GDI Test Protocol

An Overview

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Types of Tests

- Optical patternation
- Drop sizing
- High speed shadowgraphy

Suggested Test Matrix

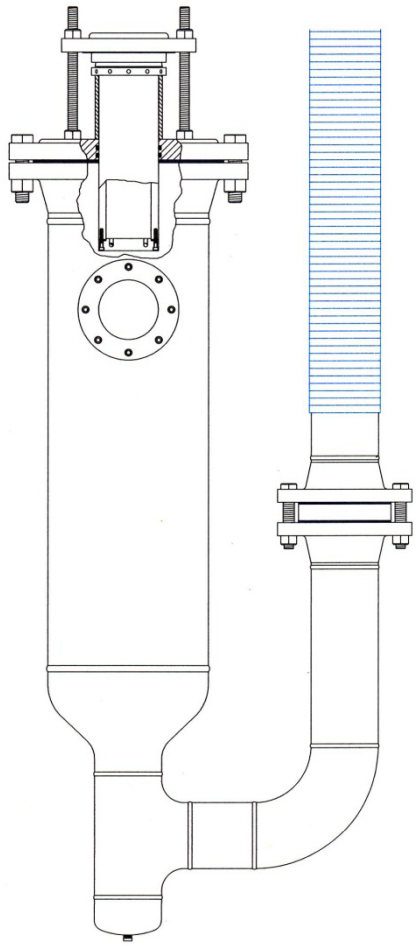
Test condition	Ambient Pressure kPa	Fuel Temperature Degrees C	Injection Pressure MPa
1	101	20	15
2	101	20	10
3	60	60	10
4	60	60	5
5	40	90	5
6	40	90	2

Injection at higher temperatures and lower than atmospheric pressures to simulate engine conditions. All tests carried out with calibrated gasoline-E10

Spray Injection Capability

- *GDI injectors up to 20 MPa*
- *Transient injections, typically 1 Hz and duty cycles as low as 500 microseconds*
- *Baseline gasoline with E10*
- *Fuel heated up to 90 C*

Spray Environment Capability



- *From 20 Kpa absolute to 1600 Kpa absolute*
- *10 inch nominal ID*
- *4 inch fused silica window on 2 sides*
- *Can be switched to sapphire for infrared diagnostics*
- *34 inch high vessel to reduce spray bounce back*
- *Fully indexable injector mount*
- *Inert nitrogen atmosphere*

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Optical Patternation

- Setscan AP400 patternator, 9.4 KHz
- Single axis extinction measurement
- Nozzle rotated eight times
- Patternation obtained from combined measurements

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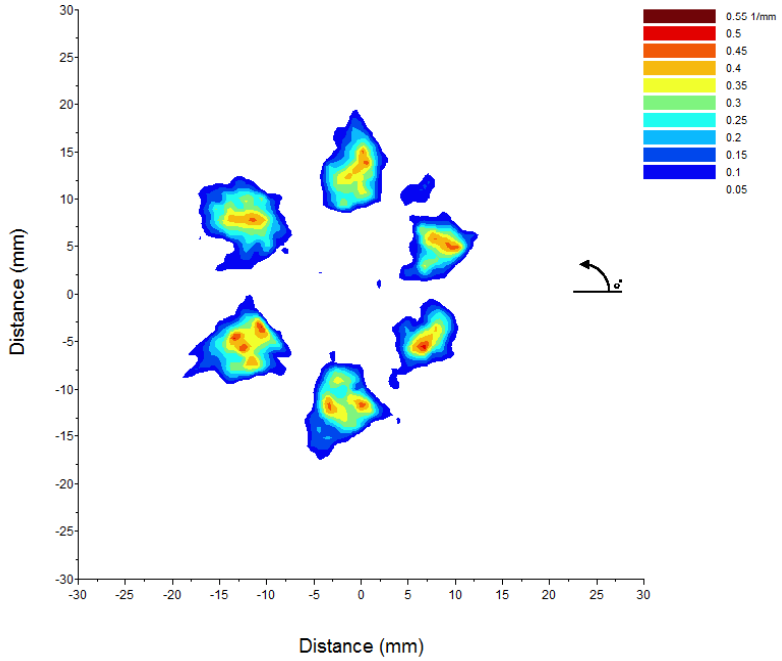
Patternator Output



