



Looking ahead to **TIER 4**



Where does **TIER 4** come from?

All emission standards, including Tier 4, are administered as a part of a federal law named the Clean Air Act. The purpose of this law is to reduce air pollution because of its hazards to human health and the environment. The Clean Air Act is managed and regulated by a federal agency known as the Environmental Protection Agency (EPA).

To better understand where the heavy equipment industry is headed, Doosan encourages you to learn about the history of Tier 4 – and the technology that makes it a reality.



1996-2015

Heavy equipment evolves to meet tiered emission standards, with Tier 4 being the final step in this process.

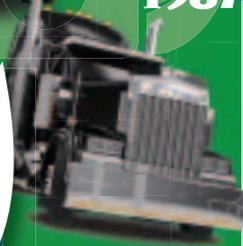
1994-2010

Cars and light trucks begin and complete an emissions reduction process. The end result is comparable to what Tier 4 will be for heavy equipment.



1987-2010

Heavy-duty trucks and buses begin and complete an emissions reduction process. The end result is comparable to what Tier 4 will be for heavy equipment.



London's Killer Fog

A toxic mix of fog and coal smoke – kills several thousand over a four-day span. The world changes its view of air pollution.



Donora, PA

For five days, a cloud of air pollution overtakes the industrial town of Donora, Pennsylvania, sickening 40% of the town. 20 die.

1952

The Motor Vehicle Pollution Act sets the first emissions reduction standards for automobiles.



EARTH DAY

1948

The Air Pollution Control Act of 1955 identifies air pollution as a national problem and provides funding for air quality improvement.

1955

1965

1963

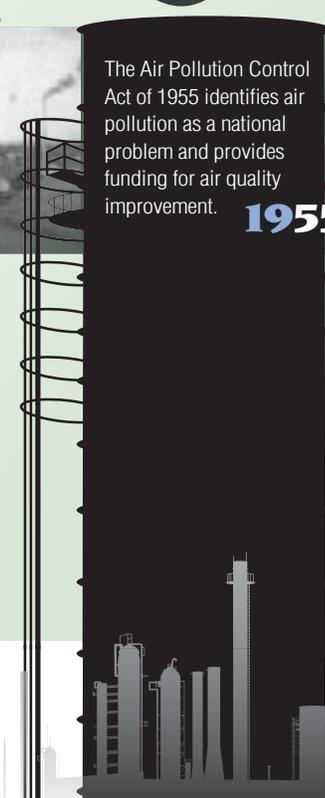
The Clean Air Act of 1963 sets emissions standards for stationary sources (power plants, steel mills, etc.) and recognizes the danger of motor vehicle exhaust.

1970

Emission standards broaden and become more stringent for automobiles and stationary sources, such as factories. Congress creates the EPA in part to assist with the implementation of these expanded standards.

1975

As a result of emissions standards set in 1970, catalytic converters begin to appear on automobile exhaust systems.



Emissions Evolution of Doosan Equipment

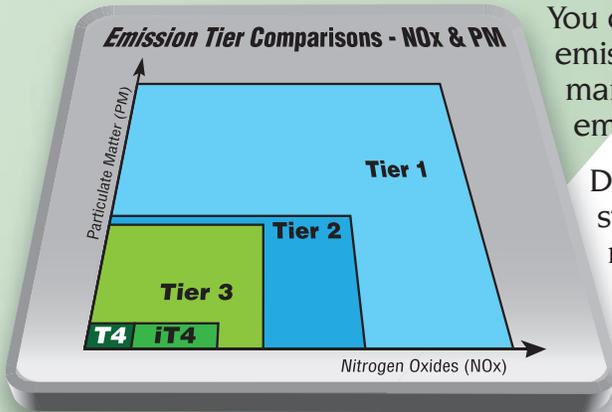


CHART 1

You don't have to retrofit your machines to the current emission standards. Federal regulations require that manufacturers build machines compliant with the emission standards in effect at the time of manufacture.

Doosan® machines have been changing to meet emission standards for several years. Many Doosan equipment models will go through as many as five different tiers of standards: Tiers 1-3, Interim Tier 4 (iT4) and Tier 4 (T4).

