Injection systems for dual fuel applications

Robert Bosch Diesel Systems, Large Engines (René Schimon)

Diesel Systems

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Introduction Large Engine (LE)

Engine categories	HD-truck derivative	High speed	Medium speed		Low speed (2-stroke-engine)
cyl.-volume (dm³):	< 2,5	2,5-6	4 – 32	33 – 290	134 - 1.800
cyl.-output (kW):	≤ 120	≤ 230	≤ 500	≤ 2.100	≤ 7.760
speed (min^{-1}):	≥ 1.400	≥ 1.400	≤ 1.400	≥ 450	≤450
FIE in 2006	UP, CRS	PF, IP, CRS	UI, UP, PF, IP	PF	PF
FIE in 2015	CRS	CRS	CRS, PF, UP	CRS, PF	PF, CRS
Application:		G&I Generator, Marine	Locomotive Generator Marine	Marine Generator	Marine



CRSN **MCRS** **HFO - CRS**

UI = Unit Injector
CRS = Common Rail System
UP = Unit Pump
PF = Single plunger pump
IP = Inline Pump

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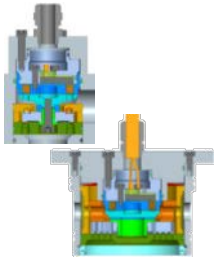
Line up – product portfolio Large Engine (LE)

natural gas | Diesel / HFO

dual fuel

LE-GV *
Large Engine Gas Valve



Modular Set of LE gas valves

* in development phase

CRSN
Common Rail System CV

CRIN CP3.3

EDC17CV41

MCRS
Modular CRS for Large Engines

CRIN-LE CP9.1-LE

EDC17CV41

HFO
Heavy Fuel Oil

CRIN-LE-22-HFO #

CP9.2 HFO #

tasting, no development yet

Conventional
mechanical components

PF-Pump

Inline pump

NHA

UI/UPS
Unit Injector / Unit Pump Syst.

EUI

UPS

Sensors:

Temp. Sensor

Knock sensor

Speed sensor

[..]

Marine Certification:

ABS CCS DNV·GL IRCLASS KR Lloyd's Register ClassNK RINA

Denoxtronic - SCR w/ urea

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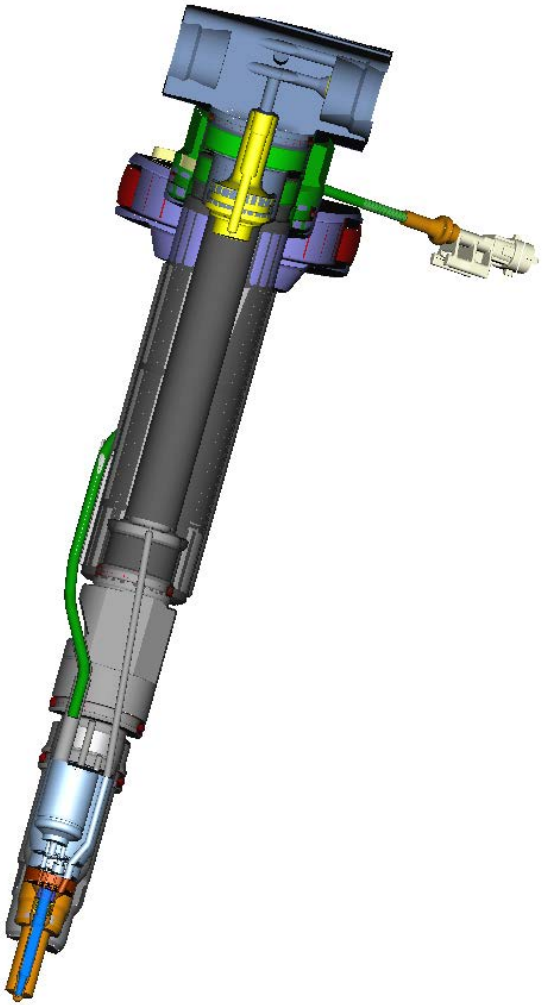
BOSCH

Content of speech:

- BOSCH Concept for Dual Fuel Systems
- Double Injector Concept for Dual Fuel Applications
- Single Injector Concept for Dual Fuel Applications
- Comparison of single and double injector concepts
- Outlook and Summarize



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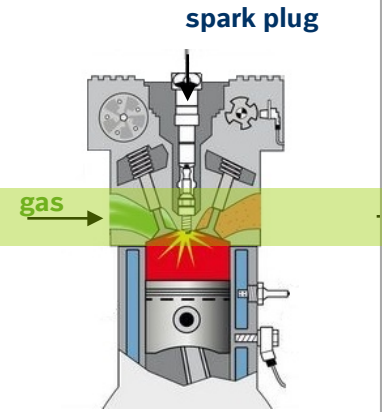
Injection Systems for Dual Fuel Application

Otto combustion cycle | Diesel combustion cycle

Gas monovalent

Premixed gas, admission into intake manifold

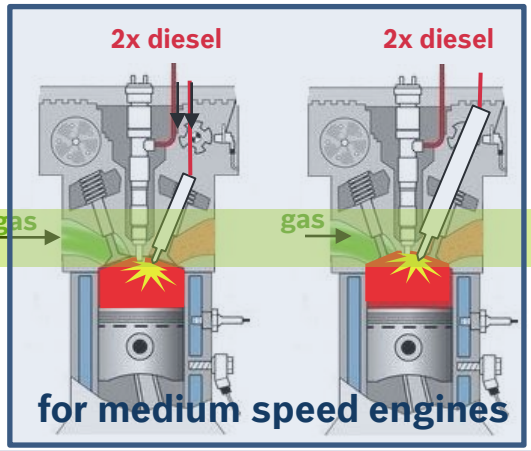
ignition via spark plug



Dual Fuel

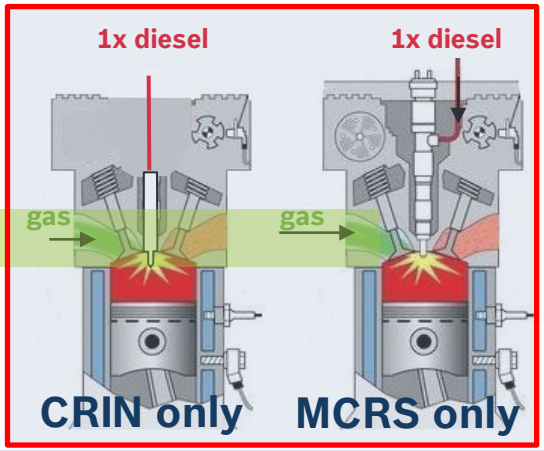
Premixed gas, admission into intake manifold

ignition via pilot diesel injection by additional CR injector



Premixed gas, admission into intake manifold

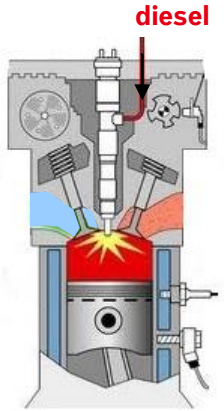
ignition via diesel injection (variable substitution)