- 15 Mpa injection pressure
- Fuel at 20 ^{O}C
- Contour maps of surface area density
- Data collected is from an ensemble average of 5 measurements, each taken at the same time in the injection cycle for a duration of 0.1 ms

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Plume Analysis

Mean plume angles (deg.)	Standard Error	% area in plume	Standard Error
10.88525	0.13938	19.32	0.65769
5.73125	0.11299	4.685	0.14321
11.53475	0.13496	21.7075	0.92435
10.4795	0.37838	17.9125	0.70649
11.51225	0.31579	23.06	0.23815
9.35075	0.5827	12.925	1.07319
Mean centroid (x, mm)	**Standard error**	**Mean centroid (y, mm)**	**Standard error**
3.26325	0.12863	-5.693	0.19278
-4.84	0.14392	14.27925	0.13002
-22.1305	0.25003	1.97025	0.06277
-29.042	0.12035	-10.7485	0.08693
-15.369	0.1288	-18.48675	0.03462
0.10125	0.12409	-20.01175	0.1702

- Good repeatability
- Centroids within 200 microns
- Plume angles within 1/2 degree
- % distribution in plumes within 1%
- Provides surface area density for each plume

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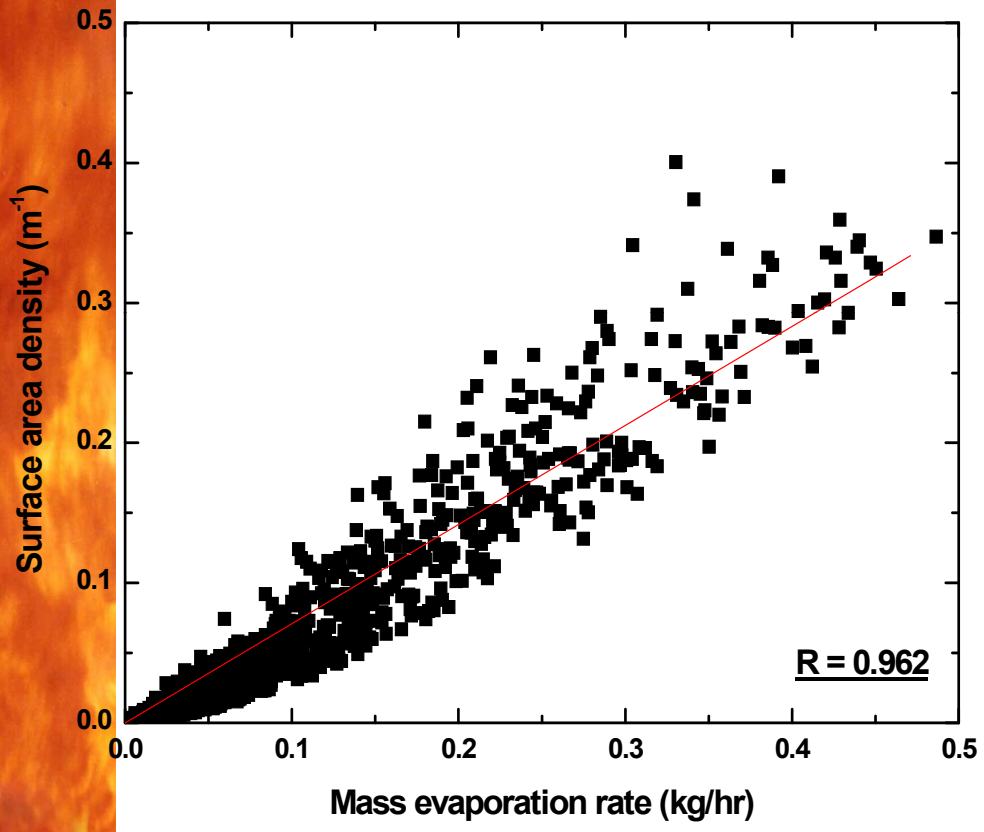
Importance of surface areas

