MINING DIESEL EMISSIONS COUNCIL

13th ANNUAL MDEC CONFERENCE
Sheraton Parkway, Toronto North, Canada
October 1 – 5, 2007

MDEC SHORT COURSE ON ENGINE AND DPF TECHNOLOGY

PRESENTED BY: KUBOTA, ECS, DCL & CEP

COORDINATED BY: MAHE GANGAL, NRCan

OCTOBER 2, 2007

MINING DIESEL
mdec
EMISSIONS COUNCIL

Diesel Workshop

MDEC Short Course on Engine and DPF Technology

Sheraton Parkway, Toronto North
Ontario, Canada

Markham Room

Tuesday, October 2, 2007

08:00 – 08:30	Registration & Gathering (Coffee available)
08:30 – 10:00	Welcome (Mahe Gangal, Co-chair MDEC Conference) Engine Technology • Combustion Fundamentals, Fuels, & Emissions (John Baxter, Kubota Canada Ltd)
10:00 – 10:30	Coffee Break
10:30 – 12:00	Engine Technology • Service & Maintenance (Walter Steffler, Kubota Canada Ltd) • Discussion & Conclusion
12:00 – 13:00	Lunch (Markham Room)
13:00 – 14:30	DPF Technology • Fundamentals (Glen Prisciak, DCL International Inc.) • Selection & Sizing (Ted Tadrous, Engine Control System Limited)
14:30 – 15:00	Coffee Break
15:00 – 16:30	DPF Technology • Retrofit & Operation (Don Malgast, Engine Control Systems Limited) • Maintenance (John Stekar, Catalytic Exhaust Products Limited) • Discussion & Conclusion

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CONTENTS

Workshop MDEC - 2007

Registration Address List

Cheryl Allen
Sr. Ventilation Eng.
CVRD - INCO
18 Rink Street
Copper Cliff, Ontario P0M 1N0
Bus: (705) 682-6857
email: callen@inco.com

Aleksandar Bugarski
Mechanical Engineer
NIOSH - PRL
626 Cochrans Mill Rd.
Pittsburgh, PA
USA 15236
Bus: (412) 386-5912
Fax: (412) 386-4917
email: abugarski@cdc.gov

Peter Burrell
Service Planner
Tracks & Wheels Equipment Brokers Inc.
400 Hwy. 69 PO Box 2592
Sudbury, Ontario P3A 4S9
Bus: (705) 566-5438
Fax: (705_ 566-5422
email: pburrell@tracksandwheels.com

Gerald Carmichael
Vice President
United Steelworkers Local 7106
68 Church St.,
Flin Flon, Manitoba R8A 1K7
Bus: (204) 687-4448
Fax: (204) 687 8176
email: amucha@usw.ca

Emanuele Cauda
Research Engineer
NIOSH PRL
626 Cochrans Mill Rd.,
Pittsburgh, PA
USA 15236
Bus: (412) 386-4518
Fax: (412) 386-4917
email: ecauda@cdc.gov

Aldo Cerilli
Worker Rep South Mine
CVRD - INCO
Copper Cliff
Sudbury, Ontario P3E 6G8
Bus: (705) 682-5037
email: acerilli@inco.com

Bob Clayton
Business Development Manager
T.F. Hudgins Inc.
PO Box 920946
Houston, Texas
USA 77292-0946
Bus: (713) 682-3651
Fax: (713) 682-1109
email: bclayton@tfhudgins.com

Manfred Duering
Cummins Deutschland GmbH
Odenwaldstrasse 23
Gross Gerau, Germany 64521
Bus: +49-6152-174112
Fax: +49-6152-174141
email: manfred.duering@cummins.com

Sanjeev K. Duggal
Manager Mining Business
Cummins Inc.
560 Jackson St.,
Columbas, Indiana
Bus: (812) 373-7645
Fax: (812) 377-1667
email: sanjeev.k.duggal@cummins.com

Steve Fedrizzi
Maintenance Supervisor
Cargill Deicing Technology
191 Portland Point Road
Lansing, New York
USA 14882
Bus: (607) 533-4221
Fax: (607) 533-4501
email: steve-fedrizzi@cargill.com

Steve Forbush
Diesel Equipment Specialist
Arch Coal Inc.
PO Box 240, Aurora Utah
USA 84620
email: sforbush@archcoal.com

John Ford
Maintenance Technician
Cargill Deicing Technology
191 Portland Point Road
Lansing, New York
USA 14822
Bus: (607) 533-4221
Fax: (607) 533-4501

Mattias Forssén
Engineer
Volvo Penta Corp
Gropegardsgatan
Gothenburg, Sweden 4175
Bus: +45 3132 21621
email: mattias.forssen@volvo.com

Sean Gannon
Mechanical Engineer
Cargill Deicing Technology
191 Portland Point Road
Lansing, New York
USA 14822
Bus: (607) 533-4221
Fax: (607) 533-4501
email: sean-gannon@cargill.com

David Griffiths
Sr. Technologist
Xstrata Nickel - Sudbury Mines/Mill
Strathcona Complex
Onaping, Ontario P0M 2R0
Bus: 996-3411
Fax: 996-6590
email: dgriffiths@sudbury.xstratanickel.ca

Kevin Hinds
GF Mobile
CVRD - INCO

Jeff Jacobs
Region Manager
Caterpillar
175 Power Forest Dr.
Weatogue, CT
USA   06089
Bus: (860) 658-3438
email: jacobs-jeffrey-a@cat.com

Kenneth Jokela
OHSE
CVRD - INCO
1991 Springdale
Sudbury, Ontario P3A 4H9
Bus: (705) 560-7820

Seppo Karhu
Sandvik Mining and Construction
Vahdontie 19, PO Box 434
Turku, Finland   20101
Bus: +358 20544 5220
Fax: +358 20544 5555
email: seppo.karhu@sandvik.com

Kevin G. Kroger
President
Puradyn Filter
2017 High Ridge Rd.,
Baynton Beach, Florida
USA   33467
Bus: (561) 547-9499
Fax: (561) 547-8629
email: kkroger@puradyn.com

Alain Landry
Mobile Maintenance Co-Ordinator
Xstrata Nickel
Craig Mine
Onaping, Ontario P0M 2R0
Bus: (705) 966-3411
Fax: (705) 966-6560
email: alandry@sudbury.xstratanickel.ca

George Larouche
HBET
CVRD - INCO
60 Mine Rd.,
Garson Ontario P3L 1N6
Bus: (705) 566-2561
email: glarouche@inco.com

James McClintock
Mine Engineer
CSCL Ojibway Mine
200 Morton Dr.,
Windsor, Ontario   N9J 3W9
Bus: (519) 972-2211
Fax: (519) 972-1777
email: jmcclintock@windsorsalt .com

Ray Marsh
Maintenance Technician
Cargill Deicing Technology
191 Portland Point Road
Lansing, New York
USA 14882

Bus: (607) 533-4221
Fax: (607) 533-4501

Shawn Matthews
Worker Safety Rep.
CVRD - INCO
54 Monique Cres.,
Garson, Ontario P3L 1C6

Bus: (705) 693-3022
email: smatthews@inco.com

Colin Morrish
Mines Inspector
Saskatchewan Labour
122-3rd Avenue North
Saskatoon, Sk S7K 6A5

Bus: (306) 933-7594
Fax: (306) 933-7339
email: cmorrish@lab.gov.sk.ca

Richard Paquin
Xstrata Nickel - Unit Chair
Mine Mill- Local 598
19 Regent St., S.
Sudbury, Ontario P3C 4B7

Bus: (705) 673-3661
Fax: (705) 673-1183
email:

Peter Saal
Chair, Health, Safety & Env. Committee
Local 6500 United Steelworkers
92 Frood Road
Sudbury, Ontario P3C 4Z4

Bus: (705) 675-3503
Fax: (705) 675-2438
email: psaal@inco.com

Mike St. Onge
Worker Rep.
CVRD - INCO
300 Brobant Street
Azilda, Ontario P0M 1B0

Bus: (705) 983-5556
Fax: (705) 966-4114
email: mst.onge@inco.com

Brent Salem
General Forman
CVRD - INCO
848 St. Andrews
Sudbury, Ontario P3A 3W7

Bus: (705) 693-4906
email: bsalem@inco.com

George H. Schnakenberg, Jr.
Research Physicist
NIOSH - PRL
626 Cochrans Mill Rd.,
Pittsburgh, PA
USA 15236

Bus: (412) 386-6655
Fax: (412) 386-4917
email: gis3@cdc.gov

Kevin Schutt
Maintenance Forman
CVRD- INCO
143 Gordon St.
Garson, Ontario P3L 1N1
Bus: (705) 525-3330
Fax: (705) 525-3271
email: kscjitt@inco.com

Bill Spelliscy
Treasurer - Health and Safety Co-Chair
United Steelworkers Local 7106
68 Church St.,
Flin Flan, Manitoba R8A 1K7
Bus: (204) 687-4448
Fax: (204) 687-8176
email: amucha@usw.ca

Glen Staskus
Health & Safety Coordinator
Xstrata Nickel - Craig Mine
Onaping Ontario P0M 2R0
Bus:(705) 966-3411
Bus: (705) 966-6560
email: sstraskus@sudbury.xstratanickel.ca

Daniel Stinnette
Engineer
Mine Ventilation Services Inc.
4946 E. Yale Ave., Suite 103
Fresno Ca
USA 93727
Bus: (559) 452-0182
Fax: (559) 452-0184
email: dan@mvsengineering.com

Karsten Taudte
Cummins Deutschland GbmH
Odenwaldstrasse 23
Gross-Gerau, Germany 64521
Bus: +49-6152-174187
Fax: +49-6152-174141
email: karsten.taudte@cummins.com

Alan Thibert
Mining Health & Safety Inspector
Ministry of Labour
217 York st., 5th Floor
London, Ontario
Bus: (519) 646-3235
Fax: (519) 672-0268
email: christine.long@ontario.ca

Frank Woit
Field Consultant
Mines & Aggregates Safety & Health Assn.
690 McKeown Ave
North Bay, Ontario P1B 9P1
Bus: (705) 474-9196
Fax: (705) 472-5800
email: frankwoit@masha.on.ca

Kubota

Welcome to MDEC Workshop

John Baxter
Engineering Manager - Engine
Kubota Canada Ltd

Tuesday 2nd October 2007

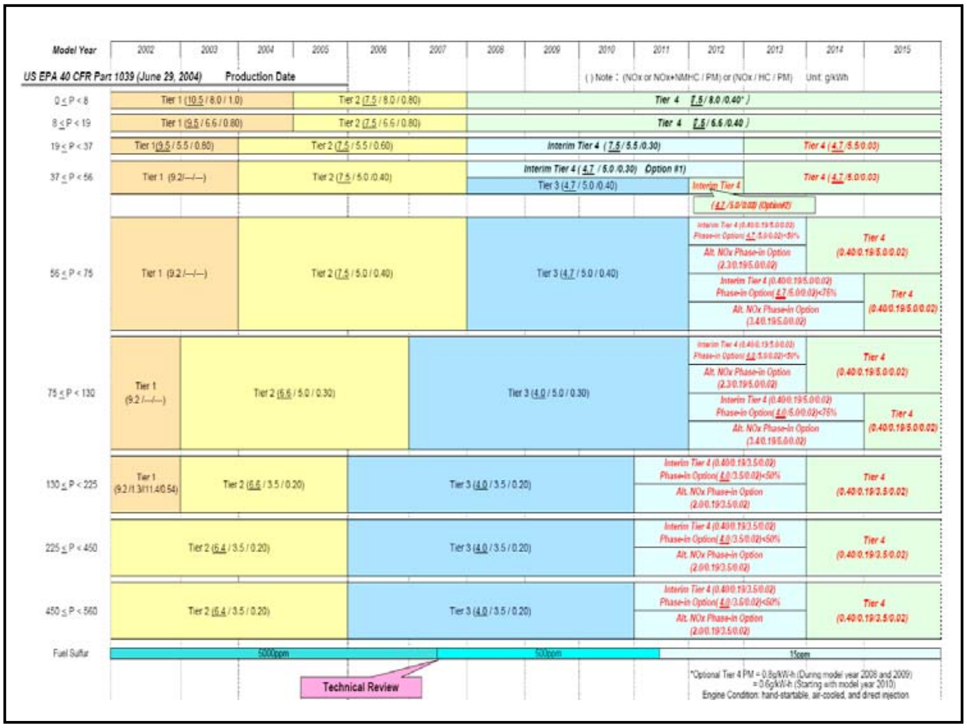
EPA Industrial Engine Emissions

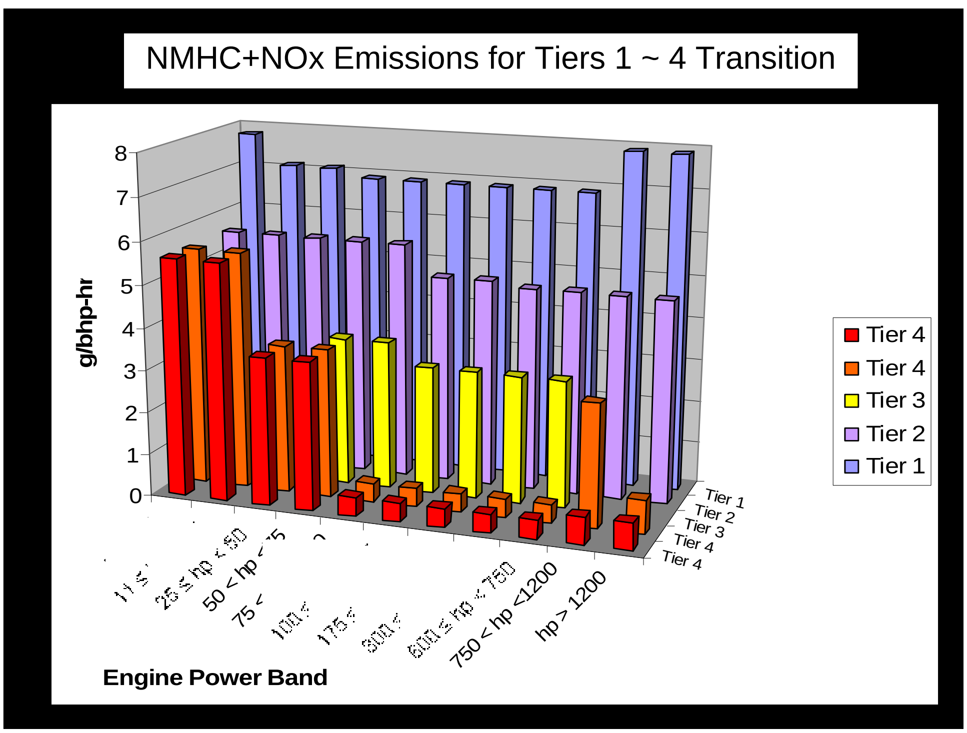
Kubota

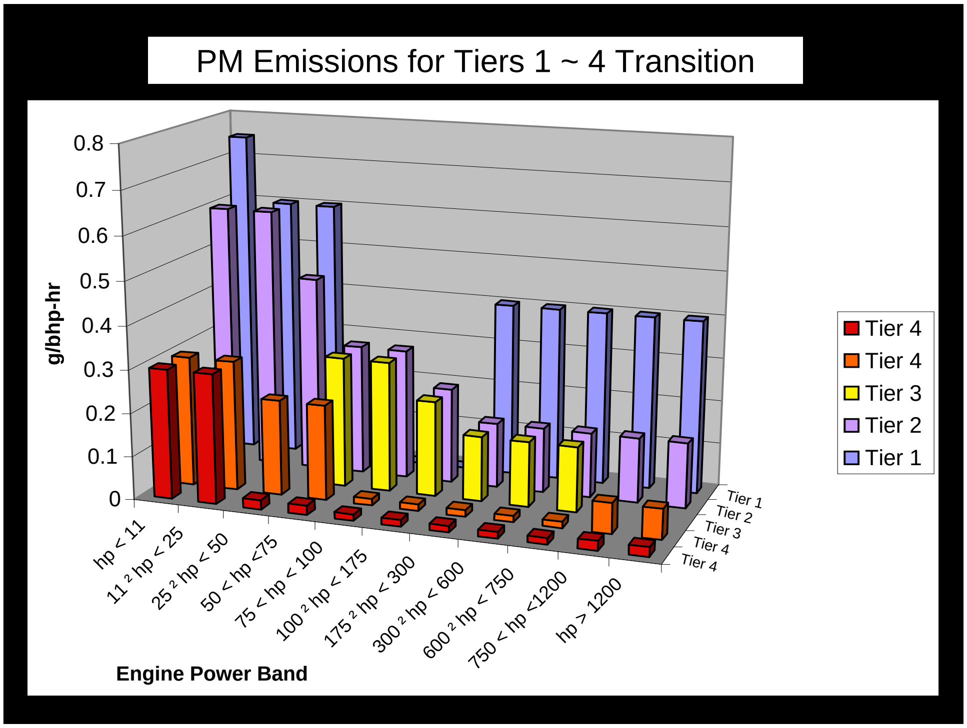
Applicable Regulations

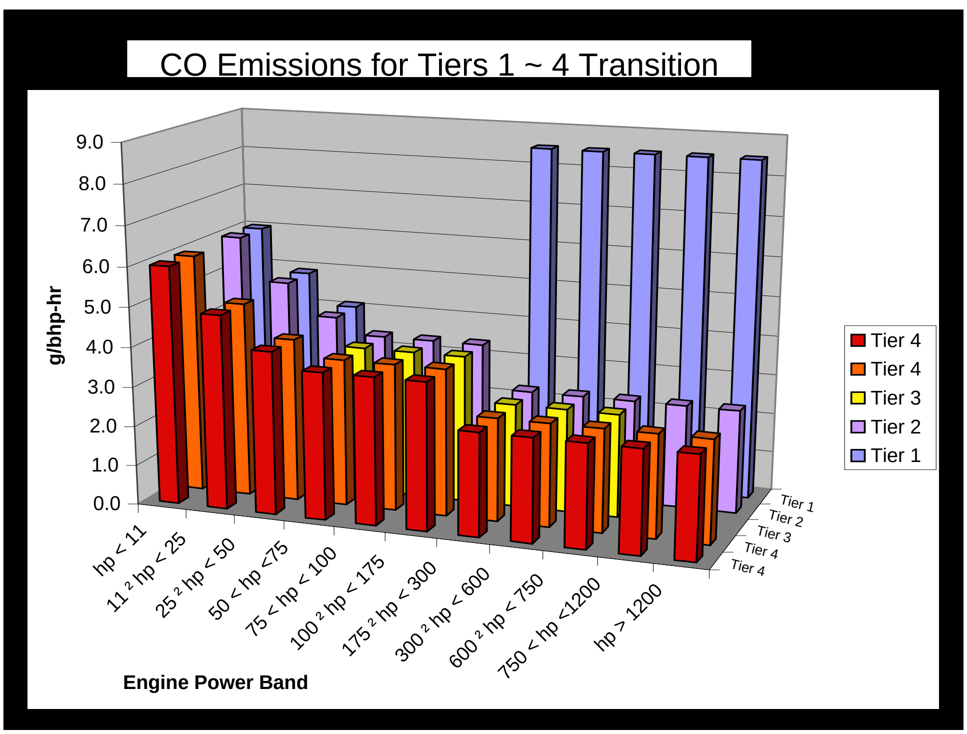
- 40 CFR Part 89 = Non-road Tier 1-3 regulations
- 40 CFR Part 1039, 1068 = Non-road Tier 4 regulations
- 40 CFR Part 60 = Stationary CI & SI regulations
- 40 CFR Part 94 = Marine CI regulations