Diesel

Diesel injection

Diesel diffusion combustion



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Double Injector Dual fuel concept: Main=conv. appl. Pilot=LE or CRIN

•Combinations:

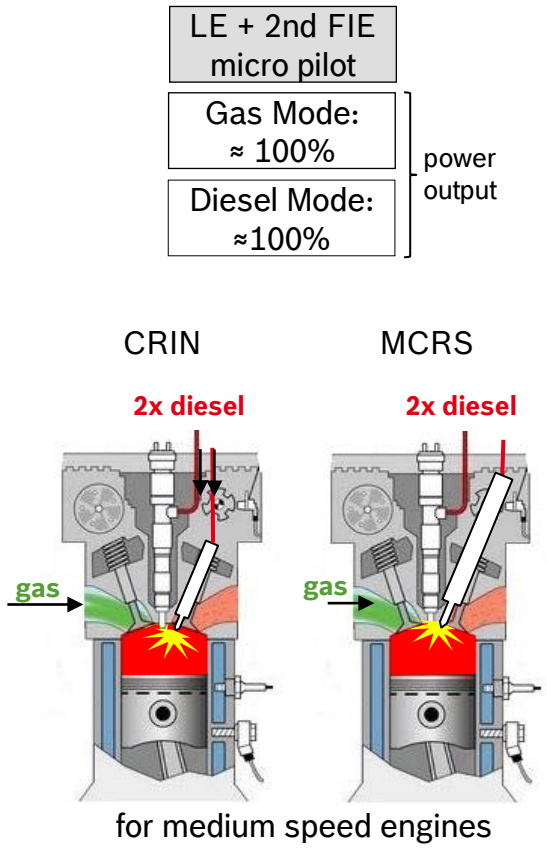
bore diameter [mm]	MAIN	PILOT
400 - 510	conventional	MCRS
up to 400	conventional	CRIN

•Optional: ~100% gas mode OR ~100% diesel mode possible (variable substitution)

•Commercial vehicle (CRIN) injector allows very small pilot quantities and is optimized for ideal fuel penetration during gas mode

•For bore diameters > 400 mm and central pilot injector position → MCRS injector designed for pilot quantities

•Critical topic: nozzle tip temperature which can lead to fuel deposits



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Double Injector Dual fuel concept: Main=conv. appl. Pilot=CRIN

Commercial Vehicle Injector
w/ top feed and side feed

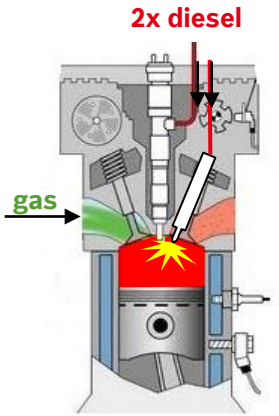
High pressure pump CP3.3
w/ gear pump ZP

LE + 2nd FIE micro pilot

Gas Mode: ≈ 100%

Diesel Mode: ≈100%

power output



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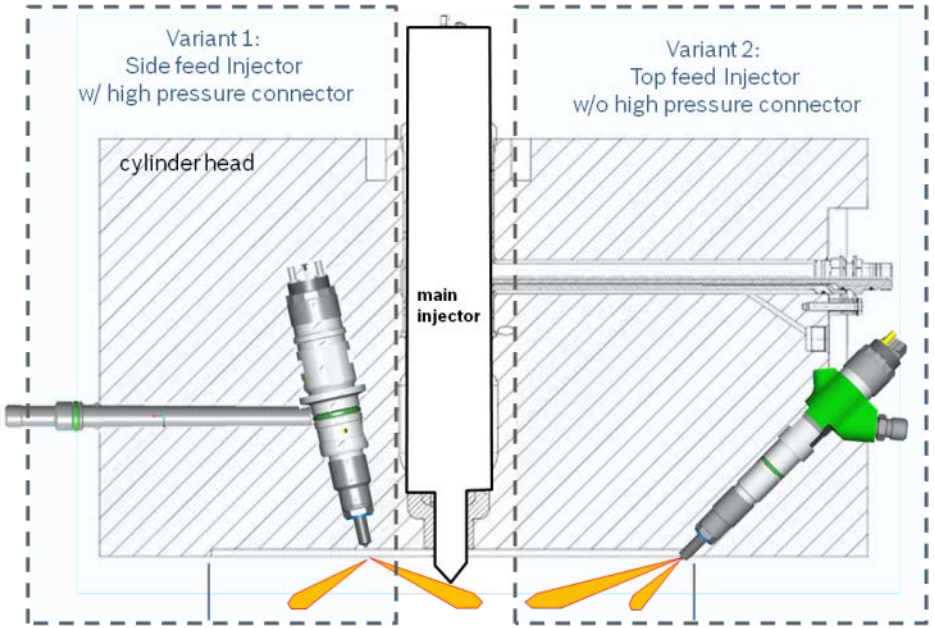
Double Injector Dual fuel concept: Main=conv. appl. Pilot=CRIN

Variants of mounting proposals:



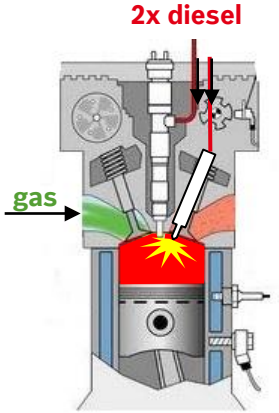
System	Engine bore diameter [mm]	Systempressure [bar]	Qe (inj. Quant.) [mm³ / stroke]	Q_{hyd} nozzle flow [cm³/30s]	NSP
CRSN3-18	350	1600	30 ... 150	350	4 - 5
CRSN2-16	200	1100 - 1600	20 ... 60	200 - 310	2 - 3