Correlation of fuel evaporation with parameters



Drop size = 0.681
Velocity = - 0.239
Mass flux = 0.903
Surface area density = 0.962

Surface area density is the most important parameter to measure if you are interested in obtaining the amount of fuel evaporated at any location in a spray

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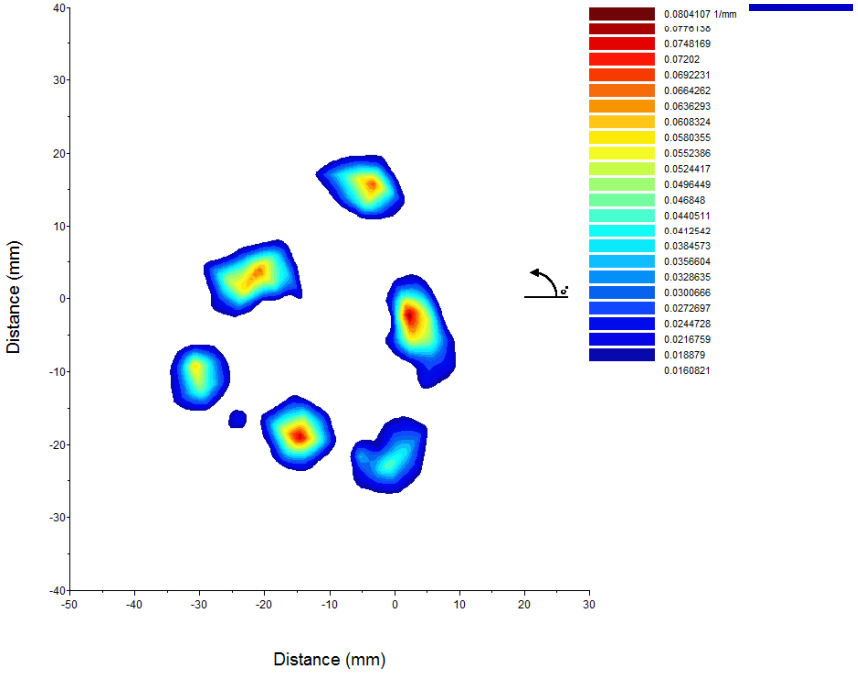
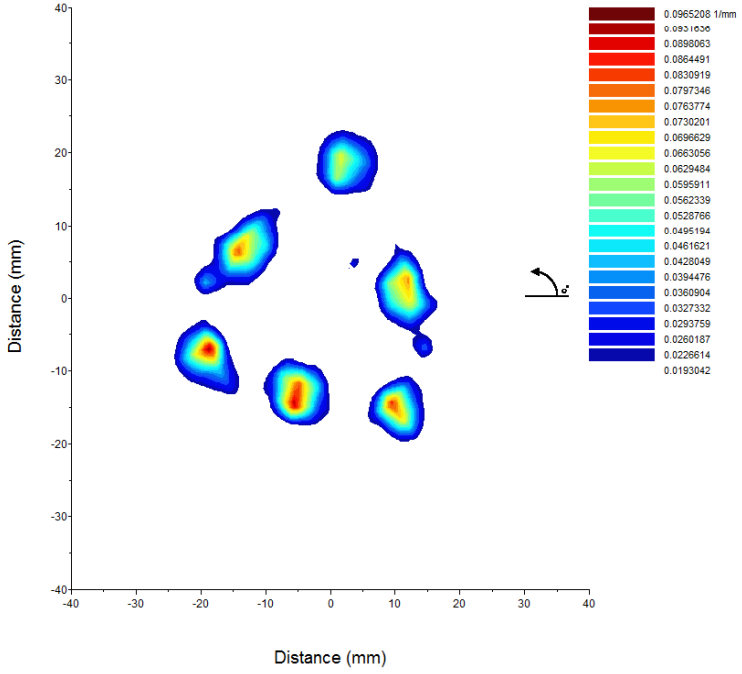
Manufacturer A Vs. Manufacturer B