Regulates:	*Carbon monoxide (CO)*
	Non-methane Hydrocarbons (NMHC)
	Nitrous Oxides (NOx)
	Or combined NMHC+NOx
	Particulate Matter (PM)

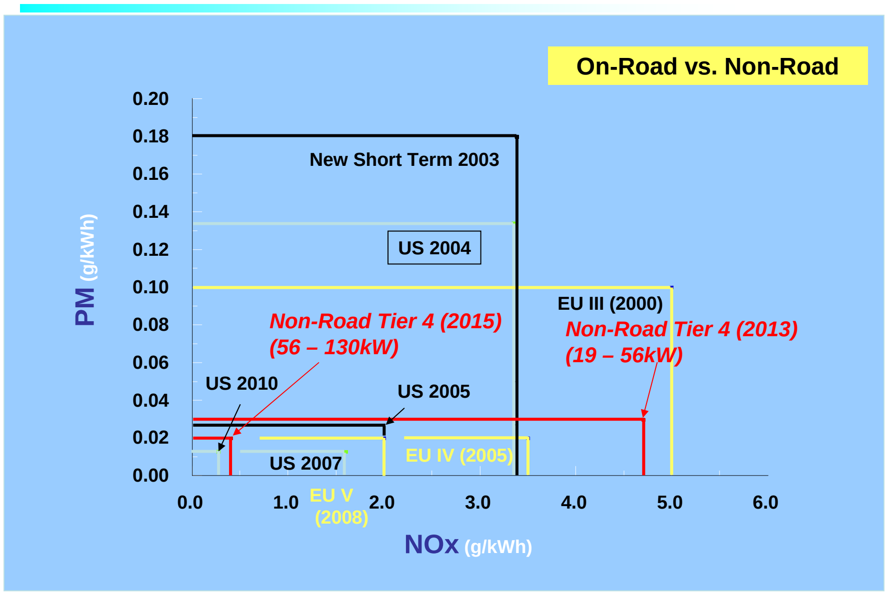

Model Year
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
US EPA 40 CFR Part 1039 (June 29, 2004)
Production Date
( ) Note： (NOx or NOx+NMHC / PM) or (NOx / HC / PM)
Unit: g/kWh
0 ≤ P < 8
Tier 1 (10.5 / 8.0 / 1.0)
Tier 2 (7.5 / 8.0 / 0.80)
Tier 4 (7.5 / 8.0 /0.40*)
8 ≤ P < 19
Tier 1 (9.5 / 6.6 / 0.80)
Tier 2 (7.5 / 6.6 / 0.80)
Tier 4 (7.5 / 6.6 /0.40)
19 ≤ P < 37
Tier 1(9.5 / 5.5 / 0.80)
Tier 2 (7.5 / 5.5 / 0.60)
Interim Tier 4 (7.5 / 5.5 /0.30)
Tier 4 (4.7 /5.5/0.03)
37 ≤ P < 56
Tier 1 (9.2/—/—)
Tier 2 (7.5 / 5.0 /0.40)
Interim Tier 4 (4.7 / 5.0 /0.30) Option #1)
Tier 3 (4.7 / 5.0 /0.40)
Interim Tier 4
(4.7 /5.0/0.03) (Option#2)
Tier 4 (4.7 /5.0/0.03)
56 ≤ P < 75
Tier 1 (9.2 /—/—)
Tier 2 (7.5 / 5.0 / 0.40)
Tier 3 (4.7 / 5.0 / 0.40)
Alt. NOx Phase-in Option
Tier 4
75 ≤ P < 130
Tier 1
(9.2 /—/—)
Tier 2 (6.6 / 5.0 / 0.30)
Tier 3 (4.0 / 5.0 / 0.30)
Alt. NOx Phase-in Option
Tier 4
130 ≤ P < 225
Tier 1
(9.2 /1.3/11.4/0.54)
Tier 2 (6.6 / 3.5 / 0.20)
Tier 3 (4.0 / 3.5 / 0.20)
Interim Tier 4 (0.40/0.19/3.5/0.02)
Phase-in Option(4.0/3.5/0.02)<50%
Alt. NOx Phase-in Option
(2.0/0.19/3.5/0.02)
Tier 4
(0.40/0.19/3.5/0.02)
225 ≤ P < 450
Tier 2 (6.4 / 3.5 / 0.20)
Tier 3 (4.0 / 3.5 / 0.20)
Interim Tier 4 (0.40/0.19/3.5/0.02)
Phase-in Option(4.0/3.5/0.02)<50%
Alt. NOx Phase-in Option
(2.0/0.19/3.5/0.02)
Tier 4
(0.40/0.19/3.5/0.02)
450 ≤ P < 560
Tier 2 (6.4 / 3.5 / 0.20)
Tier 3 (4.0 / 3.5 / 0.20)
Interim Tier 4 (0.40/0.19/3.5/0.02)
Phase-in Option(4.0/3.5/0.02)<50%
Alt. NOx Phase-in Option
(2.0/0.19/3.5/0.02)
Tier 4
(0.40/0.19/3.5/0.02)
Fuel Sulfur
5000ppm
500ppm
15ppm
Technical Review
*Optional Tier 4 PM = 0.8g/kW-h (During model year 2008 and 2009)
= 0.6g/kW-h (Starting with model year 2010)
Engine Condition: hand-startable, air-cooled, and direct injection


NMHC+NOx Emissions for Tiers 1 ~ 4 Transition
g/bhp-hr
8
7
6
5
4
3
2
1
0
Engine Power Band
25 ≤ hp < 50
50 < hp < 75
600 ≤ hp < 750
750 < hp <1200
hp > 1200
Tier 1
Tier 2
Tier 3
Tier 4
Tier 4

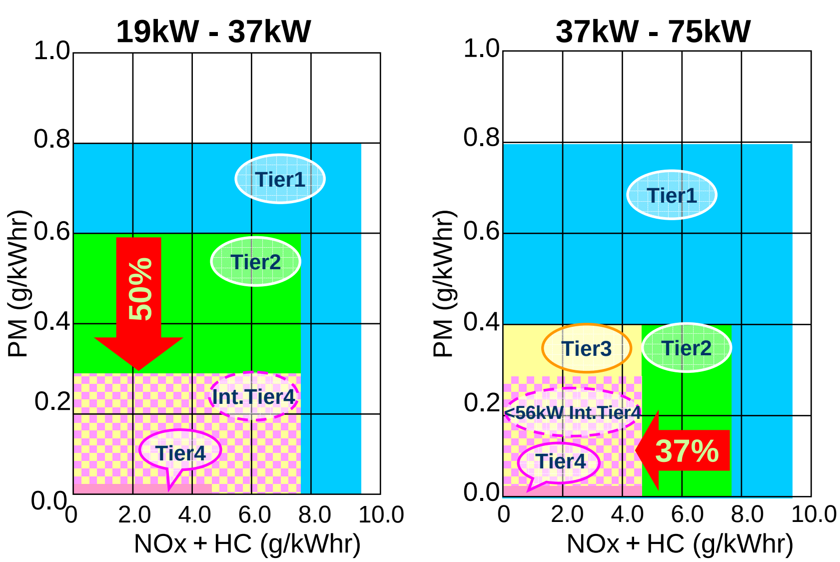

PM Emissions for Tiers 1 ~ 4 Transition
g/bhp-hr
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
hp < 11
11 ² hp < 25
25 ² hp < 50
50 < hp <75
75 < hp < 100
100 ² hp < 175
175 ² hp < 300
300 ² hp < 600
600 ² hp < 750
750 < hp <1200
hp > 1200
Engine Power Band
Tier 1
Tier 2
Tier 3
Tier 4
Tier 4
Tier 4
Tier 4
Tier 3
Tier 2
Tier 1


CO Emissions for Tiers 1 ~ 4 Transition
g/bhp-hr
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
hp < 11
11 ² hp < 25
25 ² hp < 50
50 < hp <75
75 < hp < 100
100 ² hp < 175
175 ² hp < 300
300 ² hp < 600
600 ² hp < 750
750 < hp <1200
hp > 1200
Engine Power Band
Tier 1
Tier 2
Tier 3
Tier 4
Tier 4
Tier 4
Tier 4
Tier 3
Tier 2
Tier 1

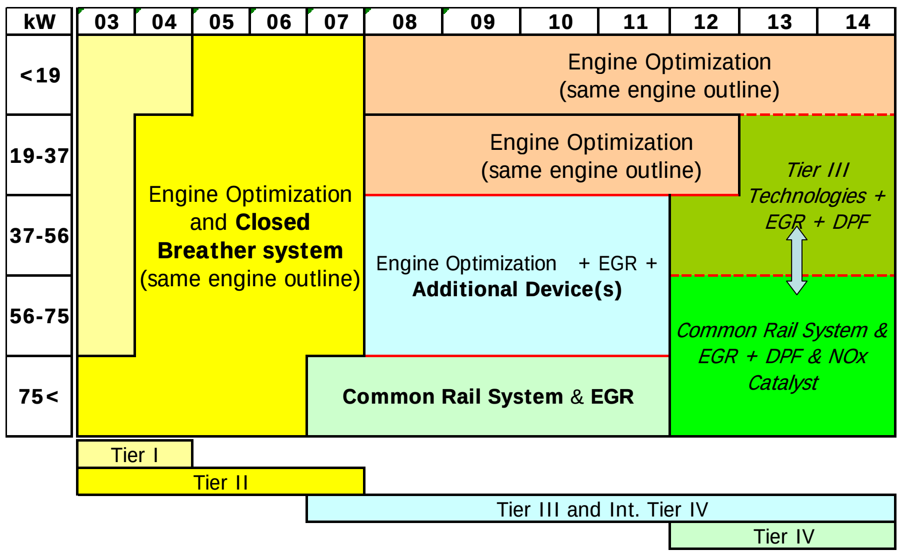
NOx vs. Particulate (PM)



Emissions Requirements by Power Class



Possible Solutions to meet EPA Regulations



Tier 4 Standards for CI

< 19 kW (25 hp)

Effective - 2008

<19kW (Tier 4) Focus = reduction of PM 50%

(Other emissions same as Tier 2)

- Internal engine optimization can be utilized
- No need for exhaust after-treatment
- EPA technology review to take place in 2007

Tier 4 Standards for CI
< 19 kW (25 hp)

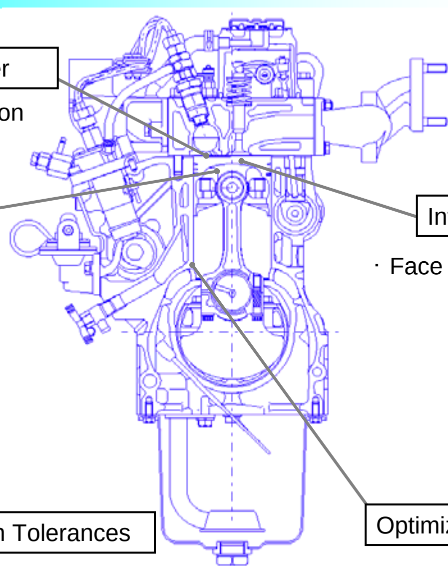
Model Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
US EPA 40 CFR Part 1039 (June 29, 2004) Production Date									( ) Note : (NOx or NOx+NMHC / PM) or (NOx / HC / PM)				Unit: g/kWh	
0 ≤ P < 8	Tier 1 (10.5 / 8.0 / 1.0)			Tier 2 (7.5 / 8.0 / 0.80)			Tier 4 (7.5 / 8.0 /0.40*)							
8 ≤ P < 19	Tier 1 (9.5 / 6.6 / 0.80)			Tier 2 (7.5 / 6.6 / 0.80)			Tier 4 (7.5 / 6.6 /0.40)							

Solutions to meet EPA Regulations

kW	03	04	05	06	07	08	09	10	11	12	13	14
<19			Engine Optimization and **Closed Breather system**			Engine Optimization (same engine outline)						

Modification Items of <19kW for Tier 4i

Kubota

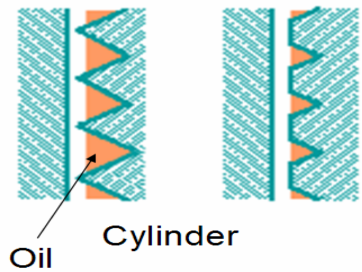


Same Engine Outline

Plateau honing

Plateau honing makes oil consumption propriety

Current machining	Plateau machining



Pistons

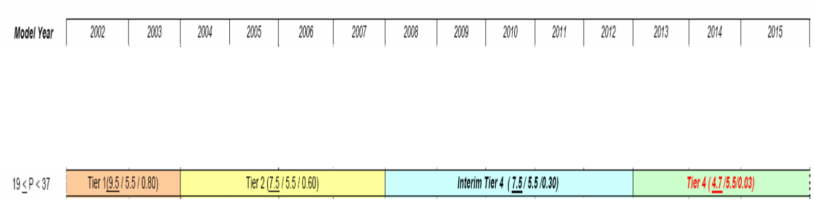
D722 D902 D905

Tier 3 – Interim Tier 4 Standards for CI
19 ≤ kW < 37 (25 ≤ hp < 50)

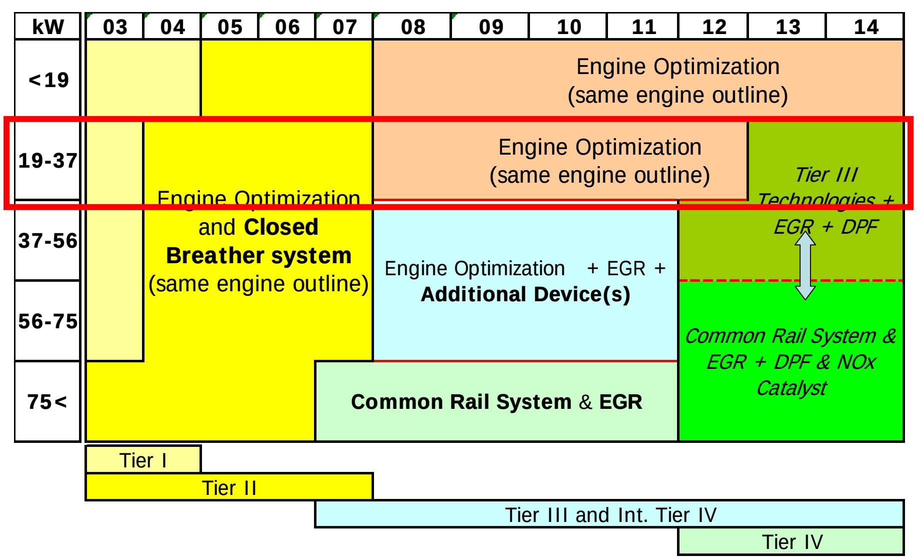
Kubota

Effective - 2008

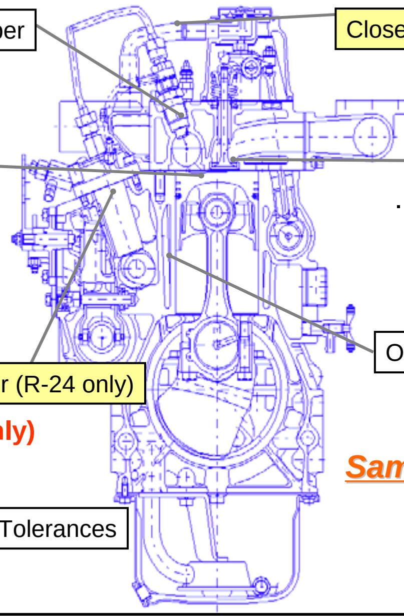
19~37kW (Int. Tier 4) Focus = reduction of PM 50% *(Other emissions same as Tier 2)*



Possible Solutions to meet EPA Regulations



Modification Items of 19~37kW for Tier 4i



Combustion chamber
· Shape optimization

Piston
· Recess shape optimization

Boost compensator (R-24 only)
(Turbo engine only)

Minimize Production Tolerances

Closed breather
(Turbo engines)

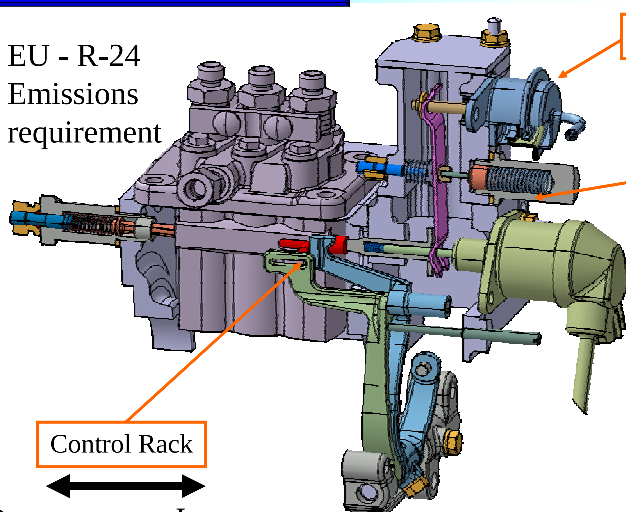
Intake / Exhaust Valve
· Face shape optimization

