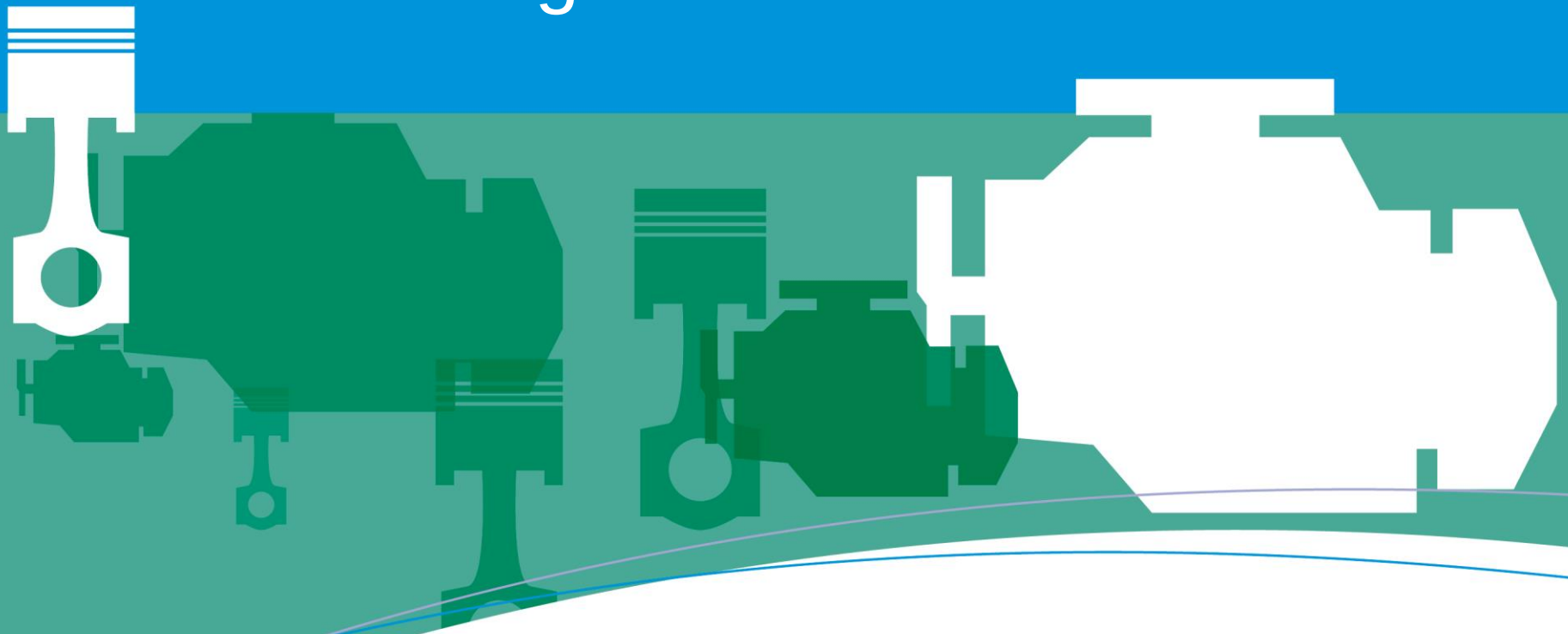
Performance you can rely on.

Small Engine Lubricants



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The small engine market

Motorcycles, scooters, mopeds

Outboards

Personal water craft

Chainsaws & garden equipment

Snowmobiles

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Topics

- Introduction to small engines and how to formulate both four stroke and two stroke oils
- Two stroke land equipment
- Two stroke outboards
- Four stroke outboards
- Four stroke motorcycles

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

These descriptions are used interchangeably for small engines

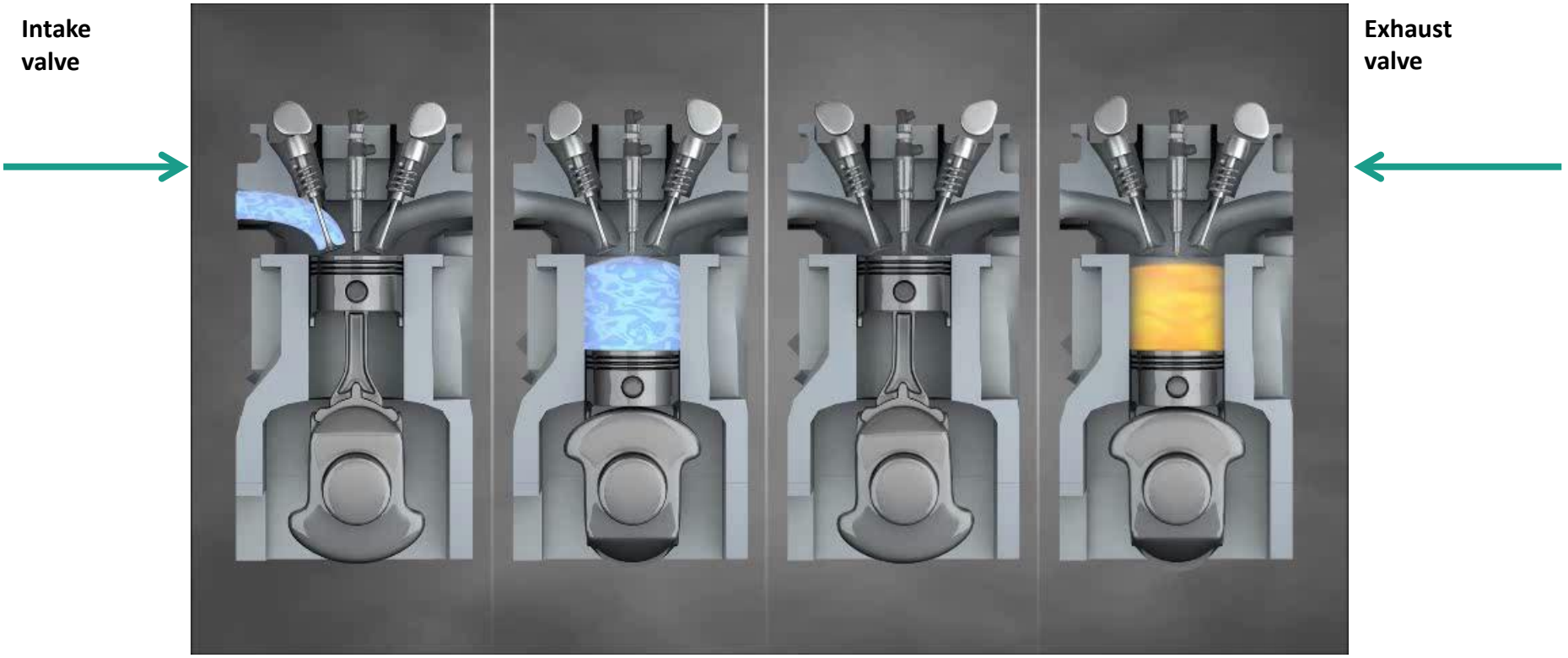
Four stroke cycle
Four stroke
Four cycle
4T

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)

Traditional four stroke engine



- 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

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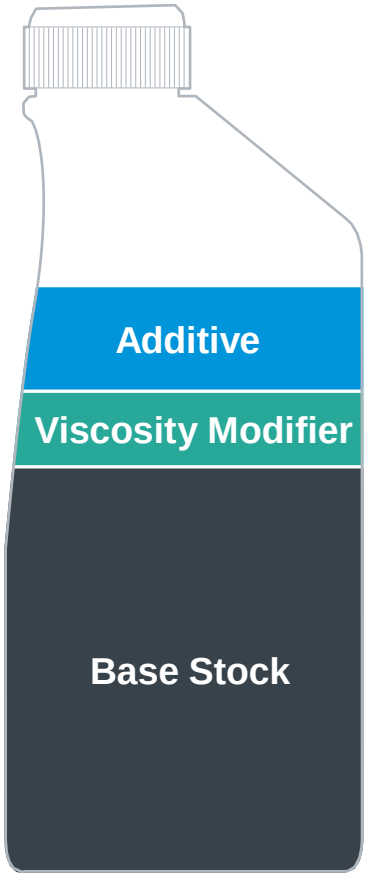
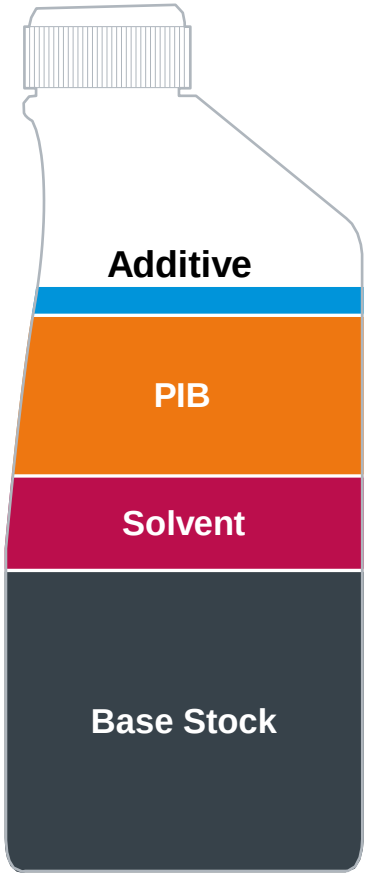
Two stroke and four stroke oils are different