LE + 2nd FIE micro pilot

Gas Mode: ≈ 100%

Diesel Mode: ≈100%

power output



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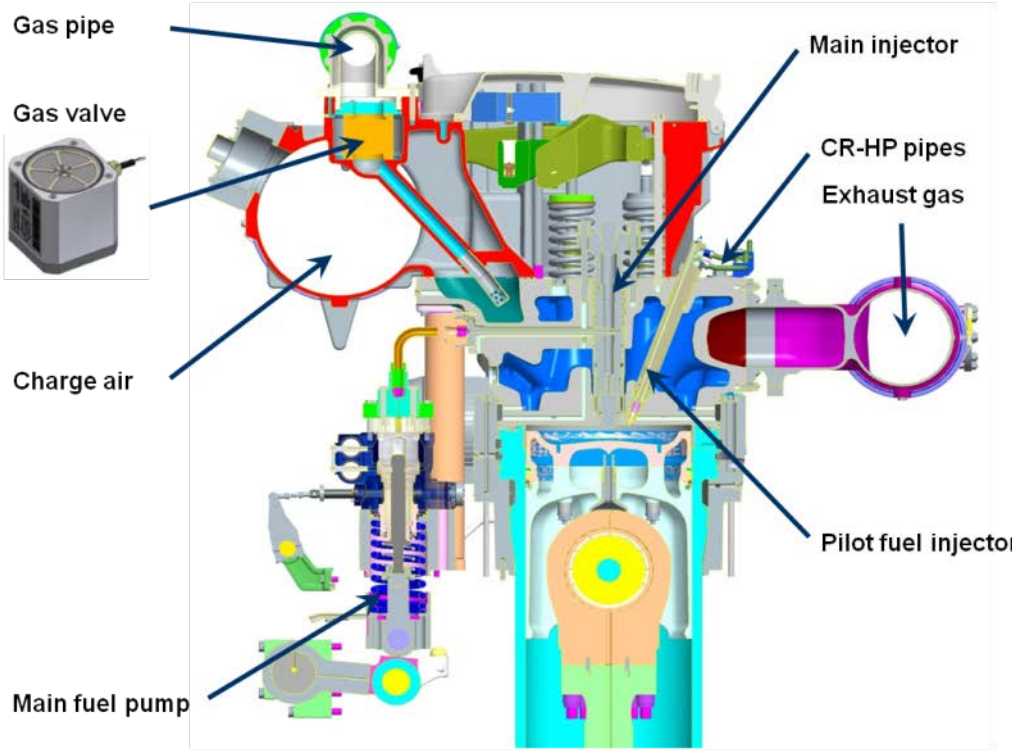
Double Injector Dual fuel concept: Main=conv. appl. Pilot=MCRS



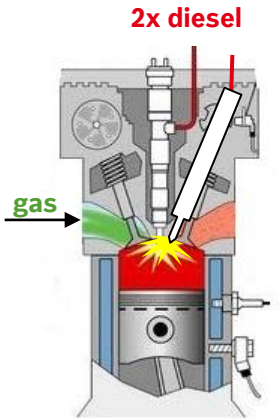
MAN 51/60DF

LE + 2nd FIE micro pilot

Gas Mode: ≈ 100%

Diesel Mode: ≈100%

power output



System	Engine bore diameter [mm]	Systempressure [bar]	Qe (inj. Quant.) [mm³ / stroke]	Q_{hyd} nozzle flow [cm³/30s]	NSP
CR	450 - 510	1050	70 - 280	800-900	4

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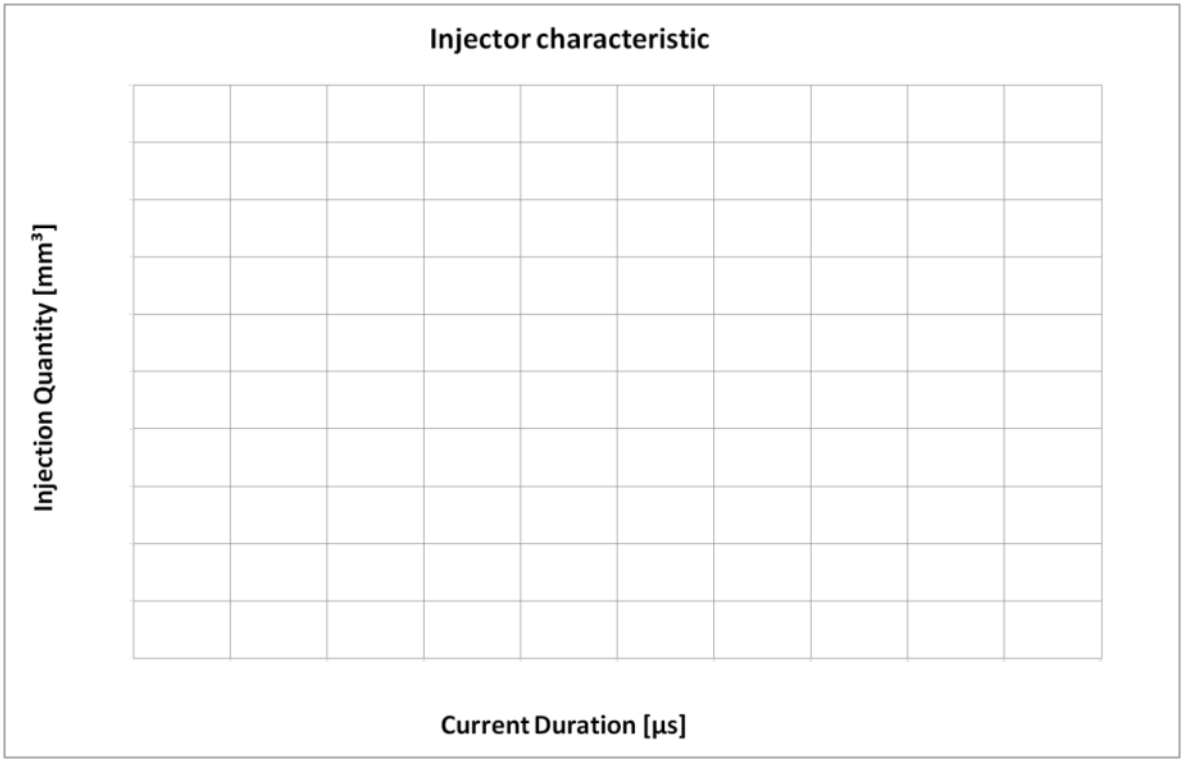
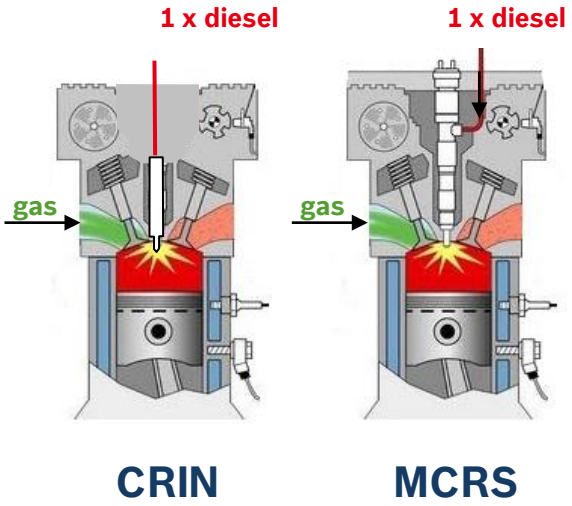
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

Requirements and behavior of the Injector:



only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
Diesel Mode: ≈0 - 30%	Diesel Mode: ≈0 - 100%



