

Cat Common Rail – The Benefits

With Cat Common Rail, the injection pressure is independent from load and speed. Utilizing injection maps the injection characteristics are optimized for every engine operating point.

For areas that are especially emissions-sensitive, soot emissions at low engine load remain well below the visibility limit. Furthermore, during normal load operation NO_x emissions can be reduced without sacrificing fuel consumption. Depending on application, as well as operating conditions, engines equipped with Cat Common Rail fuel system technology can positively impact the transient response.

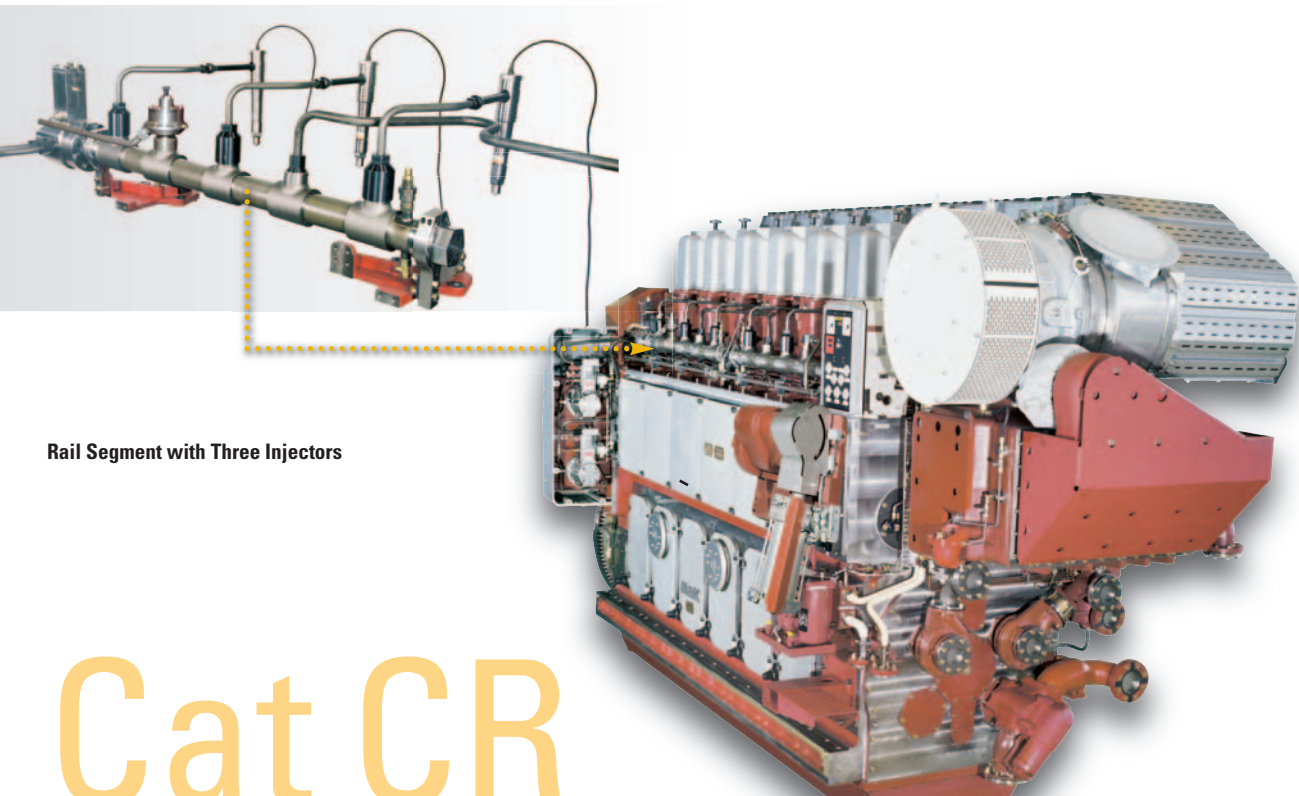
In general, the Cat Common Rail fuel system enables vessel operation without visible soot throughout the whole operating range.

In addition to that, the fuel system is capable of multiple injection. Multiple injection allows optimal combustion and low emissions at all loads. Characteristic of Cat Common Rail is the approach of using the fuel (whether it's heavy fuel oil, marine diesel oil or diesel oil) as the control fluid for the injector, thus avoiding the added complexity of a separate control fluid system.

During the development, the retrofit aspect of the complete system has been emphasized. As a result, the Cat Common Rail fuel system can be retrofitted to existing M32C engines. This means increased customer value to reach future environmental regulations.

