

Unit injector

A **unit injector (UI)** is a high-pressure integrated direct [fuel injection](#) system for [diesel engines](#), combining the [injector nozzle](#) and the [injection pump](#) in a single component. The [plunger pump](#) used is usually driven by a shared [camshaft](#). In a unit injector, the device is typically lubricated and cooled by the fuel itself.

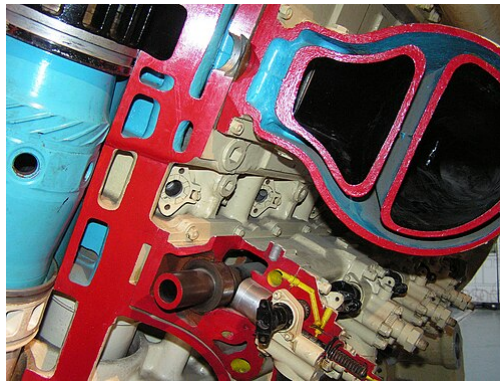


Early [Lucas](#) electronic [diesel](#) unit injector

High-pressure injection delivers power and fuel consumption benefits over earlier lower-pressure fuel injection by injecting fuel as a larger number of smaller droplets, giving a much higher ratio of surface area to volume. This provides improved vaporisation from the surface of the fuel droplets and so more efficient combining of atmospheric oxygen with vaporised fuel, delivering more complete and cleaner combustion.

History

In 1911, a patent was issued in [Great Britain](#) for a unit injector resembling those in use today to [Frederick Lamplough](#).^[1]



[Napier Deltic](#) opposed-piston two-stroke, sectioned. The unit injectors are low down, below the yellow fuel passages, driven by a camshaft to their left and injecting into the centre of the [cylinder liner](#) (pale blue).

Commercial usage of unit injectors in the [U.S.](#) began in early 1930s on [Winton](#) engines powering locomotives, boats, even [US Navy](#) submarines,^[2] and in 1934, Arthur Fielden was granted U.S. patent No.1,981,913^[3] on the unit injector design^[4] later used for the [General Motors two-stroke diesel engines](#). Most mid-sized diesel engines used a single pump and separate injectors, but some makers, such as [Detroit Diesel](#)^[5] and [Electro-Motive Diesel](#) became well known for favouring unit injectors, in which the high-pressure pump is contained within the injector itself. E.W. Kettering's 1951 ASME presentation goes into detail about the development of the modern Unit injector.^[6] Also Cummins PT (pressure-time) is a form of unit injection where the fuel injectors are on a common rail fed by a low-pressure pump and the injectors are actuated by a third lobe on the camshaft. The pressure determines how much fuel the injectors get and the time is determined by the cam.

In 1994, [Robert Bosch GmbH](#) supplied the first [electronic unit injector](#) for commercial vehicles, and other manufacturers soon followed. In 1995, Electromotive Diesel converted its [710](#) diesel engines to electronic fuel injection, using an [EUI](#) which replaces the UI.

Today, major manufacturers include [Robert Bosch GmbH](#), [CAT](#),^[7] [Cummins](#),^[8] [Delphi](#),^{[9][10]} [Detroit Diesel](#), [Electro-Motive Diesel](#).^[11]

Design and technology

The design of the unit injector eliminates the need for high-pressure fuel pipes, and with that, their associated failures, as well as allowing for much higher injection pressure to occur. The unit injector system allows accurate injection timing, and amount of control as in the [common rail](#) system.^[12]

The unit injector is fitted into the engine [cylinder head](#), where the fuel is supplied via integral ducts machined directly into the cylinder head. Each injector has its own pumping element, and in the case of electronic control, a fuel [solenoid valve](#) as well. The fuel system is divided into the

low-pressure (<500 kPa) fuel supply system, and the high-pressure injection system (<2000 bar).^[13]