A has higher surface area density (implying smaller drops)

Standard deviation and spread amongst plumes higher for A

Higher mean plume angle and spread in plume angles for A

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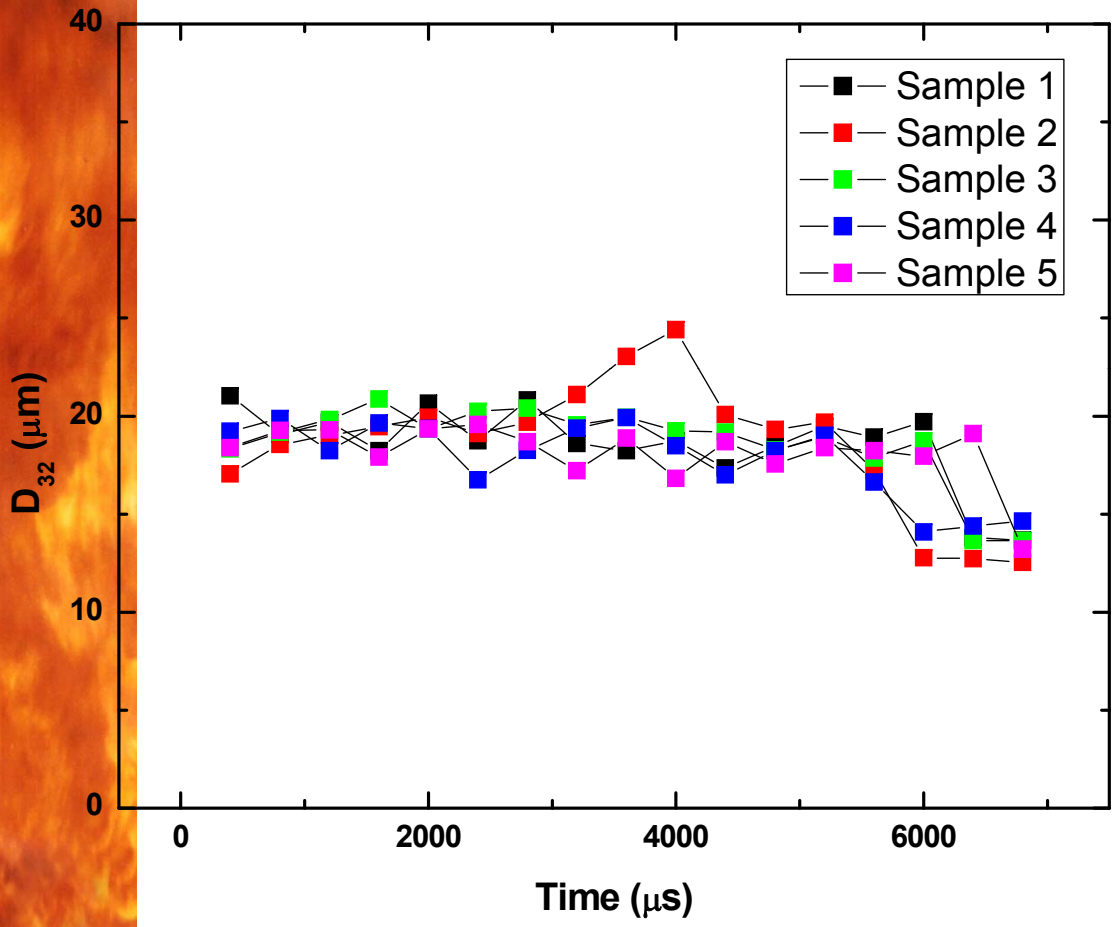
Drop Size Measurements

- Malvern Spraytec drop sizer
- Triggered using extinction level
- 2,500 Hz transient measurements
- Typically five shots obtained and averaged for drop size data

Malvern Output



- 15 Mpa injection pressure
- Fuel at 20 ^{O}C
- SMD
- 5 samples taken at each operating condition