Optimized Oil Consumption

Same Engine Outline

Boost Compensator

EU - R-24
Emissions
requirement



Actuator

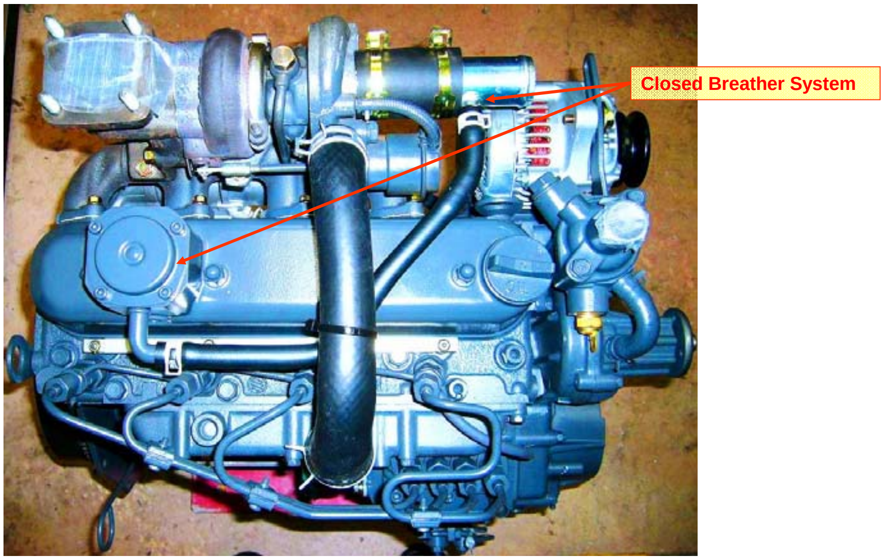
Thermostat

Control Rack

Decrease ⟷ Increase

20

Kubota



Tier 3 – Interim Tier 4 Standards for CI

37 ≤ kW < 56 (50 ≤ hp < 75)

Kubota

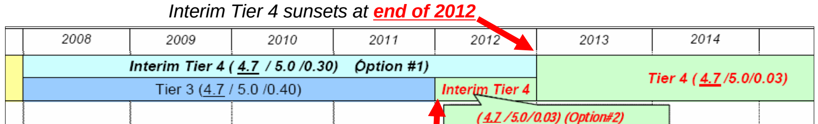
Effective - 2008

37~56kW (TWO PATHS!) Focus =

Option 1 = Interim Tier 4 –

reduce NMHC+NOx by 37%, PM levels by 25% *(CO emissions same as Tier 2)*

*Interim Tier 4 sunsets at **end of 2012***



Option 2 = Tier 3 –

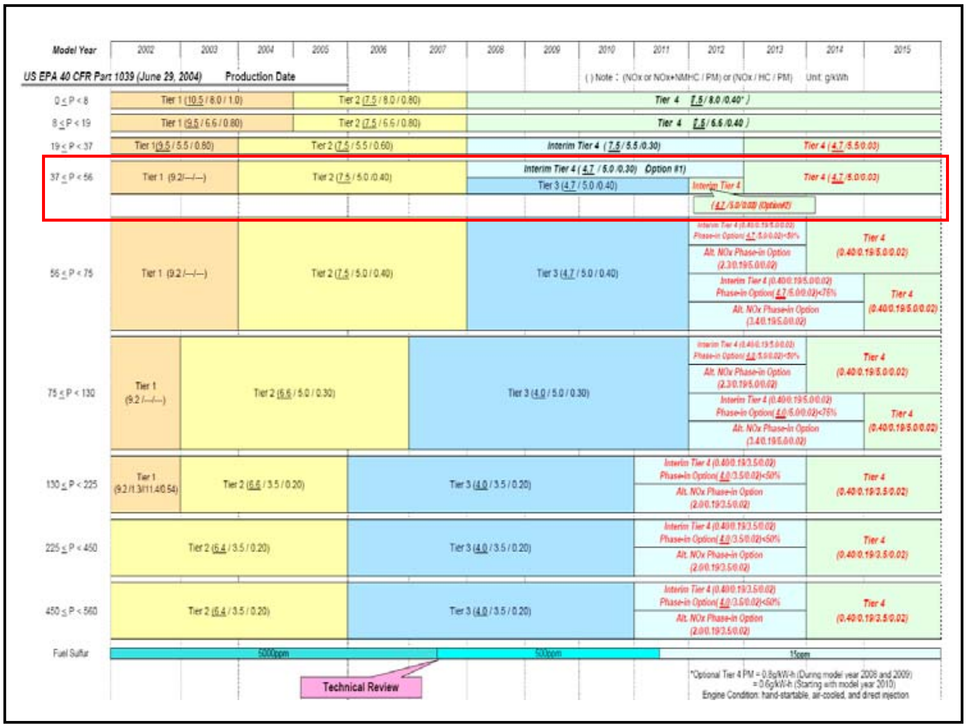
reduce NMHC+NOx by 37%
PM levels same as Tier 2

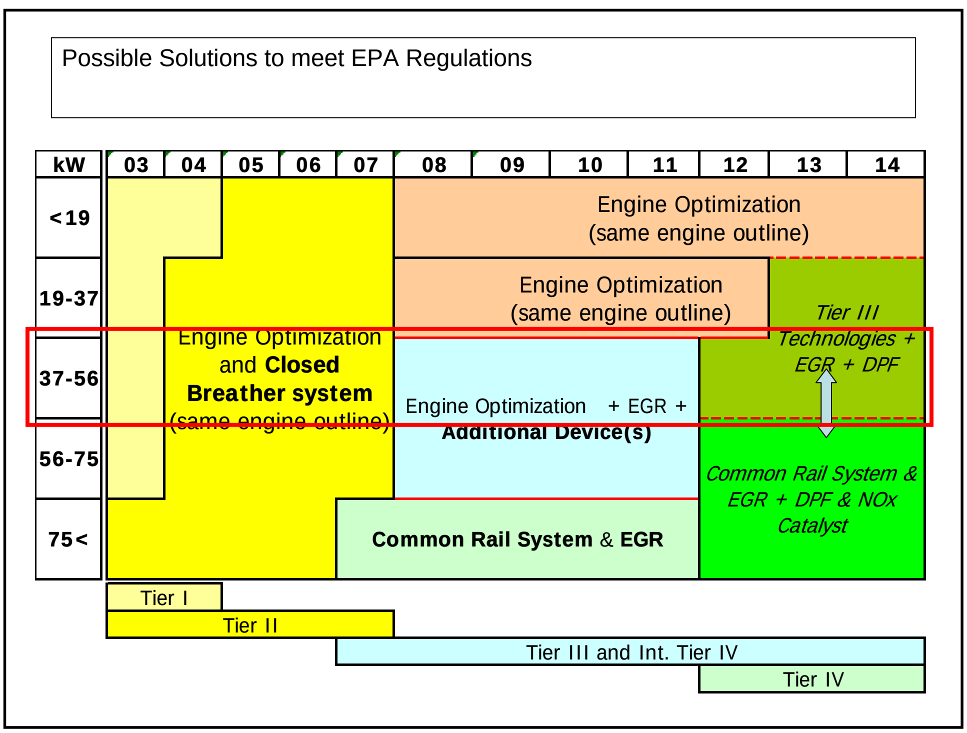
(Other emissions same as Tier 2)

*Tier 3 sunsets at **end of 2011***

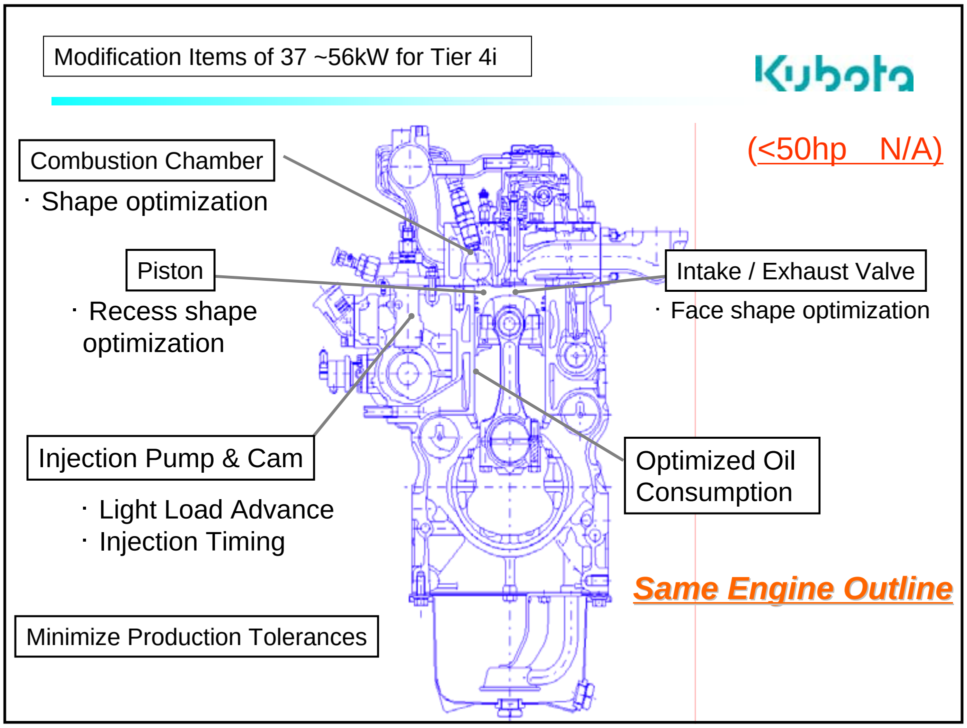
Exhaust after-treatment required one whole year earlier with option 2

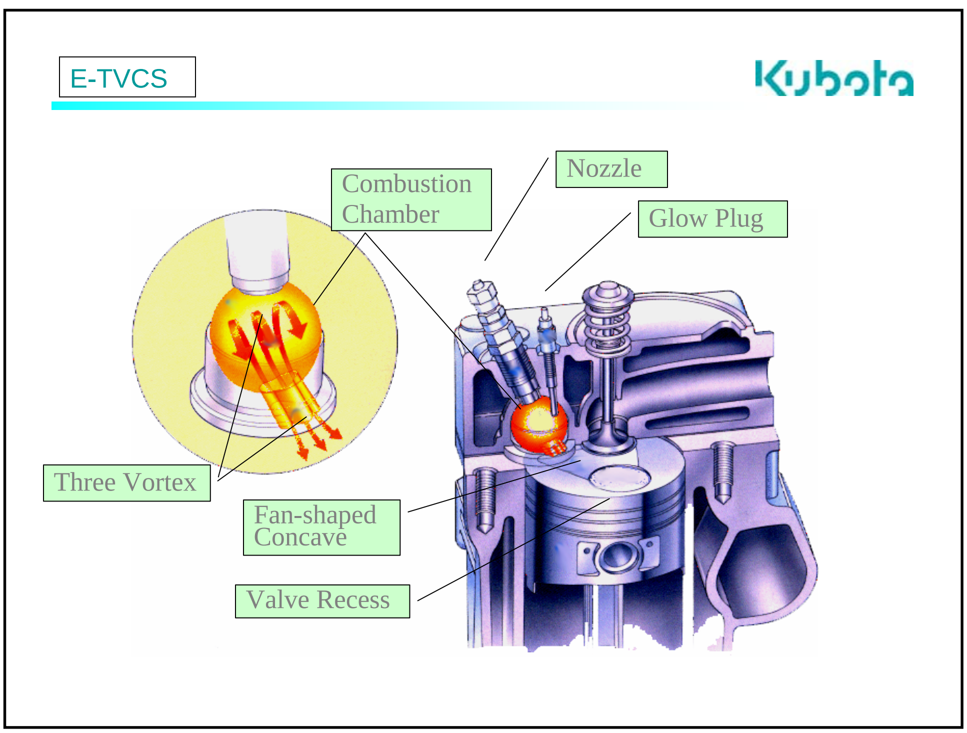
- PM reduction requires use of Low Sulfur Diesel fuel (< 500 ppm) from June 2007 (nonroad applications)





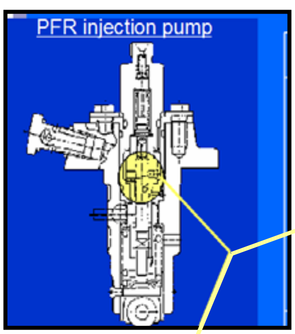
Possible Solutions to meet EPA Regulations
kW
03
04
05
06
07
08
09
10
11
12
13
14
<19
19-37
37-56
56-75
75<
Engine Optimization (same engine outline)
Engine Optimization (same engine outline)
Tier III Technologies + EGR + DPF
Engine Optimization and Closed Breather system (same engine outline)
Engine Optimization + EGR + Additional Device(s)
Common Rail System & EGR + DPF & NOx Catalyst
Common Rail System & EGR
Tier I
Tier II
Tier III and Int. Tier IV
Tier IV

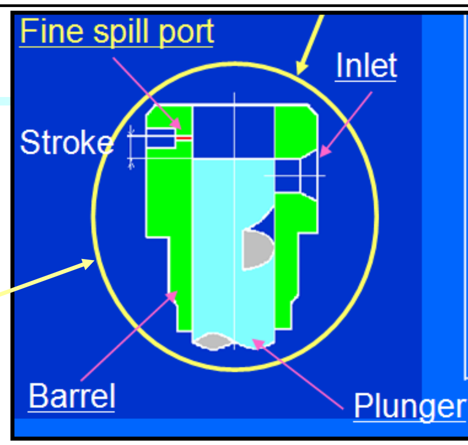

Modification Items of 37 ~56kW for Tier 4i
Kubota
(<50hp N/A)
Combustion Chamber
・Shape optimization
Piston
・Recess shape optimization
Intake / Exhaust Valve
・Face shape optimization
Injection Pump & Cam
・Light Load Advance
・Injection Timing
Optimized Oil Consumption
Same Engine Outline
Minimize Production Tolerances

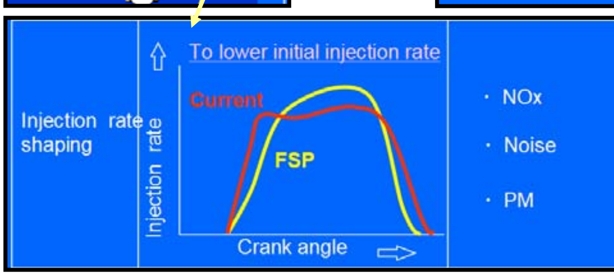

E-TVCS
Kubota
Combustion Chamber
Nozzle
Glow Plug
Three Vortex
Fan-shaped Concave
Valve Recess

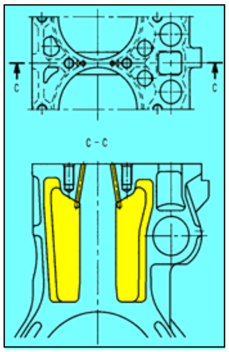
Kubota

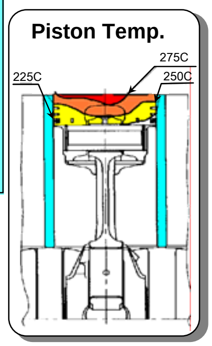
PFR Injection Pump with Fine Spill Port

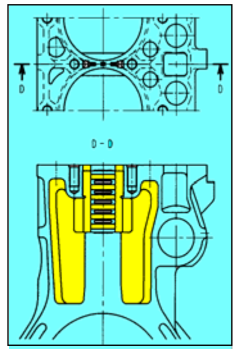


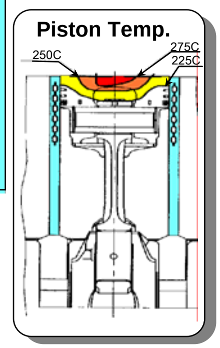












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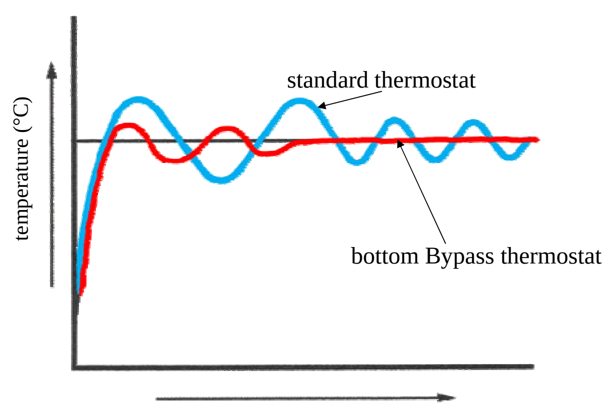
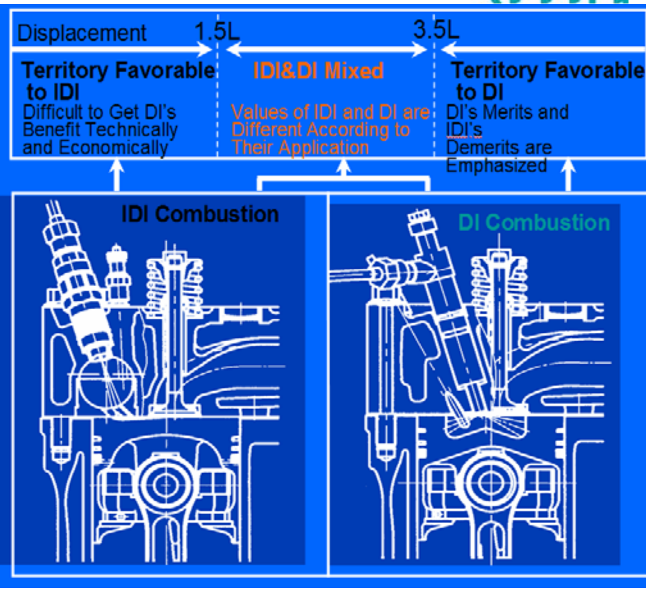
Thermostat

