Heavy-Duty Diesel engine oils

Topics in Heavy-Duty Diesel engine oil section

- Definition of HDD lubricants
- Typical Properties of HDDEO
- Function of HDDEO additive components
- Factors affecting HDD formulation
- Evolution of Heavy-Duty Diesel specifications
Definition of Heavy-Duty Diesel engine oils

• Historically, meets API 'C' (Commercial) Category requirements:
  API CH-4, CI-4, CI-4 PLUS, CJ-4 or CK-4
  – Now, includes API 'F' Category requirements: API FA-4
• For use in on-road and off-road equipment and heavy-duty truck applications
• For use in diesel engines that operate under “severe” conditions:
  – Operate continuously at or near peak power output
  – Cyclic operation

Typical properties of HDDEO

<table>
<thead>
<tr>
<th>Typical Properties</th>
<th>HDDEO</th>
<th>PCEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Additive Package, % mass</td>
<td>10 to 20</td>
<td>7 to 12</td>
</tr>
<tr>
<td>SAE Viscosity Grades</td>
<td>SAE 15W-40, 10W-30, 10W-40, 5W-40, 5W-30</td>
<td>SAE 0W-20, 0W-30, 5W-20, 5W-30, and 10W-30</td>
</tr>
<tr>
<td>HTHS Viscosity, mPa*s</td>
<td>3.0 to 4.2</td>
<td>2.6 to 3.1</td>
</tr>
<tr>
<td>TBN, mg KOH/g</td>
<td>8 to 12</td>
<td>7 to 9</td>
</tr>
<tr>
<td>Sulfated ash, % mass</td>
<td>0.9 to 1.3</td>
<td>0.8 to 0.9</td>
</tr>
<tr>
<td>Shear Stability Index of VM</td>
<td>25 to 35</td>
<td>25 to 50</td>
</tr>
<tr>
<td>Oil Drain Intervals, miles</td>
<td>Up to 75,000</td>
<td>Up to 10,000</td>
</tr>
</tbody>
</table>

*Current quality levels
### Function of typical HDDEO additive components

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical Type</th>
<th>Property/Function</th>
<th>Engine Test Stressing Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersant</td>
<td>Conventional, EGR Dispersant</td>
<td>+ Diesel Cleanliness + Soot &amp; varnish control, soot dispersancy + Filter plugging + Valve train wear</td>
<td>+ 1M-PC, 1K, 1N, 1P, 1R, C13 + VG, IIIF, VIII, M11-HST, T-8, T-11 + M11-HST, M11-EGR, ISM + M11-HST, M11-EGR, RFWT, ISM, ISB</td>
</tr>
<tr>
<td>Metal Detergents</td>
<td>Ca or Mg based sulphonates, phenates, salicylates</td>
<td>+ Diesel detergency + Cyl./ring wear control + Rust Control</td>
<td>+ 1M-PC, 1K, 1N, 1P, 1R, C13 + T-9, T-10, T-12, M11-EGR, ISM + BRT</td>
</tr>
<tr>
<td>Antioxidants</td>
<td>ZDDP, phenolic, aminic, metal and/or sulfur based</td>
<td>+ Oxidation + Bearing wear</td>
<td>+ IIIF, IIIG, T-9, T-10, T-12, T-13 + VIII, T-9, T-10, T-12</td>
</tr>
<tr>
<td>Anti-wear agents</td>
<td>ZDDP, metal based</td>
<td>+ Valve train and cyl./ring wear control</td>
<td>+ IIIF, IIIG, VG, RFWT, M11-HST, M11-EGR, T-9, T-10, T-12, ISM, ISB</td>
</tr>
<tr>
<td>Viscosity Modifier</td>
<td>OCP, Styrene Isoprene</td>
<td>+ High temp. viscosity + Dispersancy</td>
<td>+ 6V92TA, T-9, T-10, T-12 + T-8, M11-HST, M11-EGR, T-11, ISM, ISB</td>
</tr>
</tbody>
</table>

