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

Greg Tremaine
DEUTZ Corporation

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

Exempted Engine Categories

The engine company. DEUTZ

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

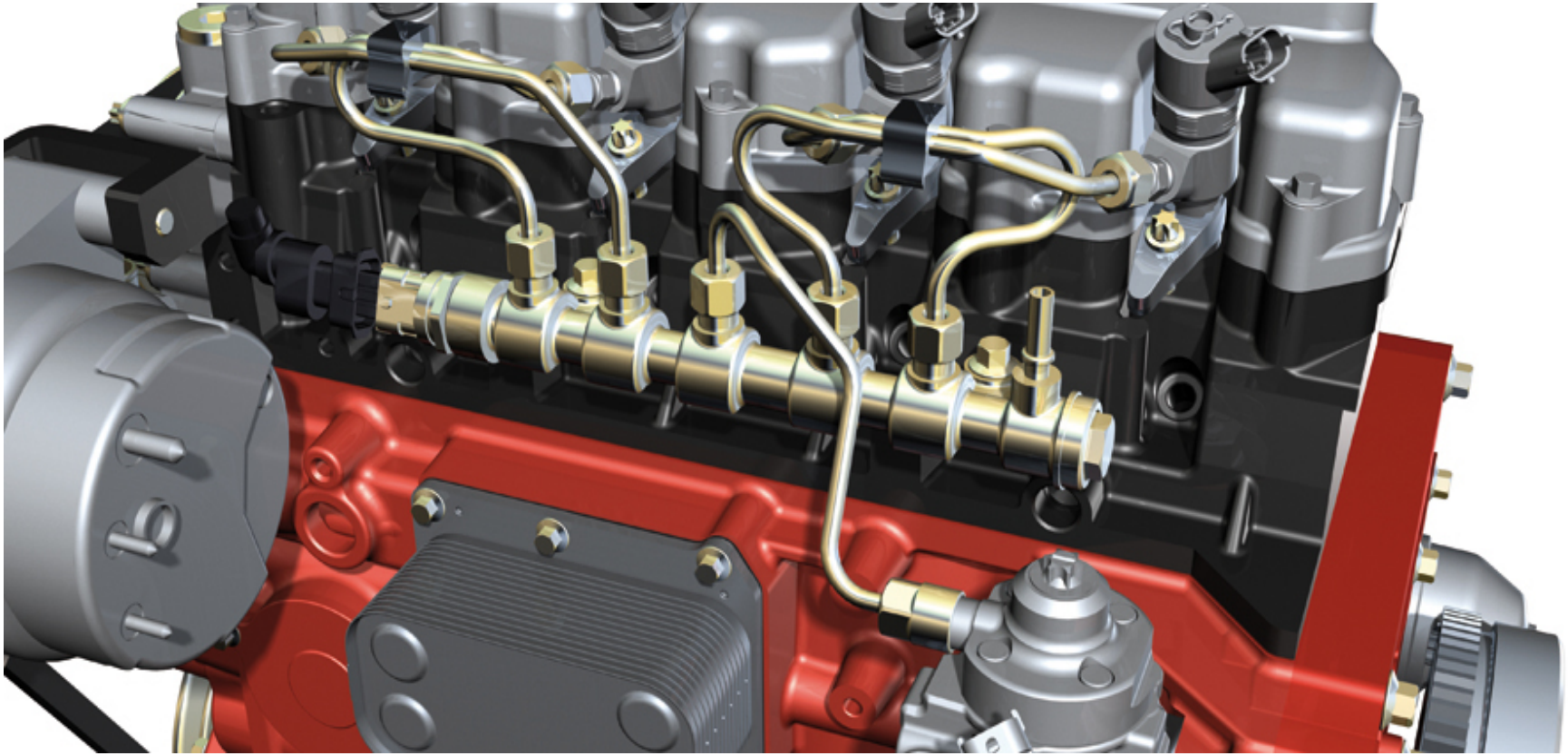
Other Exemptions

MSHA Approved Tier 3/4i Engines

The engine company. DEUTZ

Engine	Rating			Assigned Vent.		Particulate Index		Approval No.
	kW	HP	rpm	cfm	cfm/HP	cfm	cfm/HP	
D 2011 L02i	22.5	30.2	2800	1,500	50	2,000	66	07-ENA040010-0
D 2011 L02	23.5	31.5	2800	1,500	48	2,000	63	07-ENA040010-0
D 2011 L03i	35.8	48.0	2800	2,000	42	3,000	62	07-ENA040011-0
D 2011 L03	36.5	49.0	2800	2,000	41	3,000	61	07-ENA040011-0
D 2011 L04i	47.5	63.7	2600	2,500	40	4,500	71	07-ENA110013-0
TD 2011 L04i	54.7	73.4	2600	3,000	41	2,000	27	07-ENA100005-0
TD 2011 L04	52.0	69.7	2400	3,000	43	2,000	29	07-ENA100005-0
TD 2011 L04w	65.0	87.2	2600	4,000	45	6,000	68	07-ENA110014-0
D 914 L04	55.0	73.8	2300	3,500	47	4,000	54	07-ENA100007-0
D 914 L06	74.9	100.4	2300	4,500	45	4,500	45	07-ENA100006-0
TCD 914 L06 (ecEGR)	129.9	174.2	2300	6,500	37	7,000	40	07-ENA100008-0
TCD 2012 L04 2V	103	138	2400	5,000	36	3,000	22	07-ENA100001-0
	98	131	2400	5,000	38	3,000	23	
	93	124	2400	4,500	36	3,000	24	
TCD 2012 L06 2V	147	197	2400	7,500	38	7,000	36	07-ENA100002-0
	140	188	2400	7,000	37	6,000	32	
	132	177	2400	6,500	37	6,000	34	
TCD 2013 L04	126	169	2300	6,500	38	3,000	18	07-ENA110005-0
	120	161	2300	5,500	34	3,000	19	
	113	151	2300	6,000	40	2,500	17	
	105	141	2300	5,500	39	3,000	21	
TCD 2013 L06	190	255	2300	10,500	41	6,000	24	07-ENA110006-0
	173	232	2300	9,000	39	4,500	19	
	160	215	2300	7,500	35	4,500	21	
TCD 2015 V06	330	443	2100	15,500	35	7,500	17	07-ENA120002
	300	402	2100	16,000	40	7,500	19	
	240	322	2100	11,500	36	7,000	22	

The engine company.