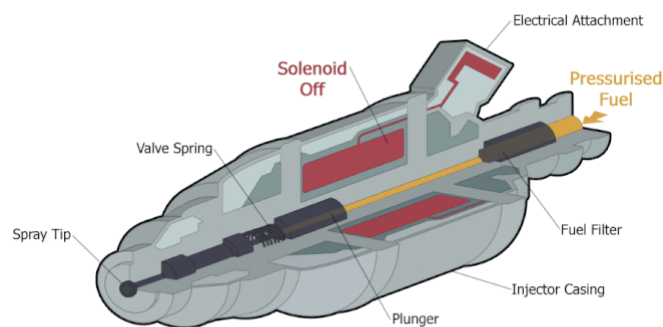
Technical characteristics:

- The special feature of the unit injector system is that an individual pump is assigned to each cylinder
- The pump and nozzle are therefore combined in a compact assembly which is installed directly in the cylinder head
- The unit injector system enables high injection pressures up to 2,200 bar.

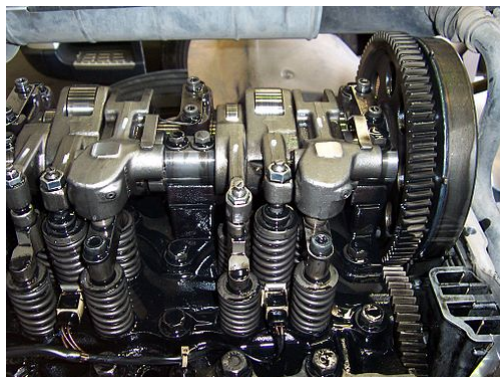
Advantages:

- High performance for clean and powerful engine
- High engine power balanced against low consumption and low engine emissions
- High degree of efficiency due to compact design
- Low noise level due to direct assembly in the engine block
- Injection pressures up to 2,200 bar for the ideal combination of air-fuel mixture.

Operation principle



Animated cut through diagram of a typical fuel injector (click to see animation)



Delphi E1 UI on the Volvo D13A engine



Delphi E1 unit injector parts

The basic operation can be described as a sequence of four separate phases: the *filling phase*, the *spill phase*, the *injection phase*, and the *pressure reduction phase*.

A low-pressure [fuel delivery pump](#) supplies [filtered diesel fuel](#) into the [cylinder head](#) fuel ducts, and into each injector fuel port of constant stroke pump plunger injector, which is [overhead camshaft](#) operated.

Fill phase

The constant stroke pump element on the way up draws fuel from the supply duct in to the chamber, and as long as the electric [solenoid valve](#) remains de-energized the fuel line is open.

Spill phase

The pump element is on the way down, and as long as the solenoid valve remains de-energized the fuel line is open and fuel flows in into the return duct.

Injection phase

The pump element is still on the way down, the solenoid is now energised and the fuel line is immediately closed. The fuel cannot pass back into the return duct, and is now compressed by the plunger until pressure exceeds specific “opening” pressure, and the injector nozzle needle lifts, allowing fuel to be injected into the [combustion chamber](#).

Pressure reduction phase

The plunger is still on its way down, the [engine ECU](#) de-energizes the solenoid when the required quantity of fuel is delivered. The fuel valve opens, fuel can flow back into the return duct, causing the pressure to drop. Which in turn causes the injector nozzle needle to shut; hence no more fuel is injected.

Summary

The start of an injection is controlled by the solenoid closing point, and the injected fuel quantity is determined by the closing time, which is the length of time the solenoid remains closed. The solenoid operation is fully controlled by the engine ECU.

Additional functions

The use of electronic control allows for special functions; such as temperature controlled injection timing, cylinder balancing (smooth idle), switching off individual cylinders under part

load for further reduction in emissions and fuel consumption, and multi-pulse injection (more than one injection occurrence during one engine cycle).