### Factors affecting formulation of Heavy-Duty engine oils

- Engine design, operation and exhaust after treatment systems to meet exhaust emissions regulations
- Diesel fuel sulfur level
- OEM requirements for service fill and or factory fill
- SAE J300, API 1509 EOLCS, ASTM D4485 and ACC Code of Practice
- Oil company logistical considerations
- Additive technology (Detergent Inhibitor package, VM, PPD)
- Military specifications
  - No longer a significant driver of quality
- Real-world performance
Changes in diesel engine hardware

- Ever tightening emissions regulations drives evolution of engine hardware
- Have achieved near zero exhaust emissions for Class 8 On-Highway vehicles
Evolution of Heavy-Duty engine oil specifications

API CI-4 & CI-4 PLUS: Introduction to EGR

- Soot from EGR equipped engines soot was more difficult to disperse than non-EGR engines
  - Oils required a new dispersant specifically for EGR equipped engines
- EGR operation increased thermal load on vehicle cooling system
  - Oils required improved oxidation stability for higher operating temperature
- Test data suggested higher levels of TBN were needed
- If SOx, NOx and water vapor condense, sulfuric and nitric acids can form
  - Aluminum intake manifold can be attacked by acids and generate aluminum oxide (sandpaper), which is drawn into engine resulting in ring and liner wear
- API CI-4 engine test conditions established to minimize EGR condensation
- In June 2003, EMA formally requested an upgrade to API CI-4 category
- Following months of negotiation, agreement to an ‘API Supplement’ CI-4 PLUS was reached in April 2004
  - Mack T-11 (EGR soot handling test)
  - 90 cycle Kurt Orbhan (improved shear stability)
**API CJ-4: Chemical constraints**

- In 2007 HD engine emissions limits began phased-in reduction to reach 1/10th of October 2002 limits on NOx and PM
  - Requires exhaust after treatment (DPF, SCR)
  - On-highway diesel sulfur reduced from 500 ppm to 15 ppm
- Lack of performance test for after treatment compatibility drove chemical limits for Sulfated Ash, Phosphorus and Sulfur (SAPS)
  - SASH (sulfated ash) ≤ 1.0%(m)
  - Phosphorous ≤ 0.12%(m)
  - Sulfur ≤ 0.4%(m)
- Introduced four new tests to ensure protection of new technology
  - Cummins ISM (replacement for M11-EGR)
  - Cummins ISB (new valve train wear test)
  - Caterpillar C13 (multi-cylinder test for piston deposits and oil consumption)
  - Mack T-12 (replacement for T-10)
- API licensing started October 15, 2006

---

**API CK-4 & FA-4: Oxidation & Fuel Economy**

- New fuel economy and greenhouse gas rules began phased implementation in 2014 with full effect in 2018
  - Reduce CO2 by 270 million tons and save 530 million barrels of oil
- At the June 2011 ASTM meeting, the EMA issued a formal request for a new API performance category to help meet these new regulations
- Areas requested for improvement versus API CJ-4
  - Shear stability
  - Oxidation
  - Aeration
  - Bio-diesel compatibility (eventually dropped)
  - New lower viscosity oils to help deliver fuel economy performance
- API first license date was December 1, 2016
API CK-4 & FA-4: Why 2 API oil categories?

API CK-4
- More Robust API CJ-4
- Recommended by all OEMs
- Full backward compatibility
- SAE xW-30 and xW-40
- HTHSV > 3.5 mPa•s
- API CK-4, ACEA E

API FA-4
- Robust CJ-4 at lower viscosity
- Some OEMs opted out
- Not backward serviceable
- SAE xW-30
- HTHSV: 2.9 – 3.2 mPa•s
- API FA-4, New ACEA F

API CK-4 has the same durability requirements as API FA-4 to minimize risks associated with the new lower viscosity fuel economy grades.