Standards for diesel exhaust emissions become **more stringent** from tier to tier. Each tier addresses numerous types of pollutants. However, Particulate Matter (PM) and Nitrogen Oxides (NOx) receive the most attention. Chart 1 explains how NOx and PM are reduced through each emission tier.



Nitrogen Oxides (NOx) are a contributor to ground level ozone, or smog.

TIER 1 for Doosan Equipment

The first set of EPA emission standards for new non-road diesel engines is referred to as Tier 1. The main goal of this emission tier was to reduce Nitrogen Oxides (NOx) emissions from these engines by roughly 30%.

For Doosan equipment, Tier 1 compliancy was ushered in from 1996-2003. Actual dates varied by engine horsepower as shown in chart 2.

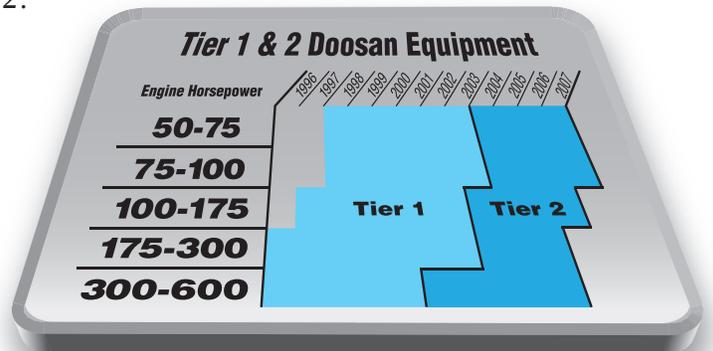


CHART 2

TIER 2 for Doosan Equipment

The second set of EPA emission standards for new non-road diesel engines is referred to as Tier 2. Major focus was on NOx, hydrocarbons (HC) and particulate matter (PM). PM reductions were as much as 25% on some engines.

Like Tier 1, the date range for Tier 2 compliancy varied by engine horsepower. Those dates, as they apply to Doosan equipment, are shown in chart 2.



Particulate matter consists of soot or unused fuel found in exhaust. This type of pollution gives dirty engine exhaust its black color.

TIER 3 for Doosan Equipment

The third set of emission standards adopted and regulated by the EPA for new, non-road diesel engines is referred to as Tier 3. These standards applied to Doosan models with engines of more than 75 horsepower, as shown in Chart 3 below. Again, NOx was the primary focus of Tier 3 with reductions of up to 39%.

How did Tiers 1-3 impact Doosan equipment?

Doosan machines span a vast range of different horsepower levels. For example, the Doosan excavator line alone ranges from 51 to 463 horsepower. Understandably, changes to equipment varied considerably, depending on the size of engine used.

As a whole, major changes to Doosan equipment included turbo charging, improvements to the engine combustion system and use of high-pressure common rail fuel injection (HPCR) systems.

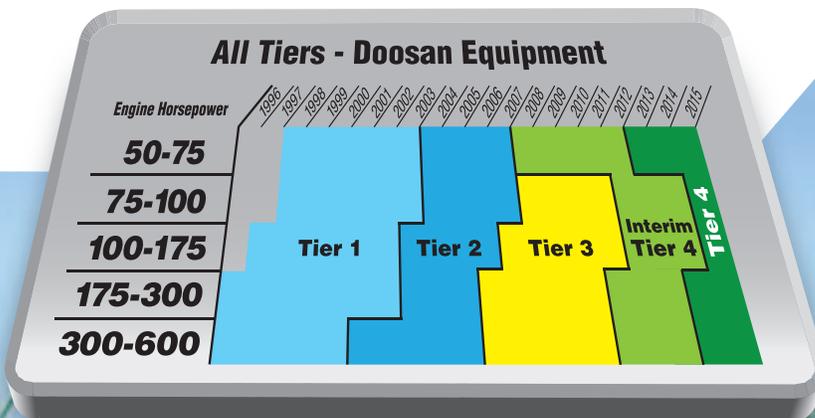


CHART 3

Interim TIER 4 (iT4) & TIER 4 (T4) for Doosan Equipment

iT4 compliancy deadlines for Doosan equipment started in 2008 (50-75 hp engines) and will continue for larger engines until 2012. T4 compliancy deadlines will span 2013-2015. Similar to previous emission tiers, further reductions to NOx and PM will be the main objective.