TCD 2.9 L4 – Product presentation
US Tier 4 final

TCD 2.9 L4, Tier 4 final

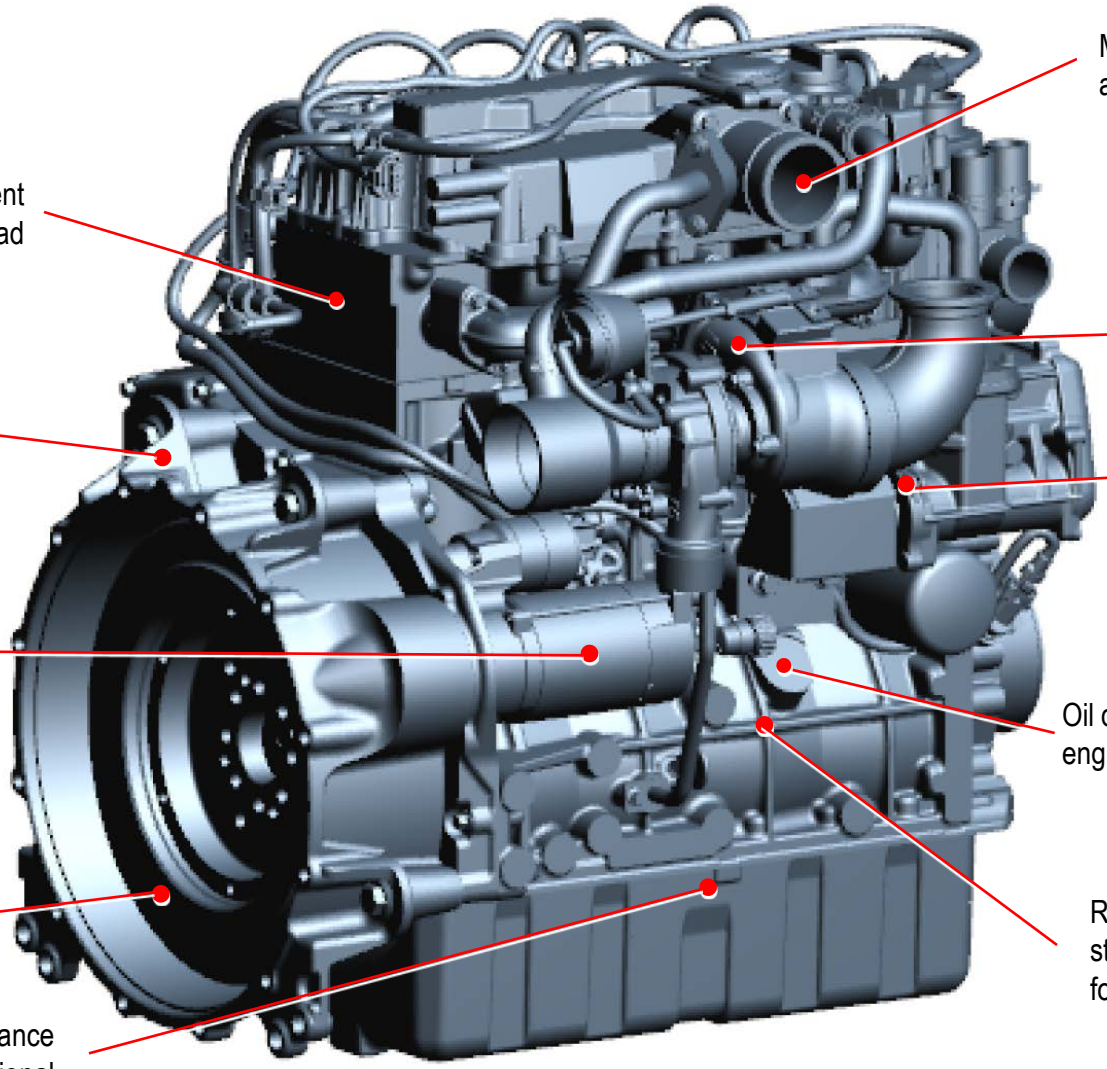
General product information

The engine company. DEUTZ

- All new in-line 4 cylinder engine
- Single displacement of .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

The engine company. DEUTZ



Multi direction intake adapter on D 2.9 L4

U-flow high efficient cylinder head

High boost waste gate turbo charger

Flywheel housing
Standard: SAE 4
Optional: SAE 3 & 5

External, controlled and cooled EGR situated close to the combustion air intake ports