API CK-4 & FA-4: Test requirements

- Combination of New and Carry forward tests from API CJ-4

<table>
<thead>
<tr>
<th>Test</th>
<th>Performance Parameters</th>
<th>Fuel Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy Tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caterpillar C13</td>
<td>Piston Deposits, Oil Consumption</td>
<td>15 ppm</td>
</tr>
<tr>
<td>Caterpillar 1N</td>
<td>Aluminum Piston Deposits, Oil Consumption</td>
<td>500 ppm</td>
</tr>
<tr>
<td>Cummins ISB</td>
<td>Valve Train Wear</td>
<td>15 ppm</td>
</tr>
<tr>
<td>Cummins ISM</td>
<td>Valve Train Wear, Filter Plugging, Sludge</td>
<td>500 ppm</td>
</tr>
<tr>
<td>Roller Follower Wear Test</td>
<td>Roller Follower Pin Wear</td>
<td>500 ppm</td>
</tr>
<tr>
<td>Mack T-11</td>
<td>Soot Induced Viscosity Increase</td>
<td>500 ppm</td>
</tr>
<tr>
<td>Mack T-11A</td>
<td>Sooted Oil Low Temperature Pumpability</td>
<td>500 ppm</td>
</tr>
<tr>
<td>Mack T-12</td>
<td>Ring/Liner Wear parameters only</td>
<td>15 ppm</td>
</tr>
<tr>
<td>Kurt Orbhan 90 cycle</td>
<td>Shear Stability Bench Test</td>
<td>No Fuel Used</td>
</tr>
</tbody>
</table>

New
- Volvo T-13
  - Oxidation
  - 15 ppm
- Caterpillar C13 Oil Aeration Test (COAT)
  - Oil Aeration
  - 15 ppm

- Add OM 501LA, OM 646LA and Volvo D12D (or their replacements), and the DD13 Scuff test for OEM specifications
API CK-4 & FA-4: Improving oxidation

ASTM D8048 (Volvo T-13 Oxidation Test)
- 13L Mack MP8 diesel engine
- 360 hours steady-state test
- Oil temperatures:
  - 130°C main gallery
  - 140°C sump
- API CK-4 & FA-4 Limits:
  - T-13 FTIR Oxidation Peak Height: 125 max
  - KV 40°C % increase (300-360 hr): 75% max
- Drove more anti-oxidants into oil
  - Largest increase of any API oil category!

![Volvo T-13 Viscosity Control](image)

- Volvo T-13 Viscosity Control
- CK-4

![Volvo T-13 Oxidation Control](image)

- Volvo T-13 Oxidation Control
- CK-4

API CK-4 & FA-4: Improving aeration

ASTM D8047 (Caterpillar-C13 Oil Aeration Test)
- 13 L diesel engine
- 50 hours duration
- Aeration is measured real time via a Micromotion meter which measures oil density
- API CK-4 & FA-4 Limits:
  - Average % aeration 40-50 hrs: 11.8% max
  - Drove rebalance of additives, promotes lighter SAE viscosity grades

![% Aeration](image)

- % Aeration
- CJ-4 reference oil
- SAE 15W-40 API CK-4
- SAE 10W-30 API FA-4
- Industry Limit Max.
## Other current HDD performance categories

### OEM specifications

<table>
<thead>
<tr>
<th>OEM</th>
<th>Specification</th>
<th>Base Industry Specification</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caterpillar</td>
<td>ECF-1-a</td>
<td>CH-4</td>
<td>+ Caterpillar 1P; SASH restrictions</td>
</tr>
<tr>
<td></td>
<td>ECF-2</td>
<td>CI-4/CI-4 PLUS</td>
<td>+ Caterpillar C13; SASH restrictions</td>
</tr>
<tr>
<td></td>
<td>ECF-3</td>
<td>CJ-4</td>
<td>None</td>
</tr>
<tr>
<td>Detroit Diesel</td>
<td>DFS 93K215</td>
<td>CH-4</td>
<td>+ Mitsubishi 4D34T4; Mack T-9 + Mack T-10; + OM501LA</td>
</tr>
<tr>
<td></td>
<td>DFS 93K214</td>
<td>CI-4 PLUS</td>
<td>+ OM501LA</td>
</tr>
<tr>
<td></td>
<td>DFS 93K218</td>
<td>CJ-4</td>
<td>+ OM501LA; + OM646LA</td>
</tr>
<tr>
<td></td>
<td>DFS 93K222</td>
<td>CK-4</td>
<td>+ OM501LA; + OM646LA +DD13 Scuff</td>
</tr>
<tr>
<td></td>
<td>DFS 93K223</td>
<td>FA-4</td>
<td>+ OM501LA; + OM646LA +DD13 Scuff</td>
</tr>
<tr>
<td>Mack</td>
<td>EO-N</td>
<td>CI-4</td>
<td>enhanced Mack T-10, T-8E, Cummins M11-EGR, Seq. IIIF requirements</td>
</tr>
<tr>
<td></td>
<td>EO-N Premium Plus '03</td>
<td>CI-4PLUS</td>
<td>enhanced Mack T-11, T-10, Cummins M11-EGR, Seq. IIIF requirements</td>
</tr>
<tr>
<td></td>
<td>EO-O Premium Plus</td>
<td>CJ-4</td>
<td>enhanced Cummins ISM, ISB, and Mack T-12 performance; + Volvo D12D; + Seq. IIIG</td>
</tr>
<tr>
<td></td>
<td>EOS-4.5</td>
<td>CK-4</td>
<td>enhanced Cummins ISM, ISB, Mack T-12 and Volvo T-13 performance; + Volvo D12D</td>
</tr>
</tbody>
</table>
### Other current HDD performance categories

