, Max	MRV mPa-s, Max w/ No Yield Stress	Kinematic Viscosity mm^2/s		HTHS @ 10^6 Sec^{-1} mPa-s, Min
			Min	Max	
0W	6200 at -35°C	60 000 at -40°C	3.8	–	–
5W	6600 at -30°C	60 000 at -35°C	3.8	–	–
10W	7000 at -25°C	60 000 at -30°C	4.1	–	–
15W	7000 at -20°C	60 000 at -25°C	5.6	–	–
20W	9500 at -15°C	60 000 at -20°C	5.6	–	–
25W	13000 at -10°C	60 000 at -15°C	9.3	–	–
8	–	–	**4.0**	**<6.1**	**1.7**
12	–	–	**5.0**	**<7.1**	**2.0**
16	–	–	**6.1**	**<8.2**	**2.3**
20	–	–	**6.9**	<9.3	2.6
30	–	–	9.3	<12.5	2.9
40	–	–	12.5	<16.3	3.5(1)
40	–	–	12.5	<16.3	3.7(2)
50	–	–	16.3	<21.9	3.7
60	–	–	21.9	<26.1	3.7

(1) For 0W, 5W, 10W Multigrades – Changed from 2.9 in 11/2007
(2) For 15W, 20W, 25W Multigrades and SAE 40 Grade

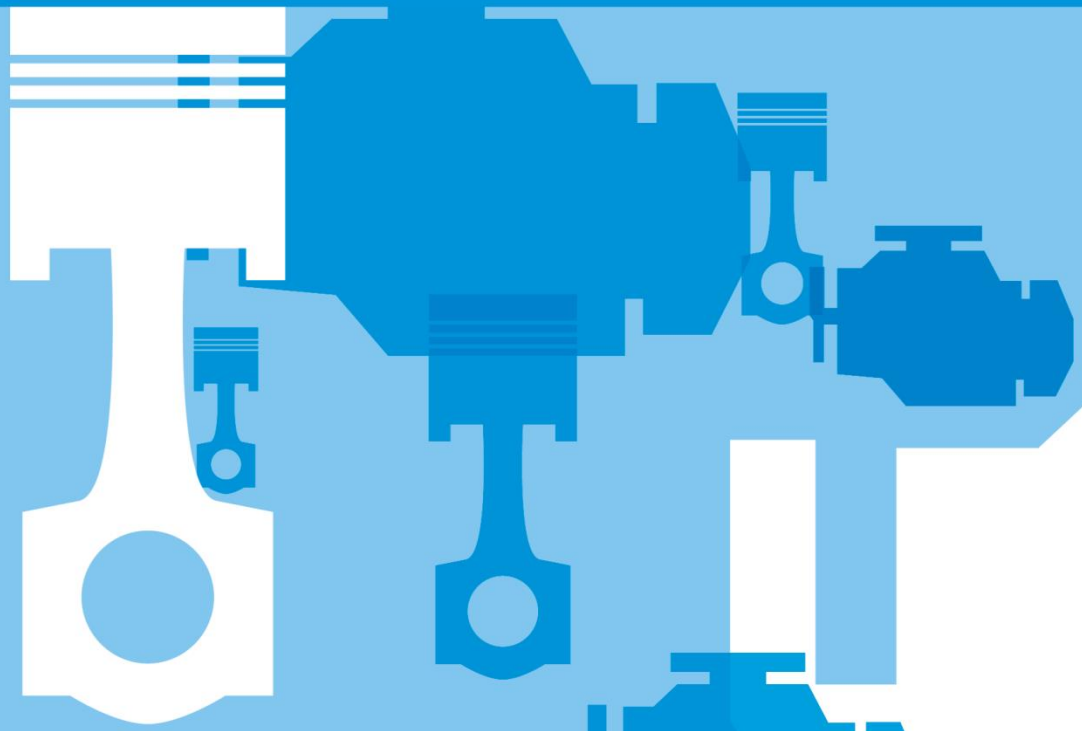
SAE J300 Engine Oil Viscosity Grades

Correct
- SAE 10W-30

Incorrect
- 10W-30
- SAE 10W/30
- SAE 10W30
- SAE 10w-30

- Labeling
  - Must label as the lowest ‘W’ grade
    - An oil that meets 5W also meets 10W, 15W, etc.
  - Oils with VM must be labeled as multigrades
- Care needs to be taken with CCS and HTHS labelling as there’s overlap between the SAE grades

Summary



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Summary

Viscosity is a measure of a fluid's resistance to flow

It depends strongly on **temperature**

Viscosity modifiers in lubricants:

Used to **reduce the influence of temperature** on lubricant viscosity

Protect engine at higher temperatures, whilst allowing flow at cooler temperatures

Chemical structure and molecular weight affect performance, which is a careful balance of **thickening efficiency** and **shear stability index**

Oil formulators must consider which VM will be most appropriate for their application

Viscosity grades are defined by SAE J300

"Oils which are formulated with polymeric viscosity index improvers for the purpose of making them multiviscosity-grade products are non-Newtonian and must be labelled with the appropriate multiviscosity grade "

Source: SAE J300

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