12 Volt / 2.6 kW
Starter motor

Oil dip stick on industrial engine standard service side

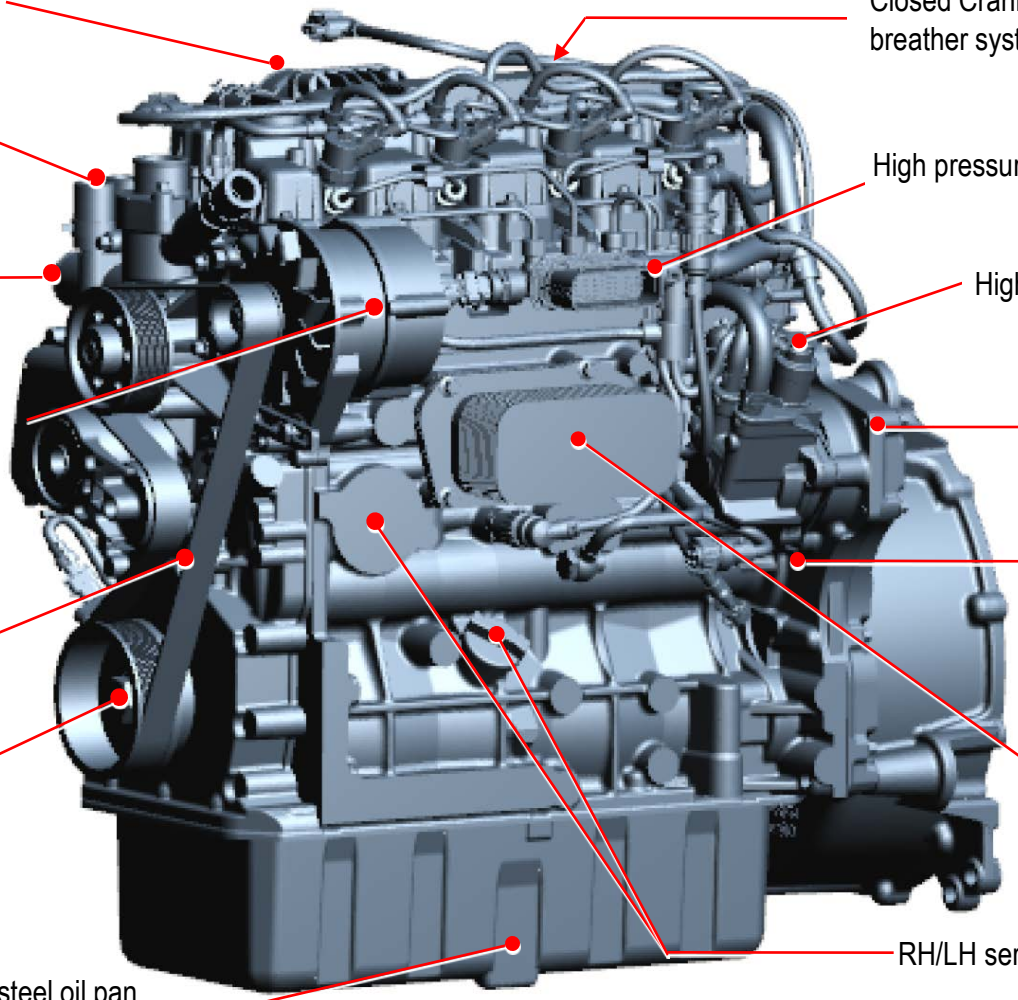
Flywheel SAE 4 as standard and optional current valid 2011 series flywheels

Ribbed – thin wall cast iron structured crankcase designed for quiet running

Counter balance shaft optional

TCD 2.9 L4, Tier 4 final
General product features – left side

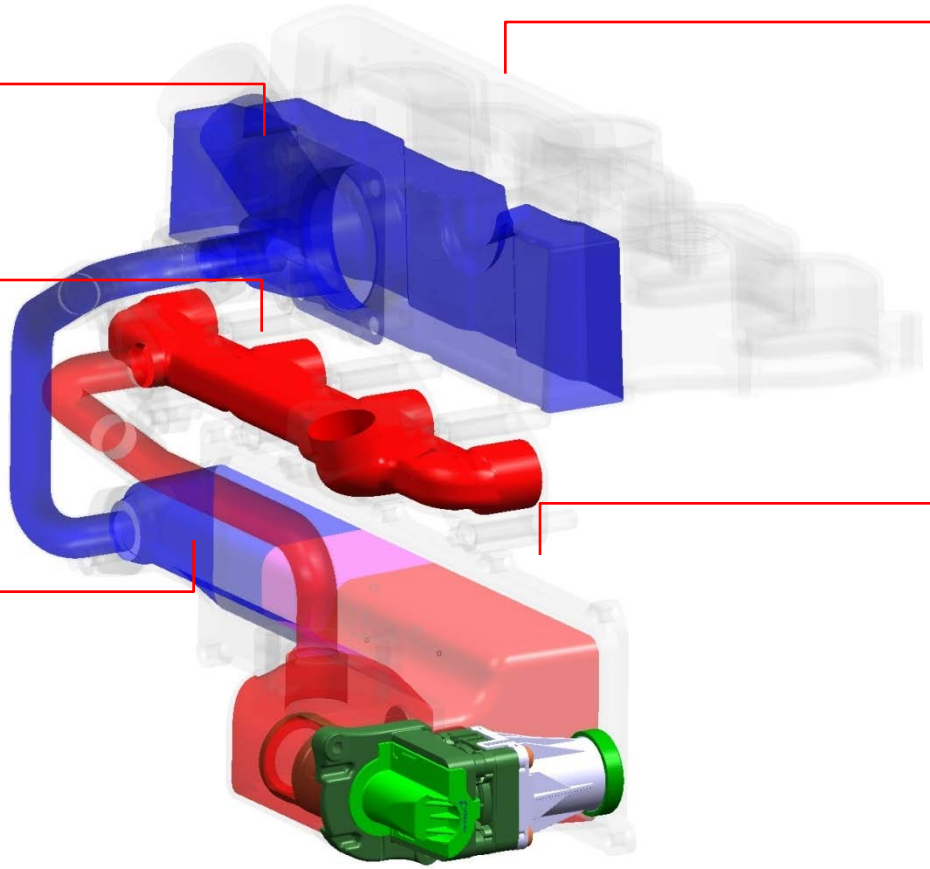
The engine company. DEUTZ



TCD 2.9 L4, Tier 4 final

General product features – exhaust gas recirculation (EGR)