#### OEM specifications

<table>
<thead>
<tr>
<th>OEM</th>
<th>Specification</th>
<th>Base Industry Specification</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cummins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CES 20078</td>
<td>CI-4PLUS</td>
<td>+ Seq. IIIIF wear; + Mitsubishi 4D34T4; + min TBN</td>
<td></td>
</tr>
<tr>
<td>CES 20081</td>
<td>CJ-4</td>
<td>enhanced Cummins ISM, ISB, and Mack T-12 performance</td>
<td></td>
</tr>
<tr>
<td>CES 20086</td>
<td>CK-4</td>
<td>enhanced Cummins ISM, ISB, Mack T-12 and Volvo T-13 performance</td>
<td></td>
</tr>
<tr>
<td>CES 20087</td>
<td>FA-4</td>
<td>enhanced Cummins ISM, ISB, Mack T-12 and Volvo T-13 performance</td>
<td></td>
</tr>
</tbody>
</table>

#### Military HD specs

- Combine diesel and gasoline engine tests with transmission tests
- **MIL-PRF-2104K**
  - 2104K is roughly equivalent to 2104J + adds SCPL “Single Common Powertrain Lubricant” grade (all-season lubricant providing extended drain intervals and reduced fuel consumption)
  - 2104J is roughly equivalent to API CI-4 + Base oil viscosity and SASH limits replace DD 2-stroke test which is no longer available
  - 2104H is roughly equivalent to API CI-4 + DD 2-stroke test 6V92TA
  - 2104G is roughly equivalent to API CG-4 / CF + DD 2-stroke test 6V92TA
  - All require partial Caterpillar TO-4 and Allison C4 testing requirements but not full approvals
- No longer a significant factor in heavy duty diesel engine oil formulation
## Summary of diesel engine oil performance criteria

- Low-temperature sludge control is not critical
- High-temperature soot dispersion was important for wear control, but is less so for low soot modern diesel engines
- Ring sticking must be controlled to prevent hone loss
- Valve train wear protection is significant, especially for new lower viscosity FA-4 oils
- Fuel sulfur levels can contribute to excessive ring and liner wear
- Incorporation of EGR tests in API CI-4 dramatically changed formulation evolution
  - Increased TBN, dispersant and antioxidant requirements
- Chemical constraints of API CJ-4 protected modern exhaust after treatment systems
  - Reduced TBN, inclusion of supplemental anti-wear additives
- Anti-oxidancy is key performance parameter with the introduction of the Volvo T-13
  - Significant increase in anti-oxidant levels

## Summary

- HDD lubricants meet API ‘C’ or ‘F’ category requirements and are formulated to be extra robust for diesel engines that operate under “severe” conditions
- Historically have had higher levels of detergency, dispersancy, and antiwear components and have been formulated to higher SAE viscosity grades than typical passenger car oils
- Continued tightening of emission limits (NOx, Particulates, GHG) have a significant impact on diesel engine design and operation, fuels and lubricant formulation
  - Drives evolution of heavy duty diesel engine oil specifications
  - Focus has been on improving soot handling and oxidation performance
  - Addition of EGR significantly impacted HDD formulation
  - Chemical limits with introduction of API CJ-4 limited use of some key components, but CJ-4 is the most robust API HD category ever developed
  - API CK-4 and FA-4 HDD oils were developed with significantly more oxidation performance, improved aeration and shear stability as well as a new subcategory of lower viscosity oils to meet fuel consumption and GHG Phase I regulations
Appendix