Control Type Thermostat & Bottom Bypass System

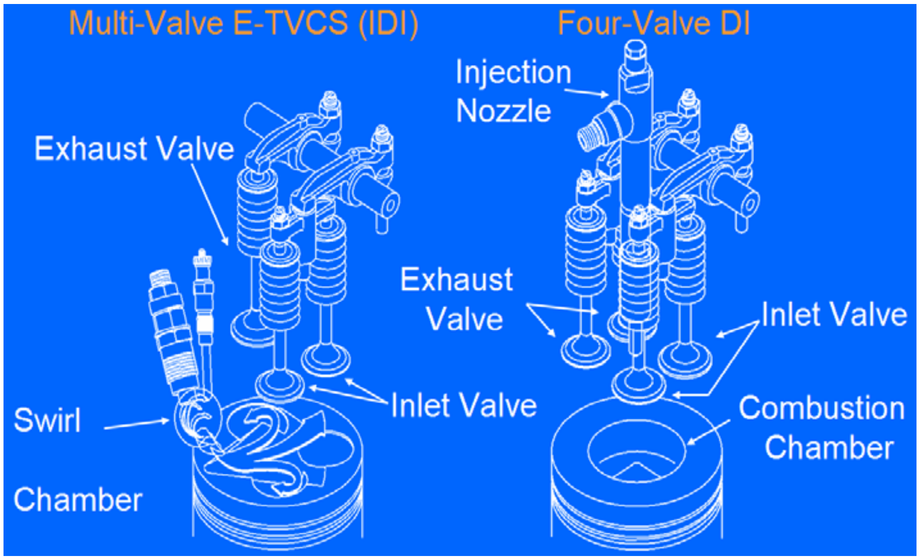


Subject	IDI	DI
Noise	✔	
Exhaust Emissions	✔	
High Load Smoke	✔	
Irritating Odor	✔	
Fuel Consumption		✔
Maintenance of Lube Oil		✔
Cooling Performance		✔
Startibility		✔

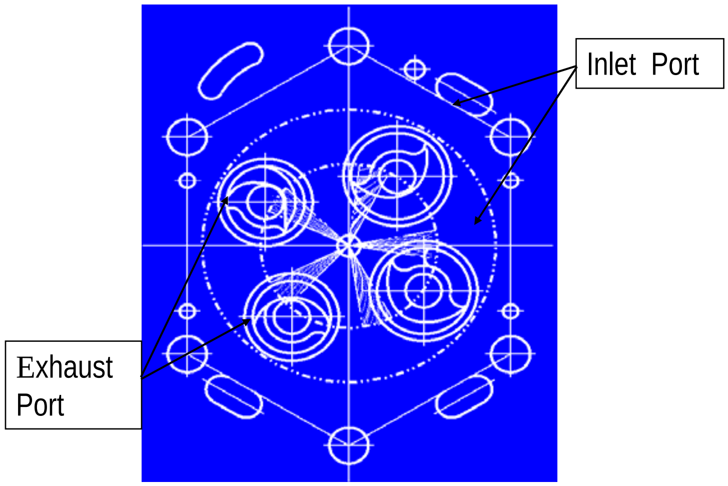


New 03M Model	
V2403-M-IDI-T	**Same Outline as V2403-M, with Turbo Charger** **No EGR required**

New V3600 Model	
V3600-NA (IDI)	**Same Outline as V3300-NA(IDI), with few minor changes – No EGR required**
V3600-T (IDI)	**Same Outline as V3300-NA(IDI), with few minor changes – No EGR required**



Molybdenum Disulfide Coating – DI Piston



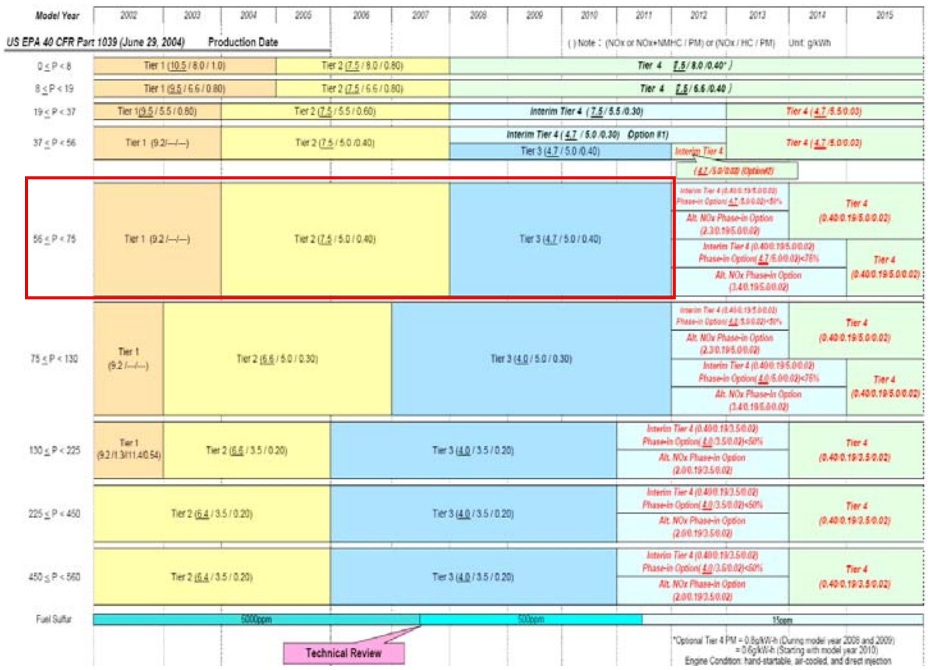
Tier 3 Standards for C I

56 ≤ kW < 75   (75 ≤ hp < 100)

Effective 2008 - finishes, end 2011.

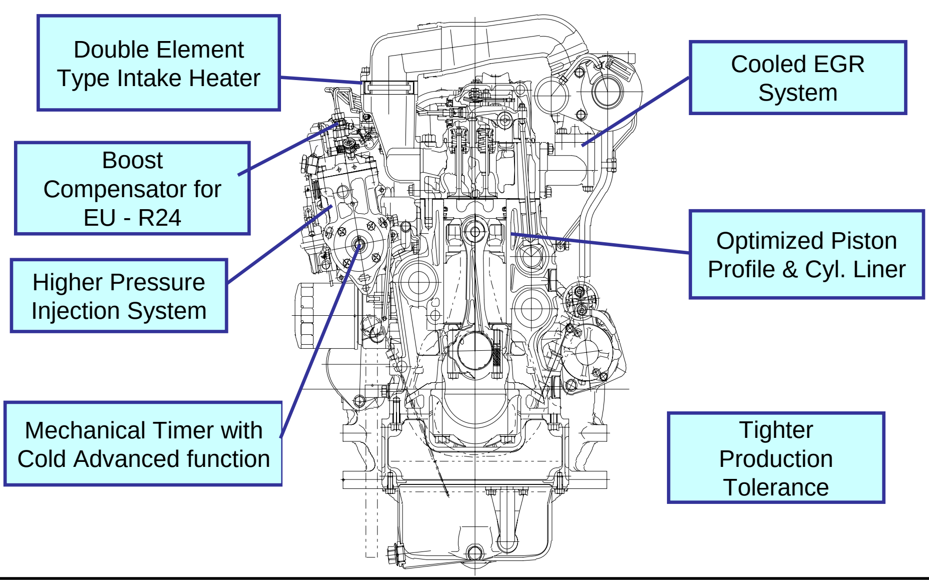
56~75kW Focus = reduction of NMHC+NOx 37%

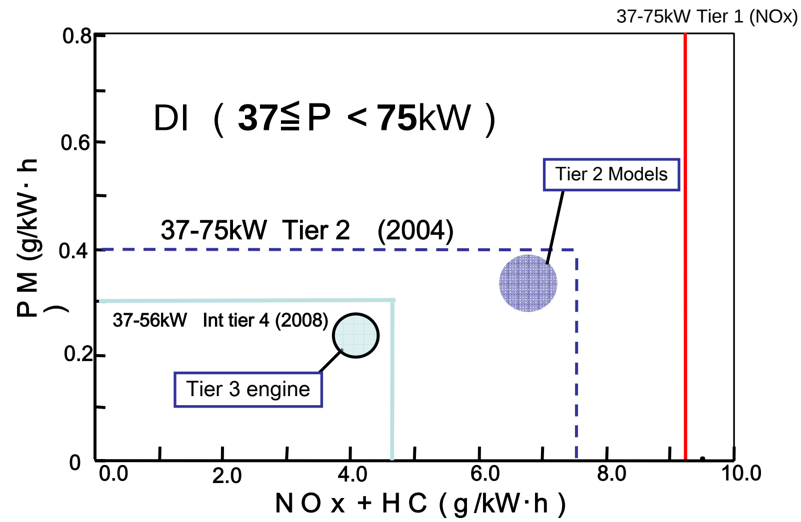
(Other emissions same as Tier 2)

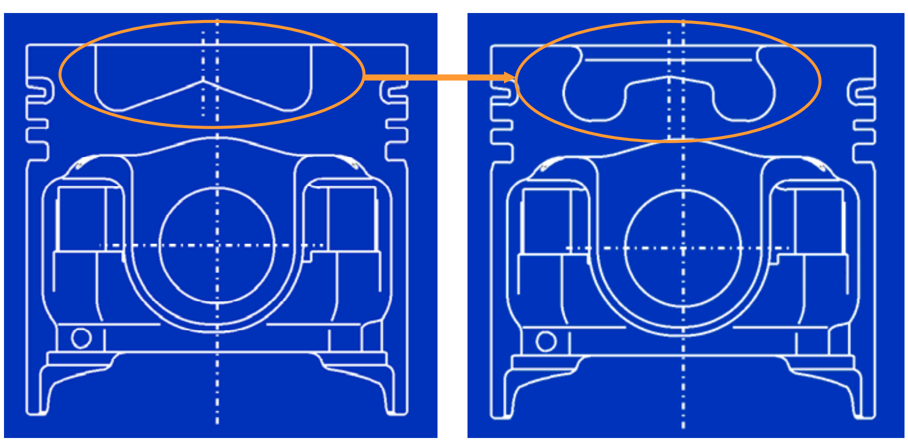


Solutions for Tier3 – 56~75kW

Kubota



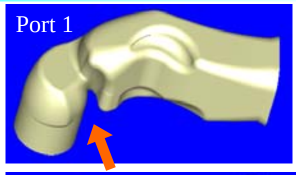

37-75kW Tier 1 (NOx)
DI（37≦P＜75kW）
Tier 2 Models
37-75kW Tier 2 (2004)
37-56kW Int tier 4 (2008)
Tier 3 engine
P M (g/kW· h)
N O x + H C (g /kW·h)
0.8
0.6
0.4
0.2
0
0.0
2.0
4.0
6.0
8.0
10.0

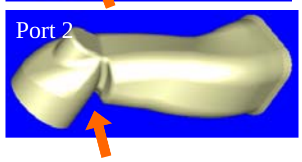


Kubota

Inlet Port

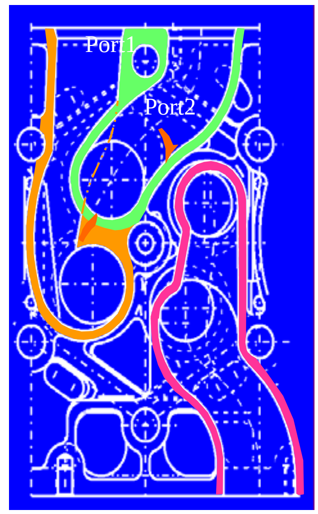
Two Inlet Port
Swirl & Direct
Port





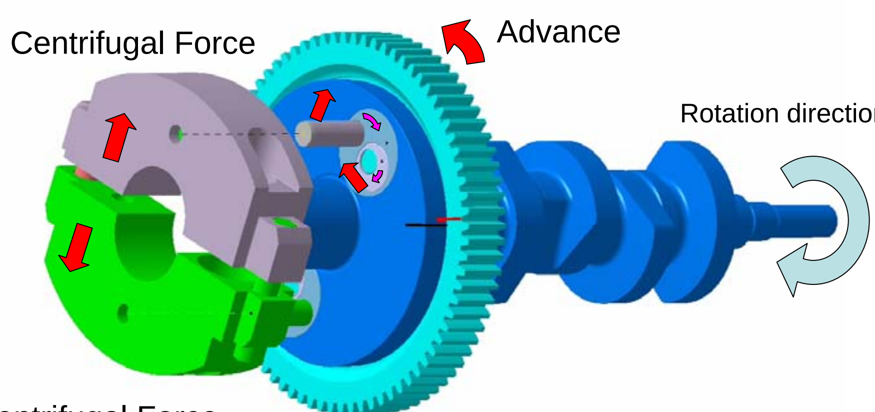
One Exhaust Port

Water Channel between Exhaust Valves

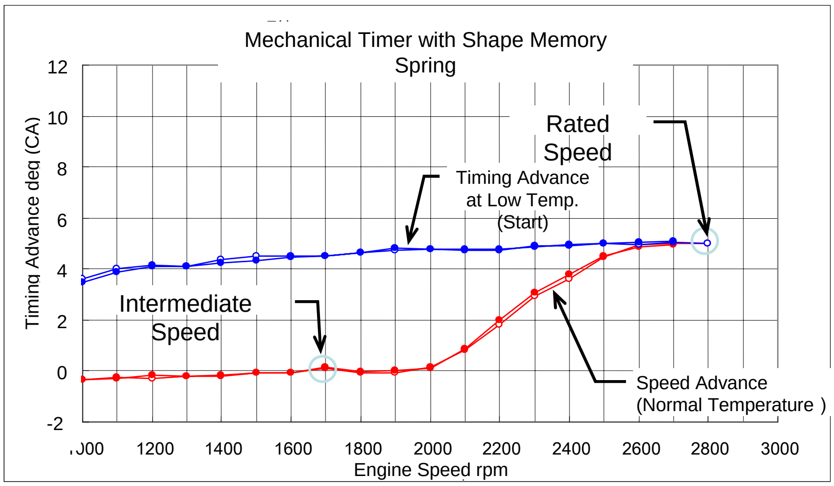


Exhaust Port

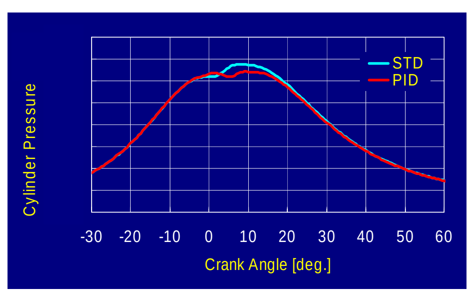
Mechanical (Speed) Timer



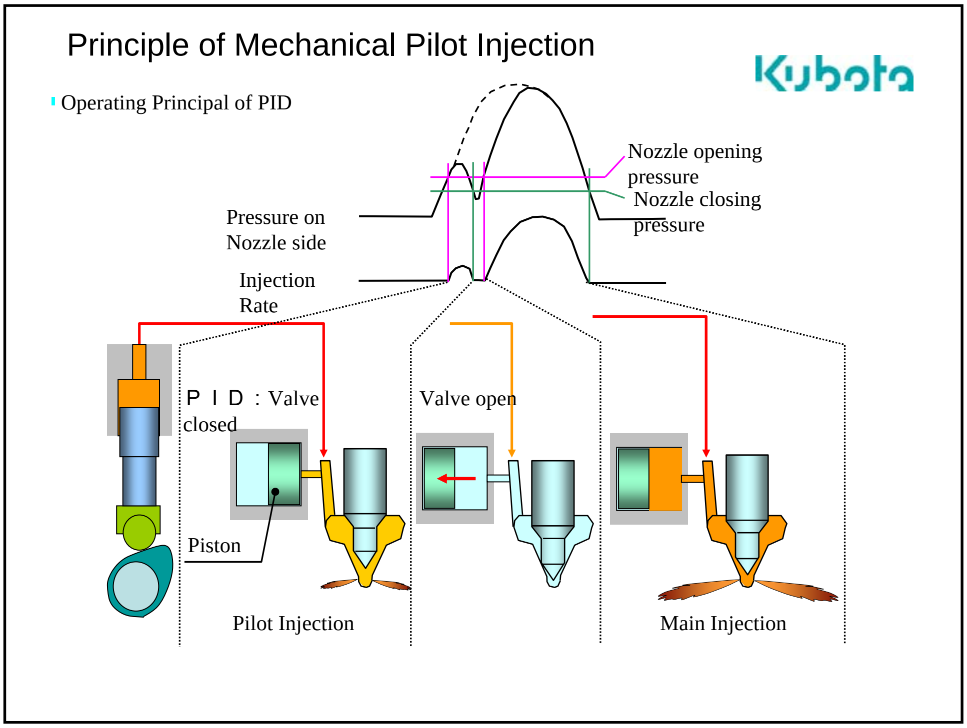
Timing Advance Function of Mechanical Timer (Temperature / Engine Speed ）

