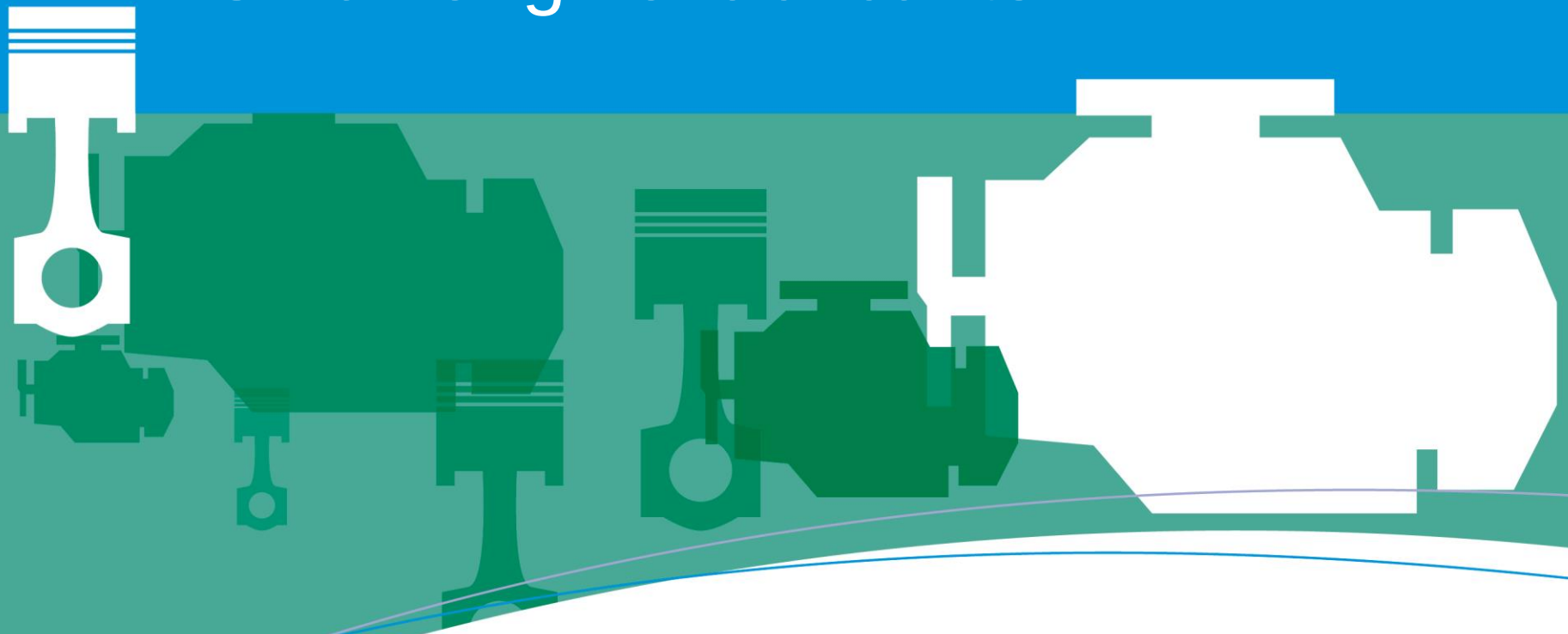
Performance you can rely on.

Small engine lubricants



InfineumInsight.com/Learn

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The small engine market

Chainsaws & Garden Equipment




Motorcycles & Mopeds




Snowmobiles




Personal Water Crafts




Outboards




Overview for today's discussion

- 2T and 4T Applications, Engines and Lubricant Needs
- Specifications
  - Snowmobiles
  - Leisure Marine
    - 2T Outboard Engine Oils- NMMA TC-W3 Outboard Oils
    - 4T Marine Engine Oils -NMMA FC-W and FC-W Catalyst Compatible
  - Motorcycles and Mopeds
    - 4T Motorcycle oils JASO T903 Specification
  - Garden Equipment and generators
    - 2T Low Ash Oils- JASO 2T Standards
- Summary

Descriptions are used interchangeably for small engines

Four stroke cycle
Four stroke
Four cycle
4T

Two stroke cycle
Two stroke
Two cycle
2T

“T” in 4T & 2T comes from the French term “temps” meaning “time” or “stroke”

(the translation is not precise)

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Both four stroke and two stroke engines are commonly used in small engine applications

Emission regulations have driven technology towards 4T engines but many 2T's are still in use

In North America

Outboards	Majority of new engines are 4T, but population is still largely 2T
Motorcycles	Population and sales are virtually all 4T
Snowmobiles	Mix of 2T and 4T new engines. Large 2T population base still exists
PWCs	Most new engines are 4T, but still a significant 2T segment
Chainsaws	Still mainly 2T, but 4T options are available
String trimmers	Still mainly 2T, but 4T options are available
Leaf blowers	Still mainly 2T, but 4T options are available
Lawn mowers	Population and sales are virtually all 4T

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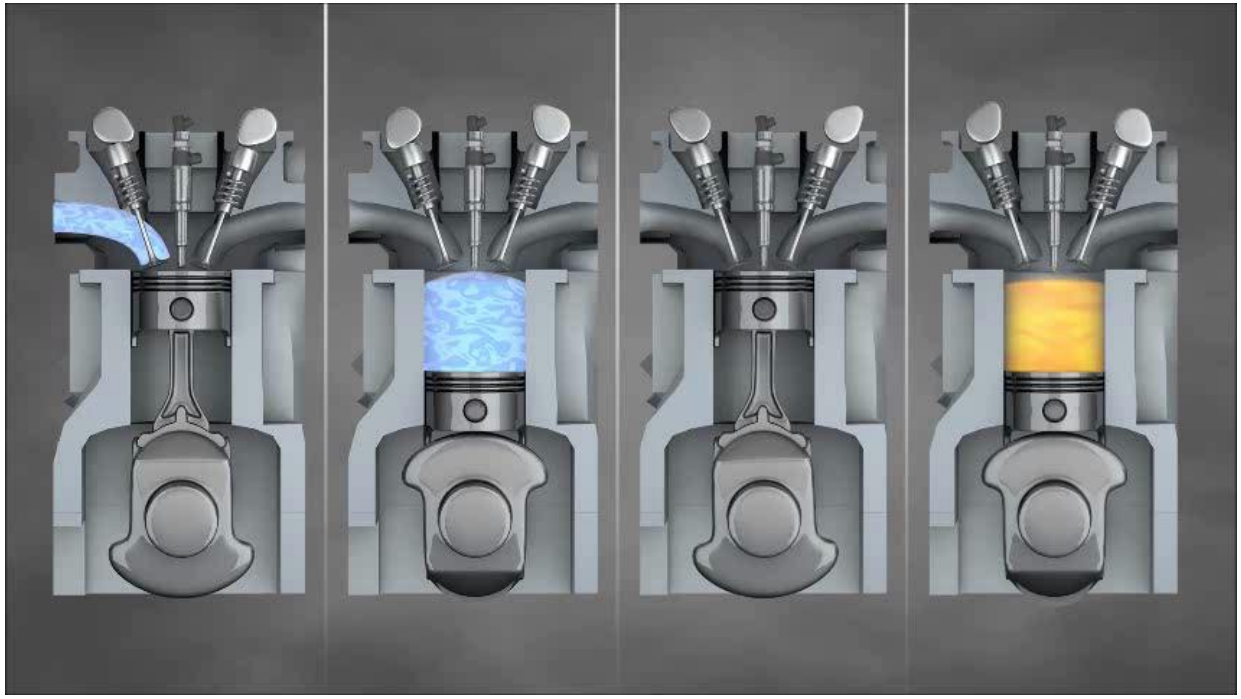
Traditional four-stroke engine

Four-stroke Cycle = Four-stroke = Four Cycle = 4T

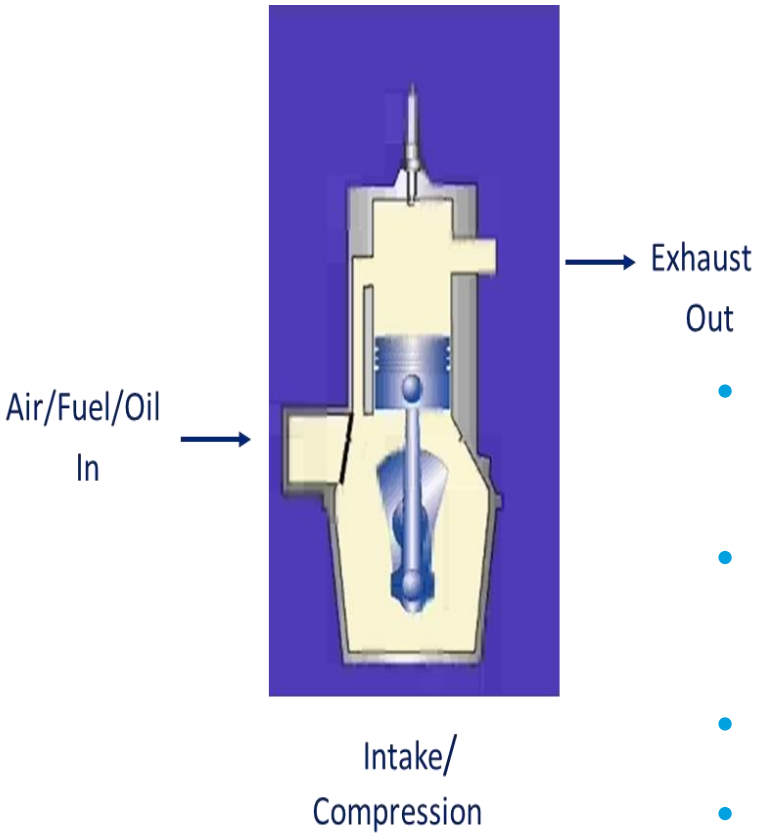


- The sump is oil filled and the oil recirculates
- Inherently low emissions

Traditional two stroke engine

- More power / less weight
- Two stroke engines mix oil with the fuel and consume the oil