Caterpillar 1N and C13 tests

Cat 1N  Cat C13
Cummins ISB and ISM tests

Mack T-11 and T-12 tests
Volvo T-13 test

Roller follower wear test
### API Categories for Diesel Engines

#### DIESEL ENGINES

<table>
<thead>
<tr>
<th>Category</th>
<th>Situation</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF-4</td>
<td>Current</td>
<td>API Service Category CF-4 is designed for use in high-speed, direct-injection, diesel engines designed to meet 2017 model-year on-highway, and Tier 4 non-road exhaust emission standards as well as previous model-year diesel engines. These oils are formulated for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm by weight. However, the use of these oils with greater than 10 ppm sulfur fuel may impact oil residence time and oil drain intervals. These oils are especially effective in controlling emission control system durability where particulate filters and other advanced aftertreatment systems are used. API CF-4 oils are also designed to provide enhanced protection against oil oxidation, viscosity loss due to shear, and oil wear as well as protection against catalyst poisoning, particulate filter backing, engine wear, piston deposits, degradation at low- and high-temperature properties, and rust-related water contamination. API CF-4 oils exceed the performance criteria of API C-4, C-3, C-2, and C-1 and are especially effective in engines calling for these API Service Categories. When using CF-4 oils with higher than 10 ppm sulfur fuel, consult the engine manufacturer for service interval recommendations.</td>
</tr>
<tr>
<td>CJ-4</td>
<td>Current</td>
<td>For high-speed, direct-injection, diesel engines designed to meet 2017 model-year on-highway and Tier 4 non-road exhaust emission standards as well as previous model-year diesel engines. These oils are formulated for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm by weight. However, the use of these oils with greater than 15 ppm sulfur fuel may impact oil residence time and oil drain intervals. API CJ-4 oils exceed the performance criteria of API CF-4 with the addition of C-4 PLUS. CJ-4 oils meet the requirements for use with diesel fuels ranging in sulfur content up to 0.05% weight. Can be used in place of CF-4, C-3, C-2, and C-1 oils. Some CJ-4 oils may not qualify for the C-4 PLUS designation.</td>
</tr>
<tr>
<td>CI-4</td>
<td>Current</td>
<td>Introduced in 2002. For high-speed, four-stroke engines designed to meet 2007 exhaust emission standards implemented in 2002. CI-4 oils are formulated for engine durability and exhaust gas re-circulation (EGR) systems. CI-4 oils were intended for use with diesel fuels ranging in sulfur content up to 0.05% weight. Can be used in place of CE, CD, CC, CF-4, and CH-4 oils. Some CI-4 oils may not qualify for the CI-4 PLUS designation.</td>
</tr>
<tr>
<td>CH-4</td>
<td>Current</td>
<td>Introduced in 1998. For high-speed, four-stroke engines designed to meet 1999 exhaust emissions standards. CH-4 oils are specifically compounded for use with diesel fuels ranging in sulfur content up to 0.05% weight. Can be used in place of CI-4, CD, CE, CC, and CF-4 oils.</td>
</tr>
</tbody>
</table>

**Source:** [http://www.api.org/~/media/Files/Certification/Engine-Oil-Diesel/Publications/MOTOR_OIL_GUIDE_120116_FINAL_WEB.pdf](http://www.api.org/~/media/Files/Certification/Engine-Oil-Diesel/Publications/MOTOR_OIL_GUIDE_120116_FINAL_WEB.pdf)