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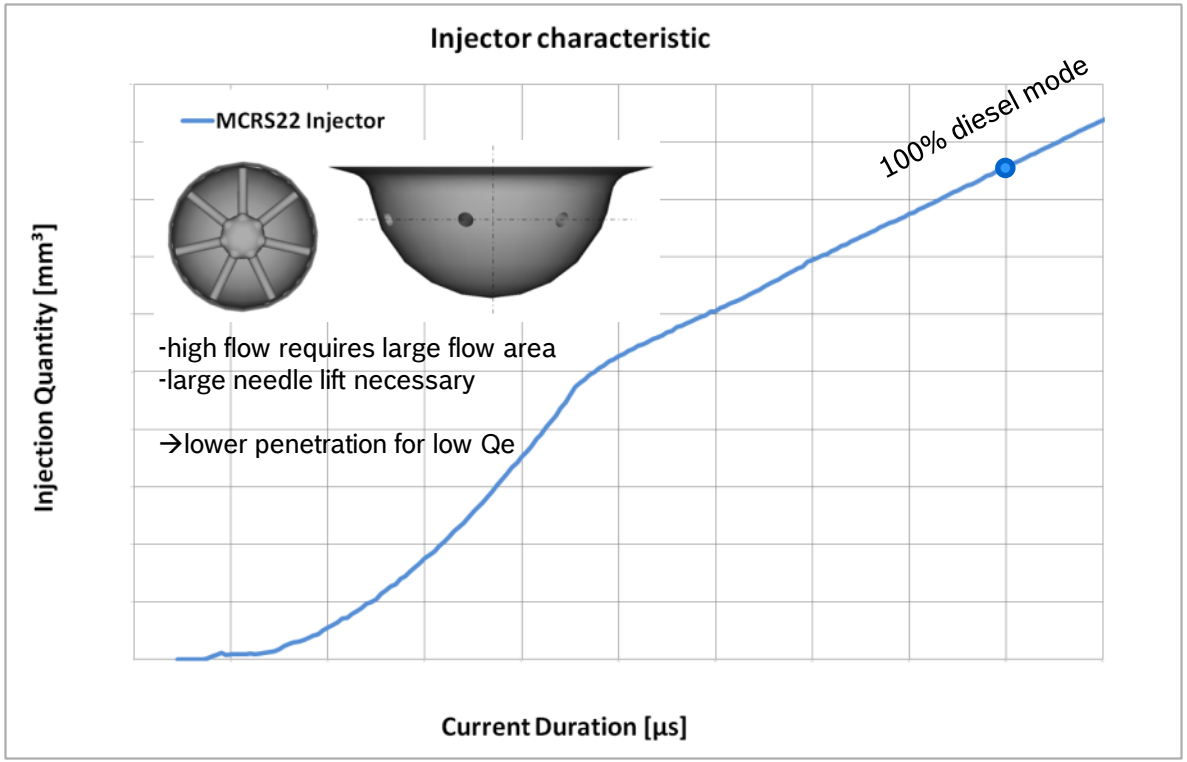
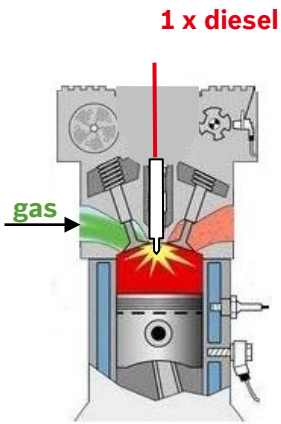
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

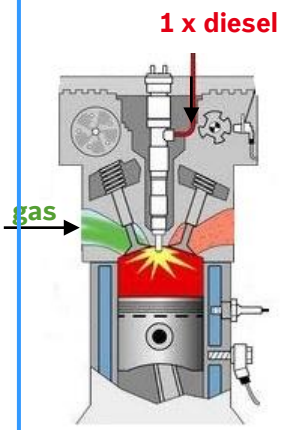
Requirements and behavior of the Injector:
Standard MCRS 22 Injector in Dual fuel application



only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
Diesel Mode: ≈0 - 30%	Diesel Mode: ≈0 - 100%



CRIN



MCRS

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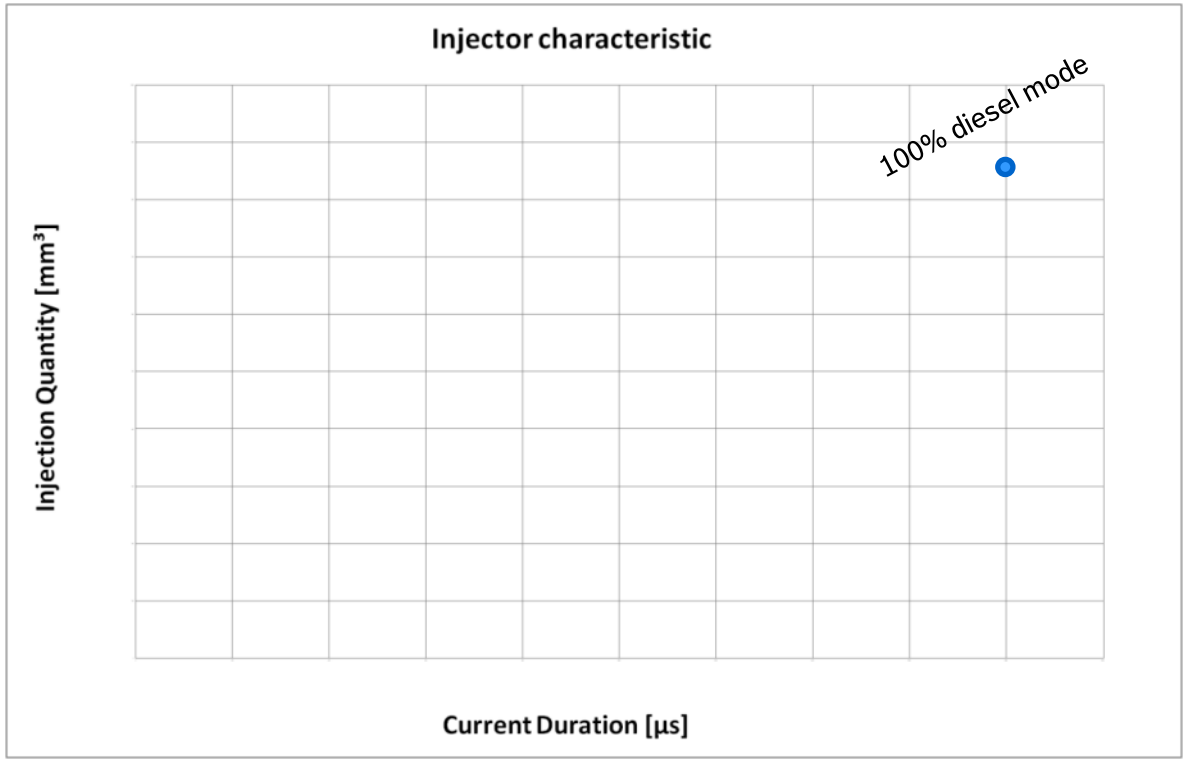
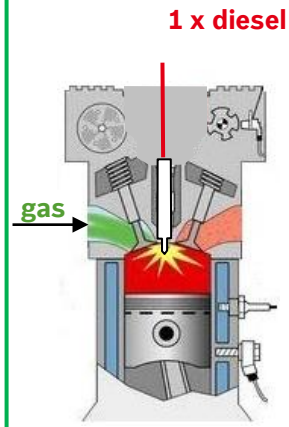
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

