“The DEUTZ Path to Tier 4 for Underground Mining Engines”

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DEUTZ Corporation

Workshop on Diesel Aerosols and Gases in Underground Metal and Nonmetal Mines
Salt Lake City UT
June 17 2012
Exempted Engine Categories

**Permanent Exemptions**
- National Security
- Manufacturer Owned
- Replacement Engine
- Extraordinary Hardship
- Hardship - Small Volume Manuf.
- OEM Hardship
- Identical Configuration
- Ancient Engine

**Temporary Exemption**
- Repairs and Alterations
- Testing
- Display
- Export
- Diplomatic or Military
- Delegated Assembly
- Partially Completed

**Excluded from Emission Standards**
- Competition
- Stationary (Subjected to 40CFR60)
- **Underground Mining (MSHA)**
  - Hobby Engine
- Engine Manf. Before Standards

**Other Special Categories**
- TPEM (Flex) Engines
- Personal-Use for Spark Ignition
- Independent Commercial Importer
- Other Exemptions
# MSHA Approved Tier 3/4i Engines

<table>
<thead>
<tr>
<th>Engine</th>
<th>Rating</th>
<th>Assigned Vent.</th>
<th>Particulate Index</th>
<th>Approval No.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>kW</td>
<td>rpm</td>
<td>cfm</td>
<td>cfm/HP</td>
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<td>2600</td>
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<tr>
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<tr>
<td>TCD 2012 L06 2V</td>
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<td></td>
<td>120</td>
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<td>2300</td>
<td>6,000</td>
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<td></td>
<td>105</td>
<td>141</td>
<td>2300</td>
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<td>2300</td>
<td>10,500</td>
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<td></td>
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<td>232</td>
<td>2300</td>
<td>9,000</td>
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<tr>
<td></td>
<td>160</td>
<td>215</td>
<td>2300</td>
<td>7,500</td>
</tr>
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<td>TCD 2015 V06</td>
<td>330</td>
<td>443</td>
<td>2100</td>
<td>15,500</td>
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<tr>
<td></td>
<td>300</td>
<td>402</td>
<td>2100</td>
<td>16,000</td>
</tr>
<tr>
<td></td>
<td>240</td>
<td>322</td>
<td>2100</td>
<td>11,500</td>
</tr>
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</table>
The engine company.

TCD 2.9 L4 – Product presentation
US Tier 4 final
TCD 2.9 L4, Tier 4 final
General product information

- All new in-line 4 cylinder engine
- Single displacement of 0.725 liter
- Total displacement of 2.9 liter
- 2 valves per cylinder, maintenance free valve train with hydraulic lifters
- Optional gear driven PTO, max torque is 73.7 lbs-ft (100 Nm), which represents 40 percent of the max torque from the engine
- Standard service side is right; left service side is optional
- Common Rail (CR) Fuel Injection Equipment
- DEUTZ EMR 4, electronic control unit
- Power range: 33.5 – 74.9 hp (25.0 – 55.9 kW)
- High peak torque: 186 lbs-ft (255 Nm) @1,800 rpm (value from the TD / TCD models)
- Rated speed:
  - D / TD / TCD: 2,600 rpm
- Engine application variants for:
  - Off-road mobile machinery
  - Stationary
TCD 2.9 L4, Tier 4 final
General product features – right side

- U-flow high efficient cylinder head
- Flywheel housing
  - Standard: SAE 4
  - Optional: SAE 3 & 5
- 12 Volt / 2.6 kW Starter motor
- Flywheel SAE 4 as standard and optional current valid 2011 series flywheels
- Counter balance shaft optional
- Multi direction intake adapter on D 2.9 L4
- High boost waste gate turbo charger
- External, controlled and cooled EGR situated close to the combustion air intake ports
- Oil dip stick on industrial engine standard service side
- Ribbed – thin wall cast iron structured crankcase designed for quiet running
TCD 2.9 L4, Tier 4 final
General product features – left side