---

### API Categories for Diesel Engines continued

<table>
<thead>
<tr>
<th>Category</th>
<th>Situation</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF-4</td>
<td>Obsolete</td>
<td>CAUTION: Not suitable for use in most diesel-powered automotive engines built after 2000.</td>
</tr>
<tr>
<td>CF-2</td>
<td>Obsolete</td>
<td>CAUTION: Not suitable for use in most diesel-powered automotive engines built after 2009. Two-stroke cycle engines may have different lubrication requirements than four-stroke engines, and the manufacturer should be consulted on lubricant recommendations.</td>
</tr>
<tr>
<td>DF</td>
<td>Obsolete</td>
<td>OBSOLETED: Introduced in 1994. For off-road, indirect-injected and other diesel engines including those using fuel with less than 0.05% sulfur. Can be used in place of CE oils.</td>
</tr>
<tr>
<td>FA-4</td>
<td>Current</td>
<td>API Service Category FA-4 describes certain SAE-50 oils specifically formulated for use in a large high-speed, four-stroke cycle diesel engines designed to meet 2017 model-year on-highway, greenhouse gas (GHG) emission standards. These oils are formulated for use in off-highway applications with diesel fuel sulfur content up to 10 ppm (0.010% by weight). Refer to individual engine manufacturer recommendations regarding compatibility with API FA-4 oils. These oils are blended to meet temperatures higher than CRG viscosity grades 5W-20, 5W-30, and 0W-20; most modern CRG emissions. These oils are especially effective in controlling emissions control system durability where particulate filters and other advanced aftertreatment systems are used. API FA-4 oils are also designed to provide enhanced protection against oil oxidation, viscosity loss due to shear, and oil wear as well as protection against catalyst poisoning, particulate filter backing, engine wear, piston deposits, degradation at low- and high-temperature properties, and rust-related water contamination. These oils are specifically formulated for use with diesel fuels ranging in sulfur content up to 10 ppm sulfur. Can be used in place of CE, CD-4, CH-4, C-4, C-3, C-2, and C-1 with the addition of FA-4 PLUS. FA-4 PLUS oils are especially effective in engines calling for these API Service Categories. When using FA-4 oils with higher than 10 ppm sulfur fuel, consult the engine manufacturer for service interval recommendations.</td>
</tr>
</tbody>
</table>

**Source:** [http://www.api.org/~/media/Files/Certification/Engine-Oil-Diesel/Publications/MOTOR_OIL_GUIDE_120116_FINAL_WEB.pdf](http://www.api.org/~/media/Files/Certification/Engine-Oil-Diesel/Publications/MOTOR_OIL_GUIDE_120116_FINAL_WEB.pdf)
API Categories for Diesel Engines

- API CF (Obsolete)
  - Spec designed for pre-chamber engines operating in high sulfur diesel fuel environments
  - The Cat 1M test was being developed using Cat 1K hardware to pass straight grades and high TBN (20-30) oils that the Cat 1K could not tolerate
  - Cat 1M was withdrawn in favor of a modified Cat 1G2
  - The modified 1G2 was eventually called the Cat 1M-PC

API Categories for Diesel Engines

- API CF-2 (Obsolete)
  - Two-stroke diesel specification
  - Comprises 6V92TA, L38 and Cat 1M-PC with different limits than CF
  - Cat 1M-PC limit is 100 WTD maximum using different deposit weighting scheme compared to API CF
  - CF-2 very difficult to achieve in multigrades
Permission is given for storage of one copy in electronic means for reference purposes. Further reproduction of any material is prohibited without prior written consent of Infineum International Limited.

The information contained in this document is based upon data believed to be reliable at the time of going to press and relates only to the matters specifically mentioned in this document. Although Infineum has used reasonable skill and care in the preparation of this information, in the absence of any overriding obligations arising under a specific contract, no representation, warranty (express or implied), or guarantee is made as to the suitability, accuracy, reliability or completeness of the information; nothing in this document shall reduce the user's responsibility to satisfy itself as to the suitability, accuracy, reliability, and completeness of such information for its particular use; there is no warranty against intellectual property infringement; and Infineum shall not be liable for any loss, damage or injury that may occur from the use of this information other than death or personal injury caused by its negligence. No statement shall be construed as an endorsement of any product or process. For greater certainty, before use of information contained in this document, particularly if the product is used for a purpose or under conditions which are abnormal or not reasonably foreseeable, this information must be reviewed with the supplier of such information.

Links to third party website from this document are provided solely for your convenience. Infineum does not control and is not responsible for the content of those third party websites. If you decide to access any of those third party websites, you do so entirely at your own risk. Please also refer to our Privacy Policy.

‘INFINEUM’, the interlocking Ripple Device, the corporate mark comprising INFINEUM and the interlocking Ripple Device and are trademarks of Infineum International Limited.

© 2018 Infineum International Limited. All rights reserved.