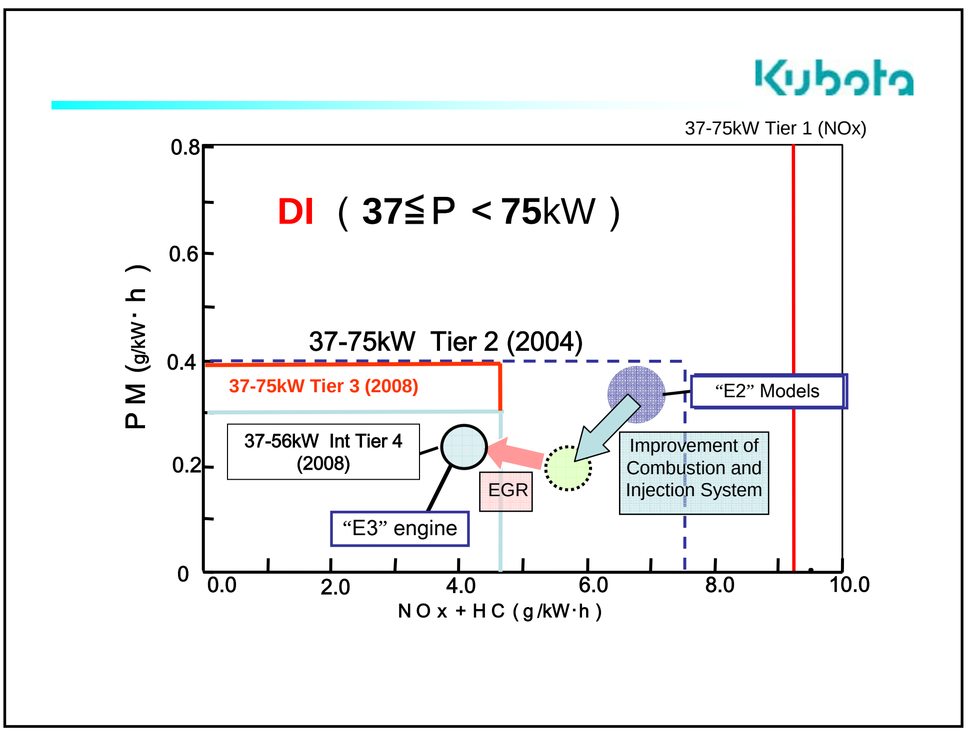


Mechanical Pilot Injection Device for PFR Injection Pump

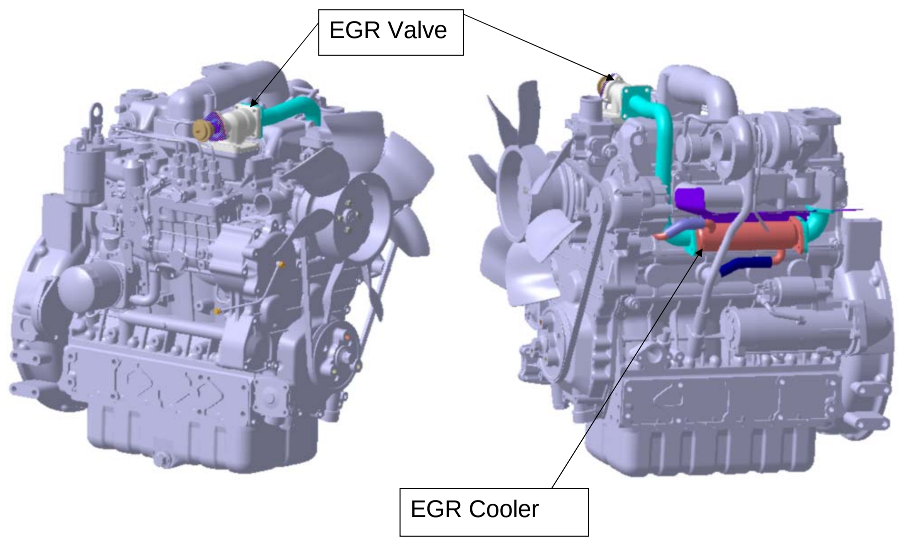


Principle of Mechanical Pilot Injection

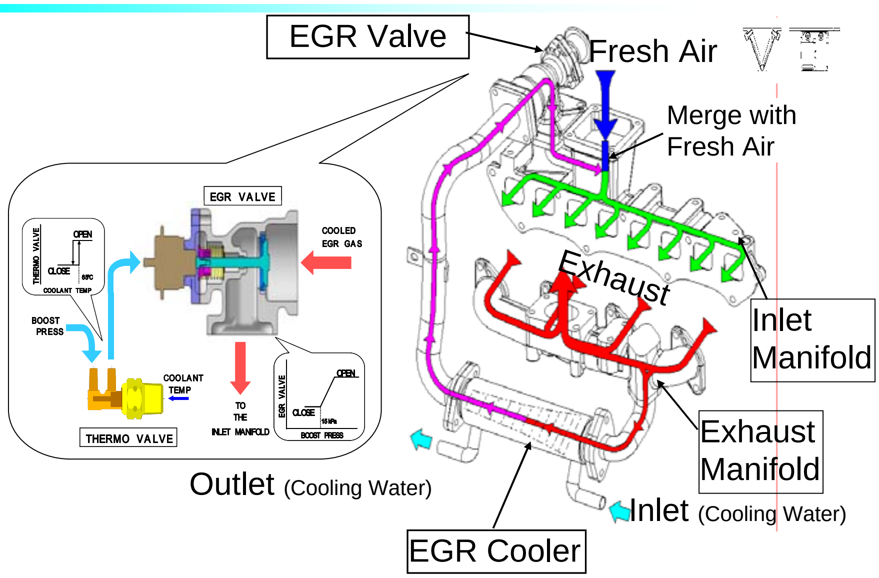




V3800-DI-T-E3



Cooled EGR System for V3800DI-T - 56 ~75kW



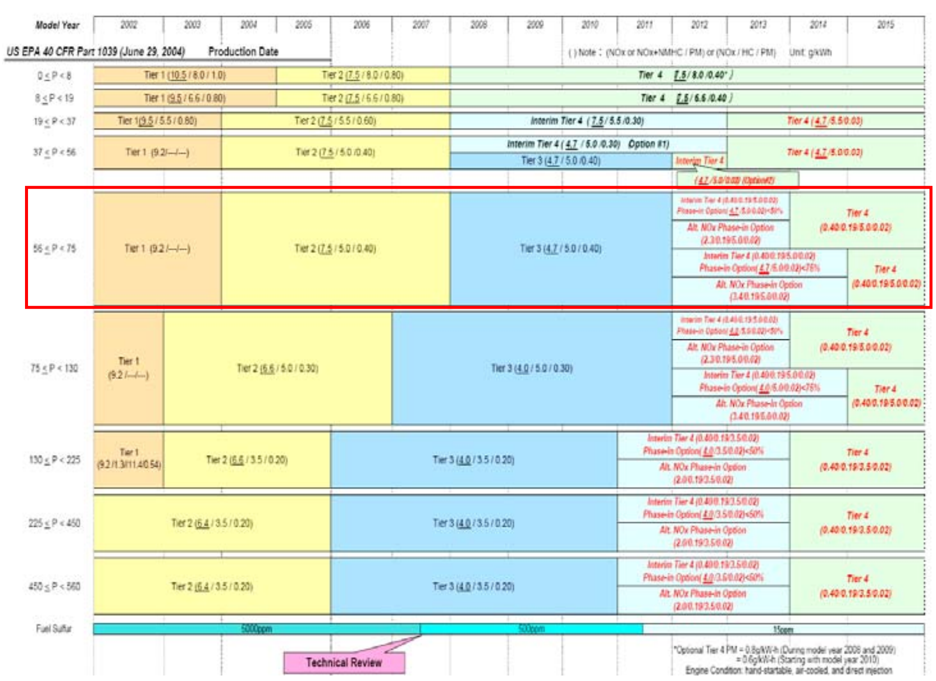
EGR

Exhaust gas is cooled approx. 390ºC by engine coolant under certain conditions.

To reduce noxious emissions by lowering the combustion temperature.

Approx. 8% of the exhaust gases under certain conditions are returned to the combustion chambers.

The cooled gases minimize temperatures and hamper nitrogen oxide formation.



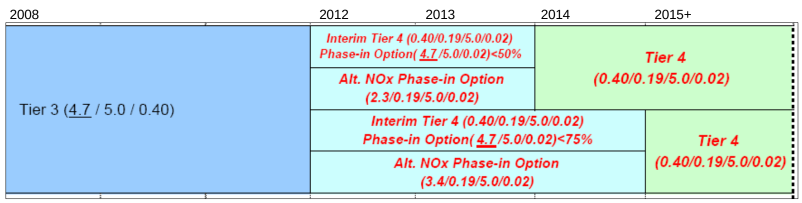
Tier 4 Standards for C I

56 ≤ kW < 75 (75 ≤ hp < 100)

Kubota

Effective 2012

- Multiple phase in options, two or three years as Interim Tier 4 with flexible NOx requirements but 95% PM reduction!!!!

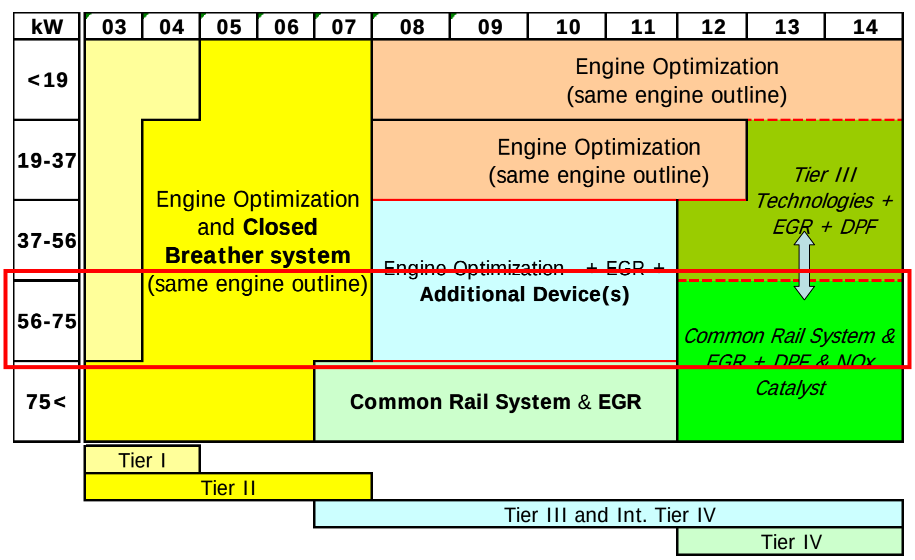


- NMHC and NOx now measured separately
  (vs. combined NMHC+NOx as in Tier 3)

Requires Ultra Low Sulfur Diesel fuel (<15 ppm) - June 2010 (nonroad applications)

Exhaust after treatment technologies currently being developed to meet 2007 on-highway diesel emission standards will be required

Possible Solutions to meet EPA Regulations



Kubota

Summary – CI Emissions Reductions **Tier 2 to Tier 4**:

<19kW (25hp)	NOx, CO same, PM drops 50%
19 ~ 37kW (25~50hp)	NOx drops 37%, PM drops 95%
37 ~ 56kW (50~75hp)	NOx drops 37%, PM drops 93%
56 ~ 75kW (75~100hp)	NOx drops 95%, PM drops 95%

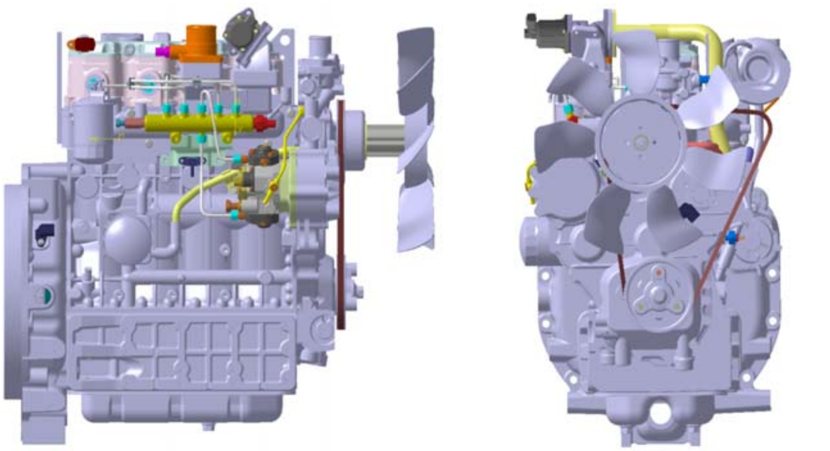
Significant reductions requiring much greater control of combustion (Engine optimization + EGR) and addition of exhaust after treatment (PM filters).

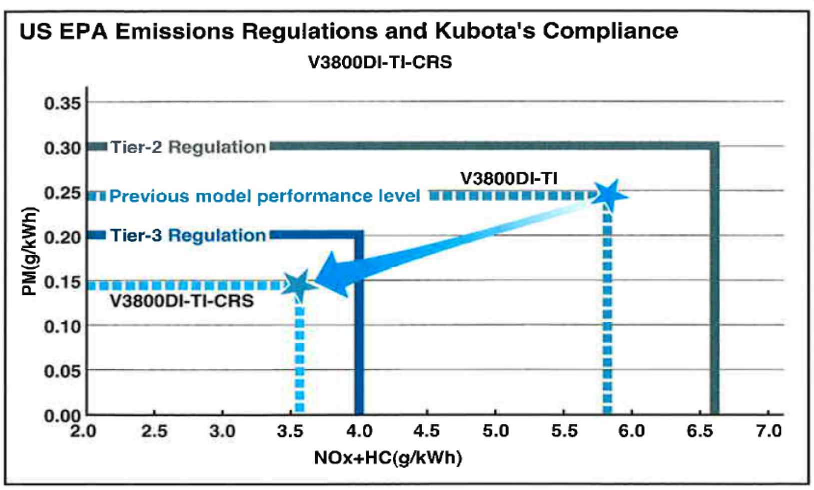
Regulations Address New Engines

Kubota

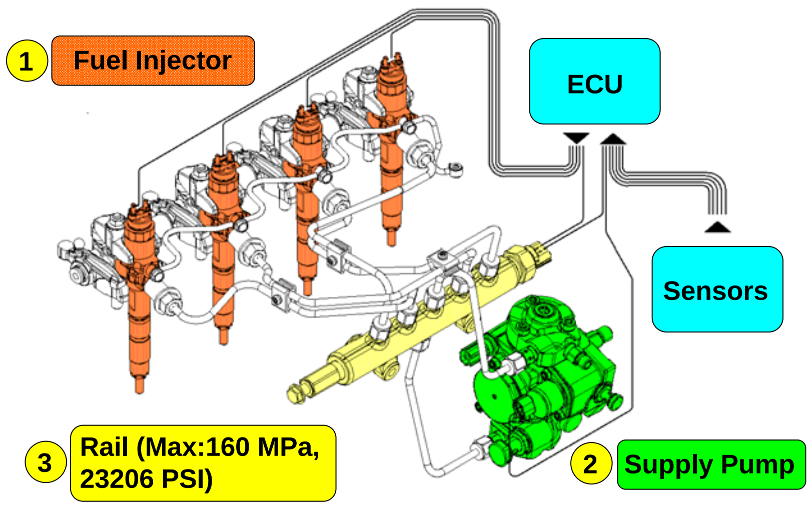
- **Electric Controlled Engines:** 2007
  - ECU, Common rail fuel injection, EGR
- **PM Control Aftertreatment:** 2012/13
  - PM filter (DPF) over 19kW engines
- **NOx Control Aftertreatment:** 2014/15
  - NOx Catalyst over 57kW engines
- **Fuel Diversity:**
  - Low sulfur diesel (LSD) 500 ppm 2007
  - Ultra low sulfur diesel (USLD) 15 ppm 2010
  - Biodiesel B5 Immediate

V38DICR-TIE3-S

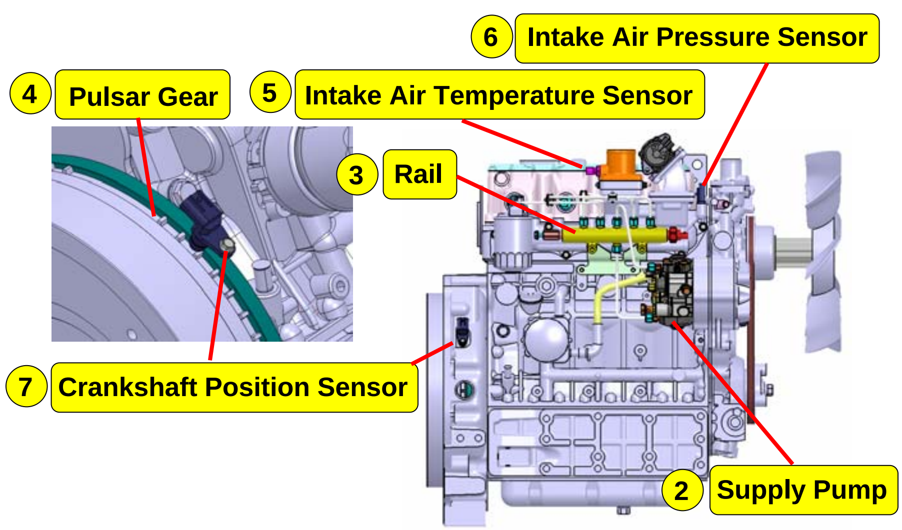


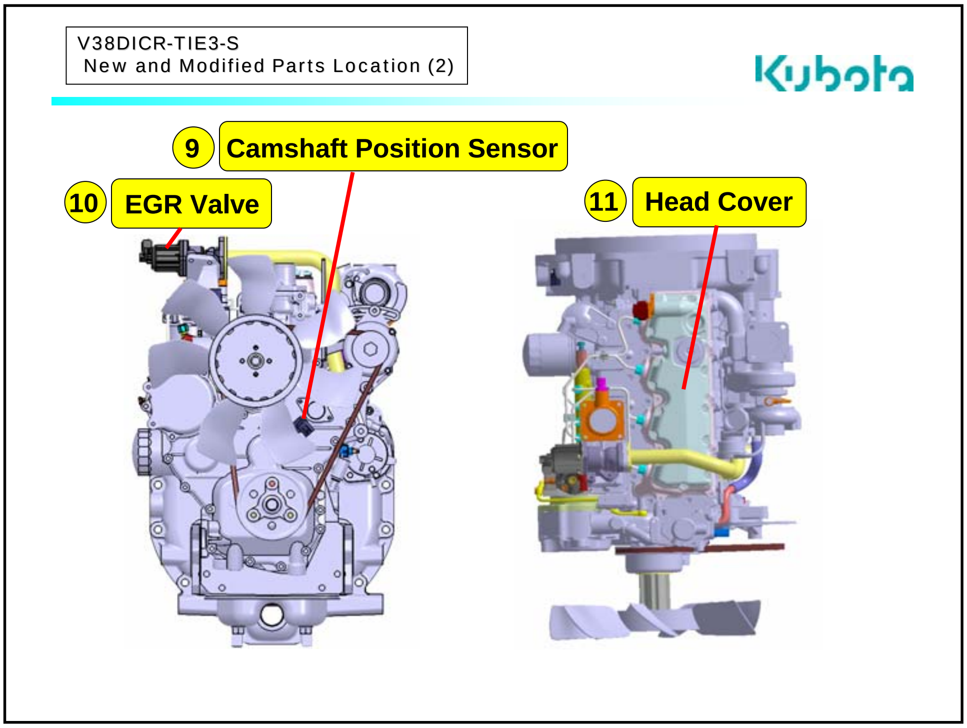


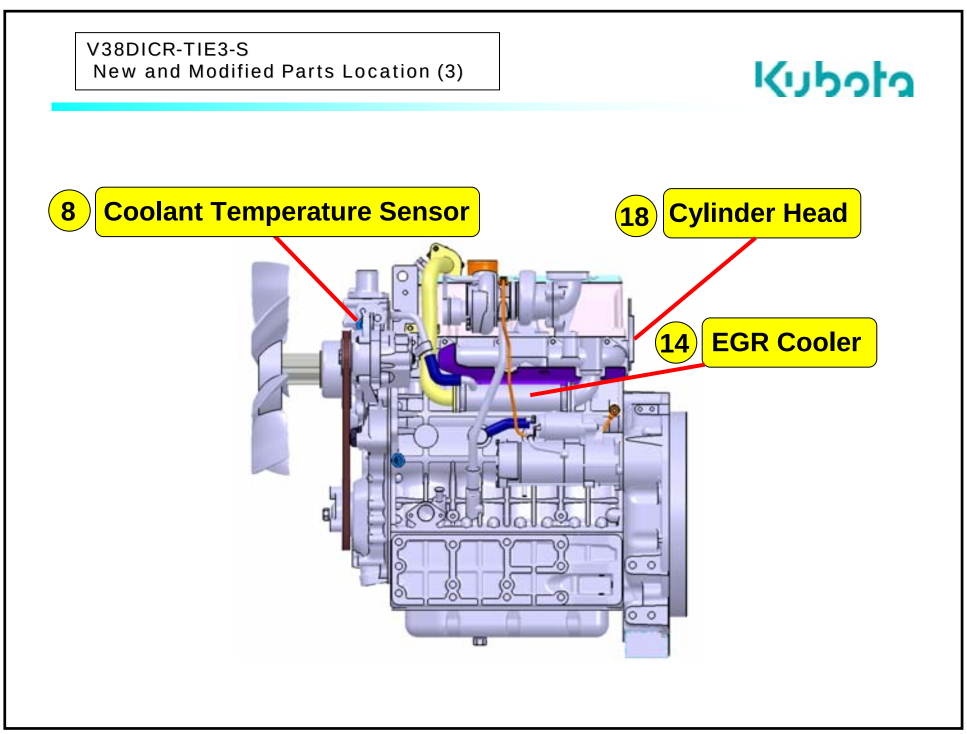
V38DICR-TIE3-S
High Pressure Common Rail System