Four stroke



Both type and amount of additive are different

Two stroke



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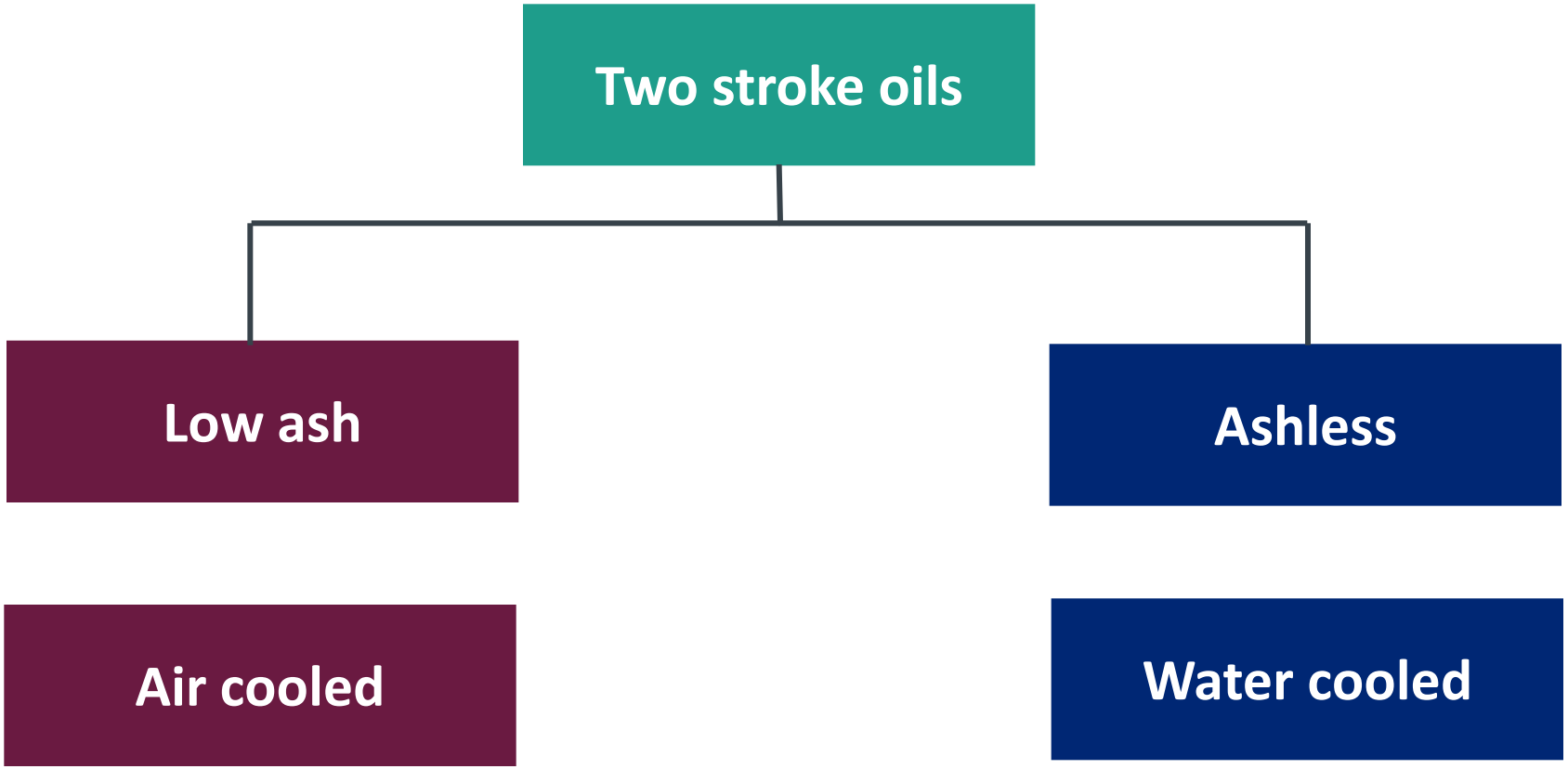
Two stroke applications

- Two stroke engines are small gasoline engines found in the following equipment:
  - Outboard engines — Water cooled
  - Personal water craft — Water cooled
  - Snowmobiles — Liquid / Air cooled
  - Micro-light aircraft — Liquid / Air cooled
  - Motorcycles / scooters / mopeds — Liquid / Air cooled
  - Lawn and garden equipment — Air cooled
  - Miscellaneous small engines — Air cooled

Two ways to formulate two stroke oils



Low ash formulations

- Low ash additives 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
- Mineral oil or synthetic ester base stocks can be used – not PAO
- Solvent is used to improve miscibility of the oil with the fuel
- Solvent also improves the finished oil fluidity and pour point
  - 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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Ashless formulations

- 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
- PolyIsoButylene is used for improved lubricity and exhaust smoke performance
- Solvent provides low temperature fluidity
  - Important for oil-injected systems

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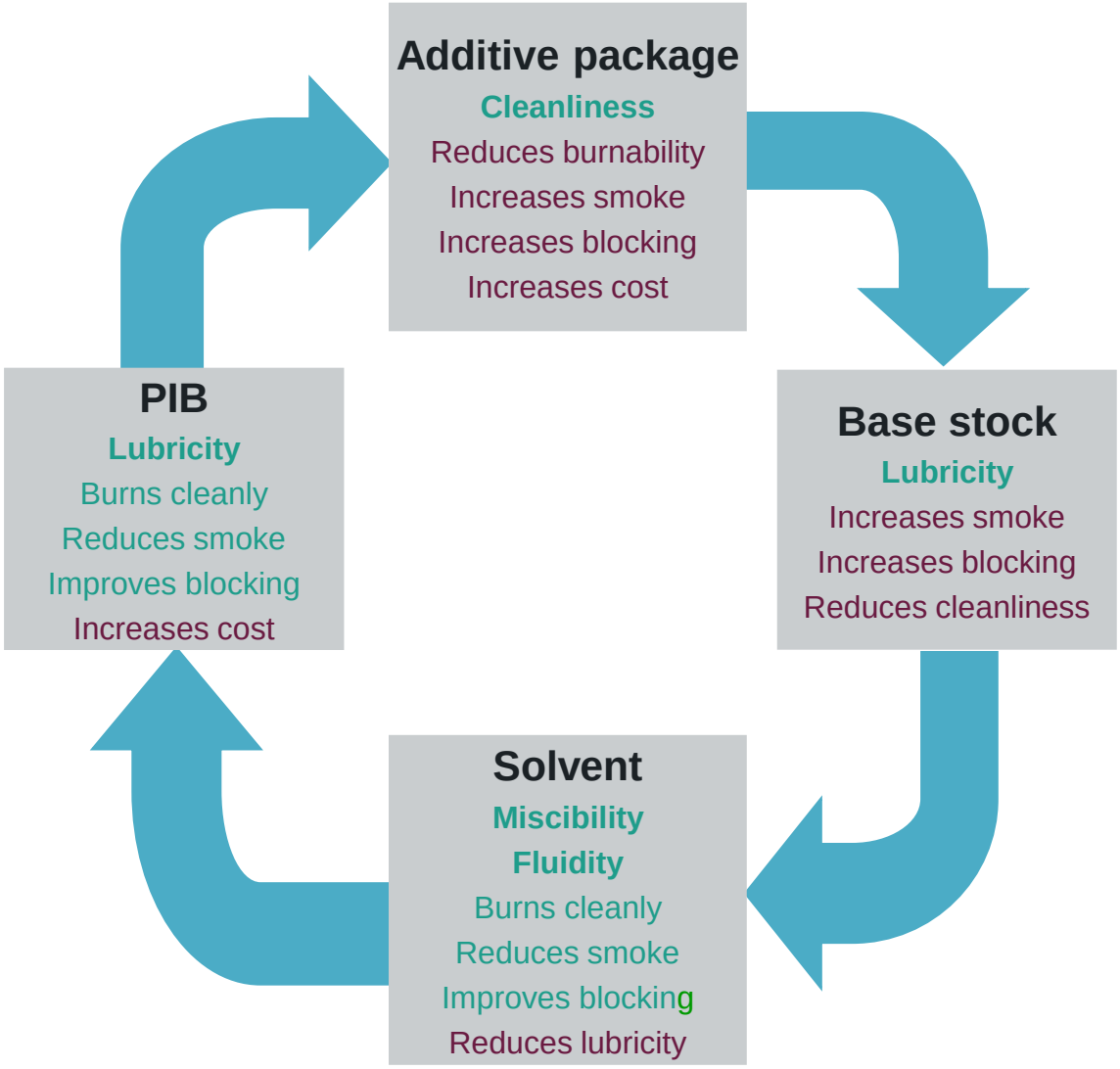
Burnability is key for two stroke oils