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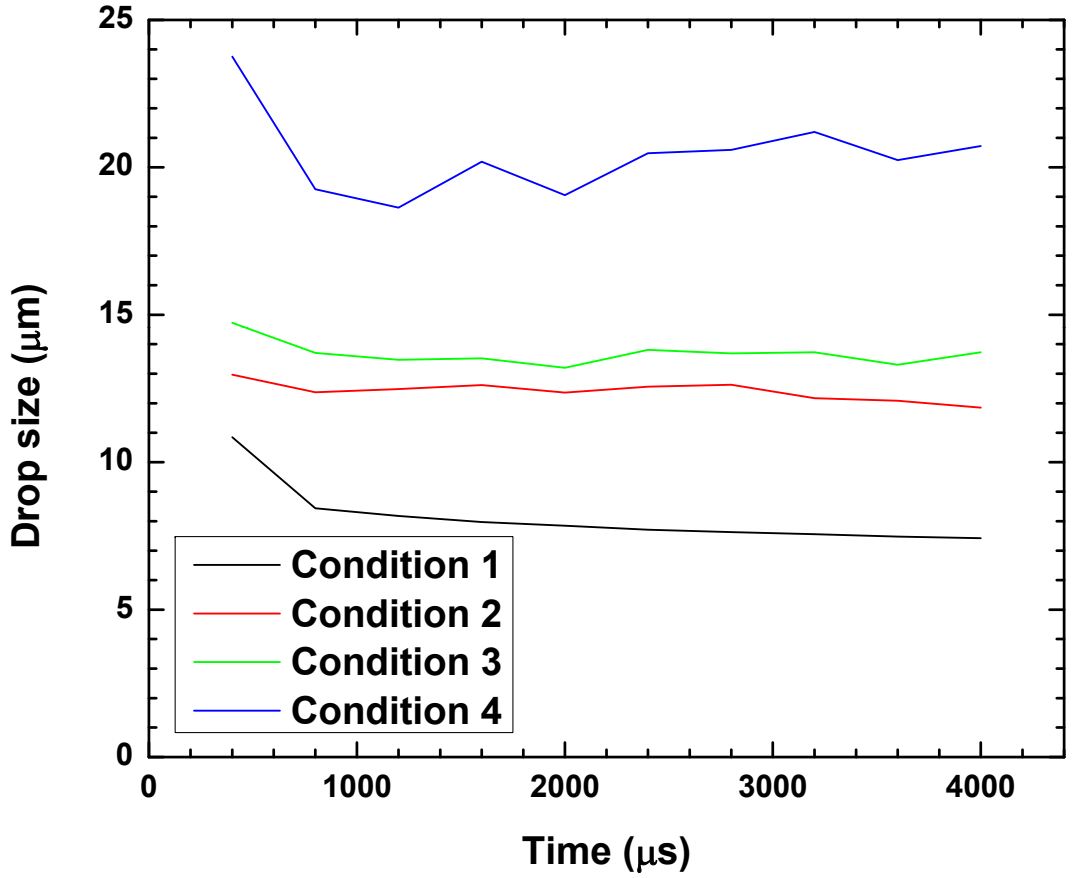
Sample Results



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High Speed Video

- Shadowgraph technique
- Triggered with injection pulse
- 10 KHz transient measurements
- Used to analyze penetration depth and spray overall shape

Sample Pictures

- Injection pressure 10 MPa gage
- Chamber pressure 40 Kpa absolute
- Fuel temperature 90 ^{O}C
- Plumes merged