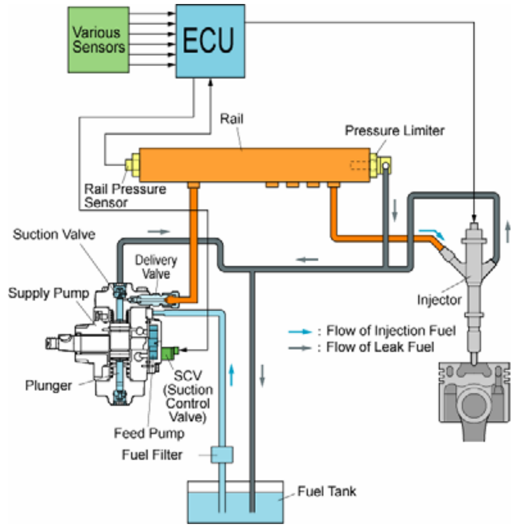
V38DICR-TIE3-S
New and Modified Parts Location (1)



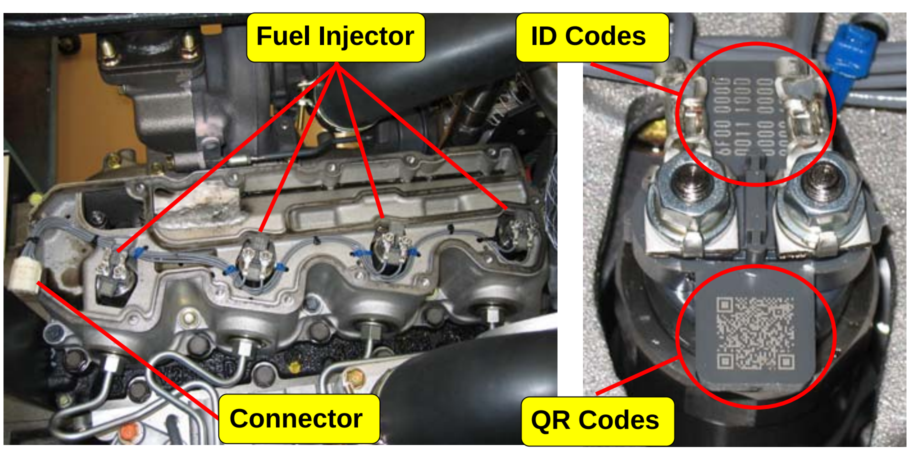

V38DICR-TIE3-S
New and Modified Parts Location (2)
Kubota
9
Camshaft Position Sensor
10
EGR Valve
11
Head Cover


V38DICR-TIE3-S
New and Modified Parts Location (3)
Kubota
8
Coolant Temperature Sensor
18
Cylinder Head
14
EGR Cooler

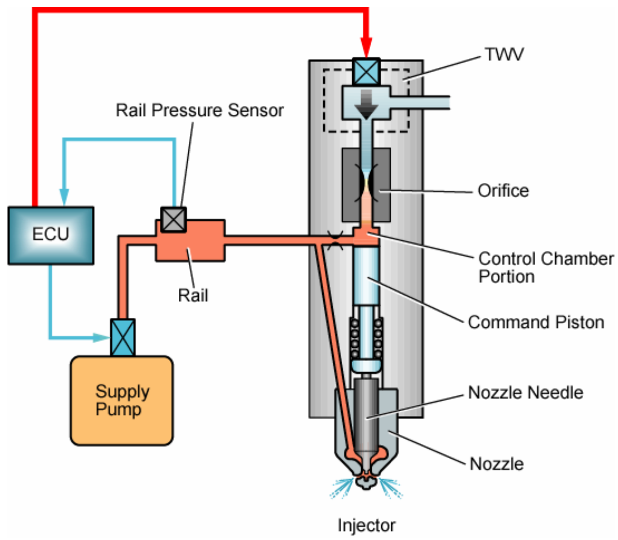
V38DICR-TIE3-S
High Pressure Common Rail System



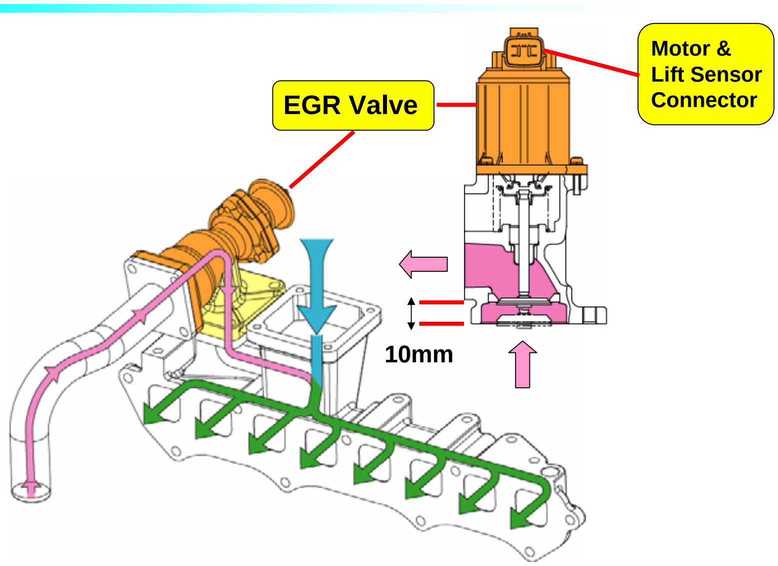
V38DICR-TIE3-S
FUEL INJECTOR EXTERNAL VIEW (1)



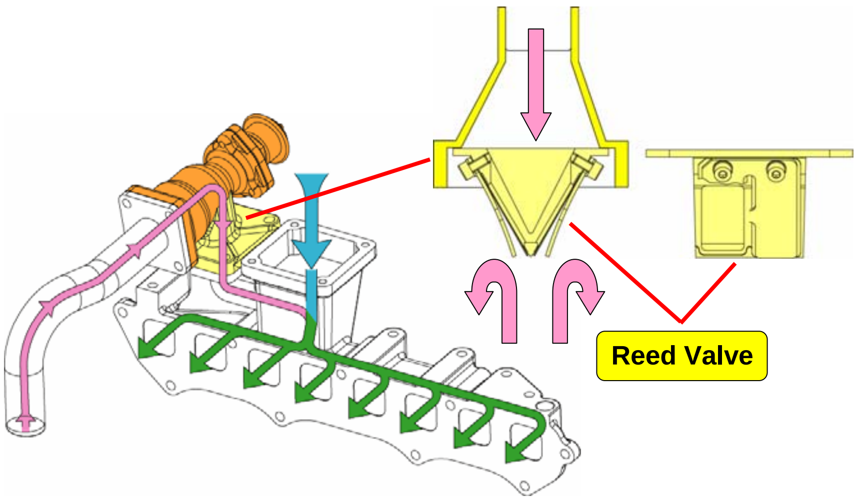
V38DICR-TIE3-S
FUEL INJECTOR



V38DICR-TIE3-S EGR VALVE

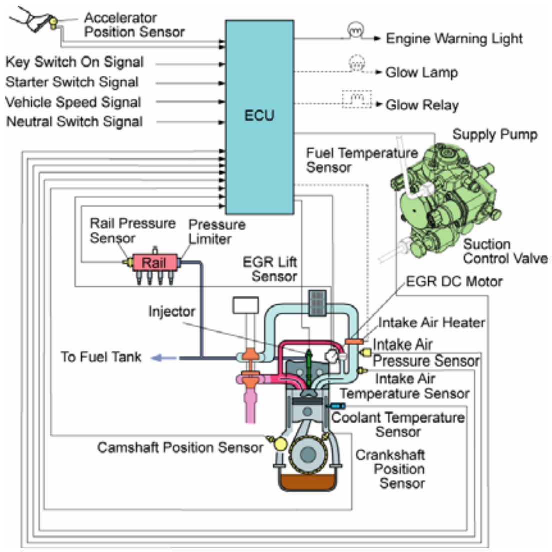


V38DICR-TIE3-S REED VALVE

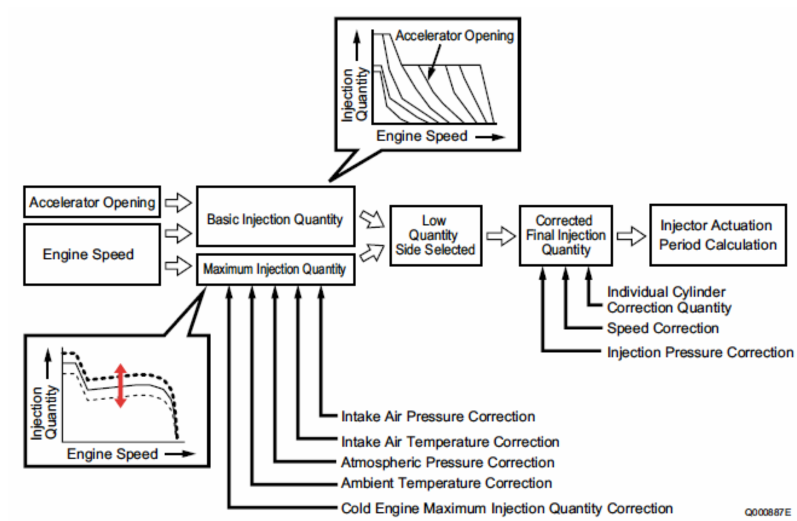


V38DICR-TIE3-S REED VALVE

Typical CRS ECU CONTROL SYSTEM DIAGRAM



Typical CRS ECU CONTROL SYSTEM



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  - Biodiesel B5 Immediate

Lube Oils for Next Tier Emissions engines

Fuel Type	API Engine Oil Classification	
	Non EGR Engines	External EGR Engines
High Sulfur Fuel 0.05% - 0.50% (500 - 5000ppm)	**CF -** If CF4, CG4, CH4, or CI4 engine oils are used with high sulfur fuel, oil change interval is cut approximately half	**High Sulfur Fuel Not recommended**
Low Sulfur Fuel <0.05% (500ppm) Ultra Low Sulfer <0.0015% (15ppm)	**CF, CF4, CG4, CH4, or CI4**	**CF or CI4** – (Class CF4, CG4 and CH4 engine oils **cannot** be used in EGR type engines)

- CJ4 req. for DPF equipped engines (not recommended for engines without DPF)

Nonroad Diesel Fuel

Kubota

ULSD

Benefits:

Allows use of Sulfur-Sensitive Control Technologies such as DOC and DPF's etc.

Challenges:

- Lower lubricity
- Plunger / in-line injection pumps, much less susceptible than Rotary types
- Fuel economy may be lowered by 2-3% (less BTU content)

Sulfur Content (ppm)	ON ROAD	OFF ROAD
3000	<1993	CURRENT
500 (0.05% wt)	1993	Jun-07
15 (0.0015% wt)	Jun-06	2010 (CURRENT IN CALIFORNIA)

Kubota "E 3" diesel engines less than 56kW (75hp) utilize EPA Tier 4 and Interm Tier 4 standards Low sulfur or Ultra low sulfur fuel is mandatory for these engines when operated in US EPA regulated areas

Biodiesel

Kubota

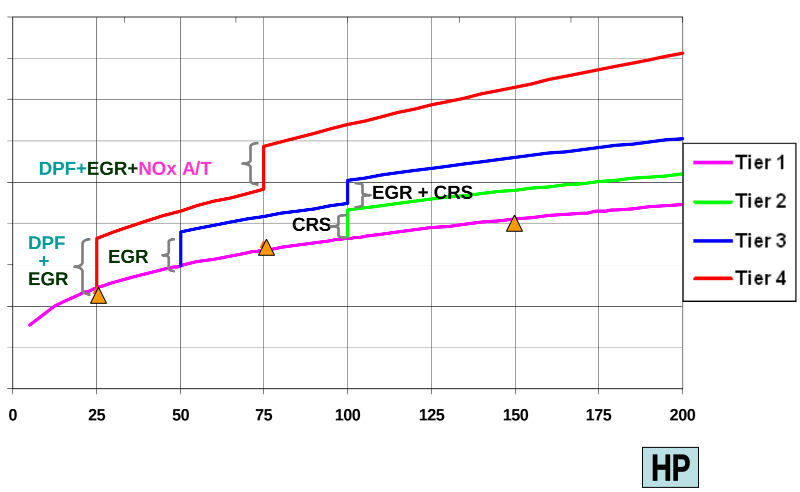
- Renewable Energy Initiatives
  Political desire to utilize, off-shore fuel dependency etc.
- Base = vegetable oil (soybean oil) in N. America
- No current ASTM standard anything < B100
  (B100 = 100% Bio Diesel, B50 = a blend of 50% Bio Diesel / 50% traditional diesel)
  B100 - ASTM standard D 6751, *Standard Spec (B100) fuel*, adopted 2002.
  Blends of BIO-DIESL ASTM D975
- Wide variation in fuel characteristics geographically

Biodiesel

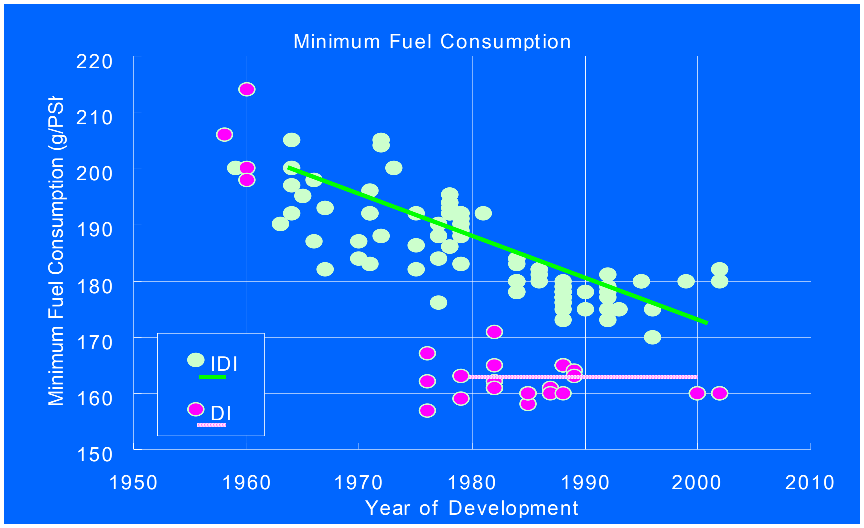
- Long term durability on engines is not fully known
- Cold weather cloud point issues - fuel heaters required
- Hygroscopic (absorbs water) fuel system corrosion
  Unknown long term effect on Injection systems
- Prone to microbial contamination (plugged filters)
- Caustic, damages paint/ elastomers

Engine Impacts

(Source: EPA Preamble)



CHANGE OF KUBOTA DIESEL ENGINES POWER DENSITY



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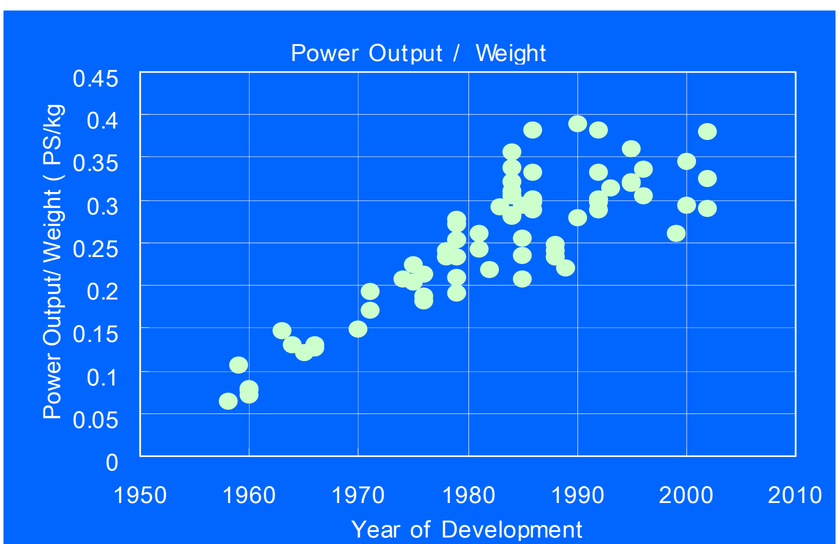
CHANGE OF KUBOTA DIESEL ENGINES POWER DENSITY