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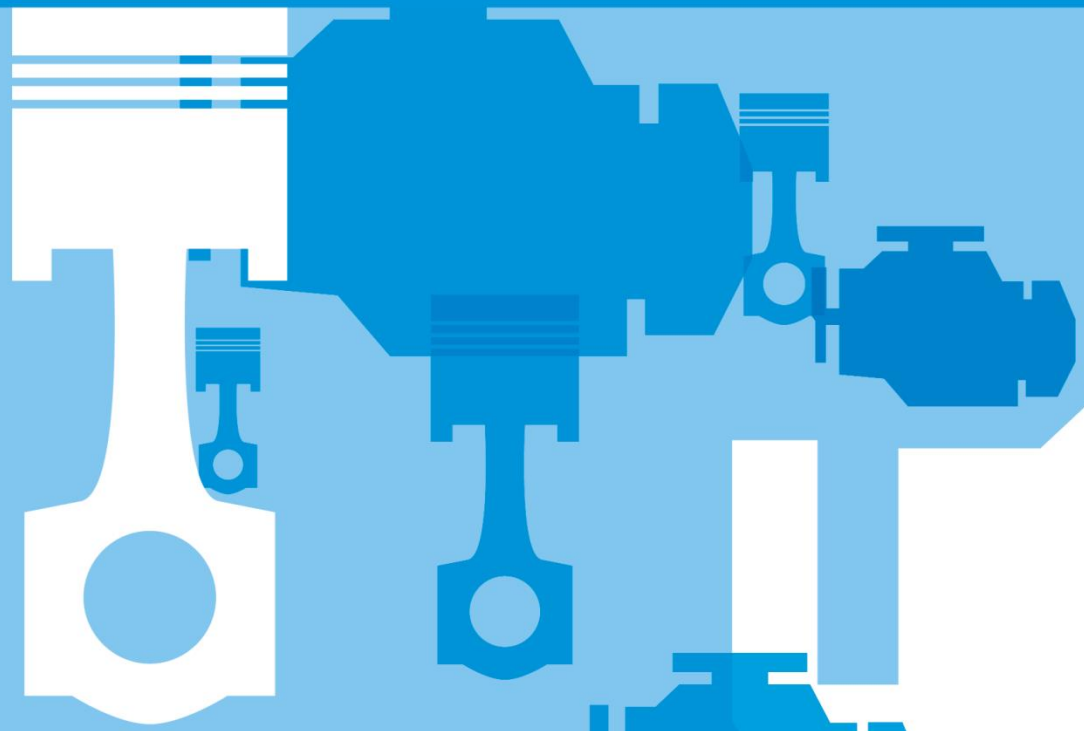
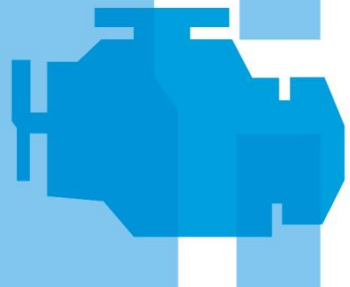
Two stroke land equipment





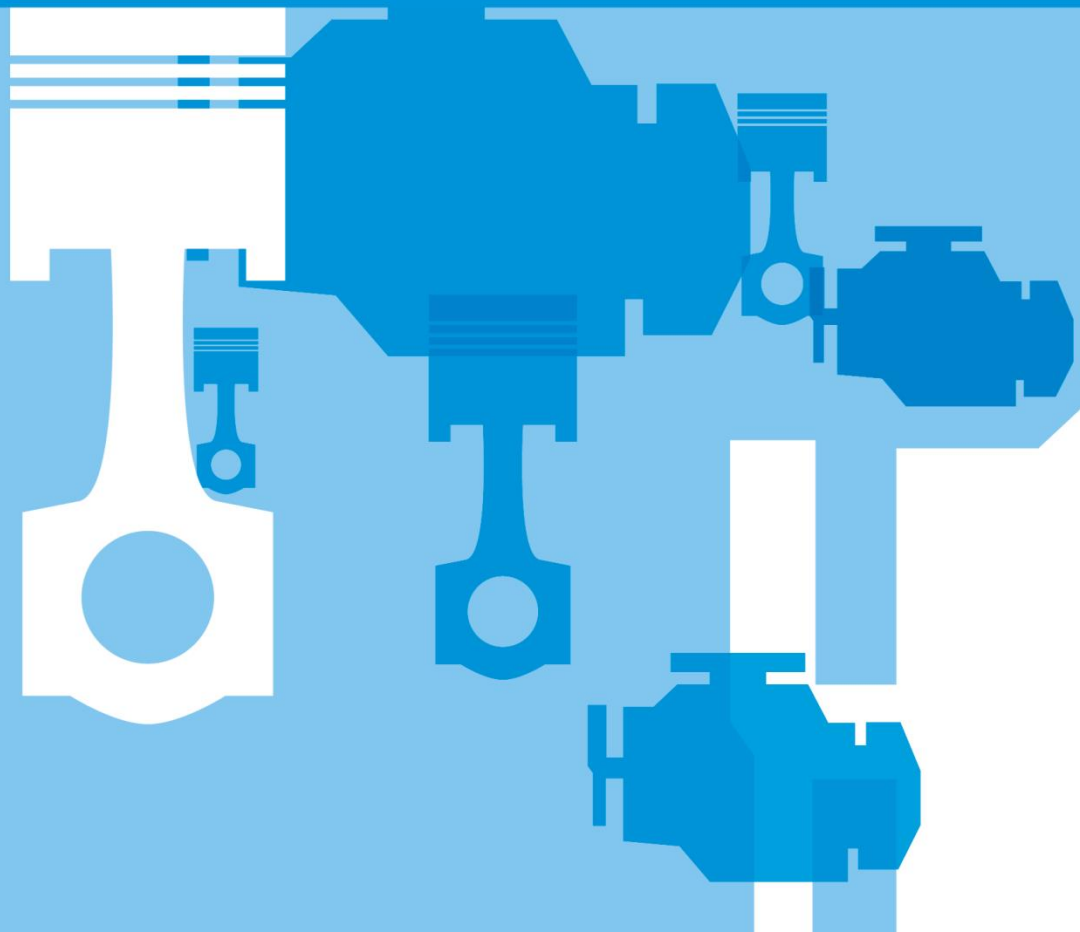
Two stroke engine – land equipment applications

- Scooters / mopeds / motorcycles
- Small quad bikes
- Lawn and garden equipment – strimmers, blowers, etc.
- Chainsaws
- Micro-light aircraft
- Any application requiring high power output and light weight

Who are the two stroke land OEMs?

- Yamaha, Suzuki, Kawasaki, Honda
- Piaggio (Vespa)
- KTM
- Husqvarna
- Echo
- Stihl
- Rotax
- Many others

Two stroke standards
American Petroleum Institute (API)



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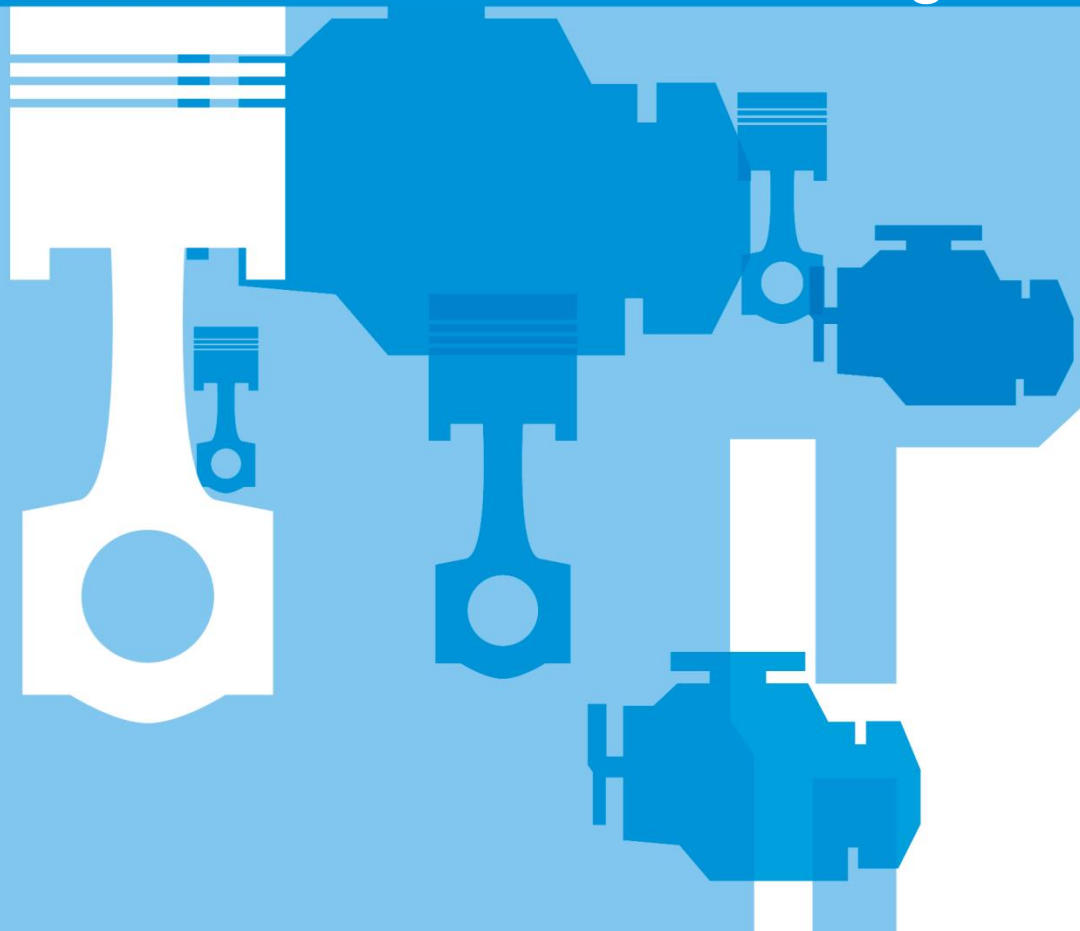
API TC is the only API specification for 2T oil air-cooled applications