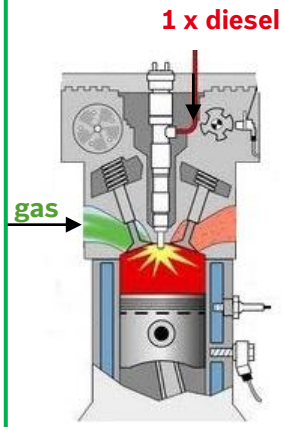
Requirements and behavior of the Injector:
Standard CRIN Injector in Dual fuel application



only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
Diesel Mode: ≈0 - 30%	Diesel Mode: ≈0 - 100%



CRIN



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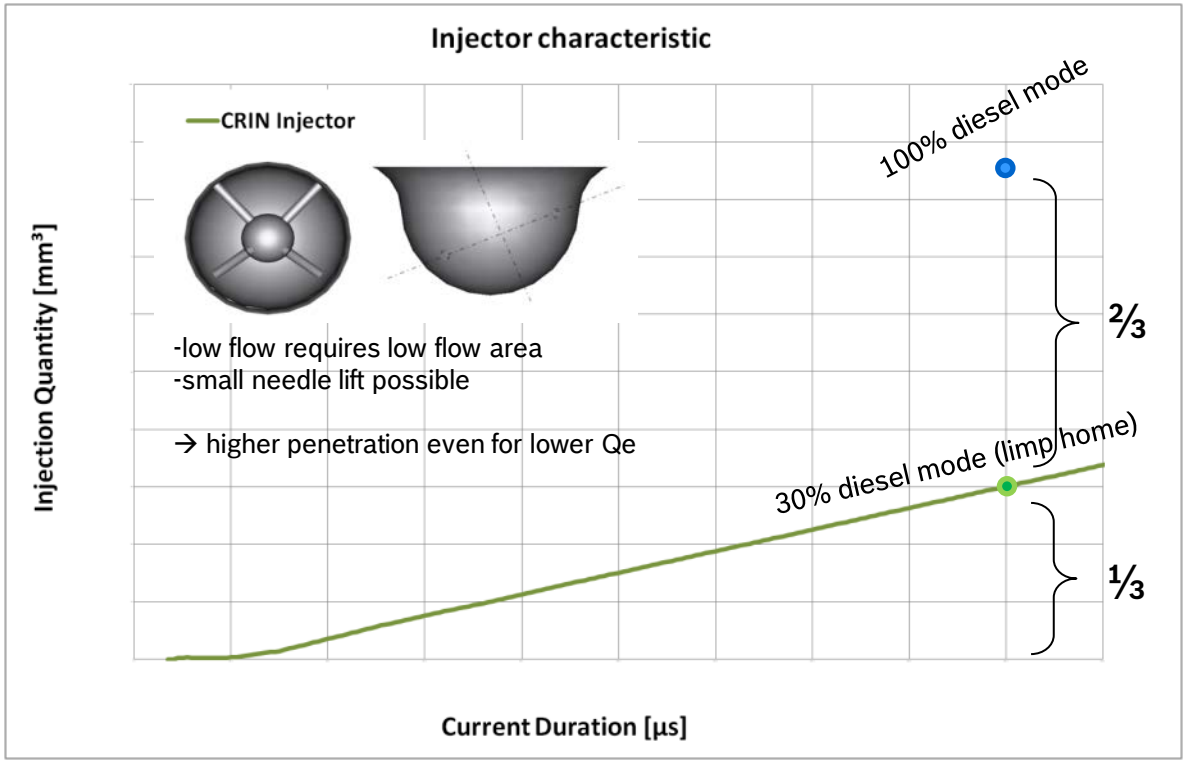
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

Requirements and behavior of the Injector:
Standard CRIN Injector in Dual fuel application



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Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
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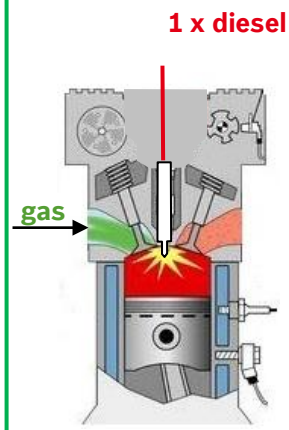
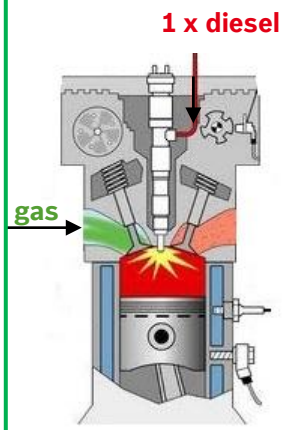