The engine company. DEUTZ



TCD 2.9 L4, Tier 4 final
Performance data

The engine company. DEUTZ

Performance Data

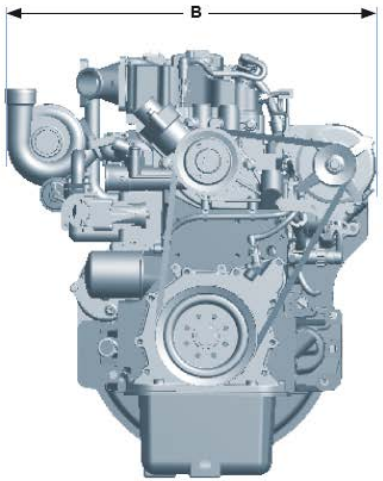
- Total displacement of 2.9 liter
- Power range from 37.5 – 74 hp (28.0 – 55.4 kW)
- Speed range from 2,200 up to 2,600 rpm

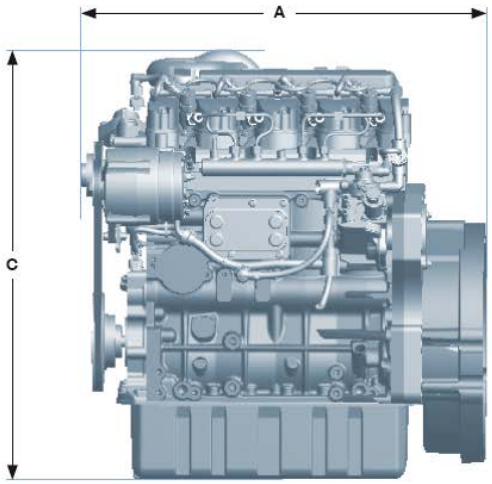
Engine Type	Rated Power Range	Maximum Ratings
D 2.9 L4	33 – 49 hp	Up to 49 hp @ 2,600 rpm Up to 108 lb ft @ 1,600 rpm
TD 2.9 L4	50 – 74 hp	Up to 74 hp @ 2,600 rpm Up to 186 lb ft @ 1,800 rpm *221 lb ft @ 1,600 rpm for Ag Applications*
TCD 2.9 L4	50 – 74 hp	Up to 74 hp @ 2,600 rpm Up to 186 lb ft @ 1,800 rpm *221 lb ft @ 1,600 rpm for Ag Applications*

TCD 2.9 L4, Tier 4 final
Dimensions and weight

The engine company. DEUTZ

- The information below reflects a standard engine and will vary by scope of supply and selected engine options.





In inch (mm)	A	B	C	Weight in lb (kg)
D 2.9 L4	25.7 (652)	18.8 (477)	27.4 (695)	463 (210)
TD 2.9 L4	25.7 (652)	21.7 (552)	27.4 (695)	496 (225)
TCD 2.9 L4	25.7 (652)	21.7 (552)	27.4 (695)	496 (225)

TCD 2.9 L4, Tier 4 final
Exhaust gas Aftertreatment (EAT) – DOC

The engine company. DEUTZ

DVERT Oxidation Catalyst (DOC)

DOC (DVERT Oxidation Catalyst)

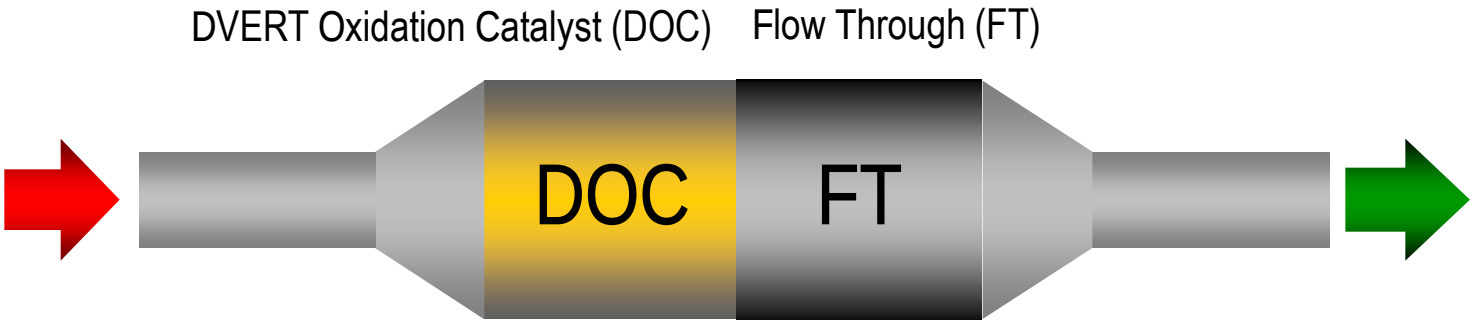
- DOC does not filter particles – it oxidizes:
  - NO to NO_2: The oxidation of NO to NO_2 is known as exothermic reaction; the heat from this process can be used for regenerating a particle filter
  - HC and CO into H_2O, and CO_2
- DOC surface is coated by platinum and palladium. Platinum is more effective, 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