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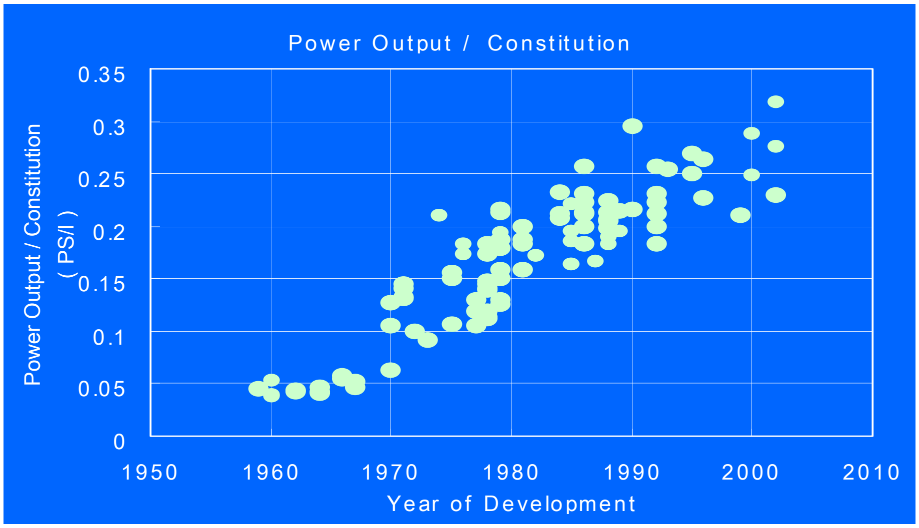
CHANGE OF KUBOTA DIESEL ENGINES POWER DENSITY



Crankcase

D902 **D905**

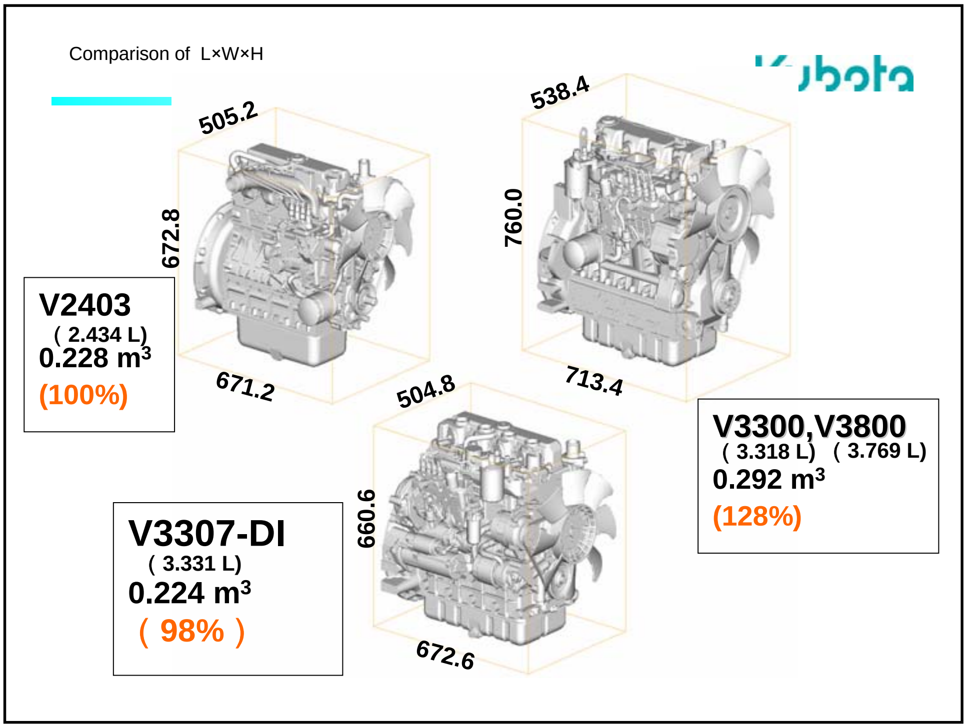
Pistons

Kubota

D722 **D902** **D905**

V3307-DI-T

Kubota



Comparison of L×W×H
505.2
672.8
671.2
V2403
(2.434 L)
0.228 m3
(100%)
538.4
760.0
713.4
V3300,V3800
(3.318 L) (3.769 L)
0.292 m3
(128%)
504.8
660.6
672.6
V3307-DI
(3.331 L)
0.224 m3
(98%)

Diesel Engine Maintenance

Presented by Walter Steffler
Kubota Canada Ltd.

MDEC Conference
Diesel Workshop

October 2, 2007

Types of Maintenance

- Break in – During the break in period, engine oil and filter should be changed after the first 50 hours of service. The engine should be warmed up for a few minutes, before heavy use.
- Daily – Checks should be performed ie oil, fuel, air (only if restrictor is present), anti- freeze. Gauges and controls
- Scheduled – As per engine manufacturer's schedule.

Maintenance Practices

Questions I should be asking of my maintenance program.

Do I have one ? Or Repair as Required.

If I do , Are there accurate records ?

How are my supplies stored ?

How are my Actual vs Manufactures maintenance schedules ?

Daily Checks

Visual walk around.

- Oil or coolant leaks
- Engine oil level and contamination
- Amount of fuel- fuel level.
- Amount of coolant – coolant level
- Check that the radiator is free of obstruction
- Damaged parts, loose bolts or fasteners

In operating position.

- Are the Gauges, Meters and Pilot lamps functioning properly?
- Proper function of the glow lamps and timers.
- When starting the engine, what is the colour of the exhaust ? Excessive smoke?
- Is there unusual engine noise ?

Fluid Checks

- **Lubricating Oil**
- **Check Oil Level**
- **Too high is as bad as too low!**
- **Look for leaks, check date/hours of last service**

- **Fuel**
- **Check Quantity**
- **Check for contamination**
- **Drain water from water separator if equipped**

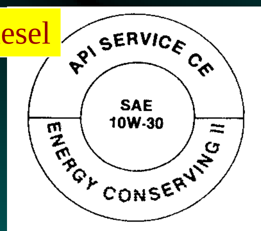
Fluid Checks

Antifreeze/Coolant
- 50/50 mix is required. Higher concentrations can cause engine damage.
- If low, top off with:
  - 50/50Antifreeze if low because of leak
  - Water if low because of evaporation
- Check both the radiator and recovery bottle !
  - With some types of leaks, the bottle could be full and the radiator empty.

OILS

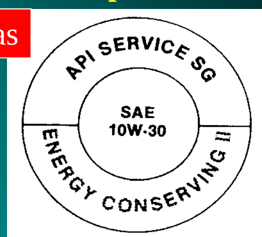
Selecting oil

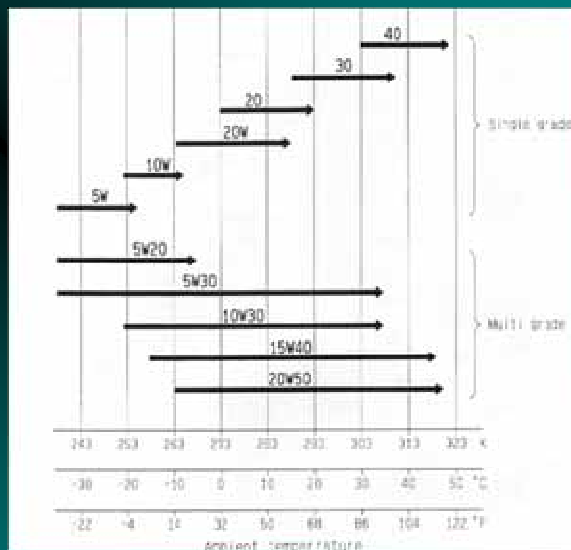
Diesel



What does the "C" represent?

Gas





What does the "S" represent?

Selecting Oil

API Classi-fication	Application
CA	Oil suitable for the diesel engine which uses high quality fuel, and is operated under comparatively mild conditions, having bearing corrosion-preventive property and high-temperature deposit-preventive property.
CB	Oil suitable for the diesel engine which uses a higher-sulfur fuel oil, and is operated under moderately mild conditions, having the quality which can prevent corrosion or high-temperature deposit under such conditions.
CC	Oil suitable for the diesel engine which is operated under fairly severe conditions, having high-temperature deposit-preventive property, rust-preventive property, corrosion-preventive property, and low-temperature sludge-preventive property.
CD	Oil suitable for the diesel engine which is operated under severe conditions, having the properties of all the excellent performance.
CE	Oil suitable for the diesel engine, which is operated under the most severe conditions, having the property to restrain oil consumption, oil deposit, and oil viscosity increase, in addition to the properties of CD.
CF	Oil suitable for the diesel engine to be mounted on the off-road vehicles, of which fuel is a high-sulfur (0.2%) fuel.
CF-4	Oil having the high-grade performance of the CE standard, which has required heat resistance and decrease of oil consumption, according to reinforcement of the emission regulations.
CG-4	Oil suitable for the diesel engine to be mounted on the 4-cycle on-road vehicles, which is adaptable to the high-top piston ring of U.S.A., and of which fuel is a low-sulfur (0.05%) fuel.

What does the "E" in "CE" represent?
What is "CF-4"?

Selecting Oil

O: Recommendable ×: Not recommendable

Lubricating oil class \ Fuel	Low sulfur	High sulfur
CF	O	O
CF-4	O	×
CG-4	O	×

As engine oils become more dedicated to specific applications, PLEASE be very careful

What happens if I do not have a regular maintenance program ?

Air Cleaners

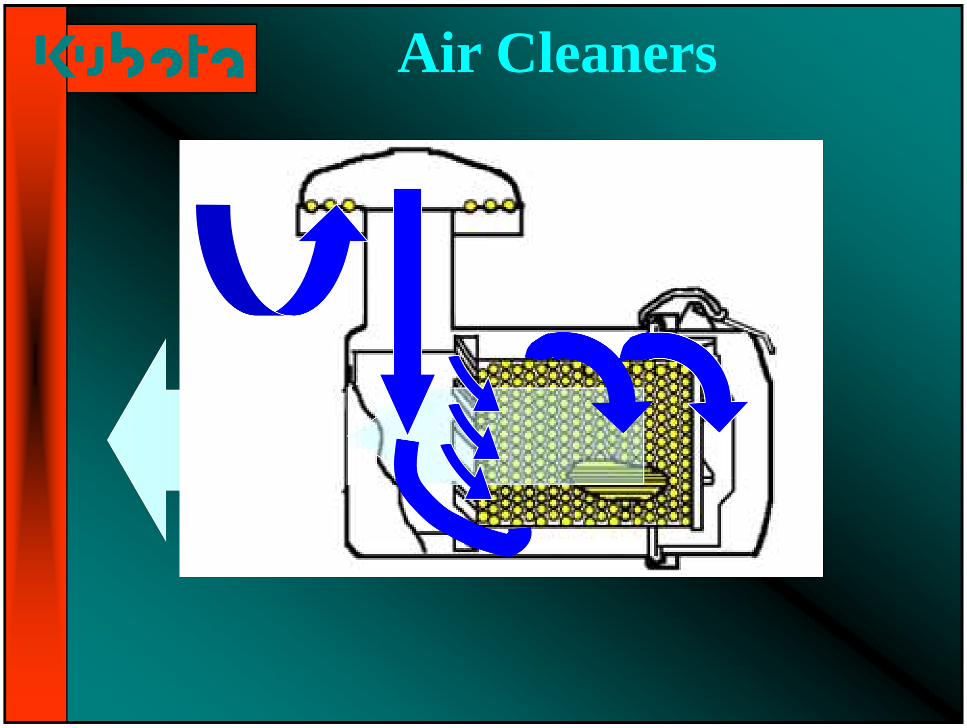
Air Cleaner System

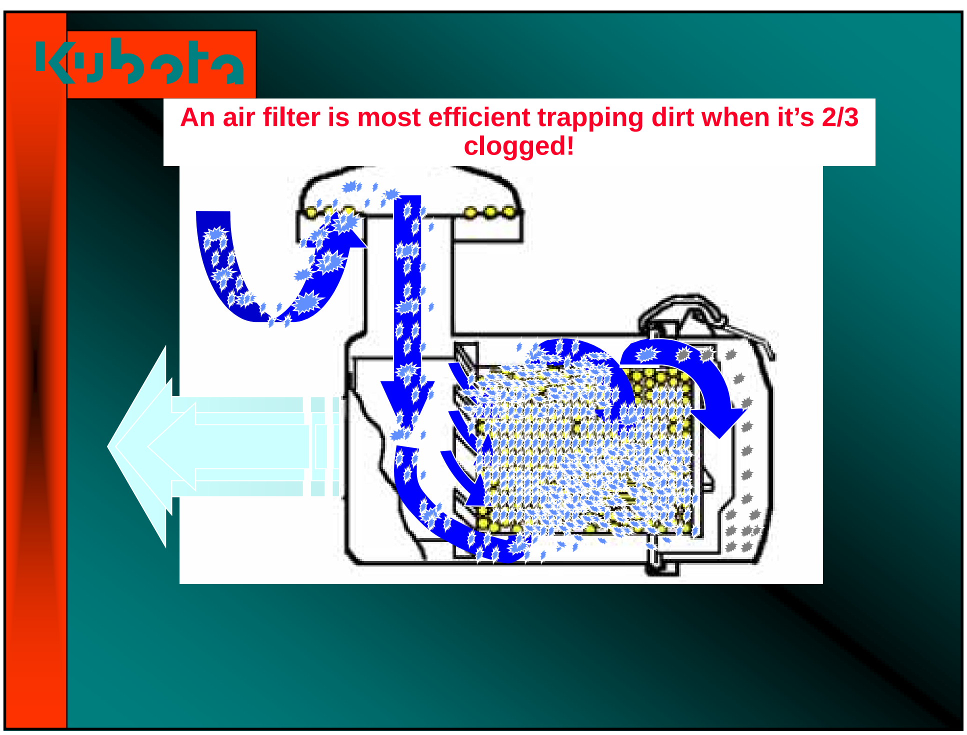
Two of the most common air cleaner servicing problems.

1) Over servicing : Filter are the least efficient when new. Filter elements increase in efficiency as dust builds up on the media.

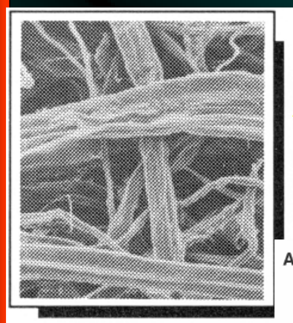
2) Improper servicing : your engine is highly vulnerable to abrasive dust contaminants during the servicing process when the filter is removed from the housing. A leading cause of engine damage is due to careless servicing procedures.

Note : It takes about 1 table spoon of dirt to damage a Diesel engine.

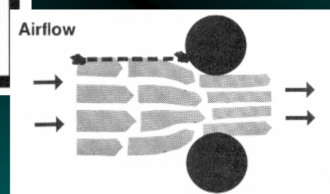

Air Cleaners


An air filter is most efficient trapping dirt when it’s 2/3 clogged!

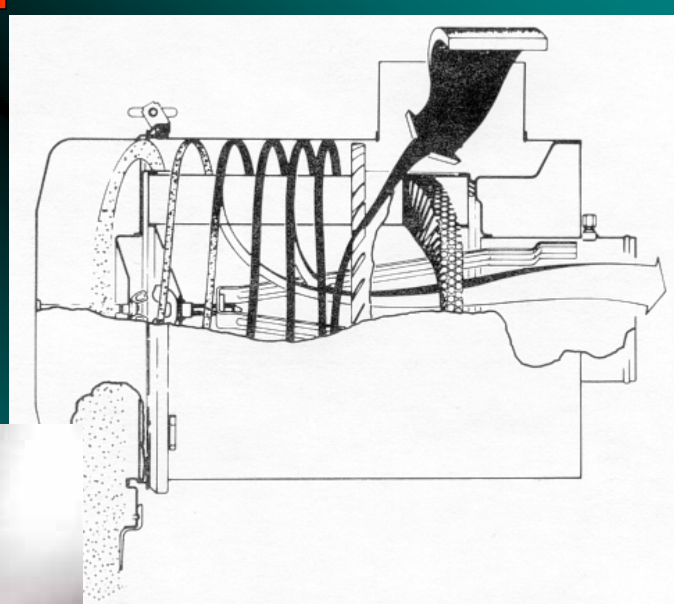
Air Cleaner Fiber



Dust particles, being denser than air, have too much momentum to go around the fibers, so the particles hit and imbed on fibers.

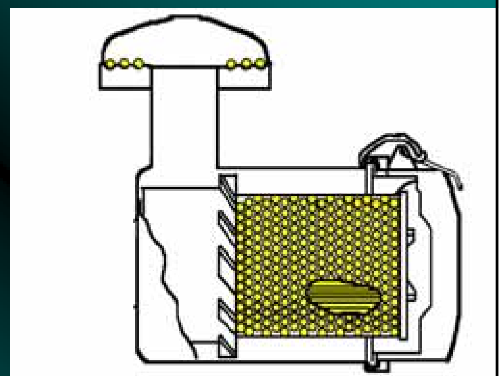


Centrifugal Type Air Cleaner



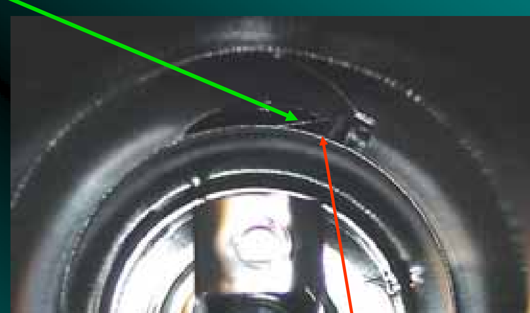
Air Cleaners

- Check the dust cup or evacuator daily (if equipped)
- Don't replace the air filter early!
- Replacing the filter at ¼ the required interval means you're 300% more likely to cause engine damage



Air Cleaner System

Centrifugal types



Baffle plate

Dust evacuator

What makes it discharge particles?