Significant decrease of specific fuel oil consumption:

- for main propulsion engine M 32 C with Cat CR up to 3% improvement,
- for generating set M 32 C with Cat CR up to 2% improvement,
- optimized combustion.



Rail Segment with Three Injectors

Cat CR



Caterpillar Marine Power Systems

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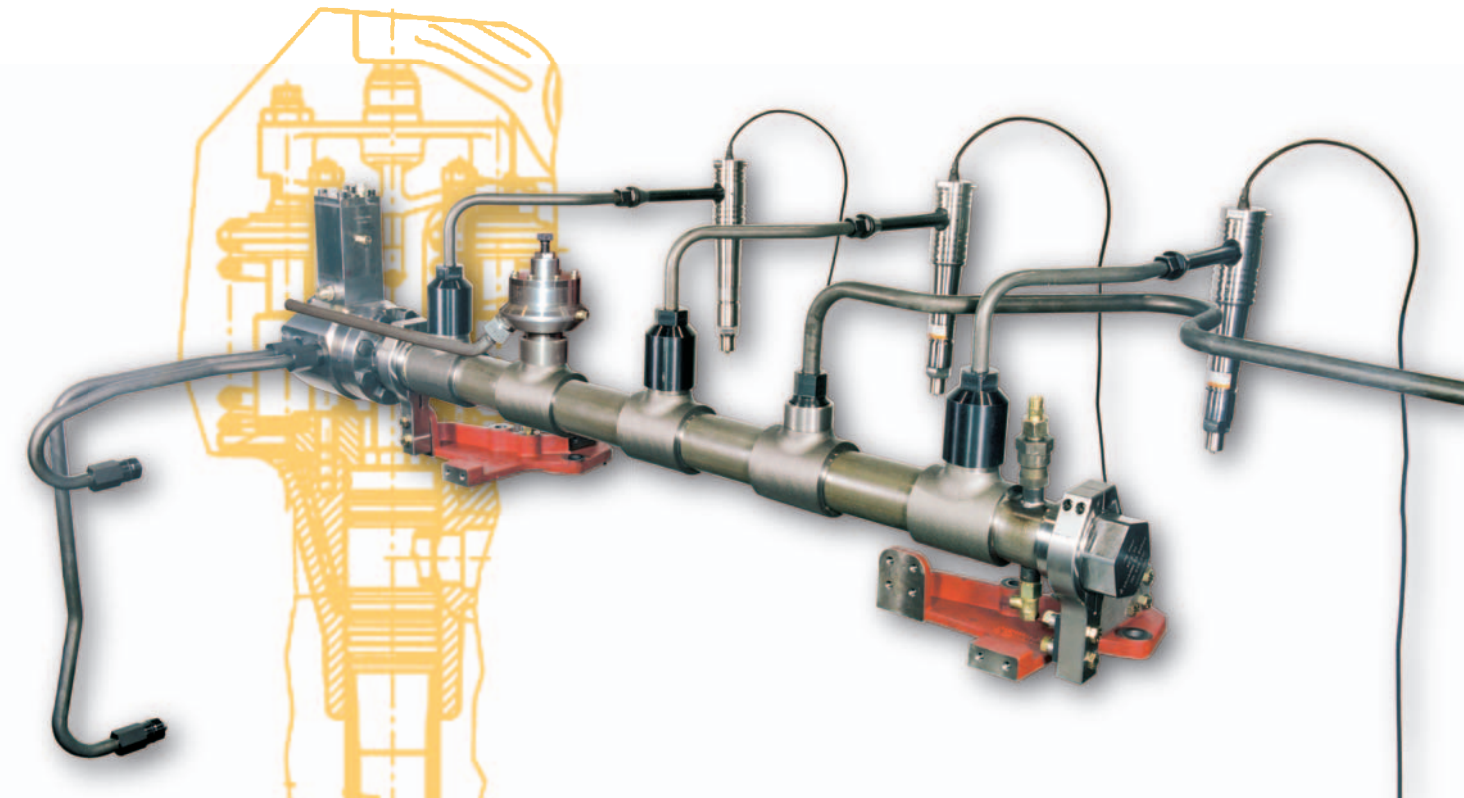
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Cat® Common Rail

Less Fuel and Reduced Emissions Mean More Environmental Care



Cat Common Rail – Fuel System

From its introduction the MaK long-stroke generation of main diesel engines has been recognized for good performance and reasonable fuel consumption, alongside outstanding reliability and long component life. MaK engines are compliant with current emission regulations without the need for additional aftertreatment. To fulfil the upcoming emission legislations the development of new combustion process supporting technologies is necessary.