CRIN



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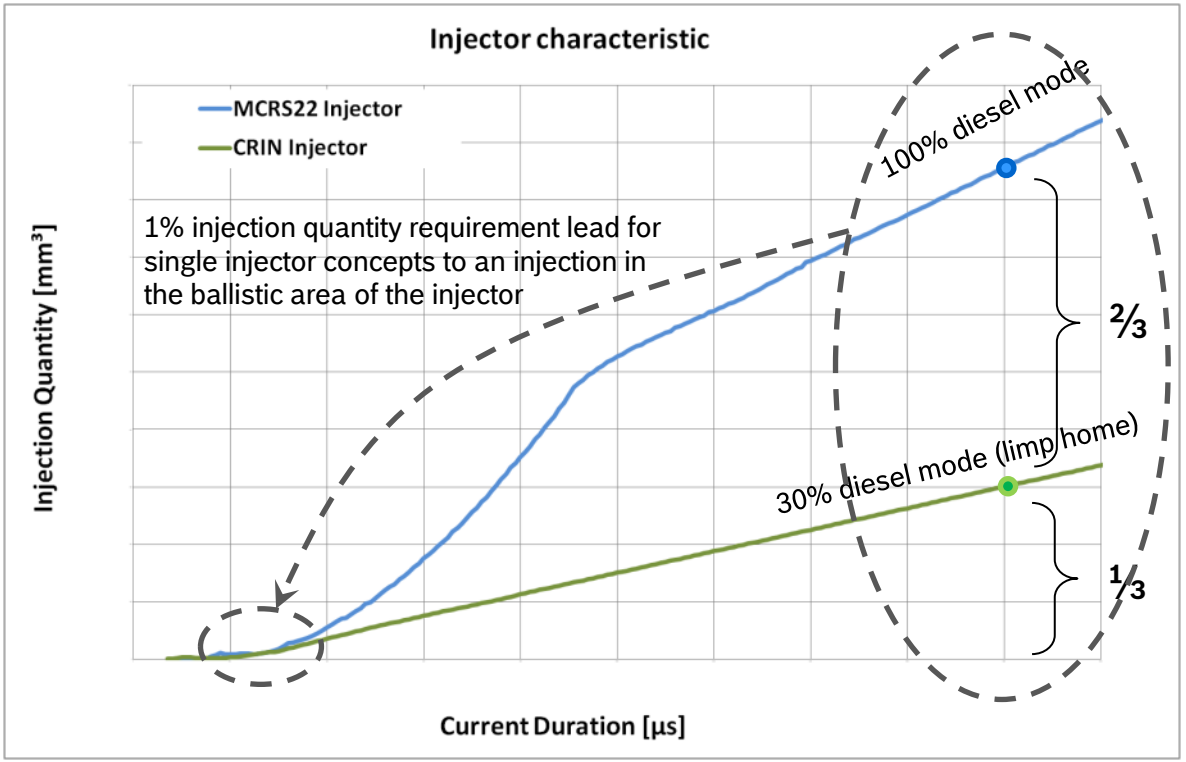
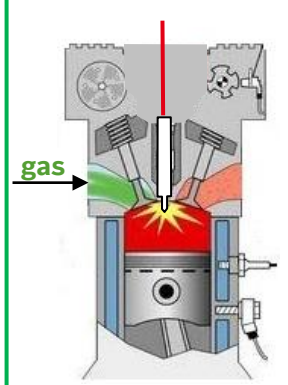
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

Requirements and behavior of the Injector: Stability of pilot injection quantities



only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
Diesel Mode: ≈0 - 30%	Diesel Mode: ≈0 - 100%



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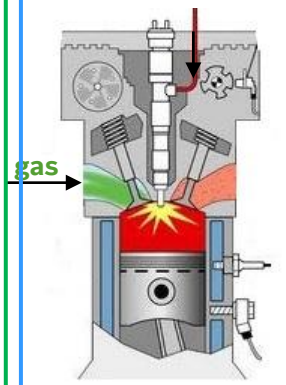

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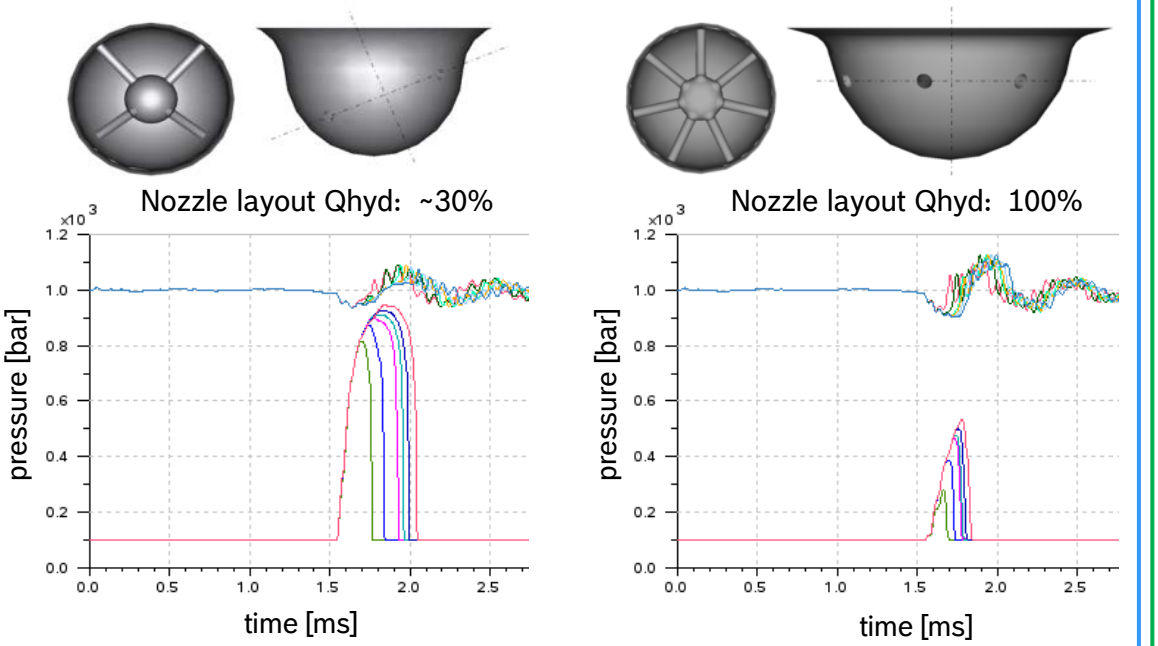
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

Requirements and behavior of the Injector: Consequence of different requirements



only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
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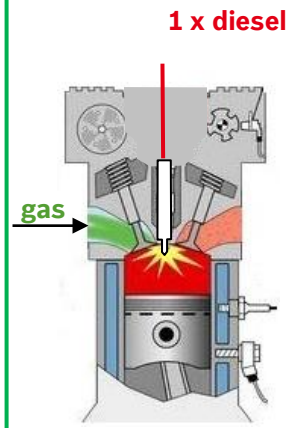