How two-stroke engines are lubricated



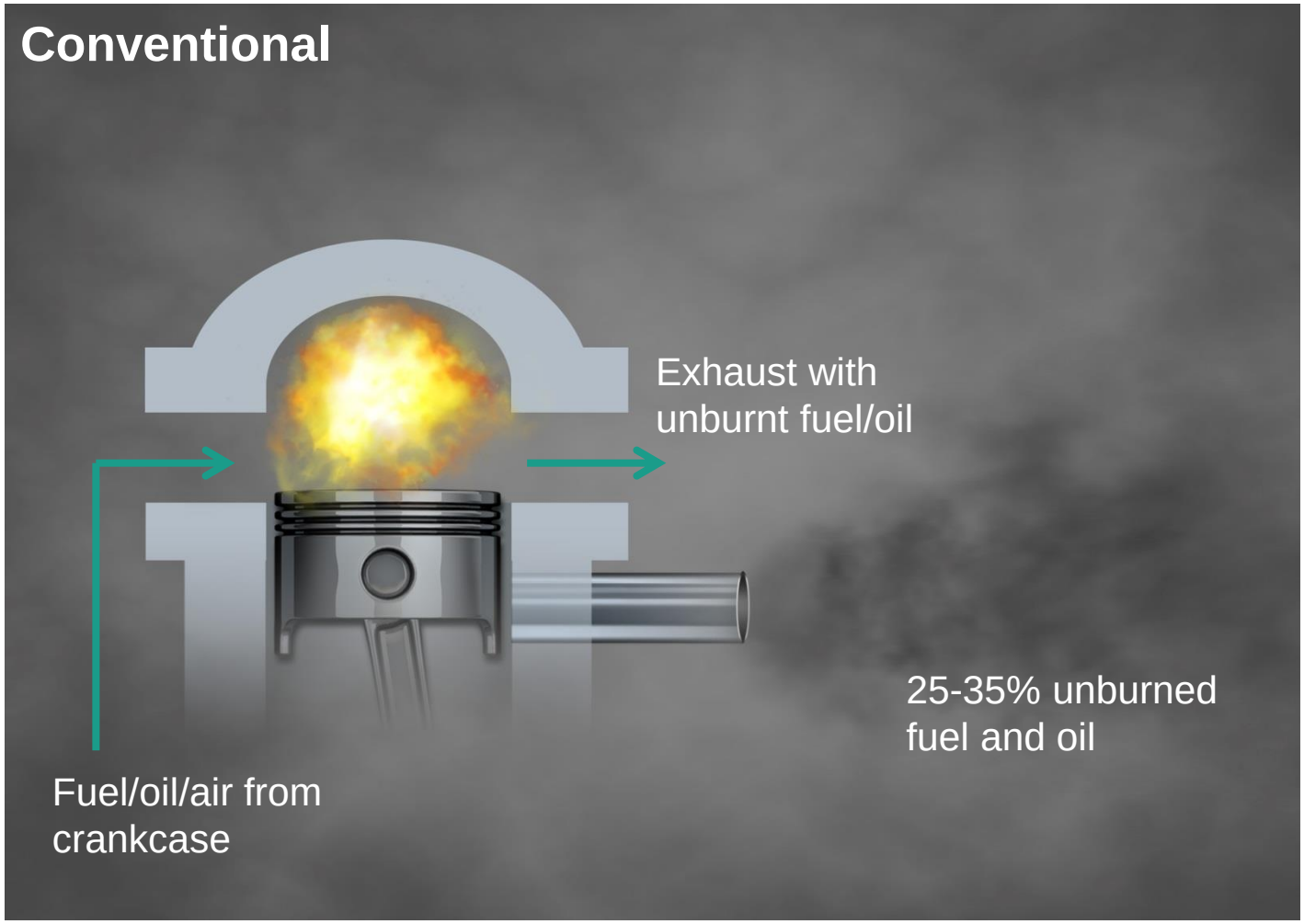
- Oil is mixed in the fuel (usually at 50:1)
  - Traditionally, oil would be mixed in the fuel tank
  - In modern engines the oil is injected into fuel line
- Evaporation of the fuel deposits oil on the cylinder walls and bearings to lubricate them
- Fuel and oil in the combustion chamber are ignited by the spark plug
- Replacement oil is delivered with fresh fuel/air
- Traditional over-fuelling design causes high emissions

Both two-stroke & four-stroke engines have advantages

- Two-stroke
  - Advantages
    - Two-stroke Engines have an excellent Power to Weight Ratio
    - Fewer Parts than a Four Stroke Engine
    - Small, Compact Engines
    - Low Cost
    - Low Nitrogen Oxides (NOx) Emissions
    - Less Engine Weight

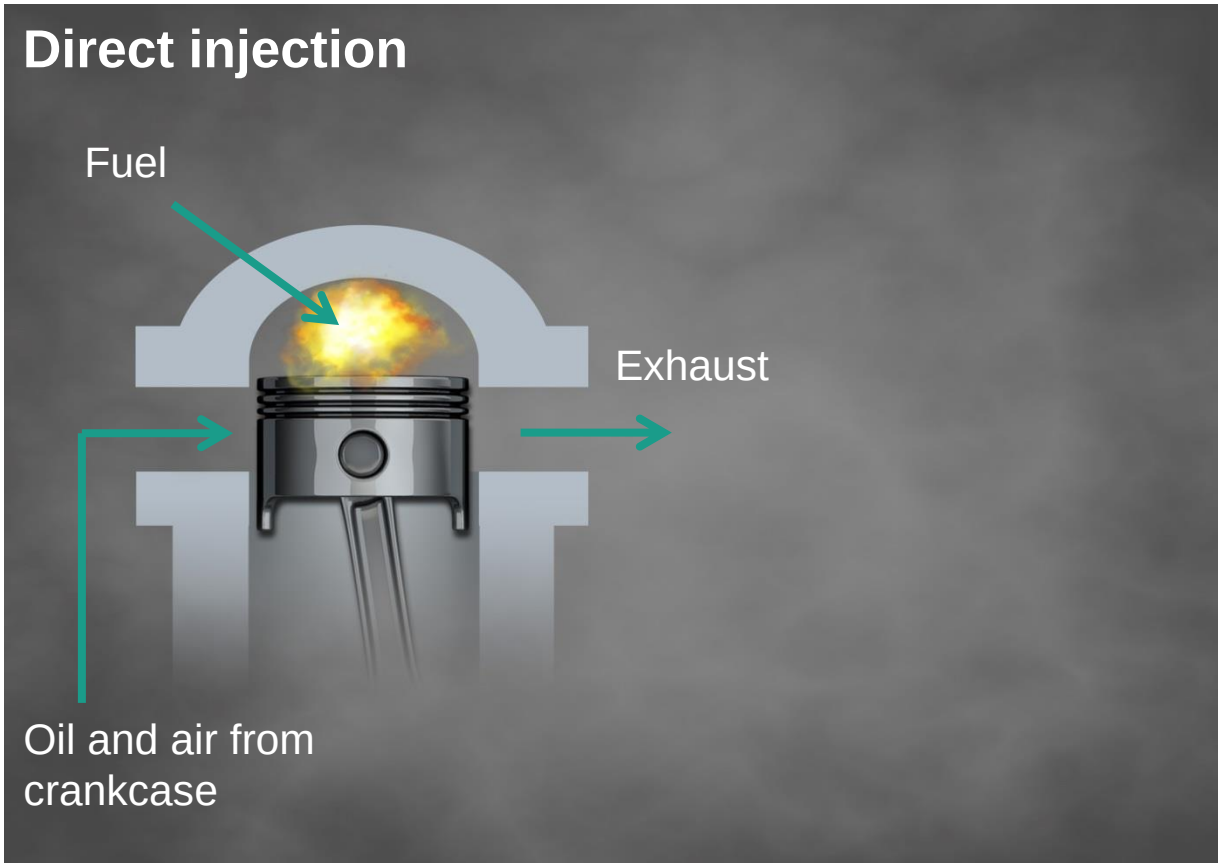
- Four-stroke
  - Advantages
    - 20-40 % Better Fuel Economy
    - Smooth and Quiet Operation
    - Low Hydrocarbon (HC) and Carbon Monoxide (CO) Emissions

Conventional 2T engines have high hydrocarbons emissions due to unburned fuel



2T direct fuel injection (DFI) is a way to address emissions

Fuel is injected when piston is top dead center

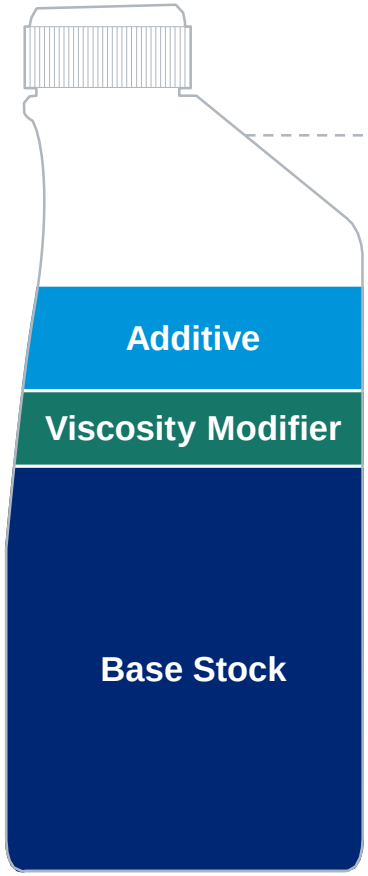


Notice: Exhaust port is blocked, therefore reduced emissions

DFI makes 2T outboard engine service more severe

- Higher temperatures
  - In traditional 2T engines, fuel vaporizes in the crankcase, cooling the engine
  - In DFI, fuel bypasses the crankcase, **raises engine temperature by 50°C**
- Less oil delivered to critical surfaces
  - In DFI, air alone carries the oil, which is less efficient
  - Oil must often be pumped to the cylinders for extra lubrication
  - Oil flow is reduced, touted as an advantage for the consumer
- Combination of less oil and higher temperatures makes DFI engines more prone to scuffing and failure
  - Deposits build up in the ring grooves behind the rings due to higher temperature, and there's less oil (cleaners) to prevent it
  - Rings are pushed out by the deposits and they apply pressure to the cylinder liners, reducing film thickness and eventually causing metal-to-metal contact (scuffing) or called ring jacking, or proudness

What goes into a 4T lubricant?



Provides

Additive
Antioxidancy
Foam / Aeration
Antiwear / EP
Friction
Dispersancy
Detergency

Viscosity Modifier
Multigrade viscosity
Low temperature flow

Base stock
Viscometrics
Oxidation
Dispersancy
Volatility

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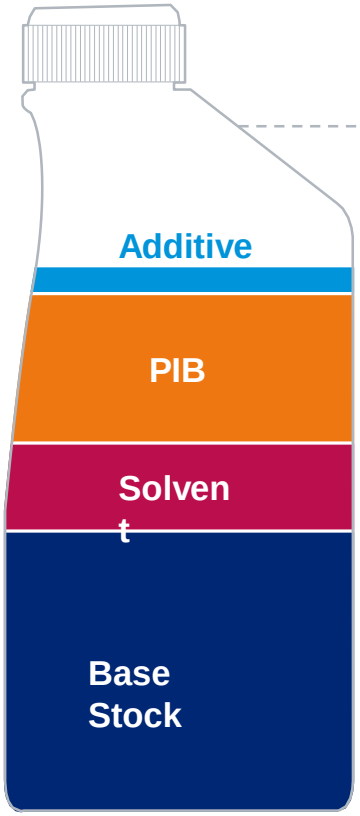
What goes into a 2T lubricant?