TCD 2.9 L4, Tier 4 final
Exhaust gas Aftertreatment (EAT) – DOC / FT

The engine company. DEUTZ



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

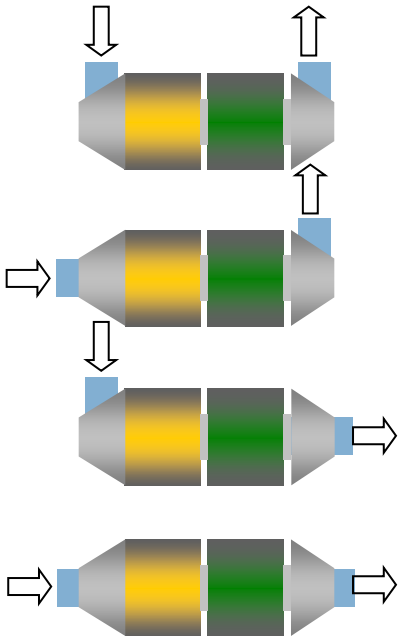
Pros and Cons

- 👍 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

The engine company. DEUTZ

- 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

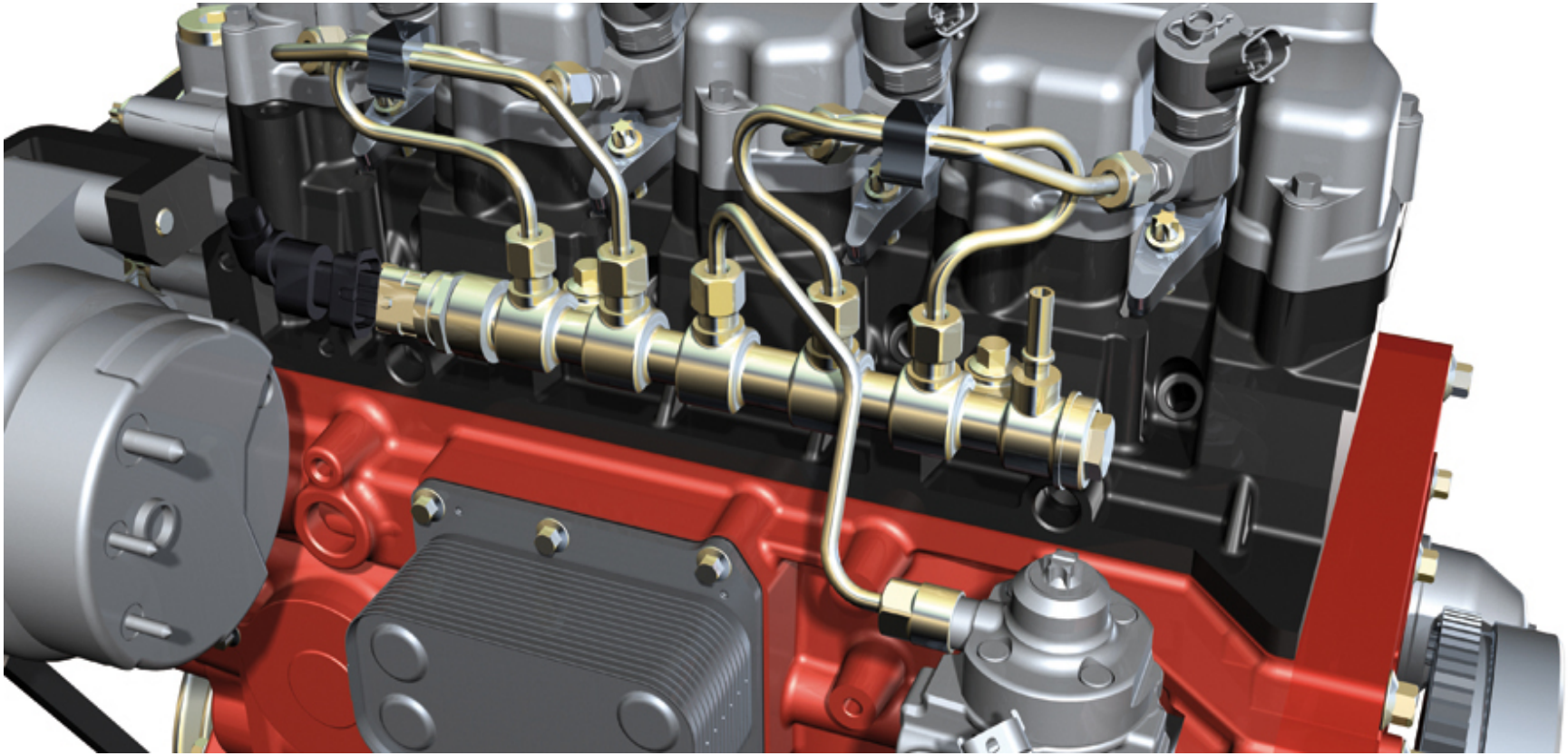


Model	Rated Power	Substrate diameter*	Substrate Length*		
			DOC	DOC / FT	DOC / CWT
D 2.9 L4	47 hp (35 kW)	7.5"	15.7"	-	NLA
TD 2.9 L4	74 hp (55 kW)	7.5"	21.0"	21.0"	NLA
TCD 2.9 L4	74 hp (55 kW)	7.5"	21.0"	-	NLA