API TC is the only current API two stroke standard

Designation	Critical lubrication requirements	Application examples	Test procedures	Status
TA	Piston scuffing Exhaust system blocking	Mopeds Lawn mowers Small generators/pumps	**Yamaha CE50S** Exhaust blocking Tightening	**Obsolete**
TB	Piston scuffing Deposit-induced pre-ignition Power loss due to combustion chamber deposits	Motorscooters Small (<250cc) motorcycles Some chainsaws	**Vespa Y350M-2** Tightening Power loss Pre-ignition	**Obsolete**
TC	Piston scuffing Deposit-induced preignition Ring sticking	Lean oil/fuel ratio chainsaws Hi-performance motorcycles Snowmobiles	**Yamaha Y350M-2** Piston deposits Ring sticking **Yamaha CE50S** Tightening Pre-ignition	**Available**
TD	Piston scuffing Ring sticking Deposit-induced pre-ignition	Outboard motors	NMMA TC-W S-18-82 OMC 90TLCOS Piston scuffing Engine deposits Ring sticking Pre-ignition Rust Miscibility	**Obsolete**

Two stroke standards: Japan Automobile Standards Organisation (JASO), International Standards Organisation (ISO)



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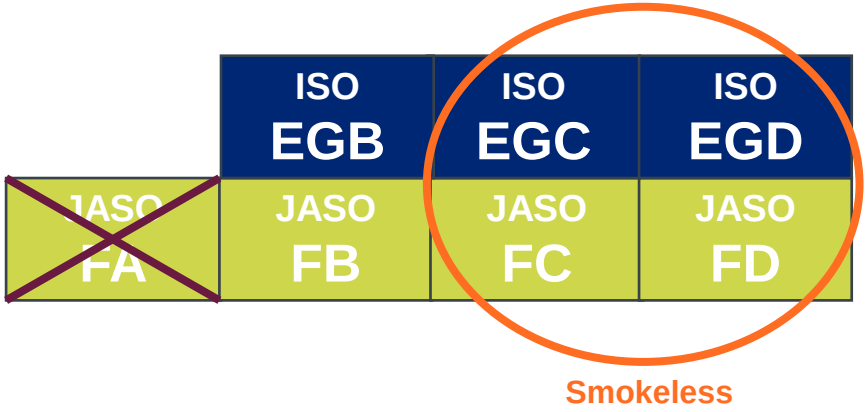
JASO created a two stroke standard, ISO followed suit globally

Detergency
JASO M 341-92

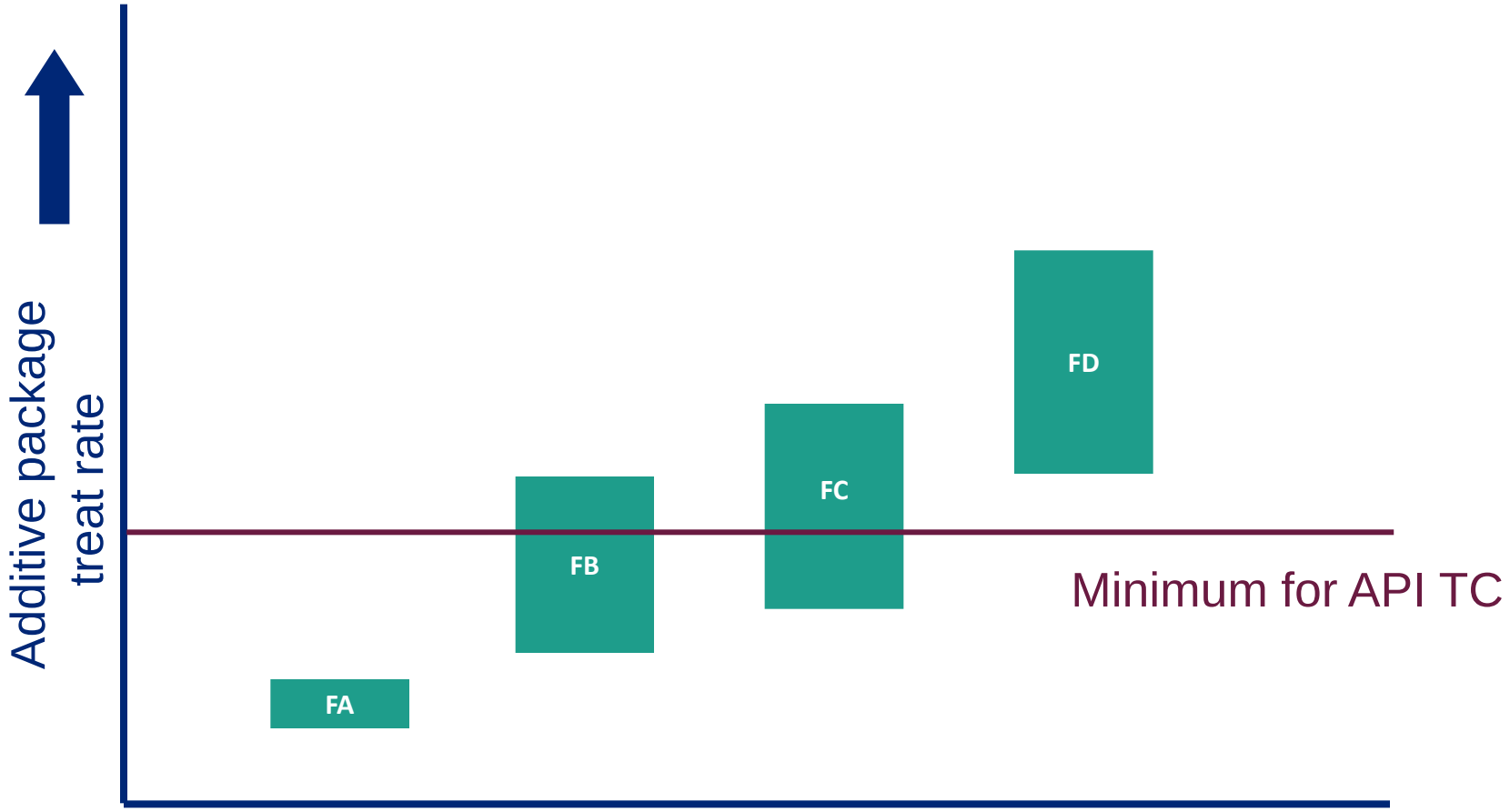
Lubricity
JASO M 340-92

Smoke
JASO M 342-92

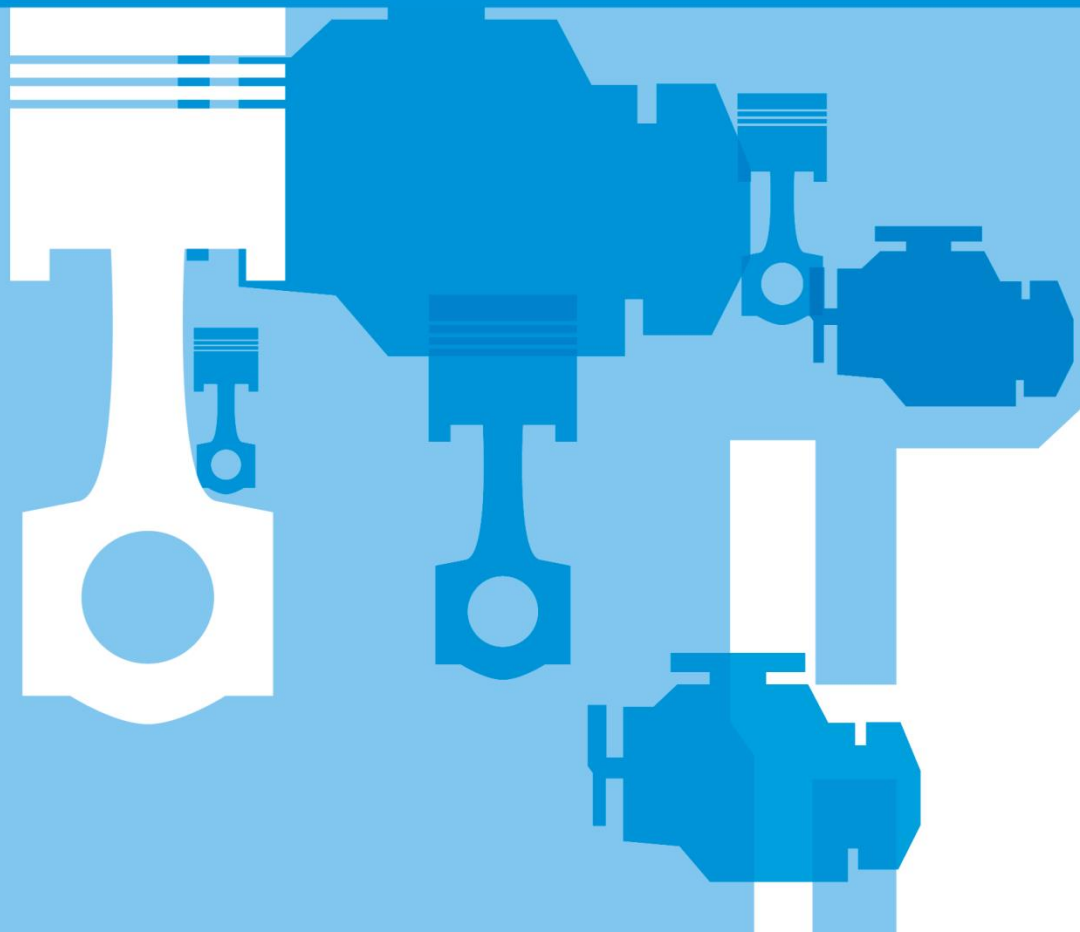
Exhaust Blocking
JASO M 343-92



API TC performance requires more than minimum treat rates



Two stroke outboard



Who are the two stroke outboard OEMs?