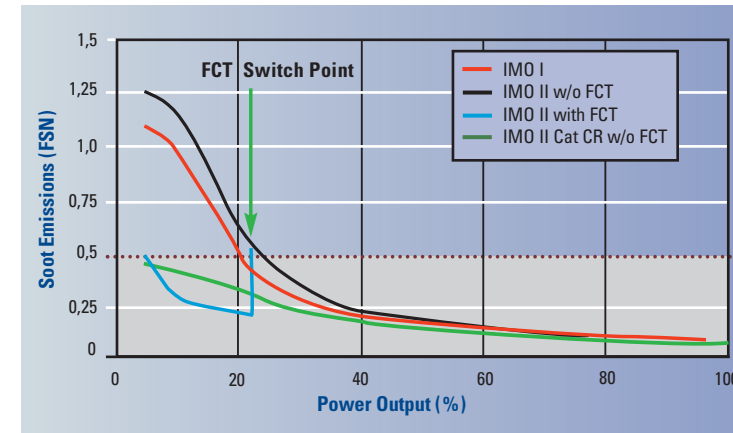
Caterpillar has made a huge investment to develop an emission reduction technology now marketed as ACERT® Technology for Caterpillar high-speed engines. After a successful demonstration in the on-highway high-speed engines, Caterpillar embarked on a stepwise migration of selected elements of ACERT® Technology across the entire product line and range of applications. The broad range of Caterpillar's marine program calls for a differentiated approach.

Key criteria are:

- Prevailing emission limits for the respective power range and timing of their introduction.
- Customer expectations in terms of engine performance, maintenance practices, fuel quality and mode of operation.

By adopting well proven elements of this technology for medium-speed engines, it is our goal to meet and exceed customer expectations by maximizing product value through:

- Superior reliability in heavy fuel operation.
- Best fuel efficiency in its class.
- Lowest engine emissions with minimum additional complexity.



Soot Emission of M32 C Cat CR, IMO II, constant speed

Visibility Limit

The goals are:

- Invisible smoke under all engine operating conditions.
- Reduce emissions beyond current and future IMO regulations, offering an attractive technology for emissions sensitive areas.
- Maintain or improve engine performance by taking advantage of the capabilities and benefits of a fully flexible fuel system.
- Continue to meet the level of reliability in heavy fuel operation expected by our marine customers.

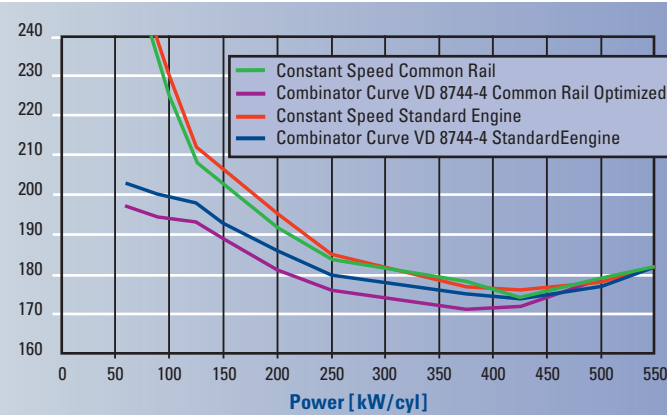
Keeping in mind the high reliability expectations of customers, Caterpillar decided to adopt a two step approach providing the most effective solutions with lowest complexity.

Flexible Camshaft Technology (FCT) has been developed and put into production. The next milestone in emissions technology is a fully flexible fuel system suitable for HFO, MDO and DO, called the Cat Common Rail (Cat CR) fuel system. Cat Common Rail is considered one major building block towards low emissions, high performance and highest customer value.

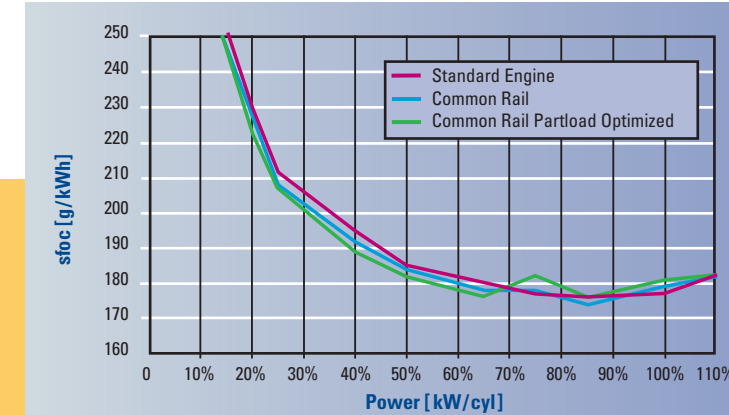
Less Fuel and Reduced Emissions Mean More Environmental Care:

Specific Fuel Oil Consumption M 32 C Cat CR IMO II (from 0,6% up to 3% Improvement)

Specific Fuel Oil Consumption M 32 C Cat CR @ 600 rpm (from 1% up to 2% Improvement)



Main Propulsion (Inline engine M 32 C Cat CR with kW/cyl, @ 600 rpm; ISO 3046/1 and LCV 42,7 MJ/kg; 5% tolerance, + 1% engine driven pump). Values for information only.



Generator Set (6, 8 and 9 M 32 C Cat CR IMO II; SFDC acc. ISO 3046/1, LCV 42,7 MJ/kg; 5% tolerance, + 1% engine driven pump). Values for information only.

Cat Common Rail – Technology

Caterpillar has chosen "inside the engine" measures as the technology with the highest customer value. In combination with the long-stroke concept and high performance air systems the Cat Common Rail (Cat CR) fuel system is the most effective technology to meet emission regulations and customer expectations.

The key features of the Cat Common Rail technology are:

- Well adapted injection pressure over the entire engine operating range.
- Fully flexible fuel injection system enabling optimized emissions and engine performance.
- Suitable for HFO, MDO and DO.
- 100% retrofittable system.

■ Cat CR System

The main components of the Cat Common Rail fuel system are a high pressure (HP) pump, rail, injector and electronics. Caterpillar's broad experience with electronically controlled engines, range of product lines and in-house design and analysis expertise allow for a unique system approach. All components are developed under Caterpillar design control.

In addition Caterpillar's expertise in electronics is a major asset to the Cat Common Rail technology.

■ Safety Concept

Safety considerations and high customer value were the main focus throughout the development, resulting in a state-of-the-art design with the following features:

- Two high pressure pumps for redundancy.
- Double-walled lines and rails.

Furthermore, redundant speed pick-ups and pressure sensors, a safety gear between pump and engine, a pressure relief valve and flow limiters all increase operational safety.

■ High Pressure Pump

Two high pressure pumps deliver the required amount of fuel to the rail and provide the desired rail pressure in closed loop control. The pump itself is based on a proven design and has been modified for HFO operation. By having two pumps for all in-line engines the amount of HP connections and components is drastically reduced and thus increases reliability. The inlet metering control of the pump ensures a high pump efficiency. The key features are:

- Two pumps for redundancy.
- Inlet metering control.
- Well adapted injection pressure.
- Closed loop control of rail pressure.

■ Rail

The double-walled rails are pressurized and act as an accumulator, with one rail segment feeding fuel to three injectors, i. e. a nine cylinder engine has only three rail segments, an eight cylinder engine has two rail segments, each feeding four injectors. This layout reduces the number of parts and the number of high pressure connections. Flow limiters prevent the cylinders from overfueling; a safety valve acts as pressure relief in case of an unwanted overpressurized rail.

Pump Drive



Rail and Cylinder



Cat Common Rail – Technology

■ Injector

Caterpillar has chosen a simple and robust approach by using the actual fuel as control fluid, thereby eliminating the need for a separate control fluid system. The injector nozzle is cooled by lube oil, a typical feature for heavy fuel operation. For the Cat CR injector, the lube oil circuit has been extended to provide cooling to the electrical components within the injector, thereby increasing the lifetime. The injector design is simple, robust and compact; the key features are:

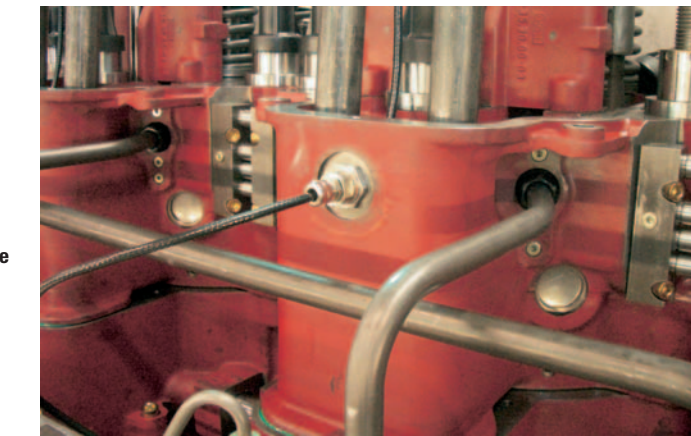
- Electronically controlled.
- Flexible injection timing and duration.
- Capability of multi shot injections.