* 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

DEUTZ®

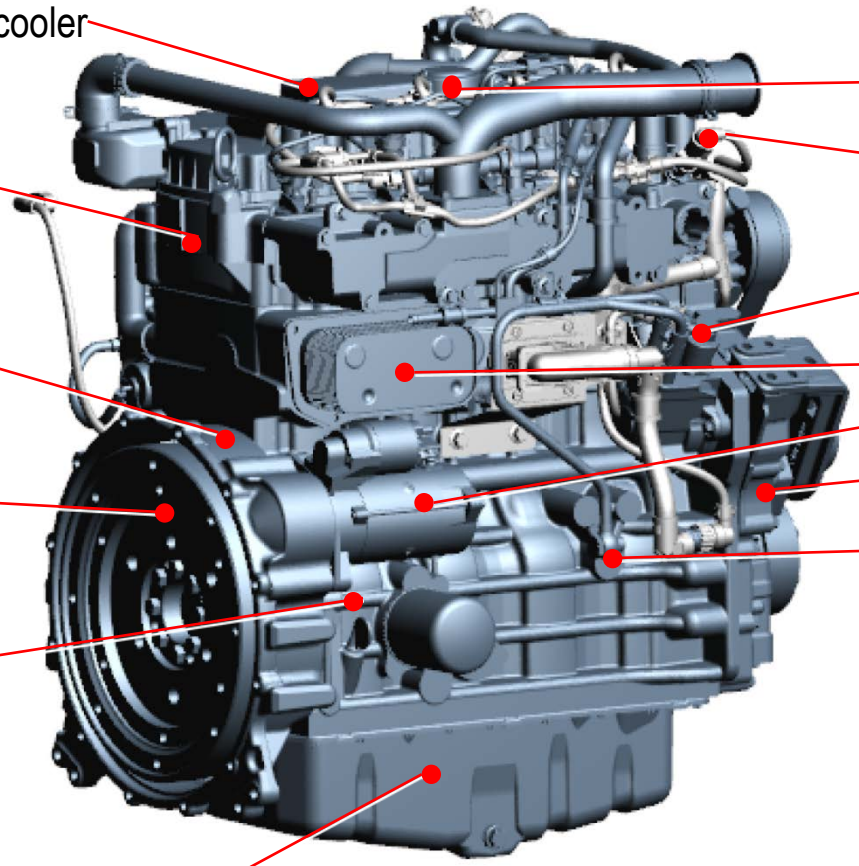
TCD 3.6 L4, Tier 4 Interim and final
General Product Information

The engine company. DEUTZ

- 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

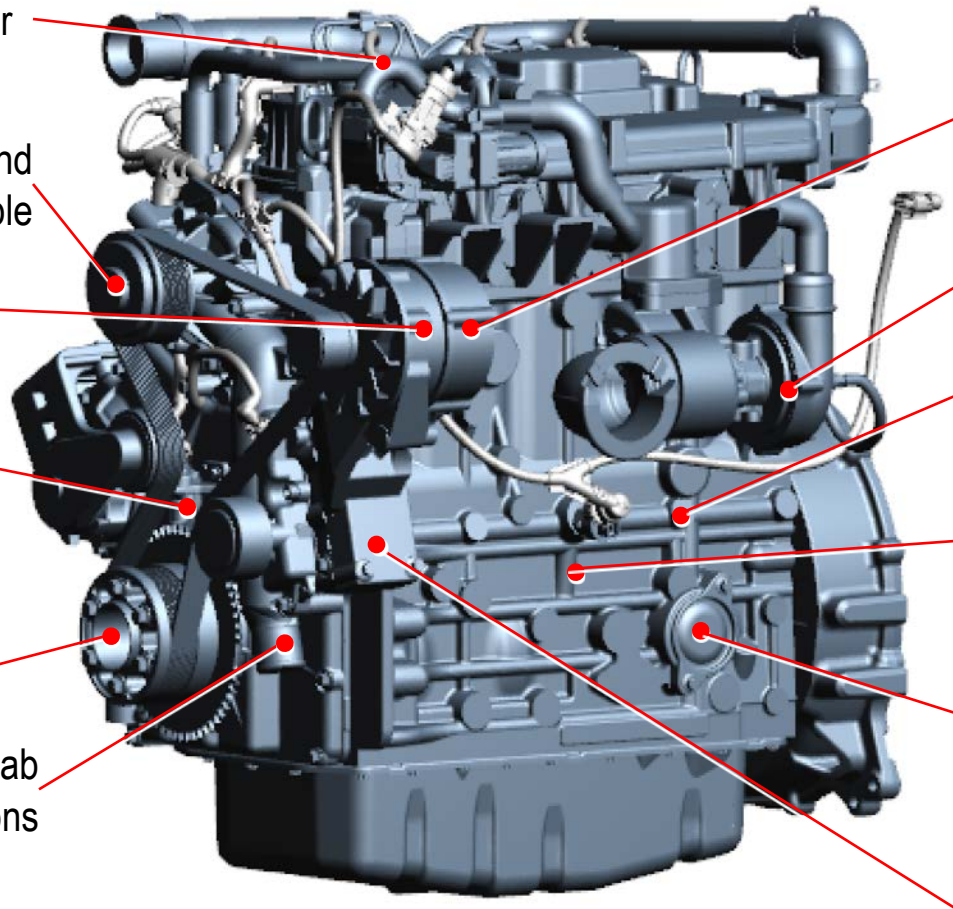
TCD 3.6 L4, Tier 4 Interim and final
General Product Features – right side