Desirable oil characteristics are cleanliness, low smoke, high lubricity, and low exhaust deposits (blocking)



Impacts

Additive
Helps Cleanliness
Hurts Burnability
Hurts Smoke
Hurts Blocking

PIB
Burns Cleanly
Reduces Smoke
Improves Blocking
Improves Lubricity

Base Stock
Improves Lubricity
Hurts Smoke/ Blocking
Hurts Cleanliness

Solvent
Improves Miscibility and Fluidity
Burns Cleanly
Improves Blocking
Hurts Lubricity

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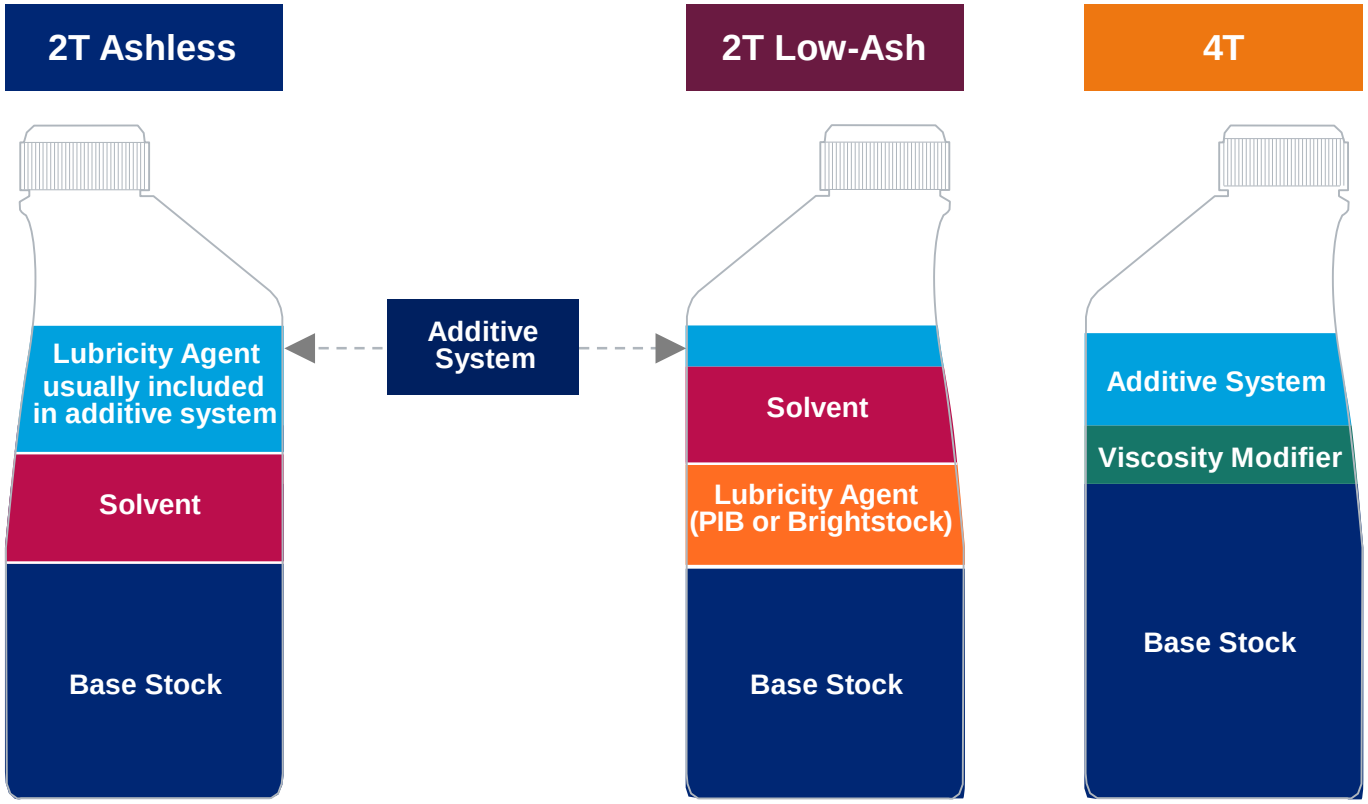
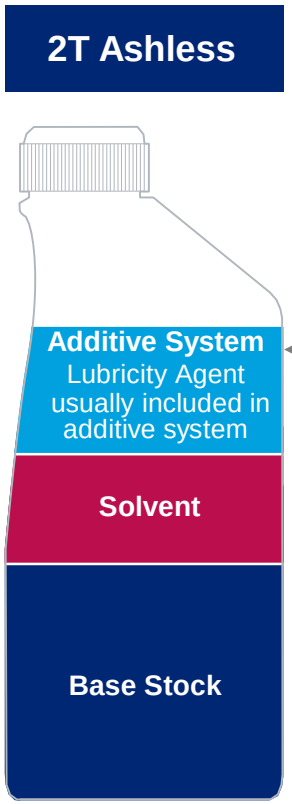
There are two types of 2T oils



Ashless Formulations



Water cooled engines

- Ashless additive system required to prevent pre-ignition in water cooled outboard engines
  - Historically, pre-ignition was a major problem for outboards
  - Engines run cooler, so ash deposits are less brittle and build up, causing pre-ignition
- Ashless formulations have specialized additive packages that treat at significantly higher levels.
  - A significant treat rate of ashless dispersants is used to compensate for not using detergent chemistry
  - Lubricity agent component incorporated into the additive package.
  - Polyisobutylene is used for improved lubricity and exhaust smoke performance
- Solvent provides low temperature fluidity
  - Important for oil-injected systems

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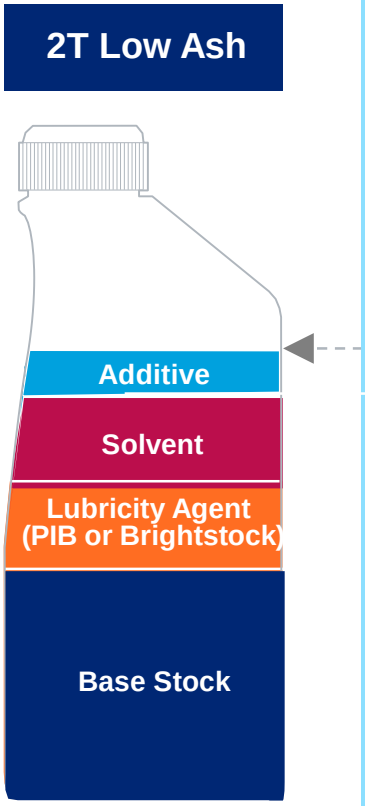
Low Ash Formulations



Air cooled engines

- Low ash additives and metal detergents are used for air cooled land equipment
  - Lower cost and lower treat rate
- Engines run hotter so can tolerate some ash without causing pre-ignition
  - Ash deposits formed are thin and brittle, so blow out of the exhaust
- Solvent is used to improve miscibility of the oil with the fuel
  - But it does lower the oil's flash point – a safety / storage consideration
- Polyisobutylene (PIB) used to improve lubricity whilst reducing exhaust smoke
  - Traditionally brightstock was used for lubricity
  - Brightstock has poor smoke performance

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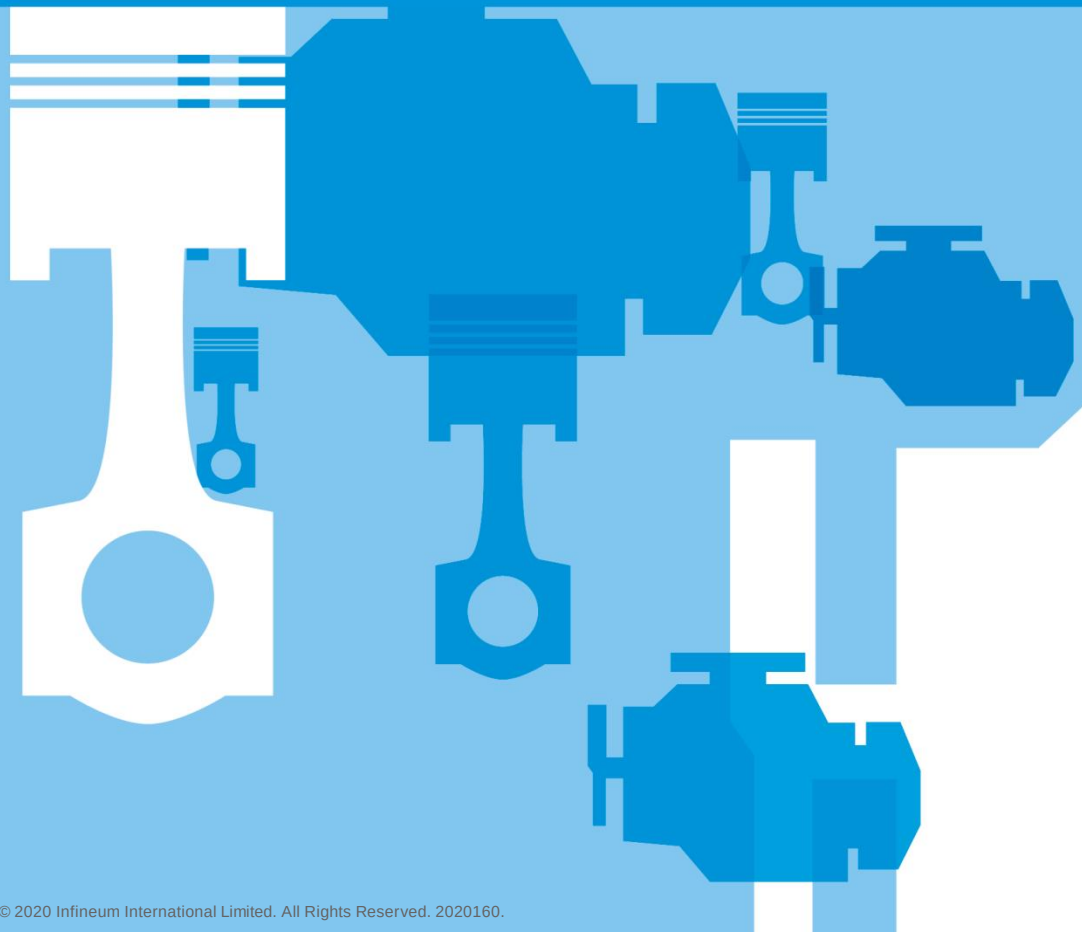
Performance you can rely on.