Usage & Applications

Unit injector fuel systems are being used on a wide variety of vehicles and engines; [commercial vehicles](#) from manufacturers such as [Volvo](#), [Cummins](#), [Detroit Diesel](#), [CAT](#), [Navistar International](#) and passenger vehicles from manufacturers such as [Land Rover](#) and [Volkswagen Group](#), among others, and [locomotives](#) from [Electromotive Diesel](#).



Bosch UI on a Scania R164 V8 engine

The Volkswagen Group mainstream [marques](#) used unit injector systems (branded "**Pumpe Düse**",^[14] commonly abbreviated to "**PD**") in their [Suction Diesel Injection](#) (SDI) and [Turbocharged Direct Injection](#) (TDI) [diesel engines](#),^[15] however this fuel injection method has been superseded by a common-rail design, such as the new 1.6 TDI.

In [North America](#), the [Volkswagen Jetta](#), [Golf](#), and [New Beetle](#) TDI 2004–2006 are *Pumpe Düse*^[16] (available in both the MK4 and MK5 generations, with BEW and BRM engine codes respectively, older models use timing belt-driven injection pump).

TDI engines incorporating PD unit injector systems manufactured by the Volkswagen Group were also installed on some cars sold in Europe and other markets where the diesel fuel was conveniently priced, amongst those there were some Chrysler/Dodge cars of the DaimlerChrysler era, e.g. the [Dodge Calibre](#) (MY07 BKD, MY08 BMR), [Dodge Journey](#), [Jeep Compass](#), [Jeep Patriot](#).

Volkswagen Group major-interest [truck](#) and diesel engine maker [Scania AB](#) also uses the unit injector system, which they call "*Pumpe-Düse-Einspritzung*", or "**PDE**".

Hydraulically actuated electronic (HEUI) development and applications

In 1993, [CAT](#) and [International Truck & Engine Corporation](#)^[17] introduced "hydraulically actuated electronic unit injection" (HEUI), where the injectors are no longer [camshaft](#)-operated and could

pressurise fuel independently of engine RPM. First available on [Navistar's 7.3L /444 cuin, V8 diesel engine](#). HEUI uses engine oil pressure to power high-pressure fuel injection, where the usual method of unit injector operation is with the [engine](#) camshaft.

HEUI applications included the Ford 7.3L and 6.0L [Power stroke](#) used between May 1993 and 2007. International also used the HEUI system for multiple engines including the [DT 466E](#), DT 570, [T-444E](#), DT-466–570, MaxxForce 5, 7, 9, 10, MaxxForce DT and VT365 engines. [Caterpillar](#) incorporated HEUI systems in the 3116, 3126, C7, C9 among others and the Daimler-Detroit Diesel Series 40 engine supplied by International also incorporated a HEUI fuel system. Isuzu fitted a HEUI system to their 3.0 LTR 4JX1 engine fitted to the Trooper and its variants. The HEUI system has been replaced by many manufacturers with [common rail](#) injection solutions, a newer technology, to meet better fuel economy and new emissions standards being introduced.

See also

- [Anti-dribble valve](#)
- [Unit pump](#)

Notes

1. DeLuca, Frank. "History of fuel injection" (<https://web.archive.org/web/20110516052152/http://www.disa.it/pdf/01HystoryOfDieselFuelInj.pdf>) (PDF). *www.disa.it*. Archived from the original (<http://www.disa.it/pdf/01HystoryOfDieselFuelInj.pdf>) (PDF) on 16 May 2011. Retrieved 28 November 2009.
2. "The Winton 201A Diesel Engine" (<https://web.archive.org/web/20090626084920/http://www.rypn.org/RyPN/articles/viewarticles.asp?filename=061130231209.txt>) . Archived from the original (<http://www.rypn.org/RyPN/articles/viewarticles.asp?filename=061130231209.txt>) on 26 June 2009. Retrieved 28 November 2009.
3. "United States Patent 1981913" (<http://www.freepatentsonline.com/1981913.html>) . 27 November 1934. Retrieved 28 November 2009.
4. "A. Fielden Fuel Pump" (<http://www.freepatentsonline.com/1981913.pdf>) (PDF). Retrieved 28 November 2009.
5. Asmus, A.; Wellington, B. (1994). *Diesel Engines and Fuel System*. Robert Bosch GmbH. ISBN 1-56091-542-0.
6. Kettering, E.W. (29 November 1951). *History and Development of the 567 Series General Motors Locomotive Engine* (<https://books.google.com/books?id=QuUiAQAAMAAJ>) . ASME 1951 Annual Meeting. Atlantic City, New Jersey: Electromotive Division, General Motors Corporation.