- Mercury Marine
- Yamaha
- Suzuki
- Tohatsu
- Bombardier Recreational Products - BRP
- Polaris
- Kawasaki

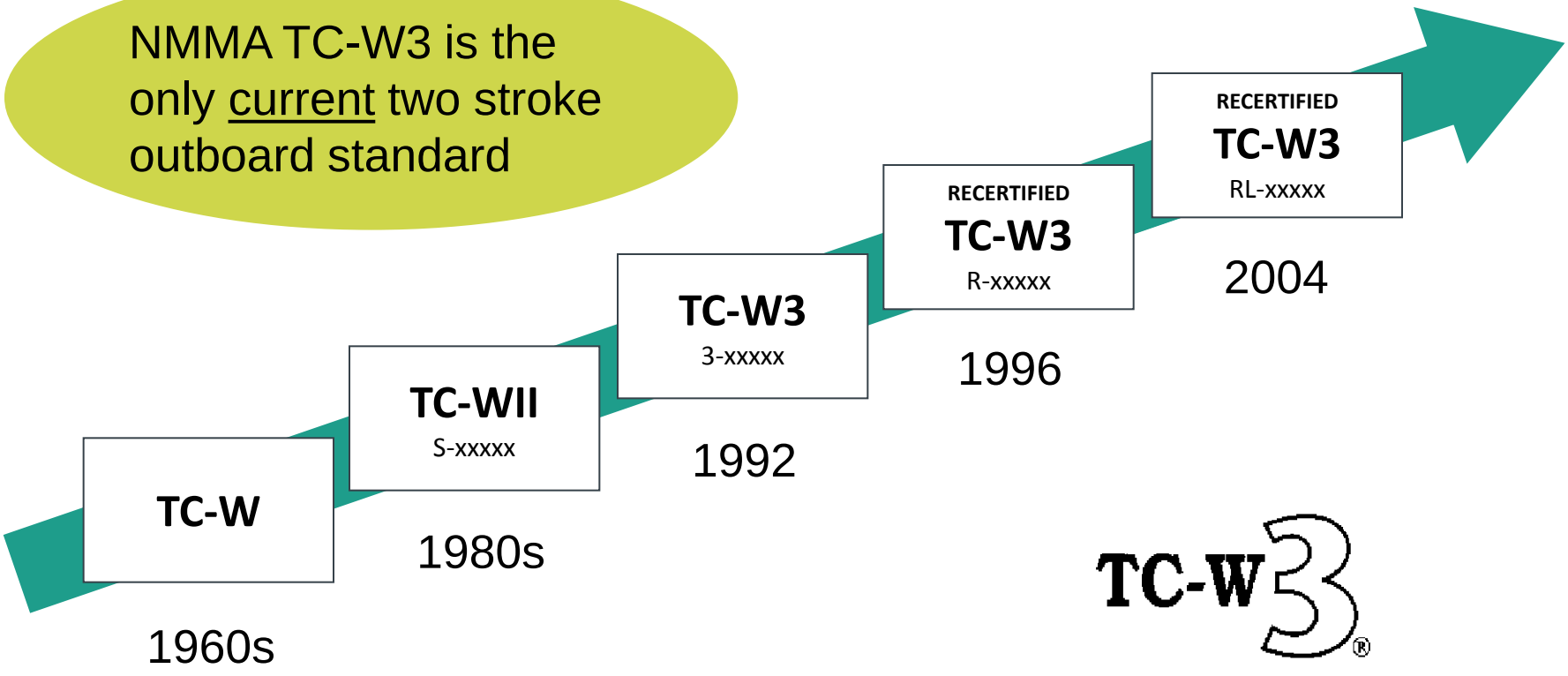
NMMA sets specifications for outboard oils

National Marine Manufacturers Association – NMMA

- OEMs
- Additive suppliers
- Oil companies
- Engine testing laboratories

NMMA two stroke outboard standards

NMMA TC-W3 is the only current two stroke outboard standard



TC-W3®

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TC-W3 demonstration programme is comprehensive and expensive

Analytical Testing
Kinematic Viscosity @ 40˚C
Total Acid Number
Cloud Point
Nitrogen
Fourier Transform Infra Red Scan

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

Engine Testing
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)

> $270k

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TC-W3 read across programmes cut testing costs

Analytical Testing
Kinematic Viscosity @ 40°C
Total Acid Number
Cloud Point
Nitrogen
Fourier Transform Infra Red Scan

Bench Testing
Fluidity @ -25°C
Miscibility @ -25°C

Engine Testing
Lubricity (Yamaha 50 cc)
AF-27 Lubricity (Honda Dio)
Detergency/Scuffing (Mercury 15 HP) x 2

Up to $50k

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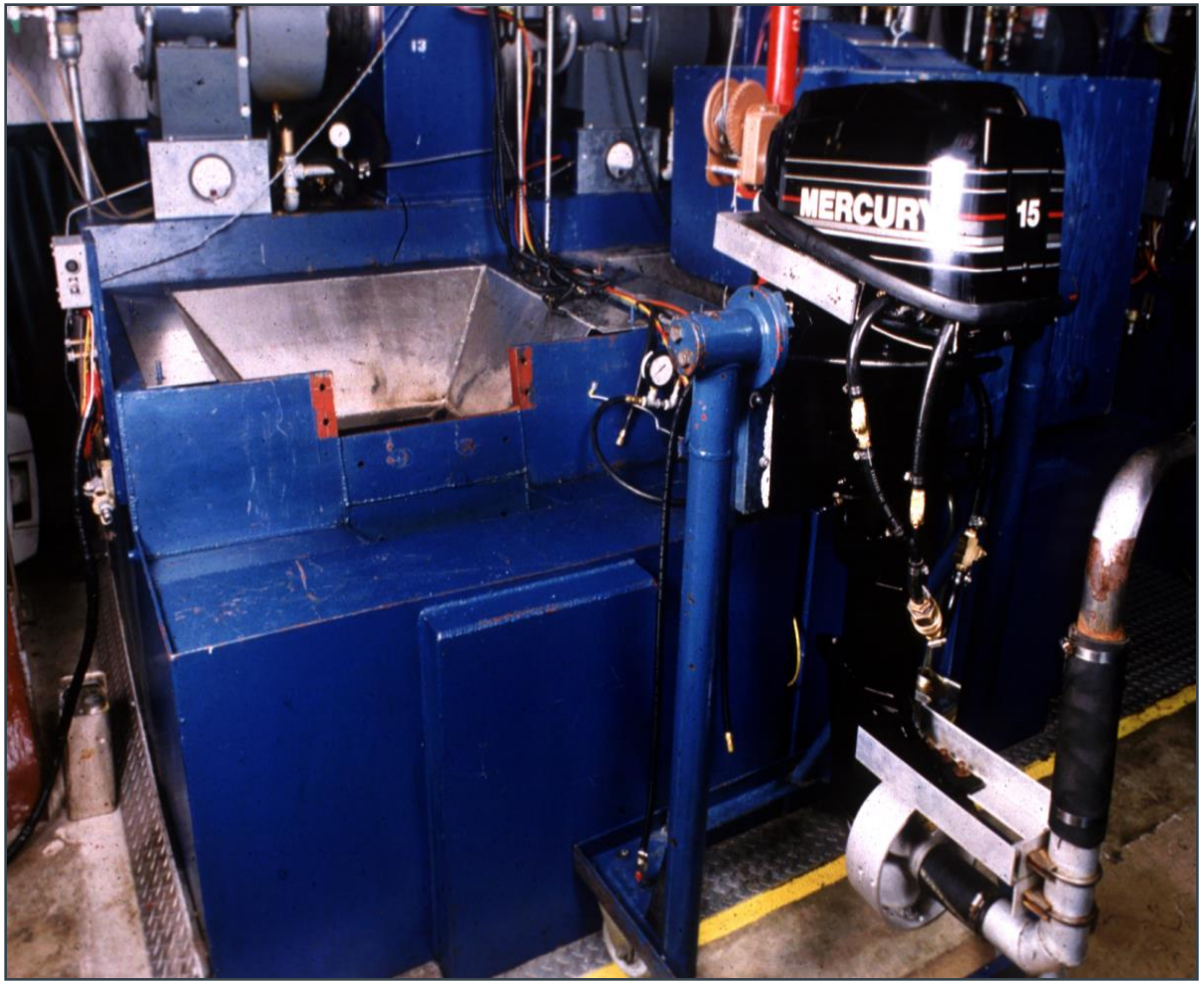
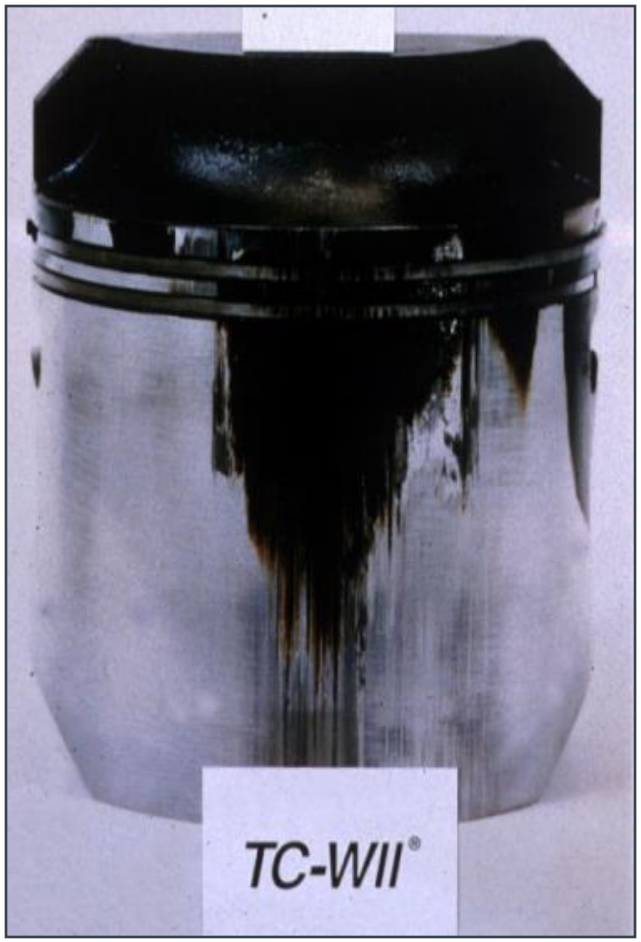
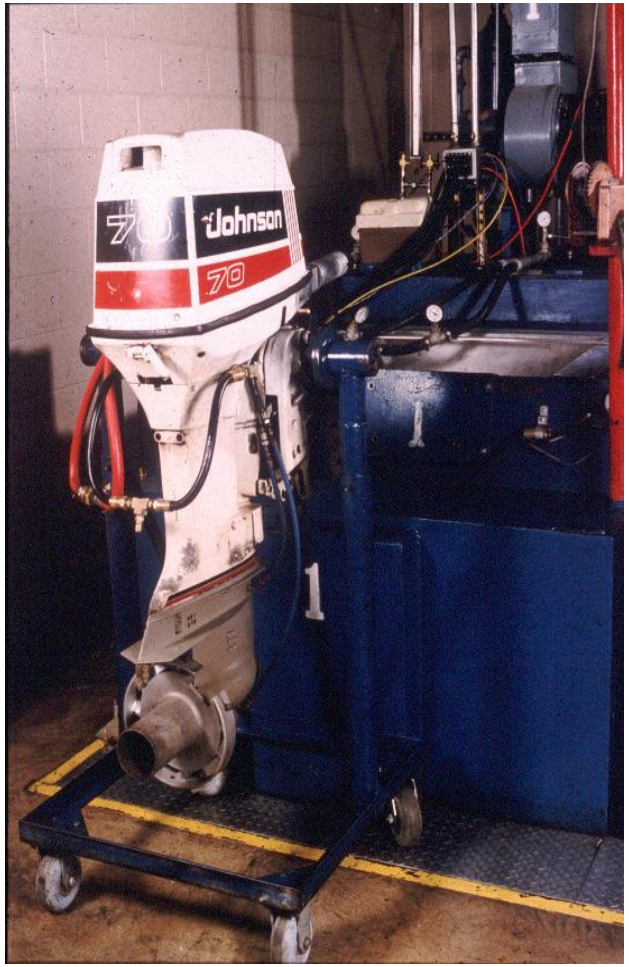
Mercury 15 HP test