■ Electronics

The key component is the Caterpillar A4E4 (or ADEM™) Electronic Control Module (ECM). The ECM acts as the brain of the Cat Common Rail fuel system. Pioneered by Caterpillar 20 years ago, the ADEM™ controller coordinates and enhances fuel delivery, air supply and other engine functions to maximize overall performance and reduce emissions output.

Having in-house expertise for core electronic components and software puts Caterpillar in a unique position and allows for an advantageous systems approach.

Based on existing software and engine control strategies, the specific needs of heavy fuel burning engines and applications can be easily adopted. Depending on engine type, application and boundary conditions, a tailor made version allows for optimal operation.



Injector Cable



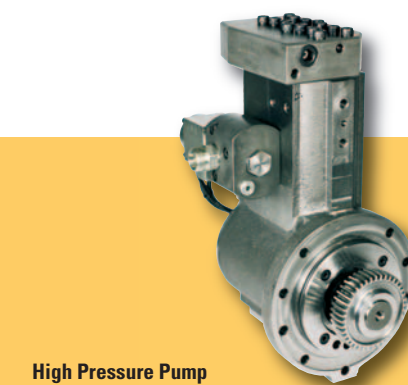
Injector

The engine protection system operates independently of the engine control system and has its own independent sensor equipment. This ensures that engine operation is monitored independently of other control systems.

The ECM functions can be divided into a core system and a performance system.

- The core system consists of:
- Control device A4E4.
 - One crankshaft speed pick-up.
 - Two camshaft speed pick-ups.
 - Two high-pressure sensors.
 - Inlet metering valve.
 - Injector drivers.

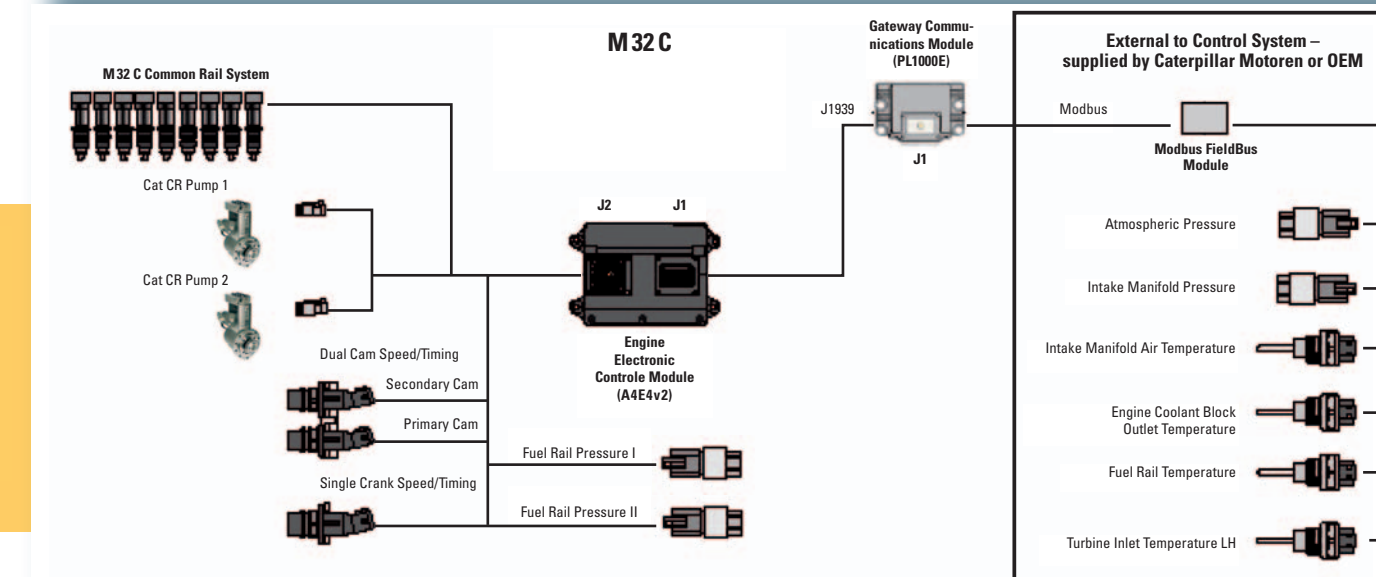
The performance system ensures optimal engine settings under all operating conditions, using information like exhaust gas temperature, charge air pressure, ambient conditions and lube oil temperature.



High Pressure Pump



Safety Gear



Control Device A4E4