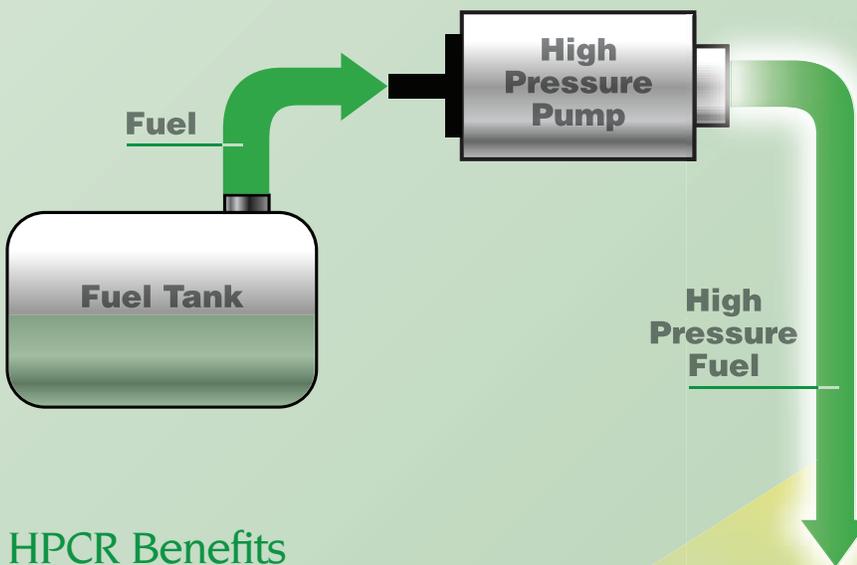
Engine Size	iT4 Compliancy Date	T4 Compliancy Date	New Systems Needed for iT4 Compliance?	New Systems Needed for T4 Compliance?
50-75 hp	Compliant	2013	Compliant	Yes
75-100 hp	2012	2015	Yes	Yes
100-175 hp	2012	2015	Yes	Yes
175-300 hp	2011	2014	Yes	Yes
300-600 hp	2011	2014	Yes	Yes

High-Pressure Common Rail Fuel System (HPCR)

The fuel injection system is a major area of focus for advancement towards clean operating diesel engines. **HPCR** is an advanced fuel injection design that better regulates **fuel pressure** and **injection timing**.

Fuel Pressure

- The pump applies high pressure to fuel (22,000 – 34,000 psi)
- The common rail stores pressurized fuel
- The injectors deliver fuel to the engine



Tier 4 is more than just emissions. It's about changing the world for the better.

Injection Timing

The electronic control unit (ECU) precisely controls injectors to allow multiple fuel injections during each combustion cycle.

Electronic Control Unit (ECU)

HPCR was added to many Doosan machines in Tier 3. Its ECU is critical for future iT4 and T4 technologies.

HPCR Benefits

High pressure transforms fuel into extremely fine mist as it leaves the injectors. Fuel mist combusts (burns) more thoroughly.

Lower Operating Costs

When fuel combusts more thoroughly, less fuel is needed to run the engine. The result is improved fuel economy.

Cleaner Exhaust

More thorough combustion leaves less leftover fuel in the exhaust. The result is cleaner exhaust.

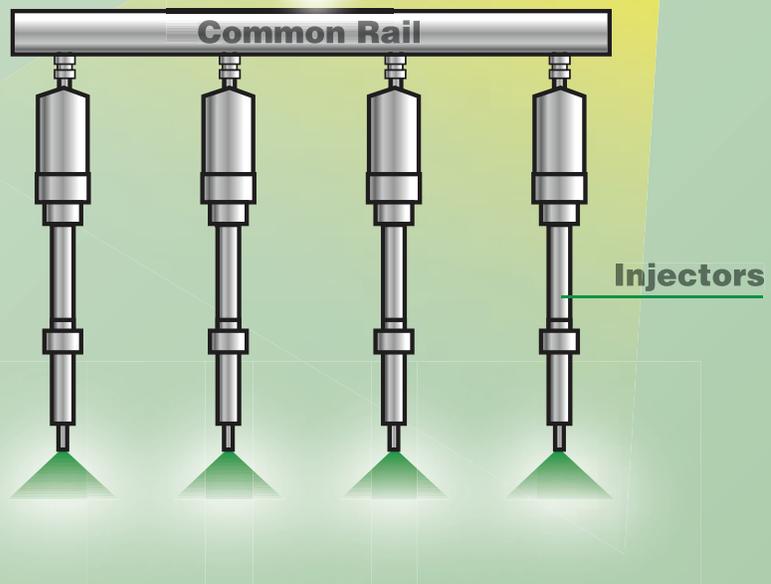
When fuel is injected multiple times during each combustion cycle, the combustion lasts longer to create more energy and lower peak engine cylinder pressure.