Snowmobile oils



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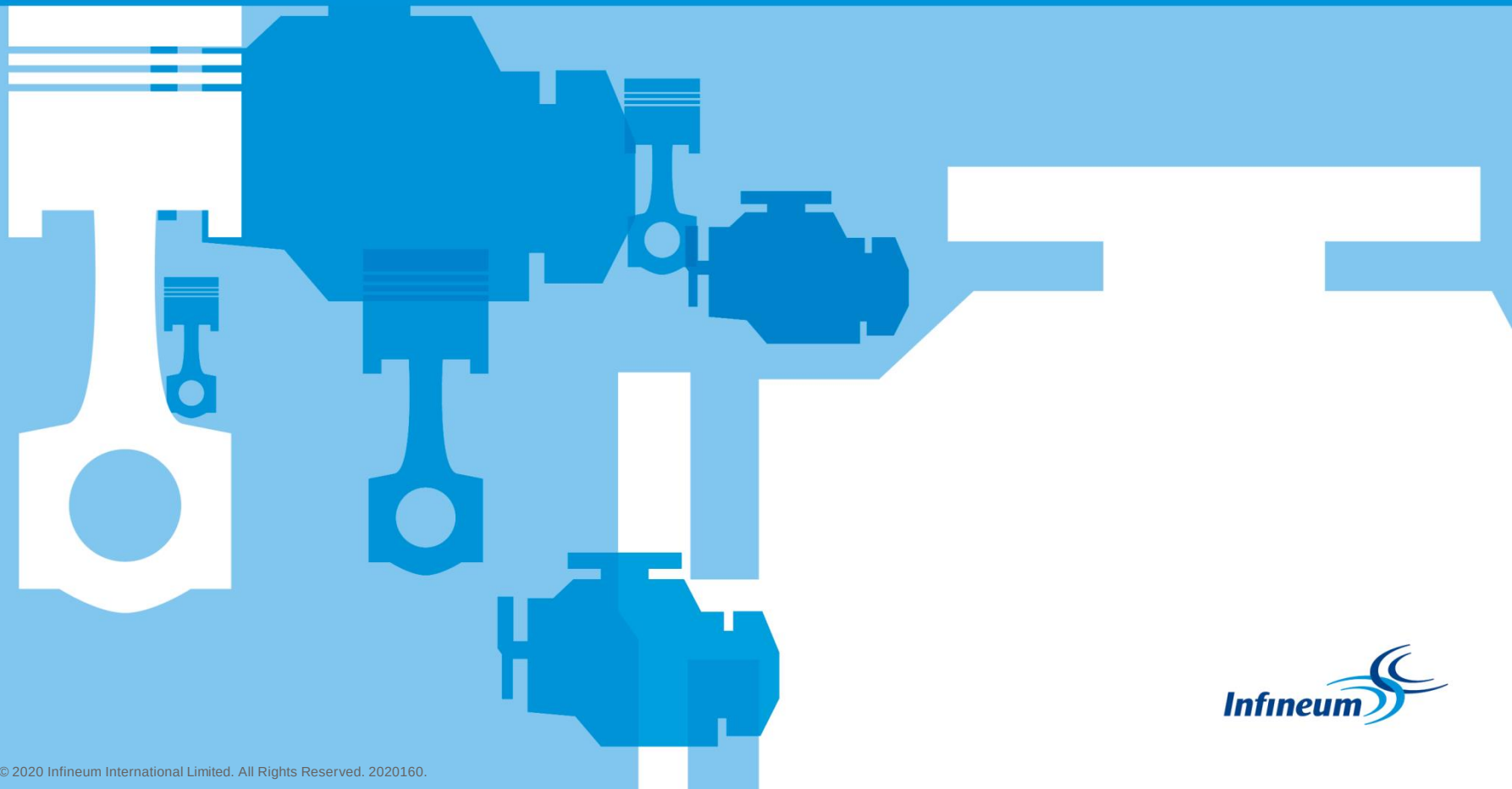
There are no industry standards for snowmobile oils

- For Two-stroke Engines:
- Both ashless and low ash additive systems recommended by OEMs
- Requires low pour point and low-temperature fluidity
  - OEMs Recommend Pour Point ≤ -40°C
  - Brookfield fluidity
    - Good: < 60,000 cP @ -40°C
    - Best: < 17,000 cP @ -40°C (J1536 grade 4)
- Exhaust odor an issue due to trail riding
- Exhaust valves (deposits) can cause poor performance at high RPM
  - Partially burned and unburned fuel and oil can create deposits on the sliding surfaces of the exhaust valves and cause them to stick

- For Four-stroke Engines:
- OEMs generally recommend 0W grades.
- Most oils are at least part-synthetic, if not full synthetic

Outboard or water cooled oils



NMMA oversees leisure marine oil quality standards

NMMA OCC Members

OEMs
Additive companies
Testing Labs
Oil Marketers

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Oil standards exist for leisure marine oils

National Marine Manufacturers Association

TC-W3®

Two-**C**ycle - **W**ater

NMMA FC·W CERTIFIED

NMMA FC·W® CATALYST COMPATIBLE

Four-**C**ycle - **W**ater

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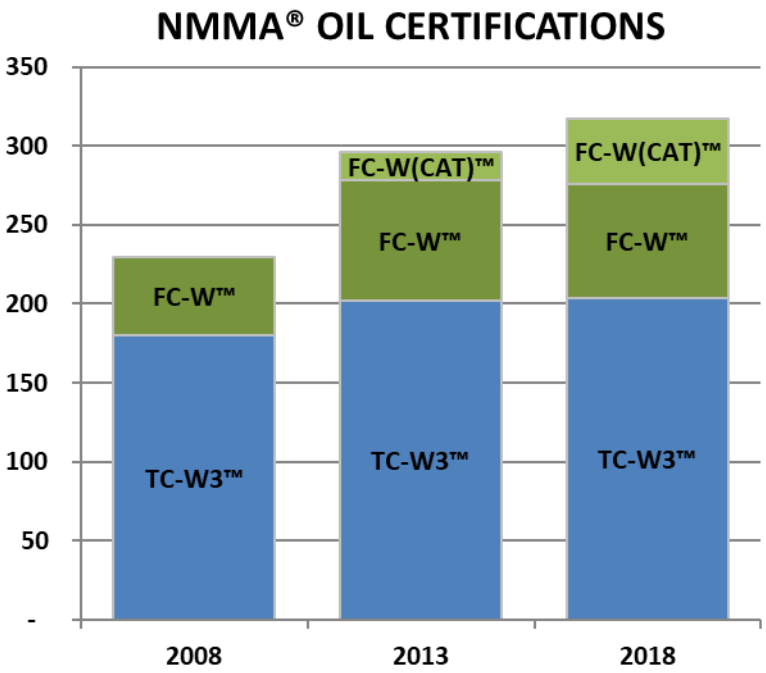
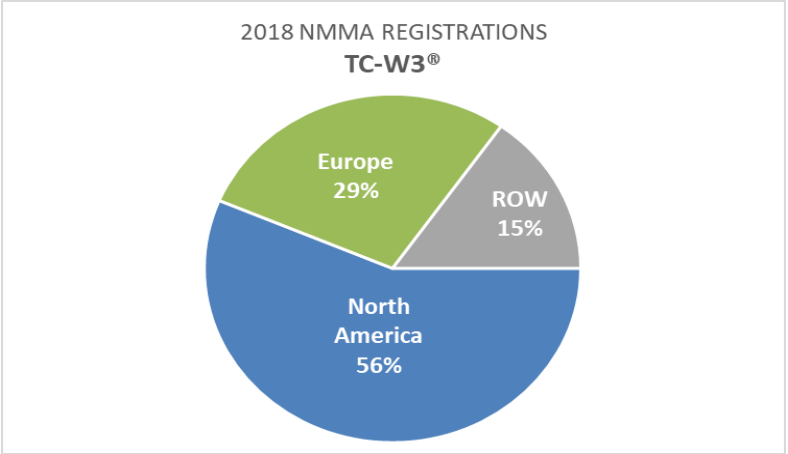
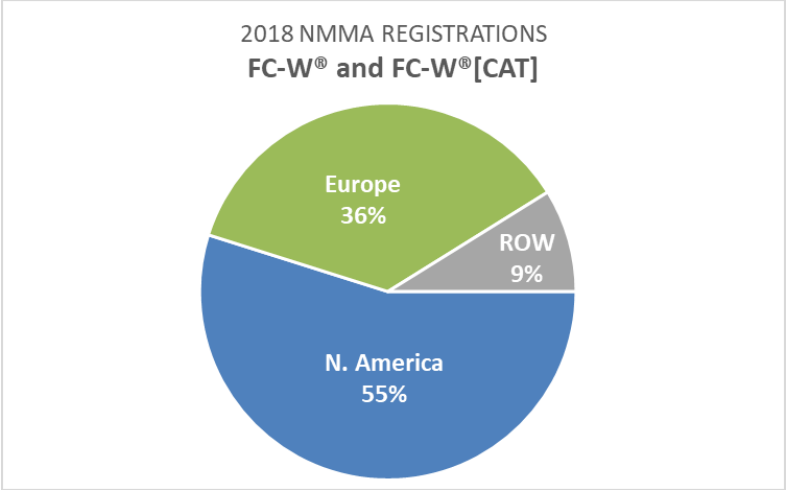
NMMA Certifications surpassing 300 world wide







DATA SOURCE: NMMA

Most outboard OEMs favor 4T technology

- 11.5 Million power boats in use in North America
  - 2017 US boating industry sales hit a 10 year high
  - Outboard engines sales are also experiencing high growth

Most OEMs are using 4T outboard engine models to meet emission regulations

- Mercury carries and 4T engine designs (Verado and SEAPRO brands), offering a new 400hp Verado in 2019
  - 2T DFI OptiMax and Pro XS brand offering

- Yamaha favors 4T Technology offering a new 425 Hp Outboard for offshore
  - Yamaha developed High Pressure Direct Injection 2T DFI- no longer in production
- BRP (Evinrude brand name) is focusing on 2T DFI. Latest E-Tech G2 250 HP model claims improved fuel efficiency and emissions

- Honda markets only 4T engines (2 hp to 250 hp)
- Suzuki markets only 4T (portables up to V6 models)