The engine company. DEUTZ



TCD 3.6 L4, Tier 4 Interim and final
General Product Features – left side

The engine company. DEUTZ



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

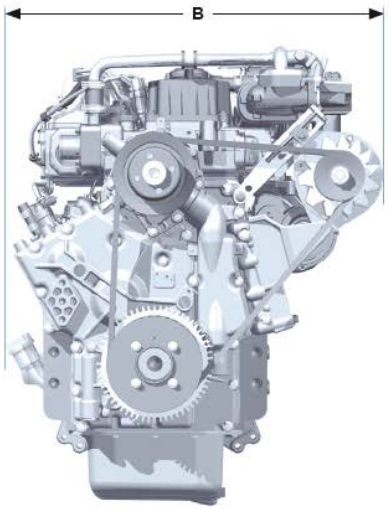
The engine company. DEUTZ

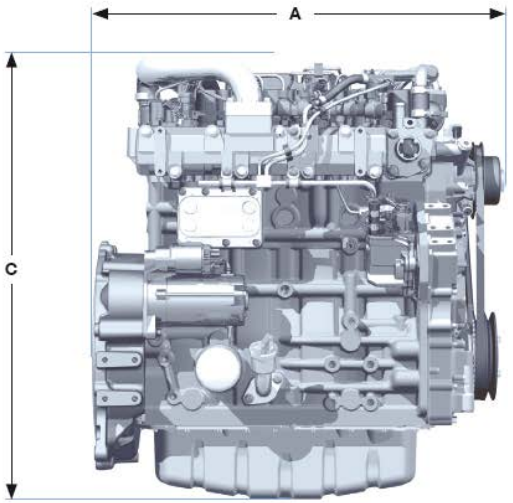
Number of cylinders		TD 3.6 L4	TCD 3.6 L4
Power	hp / kW	74.3 / 55.4	120 / 90.0
Rated speed	rpm	2,600	2,300
Maximum torque	lb-ft / Nm	243 / 330	354 / 480
Rated speed	rpm	1,600	1,600
Bore / Stroke	mm / inch	98 x 120 / 3.8 x 4.7	98 x 120 / 3.8 x 4.7
Single displacement	Liter	.905	.905
Total displacement	Liter	3.62	3.62
Specific fuel consumption	lb/hp-hr / g/kWh	.36 / 220 (TD) .34 / 210 (TCD)	.34 / 210
Weight	lb / kg	595 / 270	595 / 270

TCD 3.6 L4, Tier 4 Interim and final
Dimensions and Weight

The engine company. DEUTZ

- The information below reflects a standard engine and will vary by scope of supply and selected engine options.





In inch (mm)	A	B	C	Weight in lb (kg)
TD 3.6 L4	28.2 (716)	22.6 (573)	31.2 (792)	595 (270)
TCD 3.6 L4	28.2 (716)	22.6 (573)	31.2 (792)	595 (270)

TCD 3.6 L4, Tier 4 Interim and final
Design options

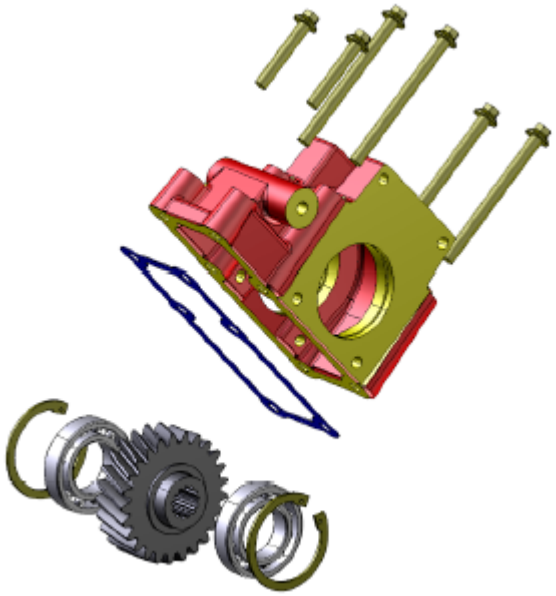
The engine company. DEUTZ

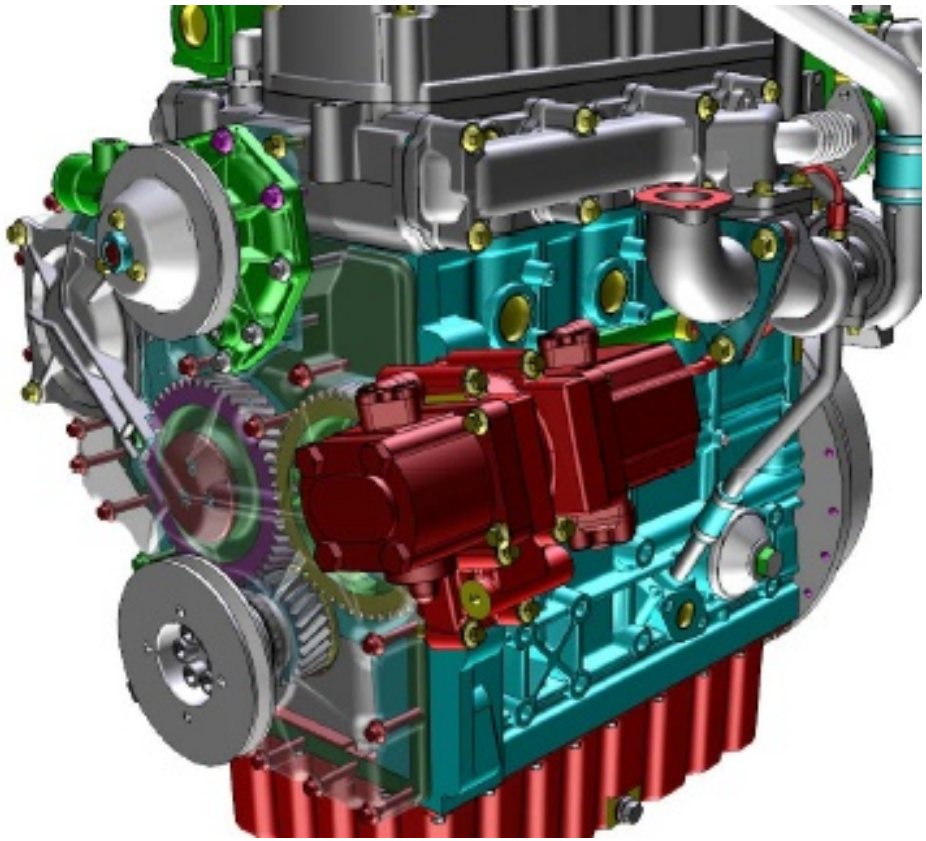
- Flywheel-end
  - SAE housings
    - Standard: SAE #4
    - Option: SAE #3
  - Flywheels
    - Current 2011 flywheel options
- Electrics
  - Standard is 12 V, optional 24 V is available
  - Standard Starter comes with 12 V, 2.3 kW
  - Standard Alternator has 14 V, 95 A
- Oil Filler / Oil Filter / Oil 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