Better Performance

Creating more energy during combustion results in more torque output from the engine.

More Operator Comfort

Lower peak engine cylinder pressure reduces engine noise levels.



Diesel exhaust from engine combustion flows out of engine

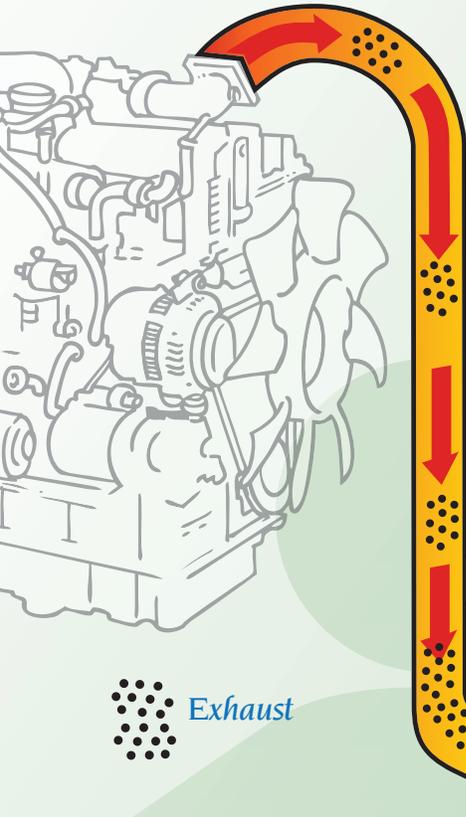
Interim Tier 4 and Tier 4 After-

Diesel Oxidation Catalysts (DOC) & Diesel Particulate Filters (DPF)

DOC/DPF systems are highly effective at reducing particulate matter (PM) contained in engine exhaust.

The DOC

Engine exhaust is **transformed** by the DOC to reduce PM. The DOC is a special catalyst that reacts with engine exhaust upon contact. The reaction transforms PM emissions in the exhaust into harmless substances such as water and carbon dioxide.



Exhaust

Diesel exhaust with heavier particulate matter concentration goes in

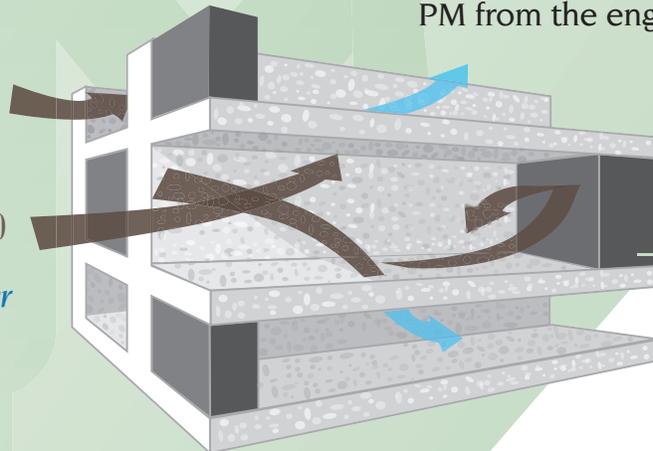
Cleaner diesel exhaust with lower particulate matter concentration comes out