- High level oil filler neck
- Thermostat and coolant outlet
- Coolant inlet, cab heater connections
- 14 Volt 55 Amp Alternator as standard
- Poly or v-belt option
- 100% PTO drive from front of crankshaft
- Pressed steel oil pan 180° reversible 2 oil drain possibilities
- Closed Crankcase breather system
- High pressure CR fuel injection system
- High pressure fuel pump
- Silenced rear heavy duty gear train
- SAE “A” flange auxiliary PTO drive (74 lb-ft) with provision for tandem hydraulic pumps
- High capacity oil cooler
- RH/LH service side options
General product features – exhaust gas recirculation (EGR)

- EGR / air mixing unit
- Exhaust gas manifold
- Aluminium die-cast EGR cooler
- EGR control valve with electric actuator
- Air intake manifold
Performance Data

- Total displacement of 2.9 liter
- Power range from 37.5 – 74 hp (28.0 – 55.4 kW)
- Speed range from 2,200 up to 2,600 rpm

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Rated Power Range</th>
<th>Maximum Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 2.9 L4</td>
<td>33 – 49 hp</td>
<td>Up to 49 hp @ 2,600 rpm Up to 108 lb ft @ 1,600 rpm</td>
</tr>
<tr>
<td>TD 2.9 L4</td>
<td>50 – 74 hp</td>
<td>Up to 74 hp @ 2,600 rpm Up to 186 lb ft @ 1,800 rpm 221 lb ft @ 1,600 rpm for Ag Applications</td>
</tr>
<tr>
<td>TCD 2.9 L4</td>
<td>50 – 74 hp</td>
<td>Up to 74 hp @ 2,600 rpm Up to 186 lb ft @ 1,800 rpm 221 lb ft @ 1,600 rpm for Ag Applications</td>
</tr>
</tbody>
</table>
The information below reflects a standard engine and will vary by scope of supply and selected engine options.

<table>
<thead>
<tr>
<th>In inch (mm)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Weight in lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 2.9 L4</td>
<td>25.7</td>
<td>18.8</td>
<td>27.4</td>
<td>463 (210)</td>
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<tr>
<td>TD 2.9 L4</td>
<td>25.7</td>
<td>21.7</td>
<td>27.4</td>
<td>496 (225)</td>
</tr>
<tr>
<td>TCD 2.9 L4</td>
<td>25.7</td>
<td>21.7</td>
<td>27.4</td>
<td>496 (225)</td>
</tr>
</tbody>
</table>
DOC (DVERT Oxidation Catalyst)

- DOC does not filter particles – it oxidizes:
  - NO to NO₂: The oxidation of NO to NO₂ is known as exothermic reaction; the heat from this process can be used for regenerating a particle filter
  - HC and CO into H₂O, and CO₂
- DOC surface is coated by platinum and palladium. Platinum is more effective, but also much more expensive (roughly five times more expensive than palladium).

Pros & Cons

- No regeneration required
- Open, maintenance-free system
- No additional fuel types, i.e. Diesel Exhaust Fluid (DEF) is needed
- Cost efficient
- Most compact EAT option
- Still adds thermal energy to the engine compartment due to the exothermic reaction
- Requires low level of engine raw emissions
Flow Through (Open Particle Filter)

- Less efficiency (up to 50%)
- Filtration inside the metallic structure
- Not an option for engines 4 Liter and greater
- No active regeneration needed
- Less expensive, but with lower efficiency

Pros and Cons

- Open, maintenance-free system
- No additional fuel types needed
- Cost-efficient
- Compact EAT option
- Still emits thermal energy due to oxidation / regeneration
- Requires low level of raw emissions
TCD 2.9 L4, Tier 4 final
Exhaust gas Aftertreatment (EAT) – Concept and Dimensions

- Modular system for DOC, and DOC / FT, with axial and or radial in- and outlets allows our customers a high flexibility for all installation requirements
- Piping has been standardized to 3.0”
- Substrate dimensions w/o canning
  - Substrate length depends on rated power

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Power</th>
<th>Substrate diameter*</th>
<th>Substrate Length*</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 2.9 L4</td>
<td>47 hp (35 kW)</td>
<td>7.5”</td>
<td>DOC 15.7” DOC / FT - DOE / CWT NLA</td>
</tr>
<tr>
<td>TD 2.9 L4</td>
<td>74 hp (55 kW)</td>
<td>7.5”</td>
<td>DOC 21.0” DOC / FT 21.0” NLA</td>
</tr>
<tr>
<td>TCD 2.9 L4</td>
<td>74 hp (55 kW)</td>
<td>7.5”</td>
<td>DOC 21.0” DOC / FT - NLA</td>
</tr>
</tbody>
</table>

* All dimensions are subject to be changed by R&D
** Optional EAT configuration
The engine company.