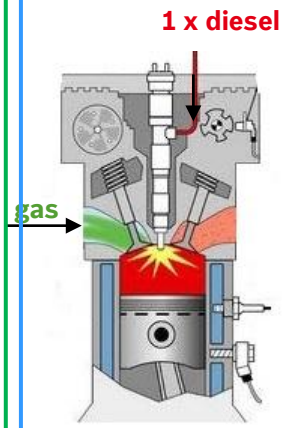

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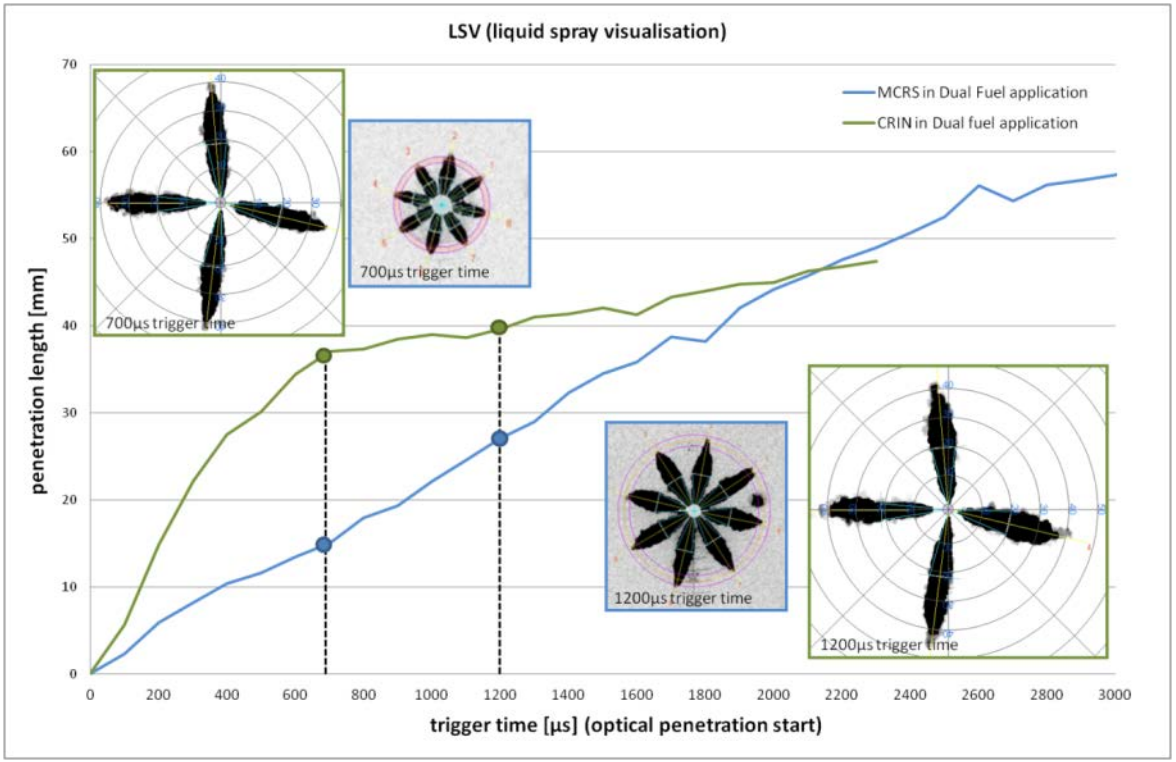
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

Requirements and behavior of the Injector: Consequence of different requirements



only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
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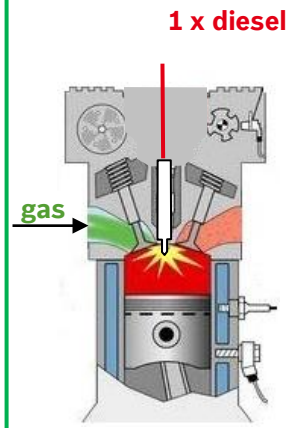
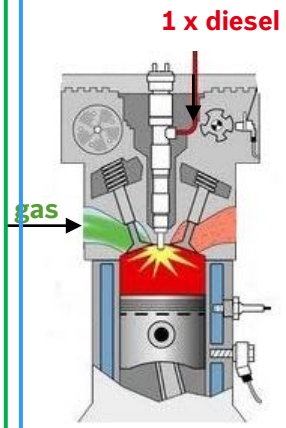


CRIN



MCRS

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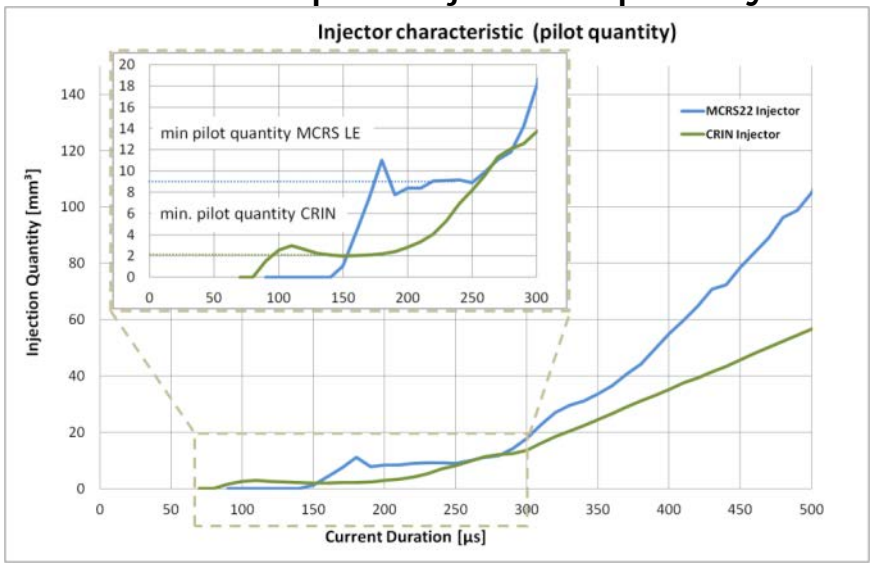
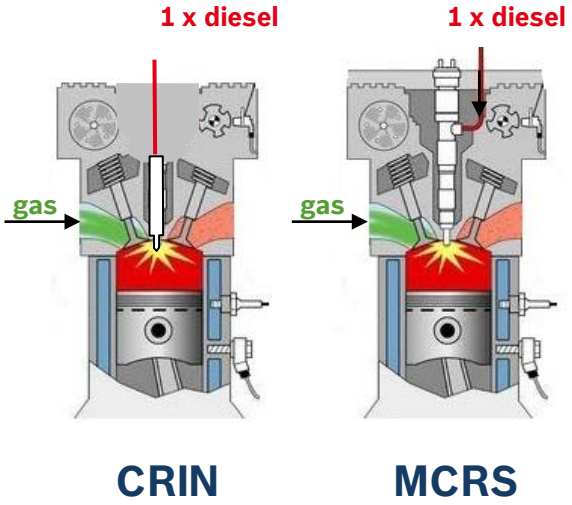
Single Injector Dual fuel concept: only one FIE (CRIN or MCRS)

Minimum pilot injection quantity:



System	Injector	typical pilot injection quantity
CRSN3-18	CRIN3-18	2 mm³/stroke @ 1400 bar
CRSN3-22 enh.	CRIN3-22 enh.	5 mm³/ stroke @ 2200 bar
MCRS-16	CRIN-LE-16	5 ... 10 mm³/ stroke
MCRS-22	CRIN-LE-22	5 ... 10 mm³/ stroke

only one FIE w/ micro pilot	only one FIE lim. pilot inj.
Gas Mode: ≈ 0 - 100%	Gas Mode: ≈ 0 - 70%
Diesel Mode: ≈0 - 30%	Diesel Mode: ≈0 - 100%