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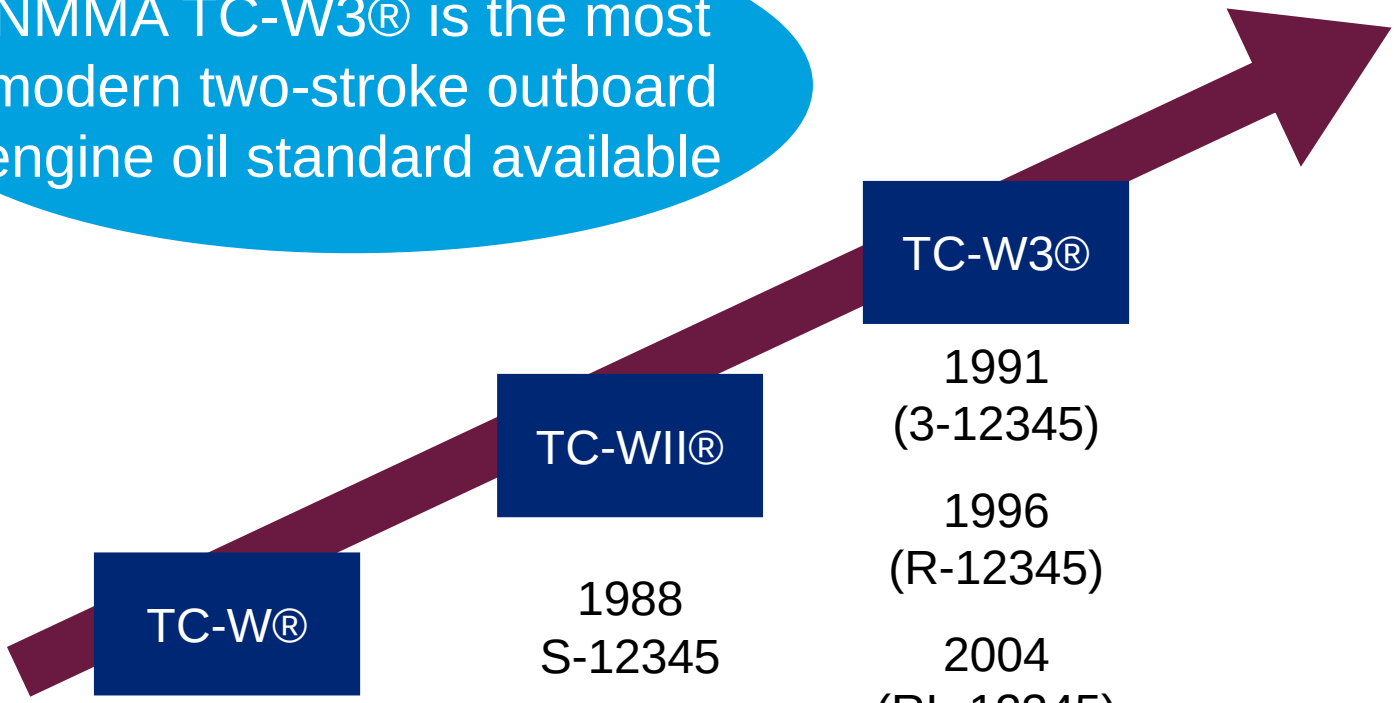
Outboard OEMs have driven NMMA to develop higher 2T oil standards

NMMA TC-W3® is the most modern two-stroke outboard engine oil standard available



Demonstration test program ensures TC-W3 oils meet engine requirements

Analytical Testing
KV @ 40°C
TAN
Cloud Point
Nitrogen
FTIR Scan

Bench Testing
Fluidity @ -25°C
Miscibility @ -25°C
Rust
Filterability
Compatibility

>$300K for a full program

Engine Testing
CE-50 Lubricity (Yamaha 50 cc)
AF-27 Lubricity (Honda Dio)
Preignition (Yamaha 50cc)
General Performance (OMC 40 HP)
Detergency/Scuffing (Mercury 15 HP) x 2
~~Ring Sticking/Detergency (OMC 70 HP)~~

NMMA TC-W3 certification Read Across Rules

Formulation changes

Allowed:

- Additive increases (+20% relative)
- Solvent concentration changes (±20% relative) and substitutions
- PPD concentration changes (±1%) and substitutions (0.5%)
- PIB concentration changes (±25% relative)
- Bright stock concentration changes (±10%)
- Base oil concentration changes (±25%) and supply changes

- NMMA Read across rules have been expanded to include base stock coverage to Group III (TC-W3: RL-12345M)

Not Allowed:

- Additive reductions and addition of new components

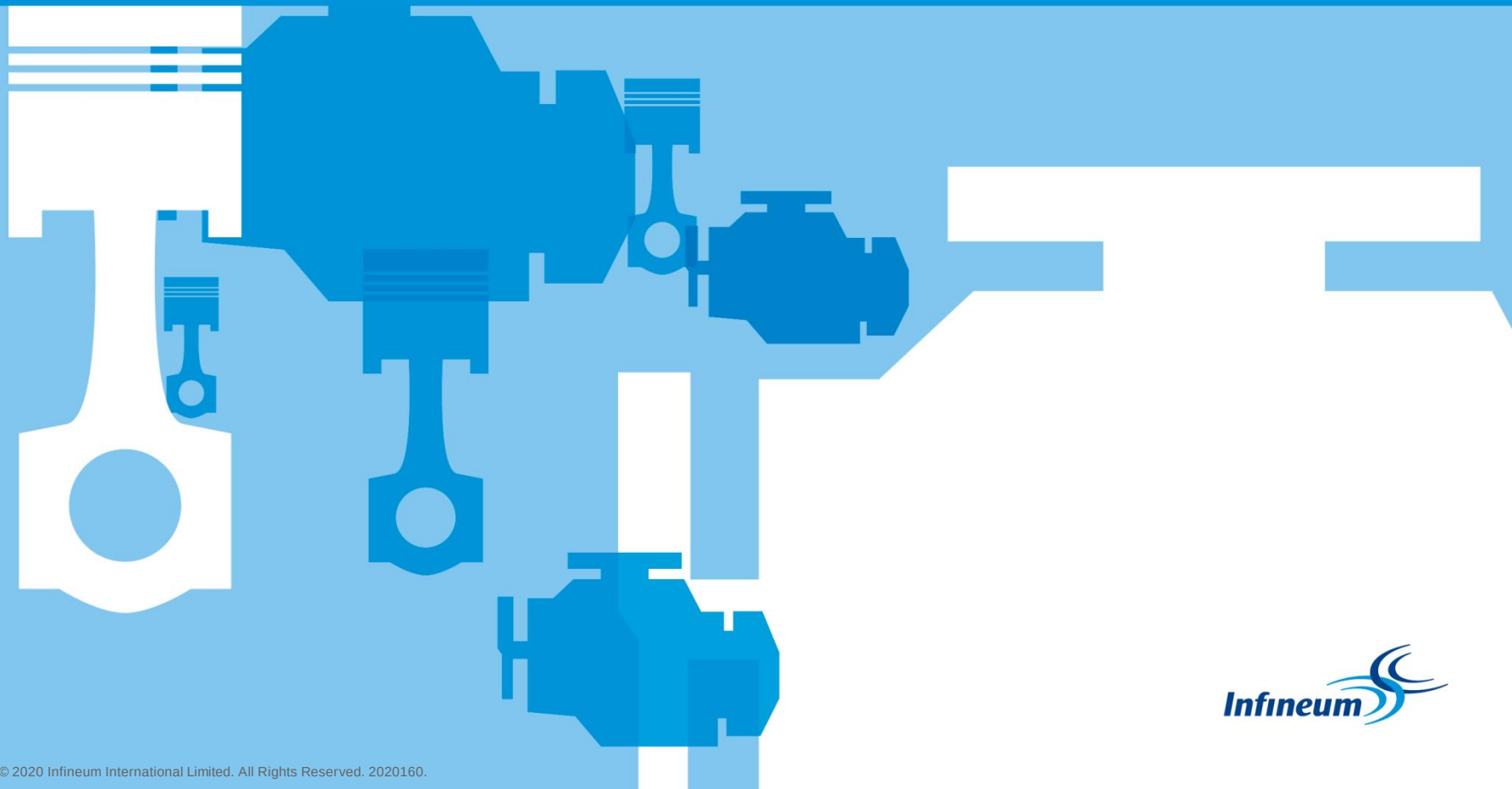
Marketers must obtain a trademark license from the NMMA

License number must appear on the oil bottle

Annual license fee per oil paid to NMMA by the oil marketer

Performance you can rely on.

Four-stroke leisure marine oils



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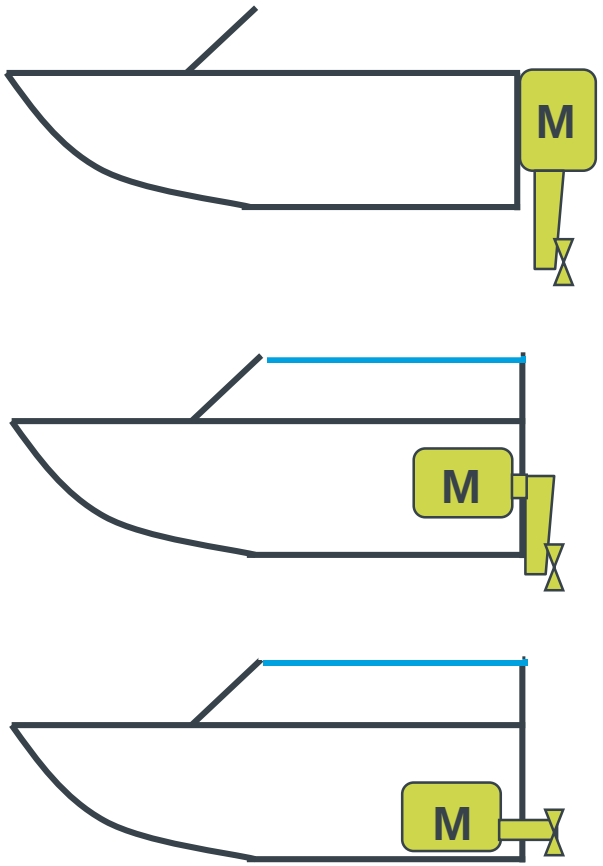
There are three types of four-stroke leisure marine engines

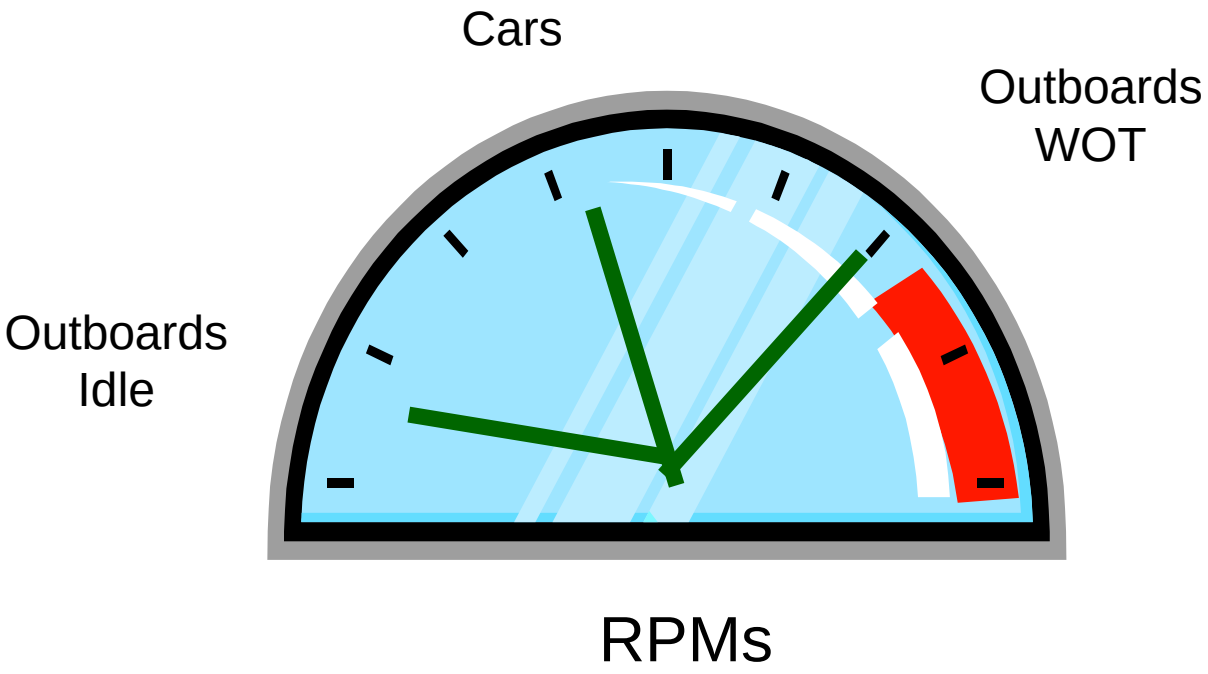


Outboard

Sterndrive = Inboard/Outboards (I/O)