7. "HEUI Fuel Systems" (<http://www.cat.com/cda/files/87775/7/pehp9526.pdf>) (PDF). *Cat.com*. Caterpillar Inc. 1999. Retrieved 4 November 2009.
8. "Fuel Systems – High-Pressure Injection (HPI) Systems" (<http://www.cummins.com/fuelsystems>) . *Cummins.com*. Cummins Inc. Retrieved 29 April 2015.
9. "Injection Systems and Components – Delphi E1 Diesel Electronic Unit Injector" (<https://web.archive.org/web/20091230112216/http://delphi.com/manufacturers/cv/powertrain/injection-systems-and-components/e1-diesel-electronic-unit-injector/>) . *Delphi.com*. Delphi Automotive LLP. - Manufacturer Products : Commercial Vehicle Industry. Archived from the original (<http://delphi.com/manufacturers/cv/powertrain/injection-systems-and-components/e1-diesel-electronic-unit-injector/>) on 30 December 2009. Retrieved 4 November 2009.
10. "Injection Systems and Components - Delphi E3 Diesel Electronic Unit Injector" (<http://delphi.com/manufacturers/cv/powertrain/injection-systems-and-components/e3-diesel-electronic-unit-injector/>) . *Delphi.com*. Delphi Automotive LLP. – Manufacturer Products : Commercial Vehicle Industry. Retrieved 4 November 2009.
11. "Denso targets French, US automakers" (<https://europe.autonews.com/article/20051017/ANE/510170842/denso-targets-french-us-automakers>) . *Europe.autonews.com*. 17 October 2005. Retrieved 8 July 2018.
12. "Pumpe Düse Einspritzung (PDE - UIS)" (https://www.kfztech.de/kfztechnik/motor/diesel/pumpe_duese.htm) . *kfztech.de* (in German). Retrieved 15 September 2009.
13. "The efficient pump injector unit" (<https://web.archive.org/web/20090331184810/http://www.boschautoparts.co.uk/pcDies6.asp?c=2&d=1>) . *BoschAutoParts.co.uk*. Robert Bosch GmbH – Automotive. Archived from the original (<http://www.boschautoparts.co.uk/pcDies6.asp?c=2&d=1>) on 31 March 2009. Retrieved 30 September 2008.
14. "1.9-Liter TDI Engine with Pump Injection (Pumpe Düse): Design and Function" (http://www.myarchive.us/richc/VW_TDI_with_PumpeDuse.pdf) (PDF). Auburn Hills, Michigan: Volkswagen of America, Inc. October 2003. Self-Study Program - Course Number 841303. Retrieved 4 November 2009.
15. "Passenger-car systems - Unit Injector System (UIS)" (https://web.archive.org/web/20091029064042/http://rb-k.bosch.de/en/powerconsumptionemissions/dieselsysteme/dieselsystem/passenger-car/injection_systems/uis/index.html) . *Automotive Technology - Diesel systems*. Robert Bosch GmbH. Archived from the original (http://rb-k.bosch.de/en/powerconsumptionemissions/dieselsysteme/dieselsystem/passenger-car/injection_systems/uis/index.html) on 29 October 2009. Retrieved 4 November 2009.
16. "Volkswagen Mk4 turbo diesel "how to" index, for 2004–2005 Jettas' and 2004–2006 New Beetles and Golfs" (<http://myturbodiesel.com/forum/showthread.php?t=331>) .