The engine company. DEUTZ

- 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



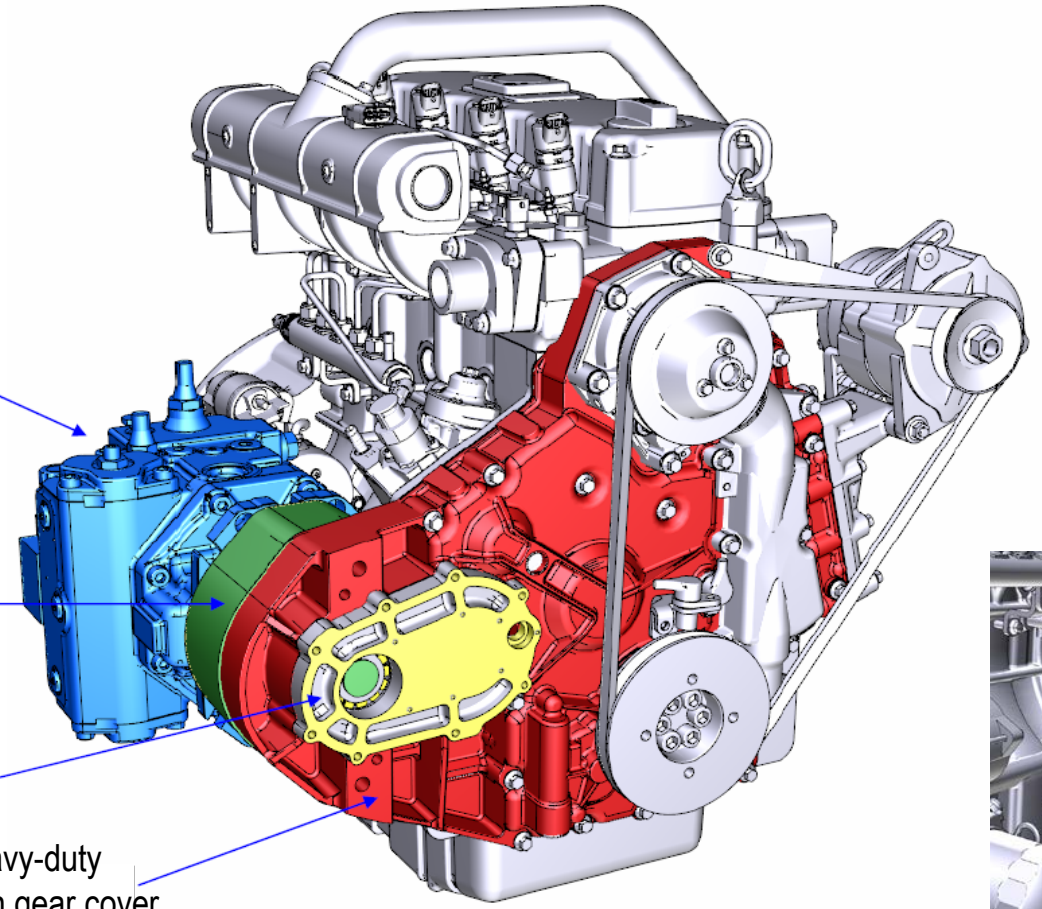


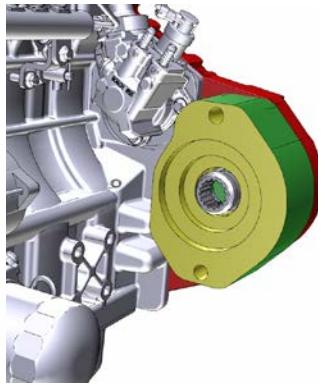
TCD 3.6 L4, Tier 4 Interim and final
Design options – 75 hp gear driven PTO

The engine company. DEUTZ

- Power take off offers a maximum output of 75 hp (56 kW) / 243 lb-ft (330 Nm)

Concept overview





TCD3.6L4 – Tier 3 with out EAT

The engine company. DEUTZ

	TCD3.6L4 Engine out measured (g-kW-hr)	Tier 3 Limit (g/kW-hr)	Tier 4i Limit (g/kW-hr)
NOx	2.3	4.0	3.4
HC	0.07	--	0.19
CO	0.5	5.0	5.0
PM	0.017	0.40	0.02

TCD 3.6 L4, Tier 4 interim and final
Exhaust Gas After Treatment (EAT)

The engine company. DEUTZ

DVERT Oxidation Catalyst (DOC)

DOC (DVERT Oxidation Catalyst)

- DOC oxidizes:
  - NO to NO_2: The oxidation of NO to NO_2 is known as exothermic reaction; the heat from this process can be used for regenerating a particle filter
  - HC and CO into H_2O, and CO_2
- 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 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

The engine company. DEUTZ

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

Rated Power	EAT Type	Dimensions		
		Outer diameter (D_O)	In- and Outlet (D_1)	Length (L)
Below 75 hp	DOC	7.5”	3.5”	15.7”

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

Rated Power	EAT Type	Dimensions		
		Outer diameter (D_O)	In- and Outlet (D_1)	Length (L)
Above 75 hp	DOC	7.5”	3.5”	21.0”