Inboard

Marine engines operate differently from car engines



4T outboards' lubrication challenge

- 4T Outboard Engines operate very differently to PCMO
  - Vertical Engine
    - Requiring exceptional bearing lubrication.
  - Driving regime (Idle to full throttle)
    - High engine speeds, causing wear concerns
    - Idle for long periods of time, causing high fuel dilution and potential for wear.
  - Operating Conditions
    - Corrosive environments
    - Cooler temperatures
    - Often operate longer than recommended between oil changes, requiring improved antioxidancy.
- Challenges to the Lubricant
  - Bearing Durability
  - Wear
  - Rust
  - Shear Stability

NMMA FC-W standard establishes oil requirements

Identification

KV40°C
VI
Specific gravity
TBN
TAN
Elementals (Report all)
Sulfur
Nitrogen
IR Spectrum

Heritage

Minimum SG quality

Viscosity Grade Testing

KV100°C (Vis grade limits)
CCS (Vis grade limits)
MRV-TP1 (Vis grade limits)

Engine Testing

Yamaha 115 hp Gen. Perf.

Performance Bench Testing

Foam, Seq. I - III (Industry limits)
Foam, Seq. IV (200/50 max)
Shear Stability (Report)
HTHS (3.3 cP min after shear)
Mercury Rust Test (< than Ref. Oil)
Noack Volatility (Report)
EOFT (50% max)

Required Testing for Basic Readacross Oil Program.
Expected Test Cost is $2K to 7k.

Required Additional Testing for Complete FC-W Approval.
Expected Test Cost is $45K – $55k.

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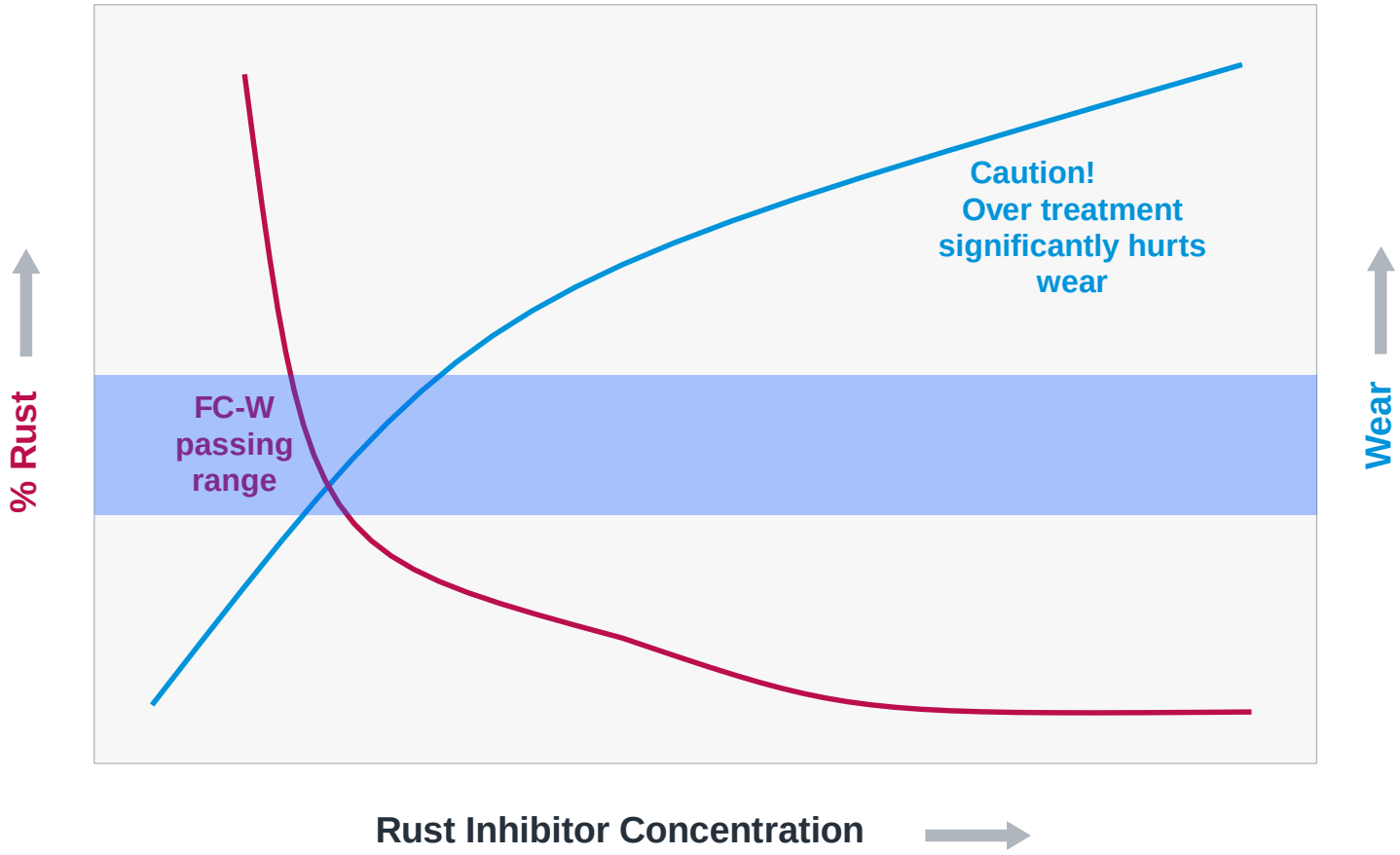
Balance is essential as anti-wear and anti-rust additives both compete for the surface



Excellent performance in the FC-W rust test requires component balance

Typical SJ PCMO
100% Rust

40% 30% 20%

NMMA Reference Oil 5973
Range of Rust Ratings

NMMA FC-W Oil
21% Rust

FC-W catalyst compatible standard was launched in September 2009

- U.S. emissions limits went into effect in 2010
- Sterndrives and inboards required catalyst systems to meet the EPA limits.
- Catalytic converters are integral to many outboard engines meeting mandates of the California Air Resource Board (CARB)
- Engine oils require careful formulation to avoid poisoning the catalyst in these engines
- The NMMA has issued a second standard for four-stroke outboard oils with catalysts to ensure availability of appropriate oils

Intended for:

- All gasoline-powered marine applications, especially those with catalytic converters
- Backwards compatible with engines calling for NMMA FC-W™

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There are differences between FC-W and FC-W catalyst compatible standards

FC-W

- Performance package: SG quality minimum
- No limit on P
- No limit on Si
- No “stay in grade” limits
- No volatility limits

FC-W Catalyst Compatible

- Performance package: SM quality minimum
- P range: 0.06 - 0.08%
- Si limit: < 0.002%
- Stay in grade
- Noack volatility: < 22%

All other current NMMA FC-W requirements and readacross rules remain the same for the catalyst-friendly oil standard.

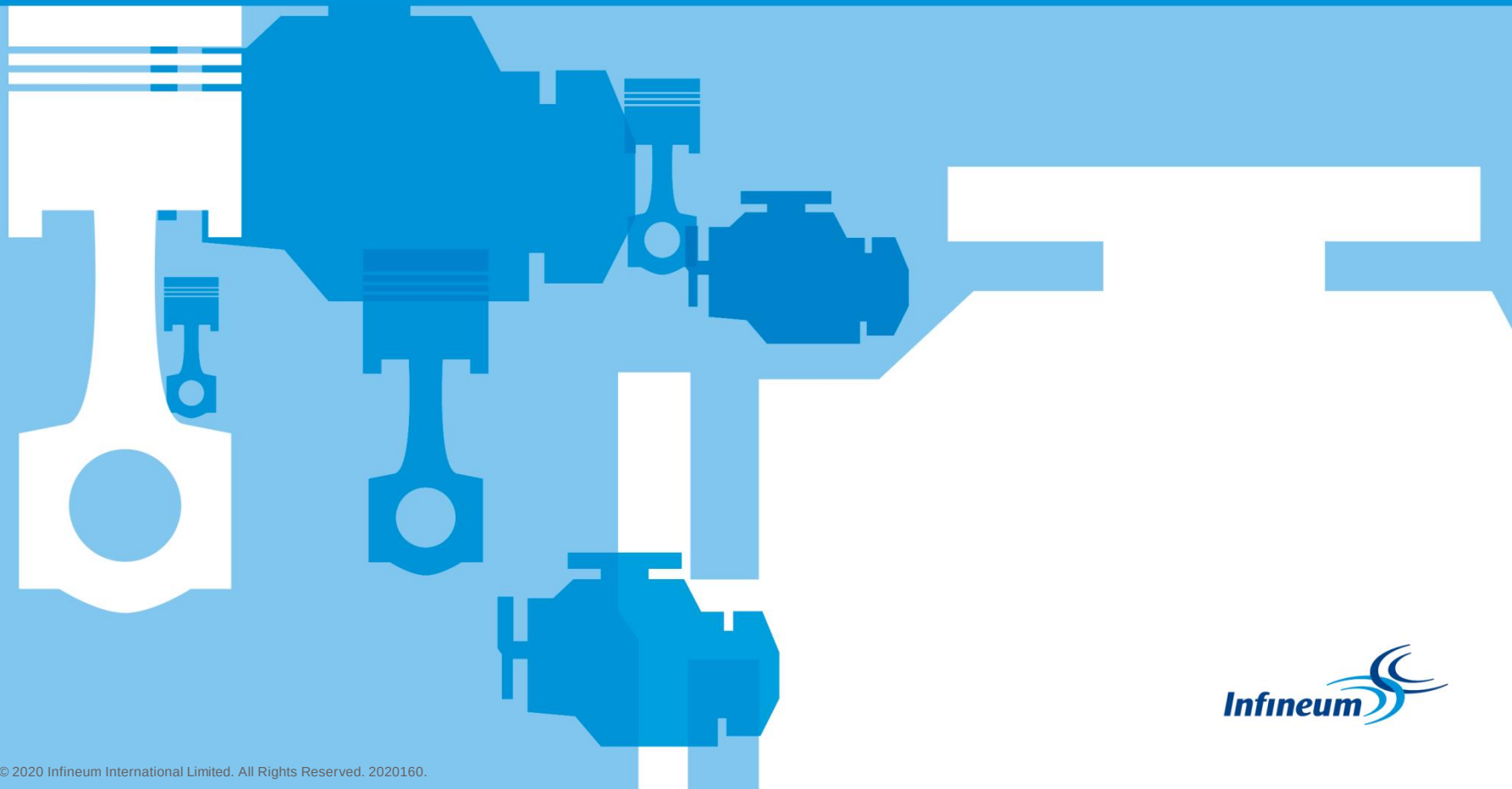
NMMA website is a good place for information

- www.NMMA.org/certification/programs/oils/
  - TC-W3 Certification Procedure Manual
  - TC-W3 Product Approval System (PAS)
  - List of marketer-certified TC-W3 oils

- www.NMMA.org/certification/programs/oils/fc-w.asp
  - FC-W Certification Procedure Manual
  - FC-W Product Approval System (PAS)
  - List of marketer-certified FC-W oils

Performance you can rely on.