The DPF

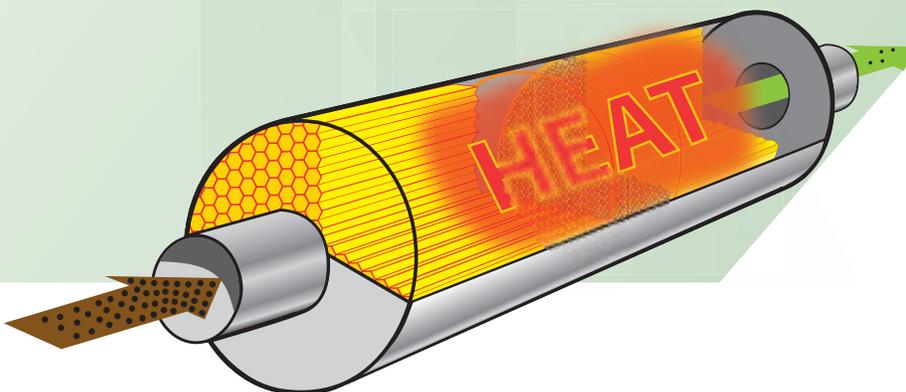
Engine exhaust is **filtered** by the DPF to reduce PM. The DPF is a special "ceramic wall flow" filtration system that further separates PM from the engine exhaust.

Wall Flow Filter

Dirty exhaust (brown arrows) passes through filter walls. PM is left behind and cleaner exhaust (blue arrows) exits.



Barriers exist to ensure exhaust passes through filter walls.



DPF Regeneration

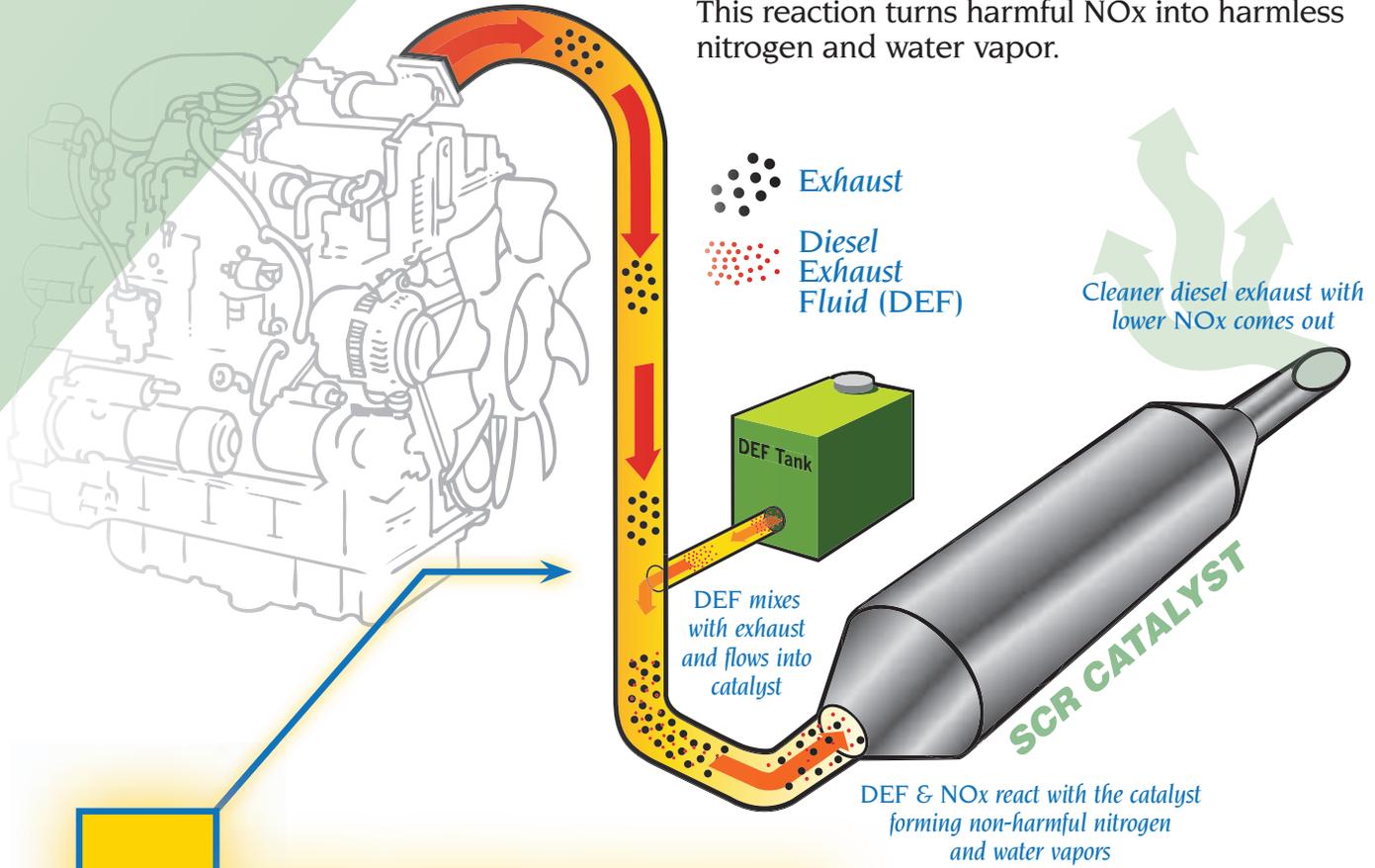
To keep the DPF clean and working efficiently, the high temperature of the exhaust itself is used to burn accumulated PM off of the DPF. This DPF cleaning process is called "regeneration."