TC-W3 oils excel in Mercury 15 HP test



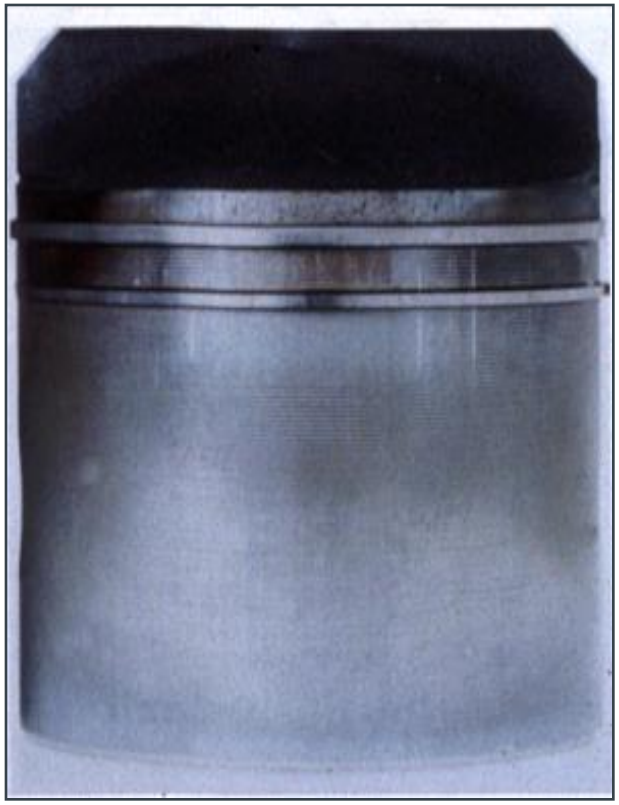
70 HP engine test



Excellent performance with TC-W3 oils in OMC 70 HP test

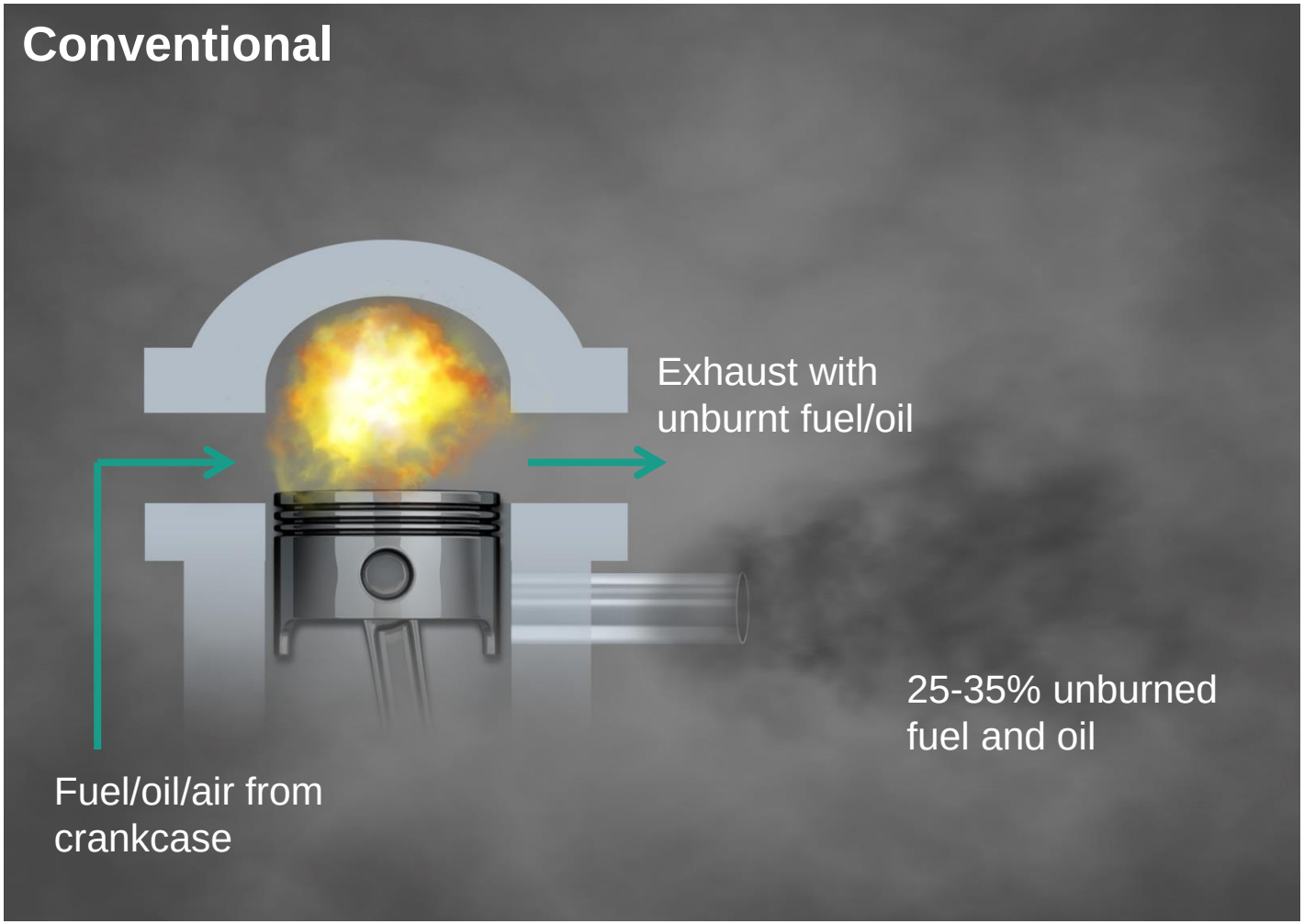
TC-W3 oil shows improved lubricity and detergency in field testing