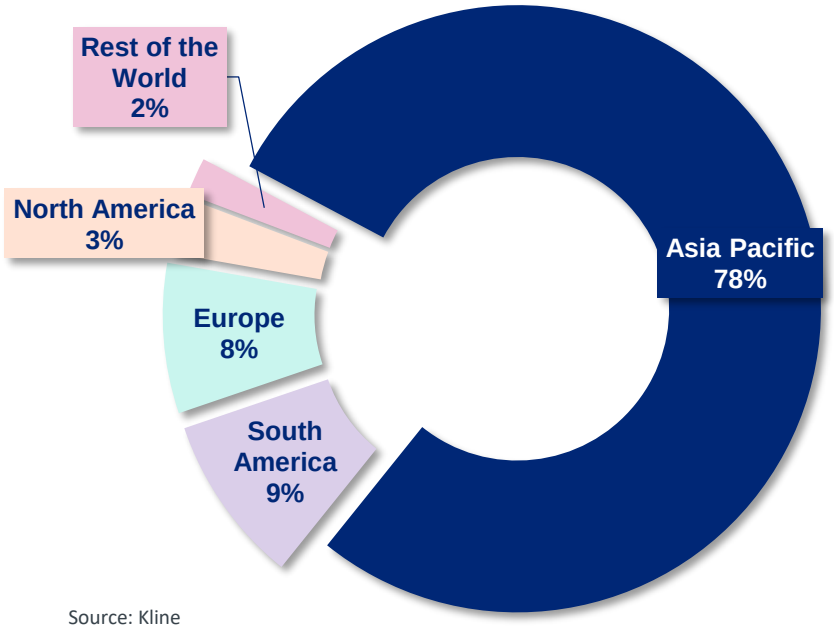
Four-stroke motorcycle oils



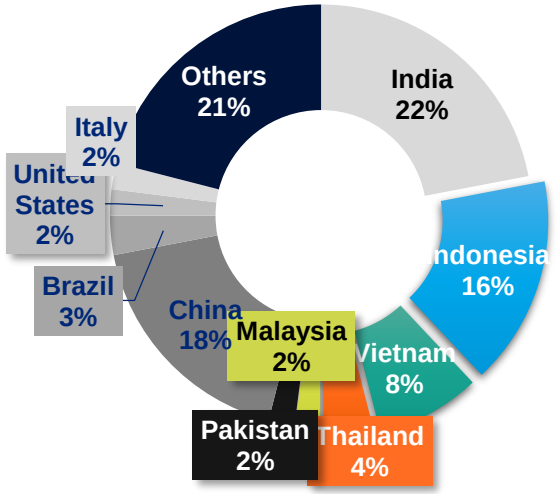
Motorcycle markets

- **AP accounts for vast majority of 2-wheeler population globally.**
  - Amongst the countries with the largest 2-wheelers population, 4 of them are in Southern Asia, ie India, Indonesia, Vietnam & Thailand
  - Demand in Southern Asia driven by rising economic conditions, lack of public transportation, poor road infrastructure, growing demographic of young and/or female riders
  - Electrification of 2 wheelers in this region is anticipated to be slow to take-off

Motorcycle Population by Region



Motorcycle Population for Selected Countries



Data Source: Kline 2017

Source: Kline
Published in: Lubricants for Motorcycles, Scooters, and Mopeds 2015: Global Market Analysis and Opportunities © Kline & Company, 2016

How are motorcycles used?

It depends on where you are in the world.

Transportation

- Generally AP
- Used for transportation and commerce
- Smaller motorcycles
- Large rider population

Recreation

- Generally North America and Europe
- Used for recreation and entertainment
- Larger road bikes and smaller racing bikes
- Smaller rider population

4T motorcycles have different lubrication needs than automobiles

- Motorcycles run under more severe conditions than cars.
  - Many are air cooled
  - run hotter and faster
  - Lower oil volumes for lubrication and cooling
- Motorcycle oils [MCO] must lubricate clutch and gears, along with engine
- Requires a balanced formulation approach
- PCMO requirements continue to diverge from those needed for MCOs
  - Low friction for PCMO fuel economy impacts MCO clutch performance
  - Low phos for PCMO for catalyst compatibility impacts MCO wear protection
  - Low viscosity for PCMO impacts MCO gear protection and oil consumption
- **MCOs must meet JASO T903:2011 or T903:2016 requirements**

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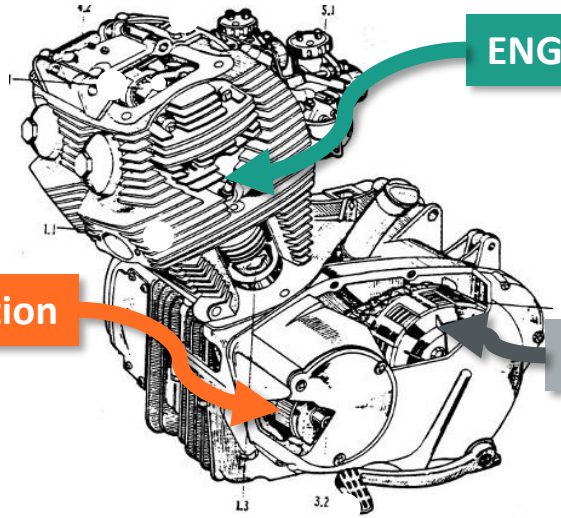
Motorcycle oil properties are defined by three lubrication functions

Engine

- High revving; air-cooled
- Small oil volume with short oil drain interval (ODI)
- SJ / SL / SM / SN quality



Gears

- High oil viscosity reduces wear
- Shear stable viscosity modifier maintains viscosity
- Gear pitting is a concern with low viscosity oils

Clutch

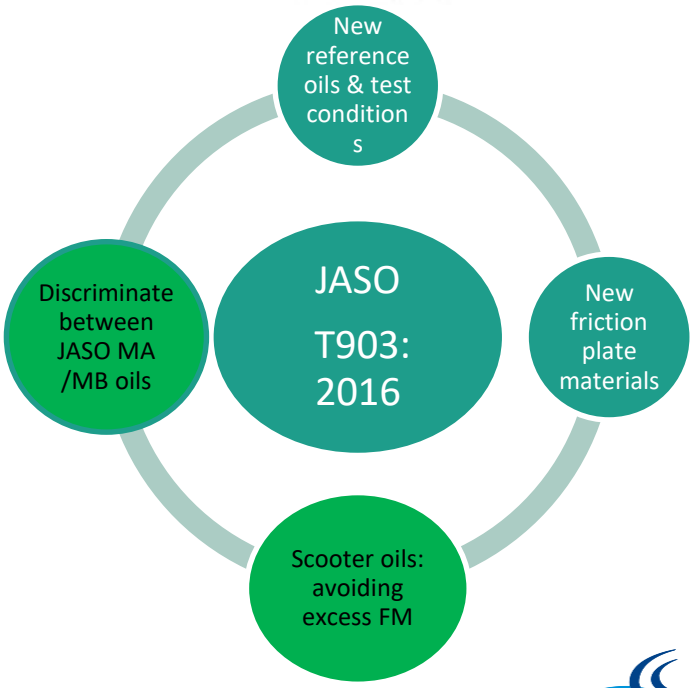
- High oil friction for fast clutch engagement
- Minimize Friction Modifiers used in PCMO

JASO T903 4T Motorcycle standard

- JASO Has Been Registering 4T Motorcycle Oils Since 1999 to address OEM concern about PCMO inadequacies
- A registration logo is available for registered oils
  - JASO MA friction quality for Motorcycle Oils
  - JASO MB friction quality for Scooters

- JASO T903:2016 is the current specification
  Minor revision was made Dec 2018

- Major revision in ~2023 may include:
  - Tighter Phosphorus chemical limit
    - Onboard diagnostic (OBD) Stage II
  - Reduction in NOACK limit
  - JASO SP and SN plus category
  - Gear pitting test



JASO T903 specification for four- stroke motorcycles has evolved

Updated Engine Requirements

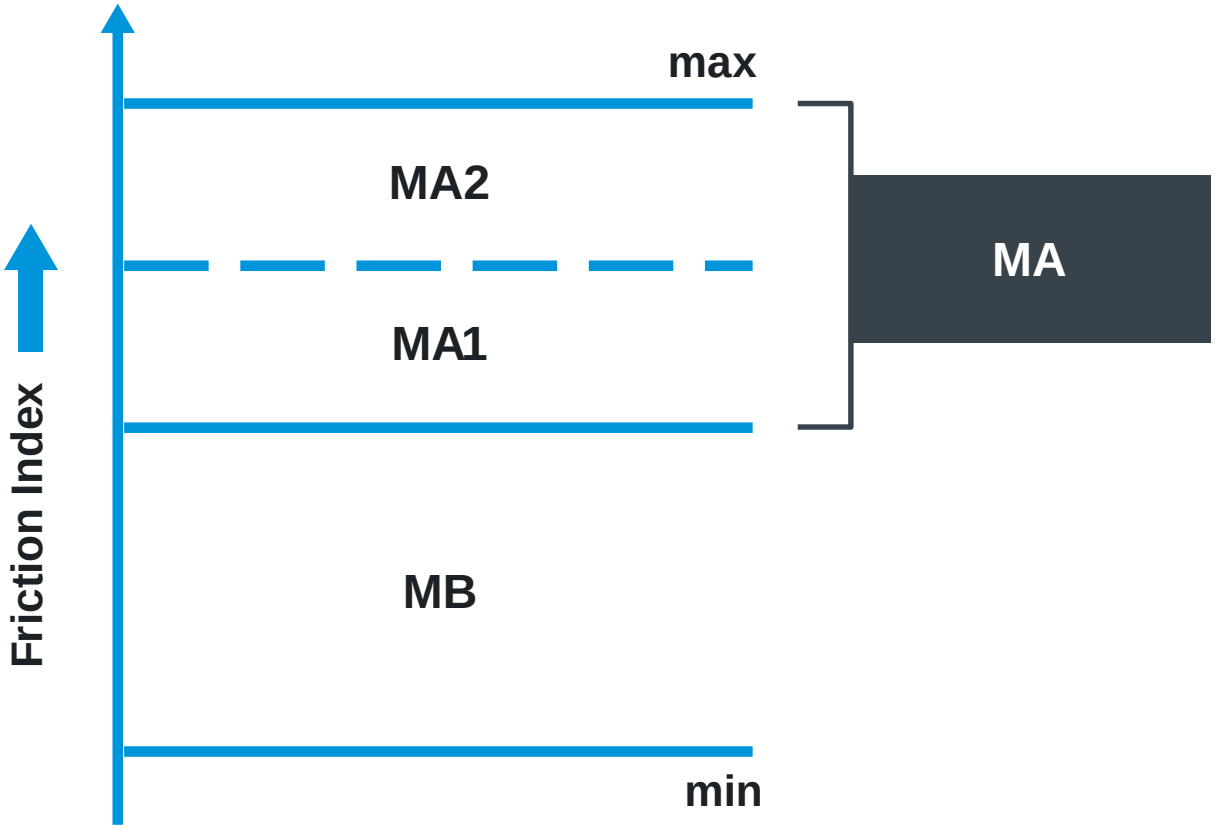
	1999 Original	2006 Revision	2011 Revision 2016 Revision
API	SE to SJ	SG to SM	SG to SN
ILSAC	GF-1, GF-2	GF-1, GF-2, GF-3	GF-1, GF-2, GF-3
ACEA	A1 to A3	A/B, C2, C3	A1/B1, A3/B3, A3/B4, A5/B5 C2, C3, C4
CCMC	G-4/G-5	Eliminated	--