TCD 3.6 L4 – Product presentation
US Tier 4 interim and final
TCD 3.6 L4, Tier 4 Interim and final
General Product Information

- Single displacement of 0.9 liter per cylinder
- Total displacement of 3.6 liter
- In-line 4 cylinder engine
- 2 valves per cylinder, maintenance free valve train with hydraulic lifters
- Two optional gear driven PTO’s with a maximum power of 40 hp (30 kW) or 75 hp (50 kW)
- Standard service side is right, left service side is optional
- Common Rail (CR) Fuel Injection Equipment
- DEUTZ EMR 4, electronic control unit
- Power range from 67.0 hp (50 kW) to 120 hp (90 kW) @ 2,300 rpm
- Peak torque is 243 lb-ft (330 Nm) @ 1,600 rpm for turbo and 354 lb-ft (480 Nm) @ 1,600 rpm for the highest rated charged air cooled version

Engine specifications for:
- Construction equipment
- GenSets
- Agricultural tractors
TCD 3.6 L4, Tier 4 Interim and final
General Product Features – right side

- EGR cooler
- X-flow 2-valve cylinder head
- Std. SAE 4 housing, SAE 3 is optional
- 2011 series flywheel options
- Ribbed – thin wall cast iron crankcase, optimized for low noise
- Sheet metal oil pan, 180° reversible, two oil drain options
- High level oil filler
- Thermostat and coolant outlet
- High pressure CR pump
- High capacity oil cooler
- 12 V / 2.3 kW starter
- Noise optimized gear train
- Oil dip stick on standard service side
TCD 3.6 L4, Tier 4 Interim and final
General Product Features – left side

- High level oil filler
- Several fan heights and ratios are available
- 14 V / 95 A standard alternator
- Poly or v-belt options
- 100% PTO at the pulley
- Coolant inlet, cab heater connections
- Engine electric comes standard with 12 V, 24 V optional
- Waste gate turbo charger
- Maintenance-free valve train with hydraulic lifters
- Ribbed – cast iron crankcase optimized for noise level
- RH/LH service options
- Provision for gear driven PTO (40.2 hp / 30.0 kW) with SAE A-flange is standard
### TCD 3.6 L4, Tier 4 Interim and final

**Performance data**

<table>
<thead>
<tr>
<th>Number of cylinders</th>
<th>TD 3.6 L4</th>
<th>TCD 3.6 L4</th>
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</thead>
<tbody>
<tr>
<td>Power</td>
<td>74.3 / 55.4</td>
<td>120 / 90.0</td>
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<tr>
<td>Rated speed</td>
<td>2,600</td>
<td>2,300</td>
</tr>
<tr>
<td>Maximum torque</td>
<td>243 / 330</td>
<td>354 / 480</td>
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<tr>
<td>Rated speed</td>
<td>1,600</td>
<td>1,600</td>
</tr>
<tr>
<td>Bore / Stroke</td>
<td>98 x 120 / 3.8 x 4.7</td>
<td>98 x 120 / 3.8 x 4.7</td>
</tr>
<tr>
<td>Single displacement</td>
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<td>.905</td>
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<tr>
<td>Total displacement</td>
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<td>3.62</td>
</tr>
<tr>
<td>Specific fuel consumption</td>
<td>.36 / 220 (TD)</td>
<td>.34 / 210</td>
</tr>
<tr>
<td>Weight</td>
<td>595 / 270</td>
<td>595 / 270</td>
</tr>
</tbody>
</table>
The information below reflects a standard engine and will vary by scope of supply and selected engine options.