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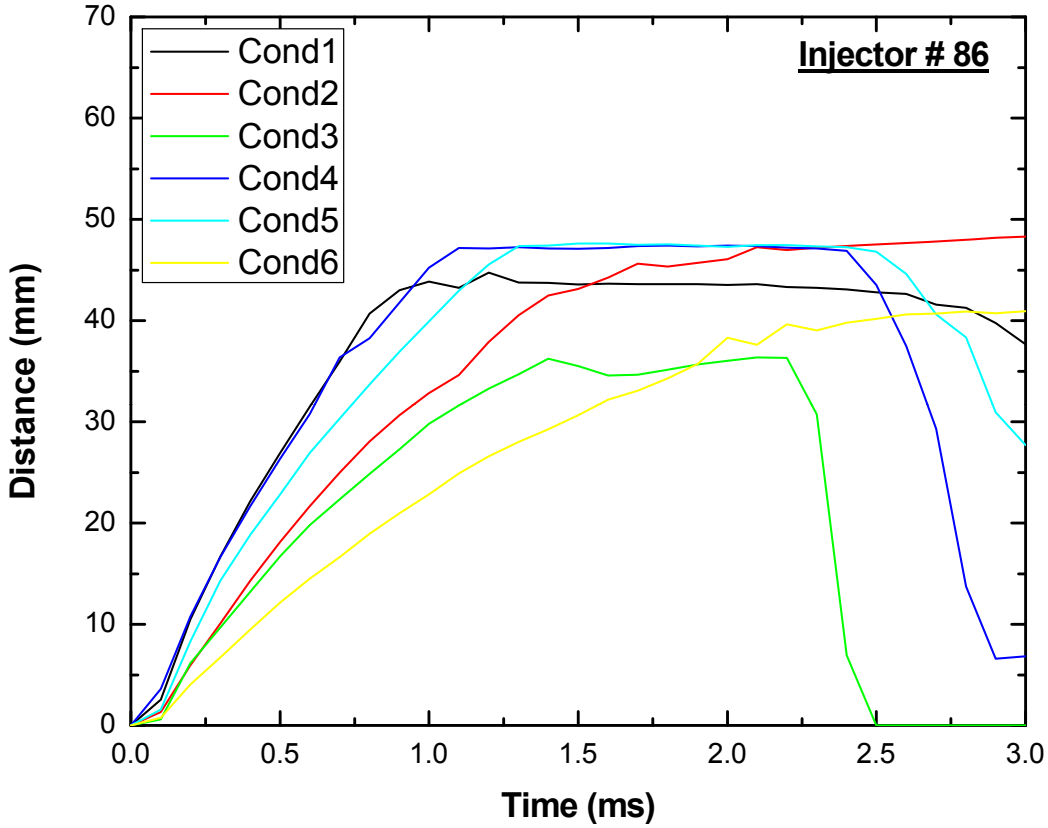
Penetration Depth from Videos



1.5 ms injection duration

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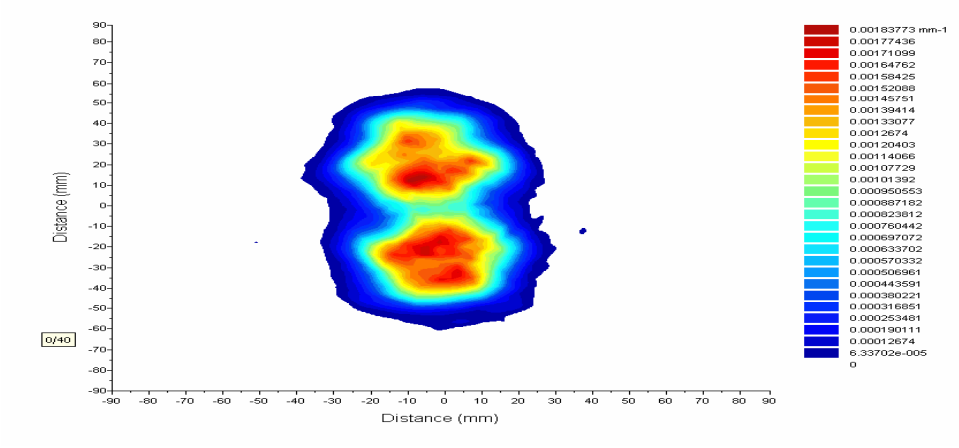
PFI Injector

- 25 Hz operation, 60 PSI
- Data collection in sync. with injector pulses
- Average of 200 shots (5 s)



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