Phosphorus Limits

JASO specified phosphorus range conflicts with later ILSAC limits

	1999 Original	2006 Revision	2011 Revision **2016 Revision**
Phosphorus	No Limits	0.08 – 0.12	0.08 – 0.12

JASO classifies friction using the SAE#2 test rig



JASO T903 four stroke motorcycle specification

Friction performance (2016)

Index/Classification	MA2	MA1	MA	MB
Dynamic friction index	$1.50 \leq x < 2.50$	$1.35 \leq x < 1.50$	$1.35 \leq x < 2.50$	$0.40 \leq x < 1.35$
Static friction index	$1.60 \leq x < 2.50$	$1.45 \leq x < 1.60$	$1.45 \leq x < 2.50$	$0.40 \leq x < 1.45$
Stop time index	$1.60 \leq x < 2.50$	$1.40 \leq x < 1.60$	$1.40 \leq x < 2.50$	$0.40 \leq x < 1.40$

Scooters

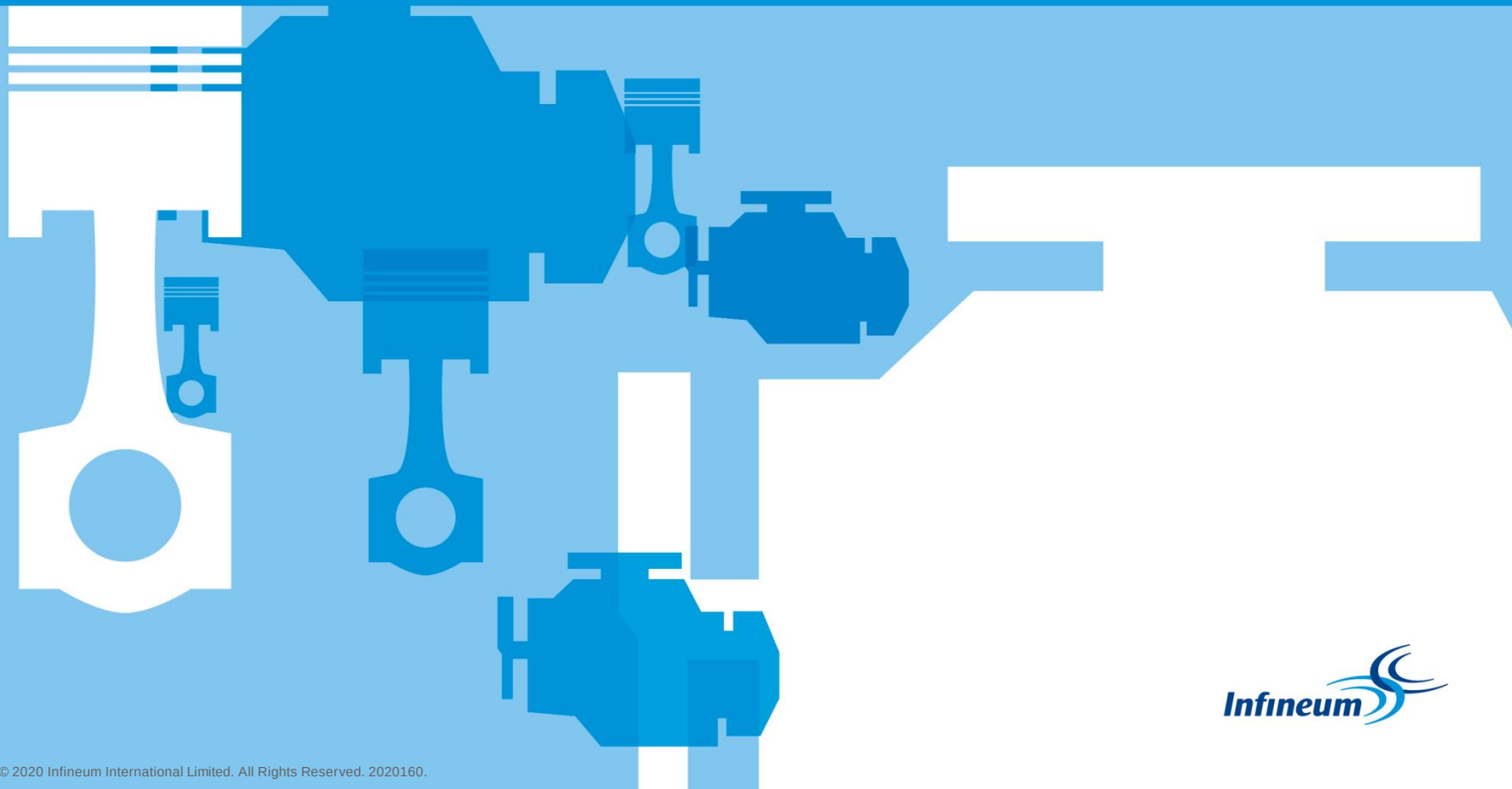
- All three indices must be MA2 to claim MA2.
- All three indices must be MA1 to claim MA1
- If the indices are from both MA1 and MA2, MA must be claimed
- MB must be claimed if at least one index is in the MB range

JASO website is a good place for information

- http://www.jalos.or.jp/onfile/jaso.htm
  - JASO T903:2011 Application Manual
  - JASO T903:2016 Application Manual
  - List of filed oils

Performance you can rely on.

Two-stroke low ash oils (air cooled or land equipment oils)



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API TC is the only API specification for 2T oil air-cooled applications

American Petroleum Institute Two-stroke Standards

Category	Application examples	Test procedures	Critical lubrication requirements
TA	Mopeds Lawn mowers Small generators/pumps	OBSOLETE	
TB	Motorscooters Small (<250cc) motorcycles Higher oil/fuel ratio chainsaws	OBSOLETE	
TC	Lean oil/fuel Ratio chainsaws Hi-performance motorcycles Snowmobiles	**Yamaha Y350M-2** Piston deposits Ring sticking **Yamaha CE50S** Tightening Preignition	Piston scuffing Deposit-induced preignition Ring sticking
TD	Outboard motors	OBSOLETE	

API TC evaluates a two-stroke oil's performance in **ring sticking**, **lubricity**, and **preignition**, all in small air-cooled two-stroke engine tests.

All other API categories are obsolete.

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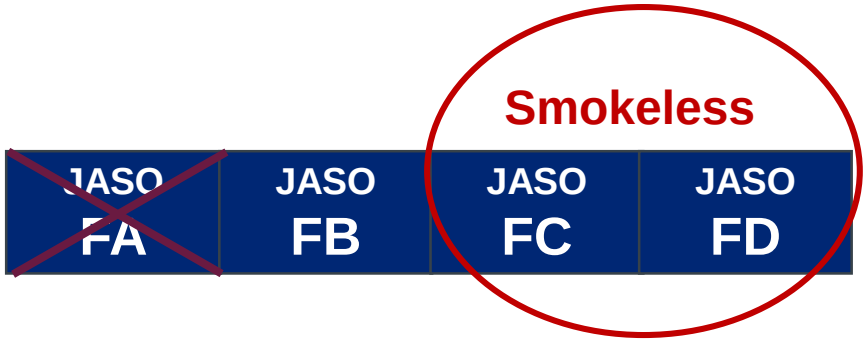
API TC does not have a certifying body

- No process exists for certifying or registering oils that have passed the API TC requirements.
- Marketers may claim API TC performance without having actually tested their oil.
    - But there must be sufficient data and/or logic for making an API TC claim.
- TC-W3 oils formulated with Infineum technologies meet API TC quality.
- API TC program cost: >$44k

Japanese OEMs created a 2T standard because they felt that API TC was inadequate

- **Detergency**
- **Lubricity**
- **Smoke**
- **Exhaust Blocking**



Increasing Quality

JASO M345 2T standard revision driven by test engine availability

Standard	Lubricant Performance Requirement	Current engine	Planned New engine
JASO M340	Lubricity test	HONDA AF27 (49cc)	Husqvana-ZENOAH (65.6cc)
JASO M341	Detergency test	HONDA AF27 (49cc)	Husqvana-ZENOAH (65.6cc)
JASO M342	Smoke test	SUZUKI SX800 (69cc)	YAMAHA (63cc)
JASO M343	Exhaust system blocking test	SUZUKI SX800 (69cc)	YAMAHA (63cc)

JASO has been registering 2T oils since 1994

- Marketer must register the oil with JASO in order to use the JASO logo.
- Logo and registration number must appear on the bottle for registered oils.
- One-time registration fee of 40,000 Yen ($400) per oil must be paid to JASO by the oil marketer.
- JASO quality claims can be made without JASO registration
- **New JASO M345:2018 standard currently being translated to English**
- **Old approvals remain valid and do not need to be re-approved**

JASO M345:2018 FAU 2H 2019

Small engine summary

- Small engine 2T & 4T oils require dedicated and balanced formulations
- 2T for outboards (water-cooled) require ashless technology
  - Quality set by NMMA TC-W3 standard
- 4T for outboard applications require rust prevention technology
  - Marine quality set by NMMA FC-W and FC-W Catalyst Compatible standard
- 4T Motorcycle applications require suitable friction and wear performance
  - JASO T903 MA and MB standards for motorcycles and scooters
- 2T for land equipment (air-cooled) require low-ash technology
  - Quality set by JASO M345 and API TC

Small engines – special applications requiring special lubricants

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