TC-WII



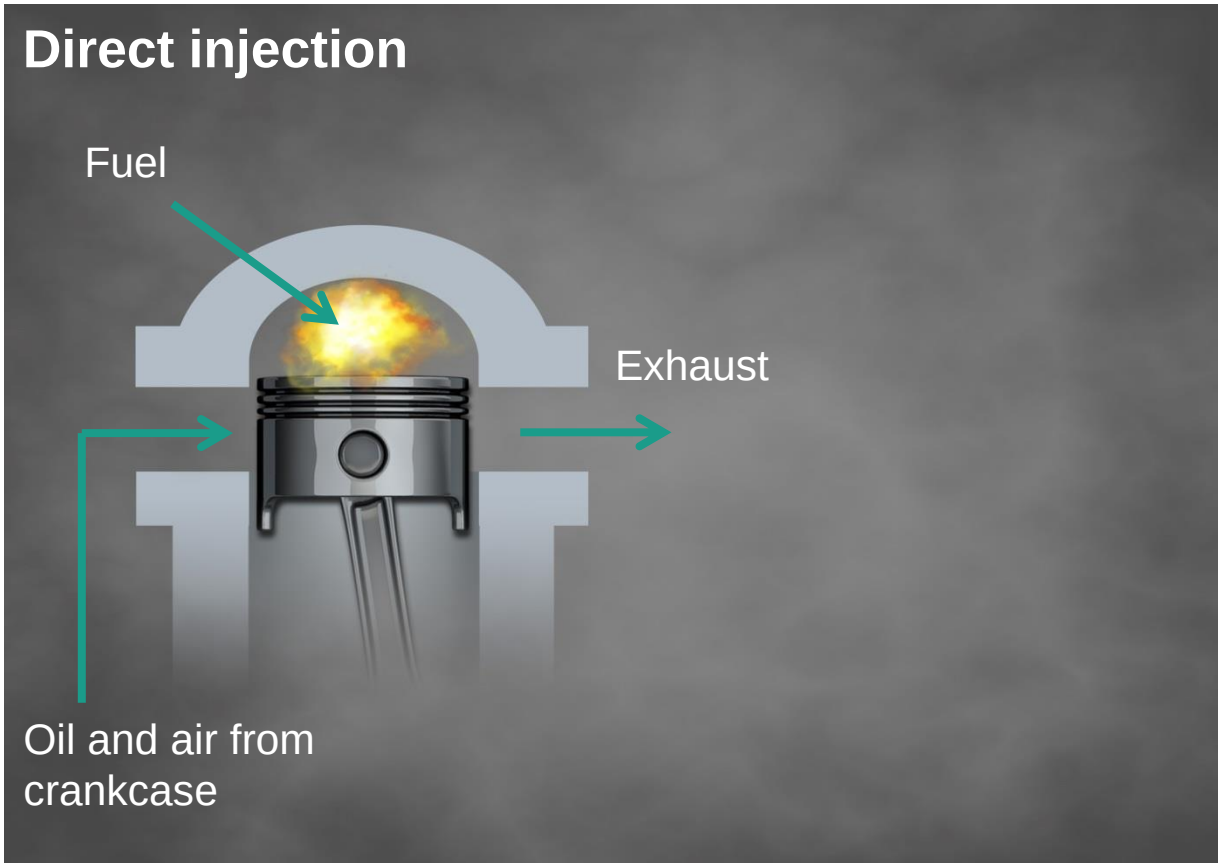
TC-W3

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



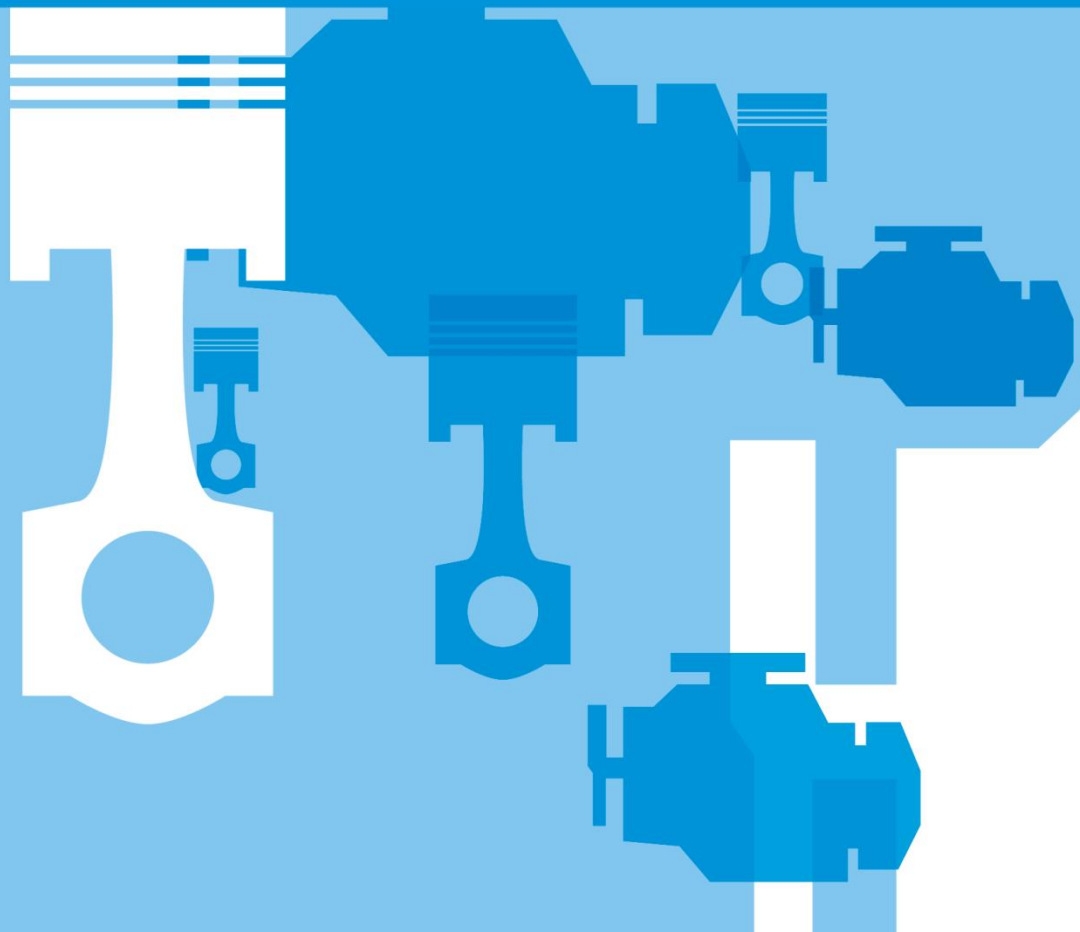
2T direct fuel injection (DFI) is a way to address emissions

Fuel is injected when piston is top dead centre



Notice: Exhaust port is blocked, therefore reduced emissions

Four stroke outboards



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The majority of marine applications are four stroke

- Stringent emission regulations have driven marine engine OEMs to expand their use of four stroke engines
  - BRP are the only OEM that promotes just two stroke
- Marine four stroke engines have different lubrication requirements compared to passenger car engines

Four stroke outboards have special requirements

- Rust
  - Engines operate in corrosive environments, causing internal rust
- Wear
  - Engines run at idle speed for long periods of time, causing high fuel dilution and increasing potential for wear
  - Engines also operate at high speeds
- Bearing durability
  - Engines have a vertical crankshaft orientation, requiring exceptional bearing lubrication
- Shear stability
  - Also important to maintain wear protection and bearing durability
- Extended use
  - Many four stroke outboards are operated longer than is recommended between oil changes, requiring improved antioxidancy

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NMMA four stroke standard

- NMMA FC-W standard was introduced in 2004
- Similar NMMA certification process and costs to the long established TC-W3
  - Marketer obtains a trademark license from the NMMA
  - Annual fee $1600 per oil
- Intended for all gasoline-powered four stroke marine applications

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NMMA FC-W standard requirements

Identification

KV40°C
VI
Specific gravity
TBN
TAN
Elementals (Report all)
Sulphur
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
General performance

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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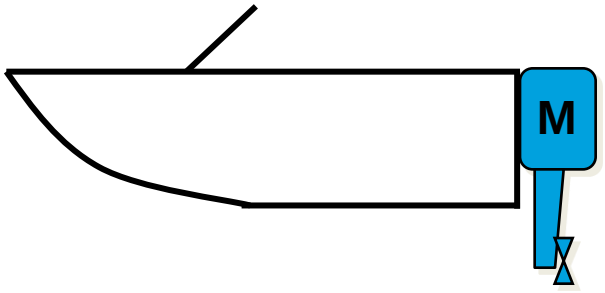
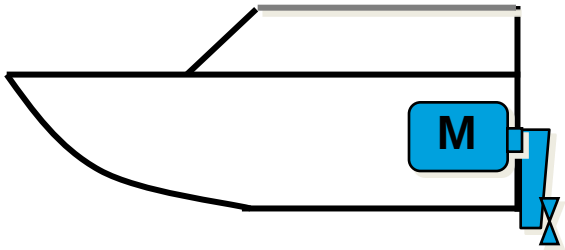
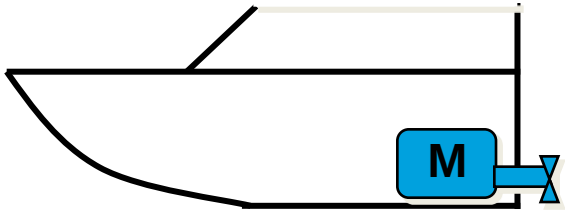
Stern drives and inboard engines are also popular forms of marine propulsion



Outboard



Sterndrive = Inboard/Outboards (I/O)



Inboard

NMMA standard: FC-W catalyst compatible

- NMMA "**FC-W Catalyst Compatible**" launched September 2009
  - Primarily for U.S. stern drive and inboard engines (not outboards)
  - Required by the U.S. EPA to use catalytic converters from 2010

- FC-W Catalyst Compatible does **not** replace the original FC-W
  - The two standards co-exist separately