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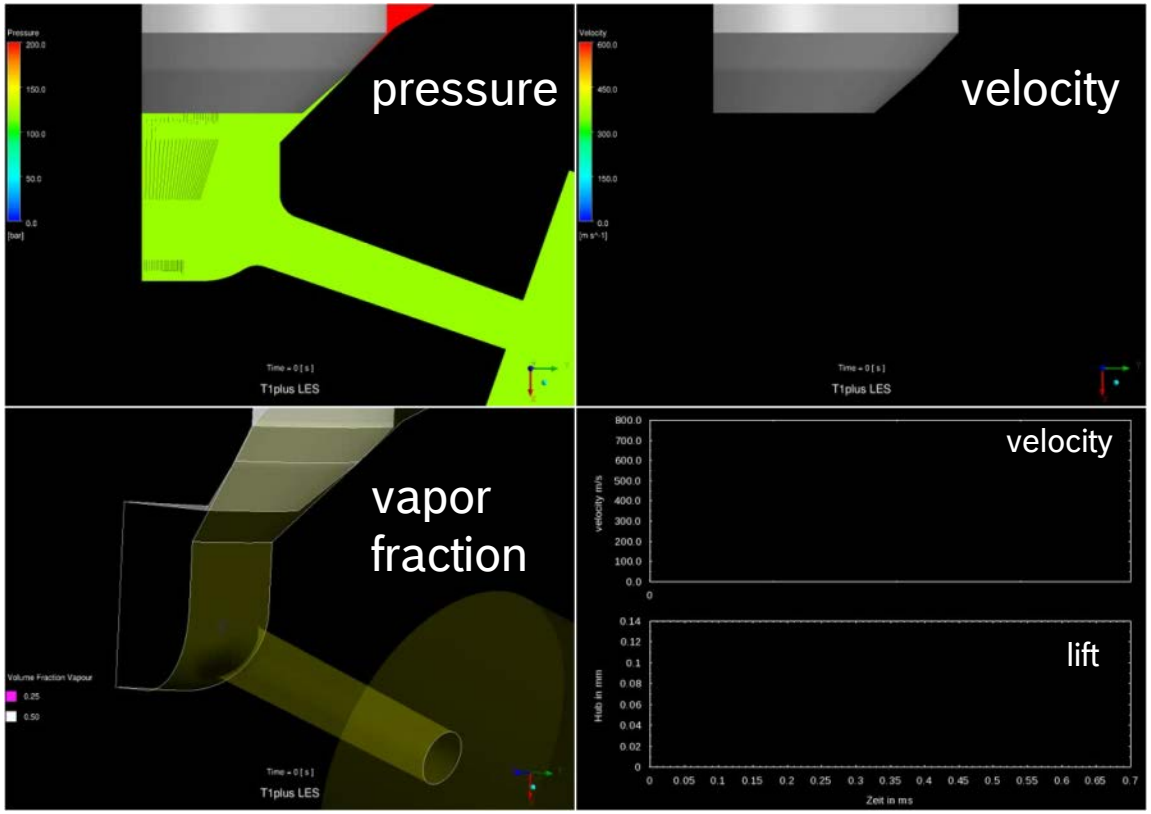
Summarize: pros and cons of each concept

Challenge for new concept of single dual fuel injector:

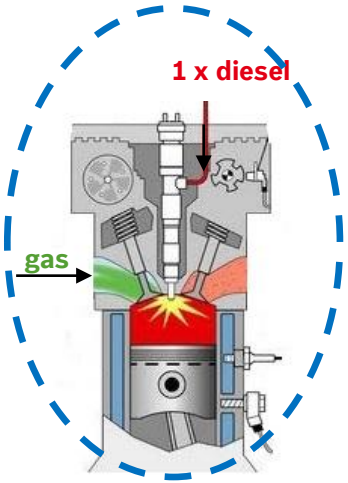
Nozzle layout Qhyd: 100%



only one FIE
lim. pilot inj.

Gas Mode:
≈ 0 - 70%

Diesel Mode:
≈0 - 100%



MCRS

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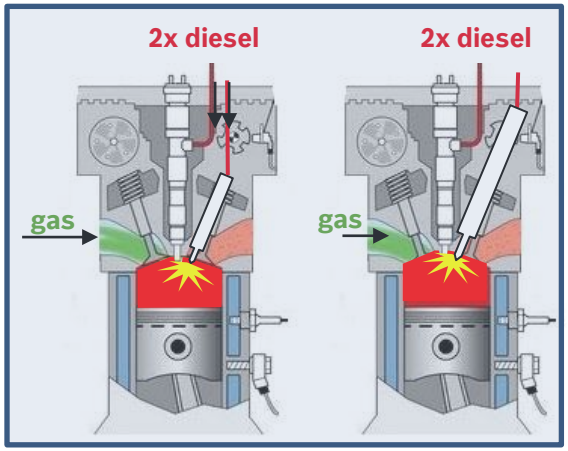
Summarize: pros and cons of each concept

Dual Fuel

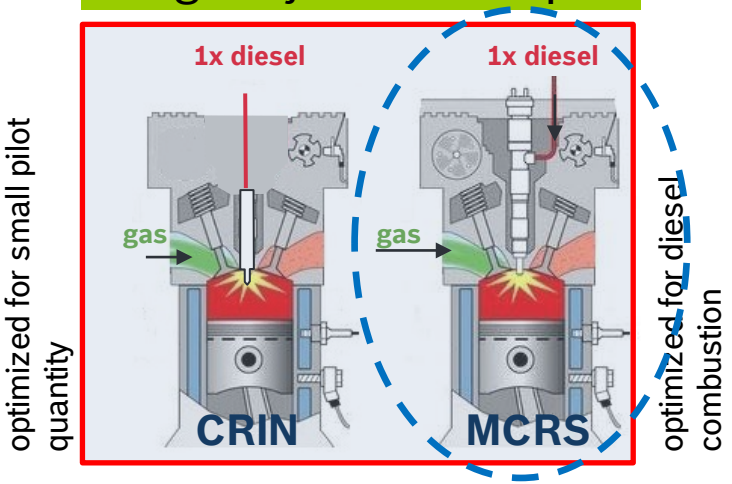
double injector concepts



+ advantages of both injectors
(small pilot quantity and 100 % diesel operation)
+ stable pilot quantity and ideal spray penetration

- 2 injector (complexity of systems increases)
- higher costs
- complex control concept
- complex packaging in cylinder head
- main injector uncooled during gas mode

single injector concepts



+ 100 % implementation of diesel packaging
+ standard CR control concept
+ lower costs (1 Injector only)

-Either small pilot quantities and limp home diesel operation max. 30 load or 100% diesel mode with currently 70 % substitution rate

Optimization will increase substitution rate (≥95%)

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Summarize / Outlook:

- For medium speed engines the double injector concept is a proven stable solution for applications with bore diameters from 200 up to 510 mm
- For single injector concepts substitution rates of 70% are applied without modification of the fuel injection system
- Target for 2nd generation DF engines:
  - MCRS 22 Injector with a substitution rate ≥ 95%

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