<table>
<thead>
<tr>
<th>In inch (mm)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Weight in lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD 3.6 L4</td>
<td>28.2 (716)</td>
<td>22.6 (573)</td>
<td>31.2 (792)</td>
<td>595 (270)</td>
</tr>
<tr>
<td>TCD 3.6 L4</td>
<td>28.2 (716)</td>
<td>22.6 (573)</td>
<td>31.2 (792)</td>
<td>595 (270)</td>
</tr>
</tbody>
</table>
TCD 3.6 L4, Tier 4 Interim and final
Design options

- **Flywheel-end**
  - SAE housings
    - Standard: SAE #4
    - Option: SAE #3
  - Flywheels
    - Current 2011 flywheel options

- **Electrics**
  - Standard is 12 V, optional 24 V is available
  - Standard Starter comes with 12 V, 2.3 kW
  - Standard Alternator has 14 V, 95 A

- **Oil Filler / Oil Filter / Oil Dip Stick**
  - Standard service side is on the right (flywheel viewed)
  - A second available oil gallery allows the flexibility to offer these functions as retro fit on the left side of the engine also

- **Hydraulic pump drives**
  - Number of position 2
    - Position “A” is the standard, gear driven, PTO and offers 40 hp – can be retrofit
    - Position “B” offers customers a maximum performance of 75 hp – can not be retro fit!
TCD 3.6 L4, Tier 4 Interim and final
Design options – 40 hp gear driven PTO

- Power take off offers a maximum output of **40 hp (30 kW)** / **96 lb-ft (130 Nm)**
- Hydraulic pumps front and / or rear mountable via SAE A-flange
- Standard gear drive and gear cover
- Retro fit to all 3.6 engine models possible
Power take off offers a maximum output of **75 hp (56 kW) / 243 lb-ft (330 Nm)**

Concept overview

- Hydraulic pump (i.e. A4VG65)
- Gear cassette
- Heavy-duty cast iron gear cover
- Hydraulic pump adapter
<table>
<thead>
<tr>
<th></th>
<th>TCD3.6L4 Engine out measured (g-kW-hr)</th>
<th>Tier 3 Limit (g/kW-hr)</th>
<th>Tier 4i Limit (g/kW-hr)</th>
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<td>NOx</td>
<td>2.3</td>
<td>4.0</td>
<td>3.4</td>
</tr>
<tr>
<td>HC</td>
<td>0.07</td>
<td>--</td>
<td>0.19</td>
</tr>
<tr>
<td>CO</td>
<td>0.5</td>
<td>5.0</td>
<td>5.0</td>
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<tr>
<td>PM</td>
<td>0.017</td>
<td>0.40</td>
<td>0.02</td>
</tr>
</tbody>
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Pros & Cons

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- Open, maintenance-free system
- No additional fuel types, i.e. Diesel Exhaust Fluid (DEF) is needed
- Cost efficient
- Most compact EAT option
- Still emits thermal energy due to oxidation
- Requires low level of engine raw emissions
TCD 3.6 L4, Tier 4 interim and final
Overview EAT, Dimensions

Tier 4 interim above 75 hp (56 kW) and Tier 4 final below 75 hp (56 kW)
- The modular system for DOC and DOC / WF with axial and / or radial in- and outlets allows a high flexibility for customers needing to install an emission compliant, compact engine
- Dimensions below 75 hp (Tier 4 final) – DOC only

<table>
<thead>
<tr>
<th>Rated Power</th>
<th>EAT Type</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Outer diameter (DO)</td>
</tr>
<tr>
<td>Below 75 hp</td>
<td>DOC</td>
<td>7.5”</td>
</tr>
</tbody>
</table>

- Dimensions above 75 hp (Tier 4 interim) – DOC only

<table>
<thead>
<tr>
<th>Rated Power</th>
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</tr>
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<tr>
<td></td>
<td></td>
<td>Outer diameter (DO)</td>
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<tr>
<td>Above 75 hp</td>
<td>DOC</td>
<td>7.5”</td>
</tr>
</tbody>
</table>