Treatment TECHNOLOGIES

Selective Catalyst Reduction (SCR)

Engine exhaust is **transformed** by SCR to reduce nitrogen oxides (NOx). SCR uses an ammonia and water-based liquid called Diesel Exhaust Fluid (DEF). Combining exhaust with DEF causes it to react with a SCR catalyst. This reaction turns harmful NOx into harmless nitrogen and water vapor.

Exhaust from engine combustion flows out of engine

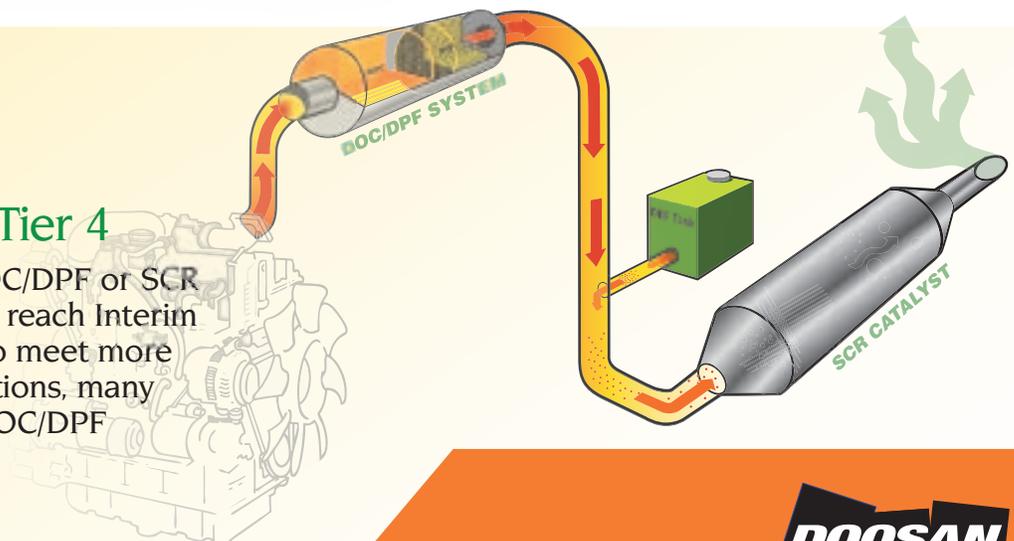


ECU

HPCR is critical to after-treatment systems. The ECU controls and monitors regeneration and DEF mixture.

Teaming up for Tier 4

In many situations, DOC/DPF or SCR systems are enough to reach Interim Tier 4 requirements. To meet more stringent Tier 4 regulations, many machines will utilize DOC/DPF and SCR together.



DOOSAN

Health and Environment Benefits for All Tiers

Tier 4 is more than just emissions. It's about changing the world for the better. Doosan is working hard with the entire equipment industry to do our part.

- Standards for Tiers 1-3 reduce emissions from a typical non-road diesel engine by up to two-thirds.
- The EPA estimates that in 2010, NOx emissions will be reduced by about a million tons per year – the equivalent of taking 35 million cars off the road.
- Respiratory problems and disease caused by ozone and PM will decline – as will acid rain, crop damage and smog.
- By 2030, the EPA estimates that 12,000 deaths, 8,900 hospitalizations and one million lost work days will be prevented annually.



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