- FC-W Catalyst Compatible includes the original FC-W requirements **plus** additional requirements
  - API SM quality minimum
  - Phosphorus limit: 0.06 – 0.08%
  - Silicon limit: < 0.002%
  - Stay-in-grade viscosity per SAE J300
  - Noack volatility: ≤ 22%

- Oils meeting FC-W Catalyst Compatible can be used where the original FC-W is recommended

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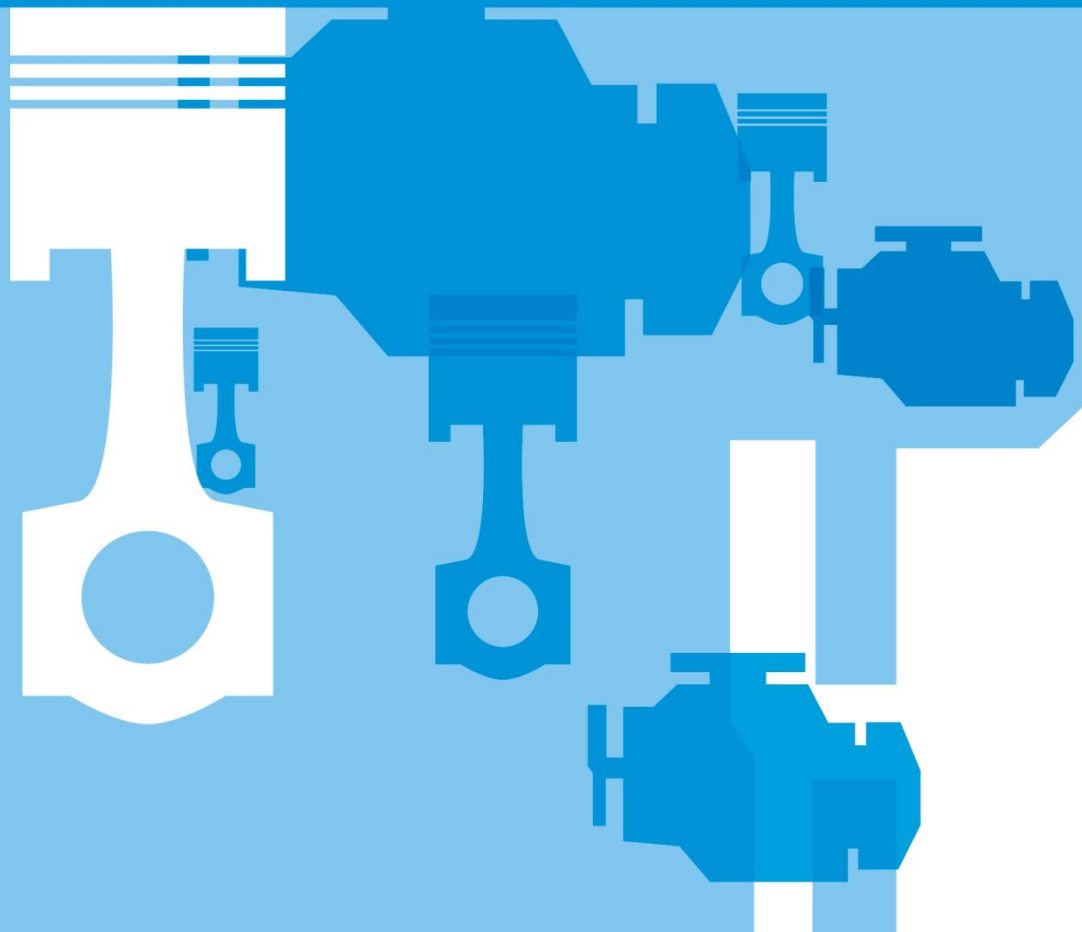
Four stroke motorcycles



Four stroke motorcycles have different needs to passenger cars

- The requirements for motorcycle oils continue to diverge from passenger car oils
- Chemical limits between API and JASO e.g. phosphorous (for ILSAC grades) make formulating to meet applications simultaneously increasingly difficult
- Bench tests and field experience show better performance and rider experience through dedicated motorcycle products

Specification	Min P %	Max P %
API SM	0.06	0.08
API SN		0.08
JASO	0.08	0.12

Motorcycles
Vs Passenger cars

- Air cooled
- Run hotter
- Run faster
- Oils lubricate
  - Engine
  - Clutch
  - Transmission
- Lower oil volume
- Fuel economy FMs lead to clutch slippage
- Lower viscosity can lead to
  - Gear pitting
  - High volatility and high oil consumption

JASO T903 four stroke motorcycle standard

- **JASO has been registering four stroke motorcycle oils since 1999**
  - Introduction driven by OEM concern about suitability of some conventional passenger car lubricants

- Latest update – JASO T903:2016

- JASO programme cost: $5k

- One-time registration fee of 40,000 Yen ($400) per oil must be paid to JASO by the oil marketer

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	SG to SN
ILSAC	GF-1, GF-2	GF-1, GF-2, GF-3	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	A1/B1, A3/B3, A3/B4, A5/B5 C2, C3, C4
CCMC	G-4/G-5	Eliminated	--	--

Phosphorus limit remains the same

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

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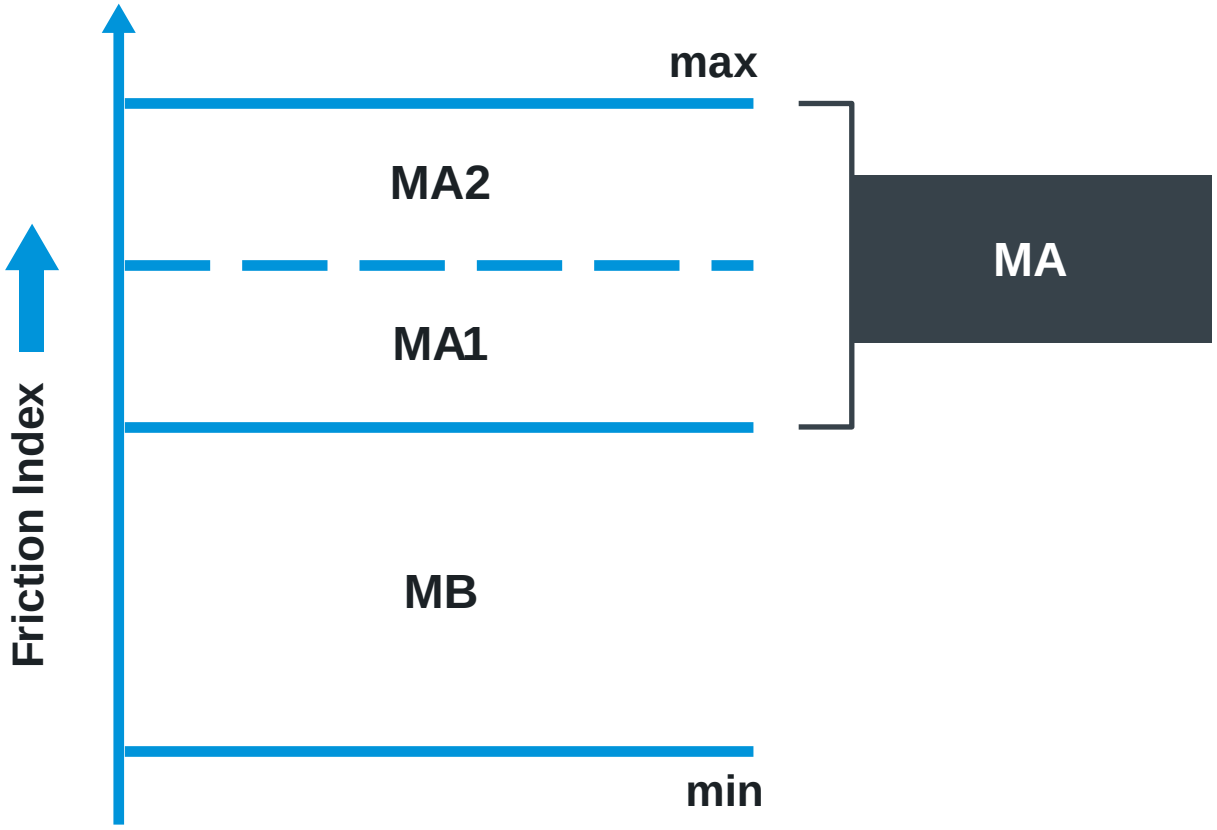
JASO classifies friction using the SAE#2 test rig



JASO T903 four stroke motorcycle specification (revised 2016)

API	SG, SH, SJ, SL, SM, SN	
ILSAC	GF-1, GF-2, GF-3	
ACEA	A1/B1, A3/B3, A3/B4, A5/B5, C2, C3, C4	

Molybdenum		Report	
Sulfated ash		≤ 1.2 mass%	JIS K 2272
Phosphorus		0.08 – 0.12 mass%	JPI-5S-38
NOACK volatility		≤ 20 mass% loss	JPI-5S-41
HTHS		≥ 2.9 cP	JPI-5S-36
Foaming Tendency	Seq. I Seq. II Seq. III	≤ 10/0 vol.% ≤ 50/0 vol.% ≤ 10/0 vol.%	JIS K2518
Shear stability	XW-30 XW-40 XW-50	≥ 9.0 cSt ≥ 12.0 cSt ≥ 15.0	JPI-5S-29
	Other grades	Stay-in-grade	

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	$1.60 \leq x < 2.50$	$1.40 \leq x < 1.60$	$1.40 \leq x < 2.50$	$0.40 \leq x < 1.40$

- 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

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Small engines – special applications requiring special lubricants

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