Air Intake Systems

Air Cleaner Styles (Kubota / After-market)

- Plastic / Steel / Pre-cleaners
- Single / Dual Element / Minders

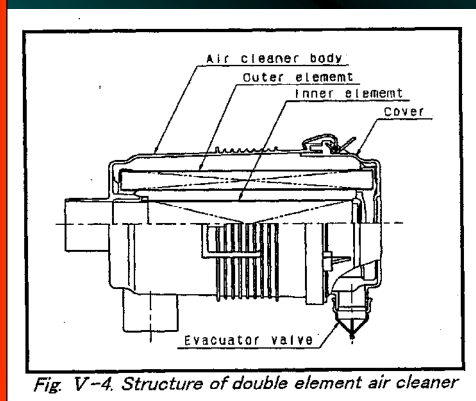


Fig. V-4. Structure of double element air cleaner

Air Cleaner System

Radial Seal type

Air filter element seats on tapered "cone" in end of canister.


Air Cleaner System
Conventional type
Check for good seating of sealing washer
Check for good seating of air cleaner element against base of air cleaner housing.


Air Cleaner System
Lip type seal,
as air intake restriction increases, lip seal tightens
Square type seal
NOT ALL SEALS ARE GOOD!
This type of seal cost big $$$$$

Air Cleaner System

Inspection of element

Any problems?

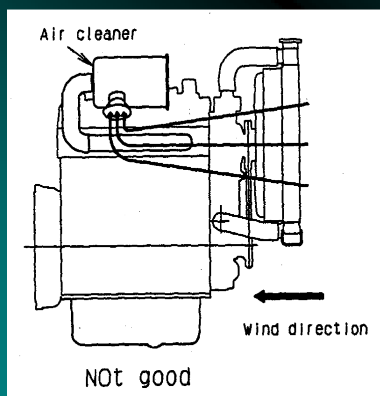
Air Cleaner System

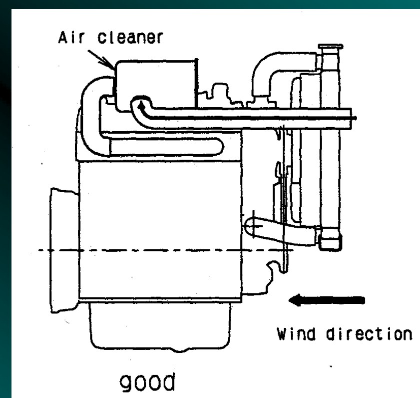
Poor air inlet system security, abrasive dust can enter inlet and engine failure results.

Air Intake Systems

Air Cleaner Location / Mounting

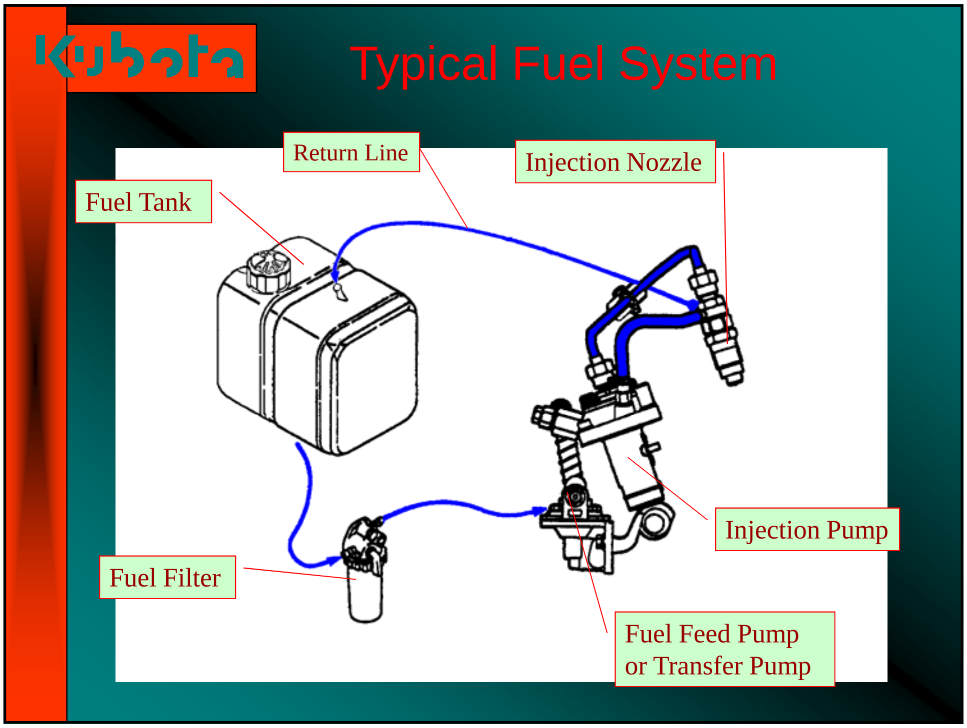
Intake Air Temperature

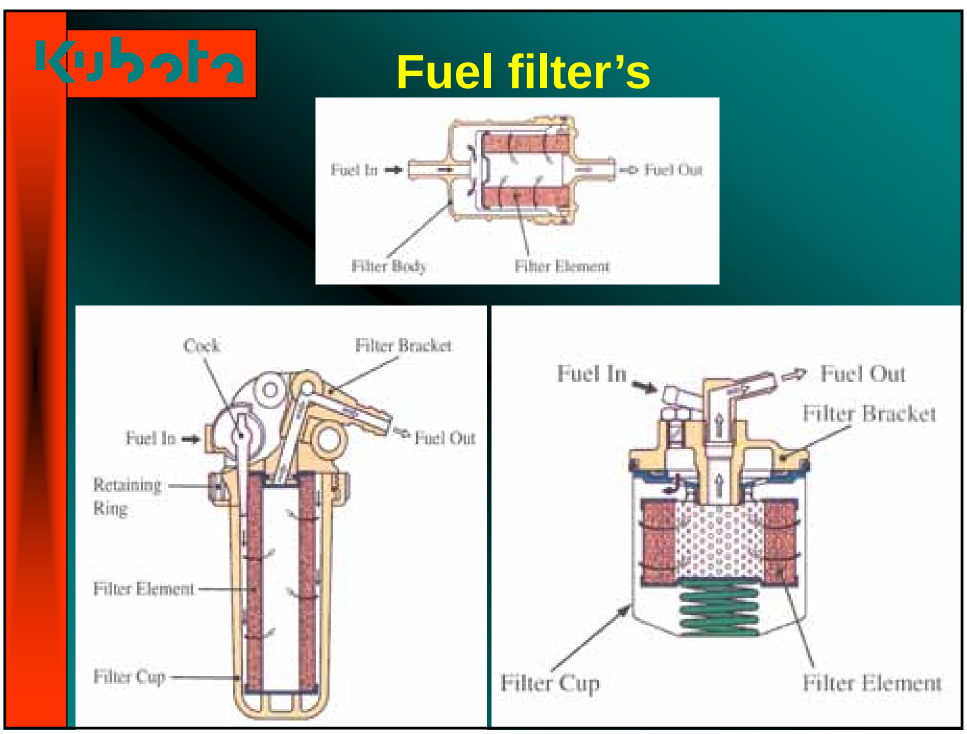


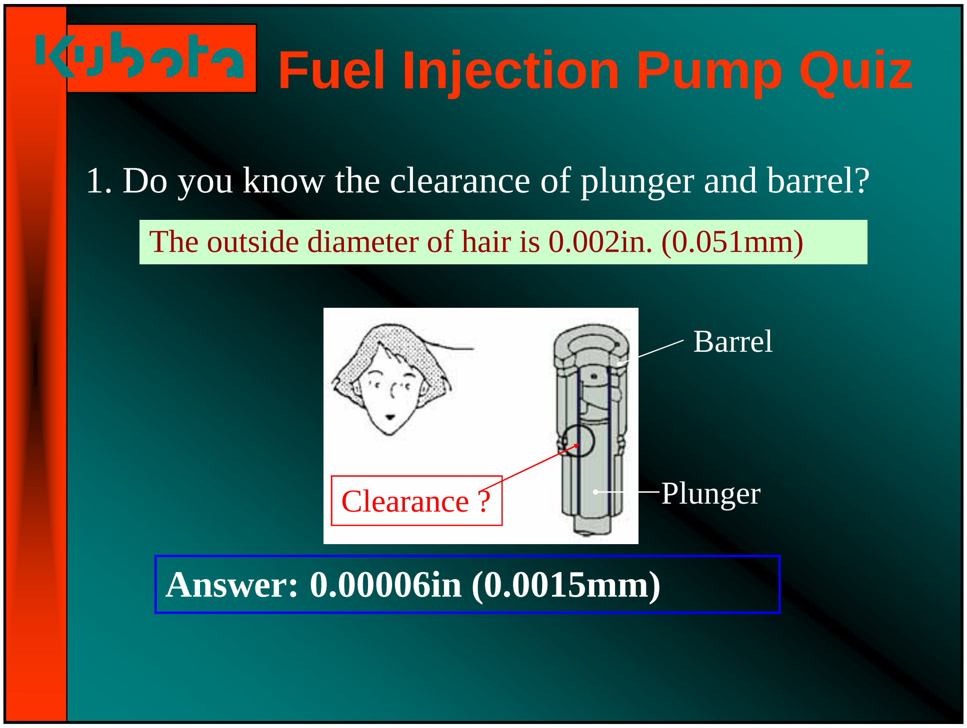


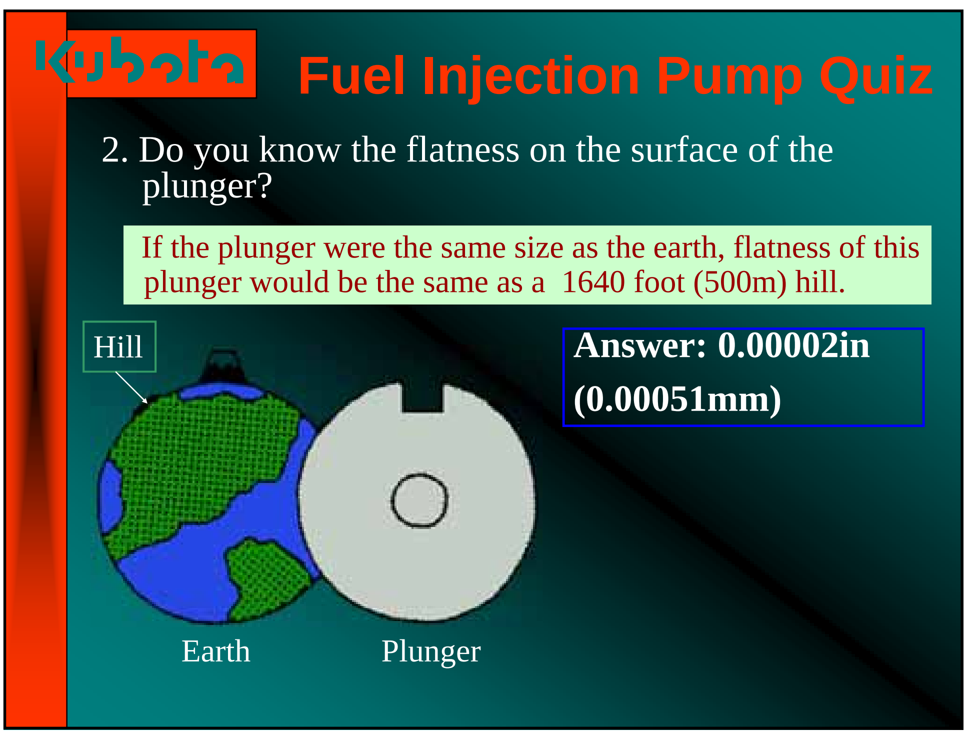
Fuel System

Diesel


Typical Fuel System
Return Line
Injection Nozzle
Fuel Tank
Injection Pump
Fuel Filter
Fuel Feed Pump
or Transfer Pump

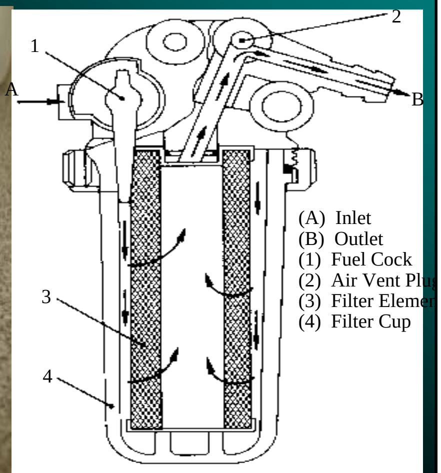

Fuel filter's
Fuel In
Fuel Out
Filter Body
Filter Element
Cock
Filter Bracket
Fuel In
Fuel Out
Retaining
Ring
Filter Element
Filter Cup
Fuel In
Fuel Out
Filter Bracket
Filter Cup
Filter Element


Fuel Injection Pump Quiz
1. Do you know the clearance of plunger and barrel?
The outside diameter of hair is 0.002in. (0.051mm)
Barrel
Clearance ?
Plunger
Answer: 0.00006in (0.0015mm)


Fuel Injection Pump Quiz
2. Do you know the flatness on the surface of the plunger?
If the plunger were the same size as the earth, flatness of this plunger would be the same as a 1640 foot (500m) hill.
Hill
Answer: 0.00002in (0.00051mm)
Earth
Plunger

OEM VS JOBBERS

Just because the filters look the same does not mean they are!



Fuel Quality and Handling

- What type of fuel is being used ?
- How is the fuel stored ?
- Is there a water separator on the storage tanks ?
- If one is installed , How often is it serviced ?
- Are there separators on the equipment ? How are they maintained.

Fuel

➢Fuel stored in outside tanks are susceptible to condensation build up. Micro organisms can build up to plug filters destroy the injection pumps and nozzles.

Bio diesels

➢ Biodiesel can be blended with petroleum-based diesel. Most manufactures allow up to 20% blended fuels.

➢ Biodiesels are affected more by cold temperatures so heaters may have to be installed.

Cooling System

Cooling System

- Things I should check.
- Fan belt- Check for cracks, tears, pieces missing and tension.
- Anti freeze – Correct level, correct mixture (50/50)
- Radiator clean and free from obstruction.
- Is my coolant mixture pre-mixed or not?

Boiling Points of Coolant vs. Water

Maximum operating temperature - below thermostat = 110C (230F)
Normal operating temperature = 72 to 98C (161 to 208F)

Boiling point of coolant.

Rad cap pressure	% of water / antifreeze	Boiling point Celsius	Fahrenheit
0 psi (0 kg/cm2)	**100 % water**	**100**	**212**
	50 / 50	**108**	**226**
13 psi (0.9 kg/cm2)	**100 % water**	**118**	**244**
	50 / 50	**126**	**259**

Maximum antifreeze concentration = 60%

Silicate Gelation

Caused by overdosing high silicate antifreeze and supplemental coolant additives (SCA's)

Purpose of Silicate: Aluminum protection

Radiator Core Condition

The Screen in front of the radiator is extremely important to prevent the radiator plugging, especially in turf applications

Check for restriction BETWEEN radiator and oil coolers

Valve Adjustment

To Adjust Bridge:

•Loosen Lock Nut.

•Push down on bridge gently

•Turn Adjusting Screw until it just contacts valve stem

•Tighten Lock Nut

•Adjust valves to proper specification

Intake Valve “Bridge

CONCLUSION

Factors that affect my engines life.

- Application
- Load factors
- Oil change interval
- Air cleaner service
- Type of fuels used
- Most important factor is “Preventive Maintenance”. NOT just repair.
- Follow manufactures recommendation on maintenance intervals.

Thank You.

MDEC

Mining Diesel Emissions Council
October 1st – 5th, 2007

WORKSHOP

Diesel Particulate Filter

Fundamentals

Selection & Sizing

Retrofit & Operation

Maintenance

Presented By Glen Prisciak
DCL International Inc.

WORKSHOP

Diesel Particulate Filter
Fundamentals

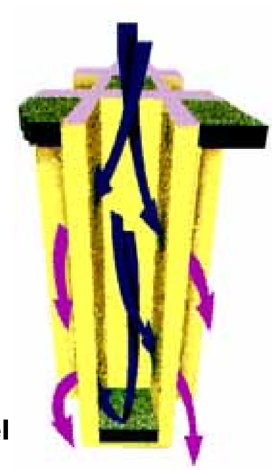
Overview - Fundamentals

- **What is a DPF and how does it work?**
- **Substrates and substrate properties**
- **Details of trapping mechanisms and backpressure derivatives**
- **DPF systems and regeneration strategies**
  - **Active off-board**
  - **Active on-board**
  - **Passive**

WORKSHOP
Diesel Particulate Filter
Fundamentals

What is a DPF and how does it work?

- DPF – device that is designed to remove particulates from diesel exhaust stream
  - efficiencies up to 99.99% depending on PM measuring/defining
  - most commonly referenced as a mass based efficiency
  - typically > 85% efficiency by mass
    - highly dependent on S content in fuel



WORKSHOP
Diesel Particulate Filter
Fundamentals

Substrate Materials

- Cordierite ($2MgO_2 . Al_2O_5 . 5SiO_2$)
- Silicon Carbide (SiC)
- Aluminum Titanate
- Suppliers
  - Corning, NGK, Ibiden, Saint-Gobain, Denso

Desired Properties

- High filtration efficiency
- High melting point
- High soot capacity
- High thermal shock resistance
- High strength/integrity
- Chemical stability
- Low weight
- Low cost

WORKSHOP
Diesel Particulate Filter
Fundamentals

Cordierite

- Low thermal expansion coefficient
- Good mechanical strength
- Lower) melting point (~1450°C)
- Low heat capacity

SiC

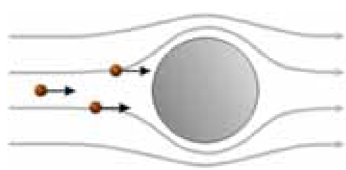
- High thermal expansion coefficient
- High melting point (~2700°C)
- High heat capacity

Courtesy: www. ngk.co.jp

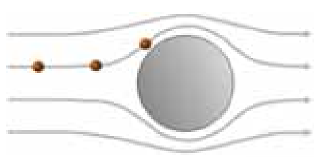
WORKSHOP
Diesel Particulate Filter
Fundamentals

Trapping Mechanisms

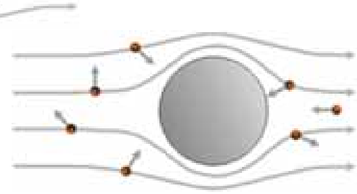
- Inertial Impaction



- Interception



- Diffusional Deposition
  (Brownian Diffusion)



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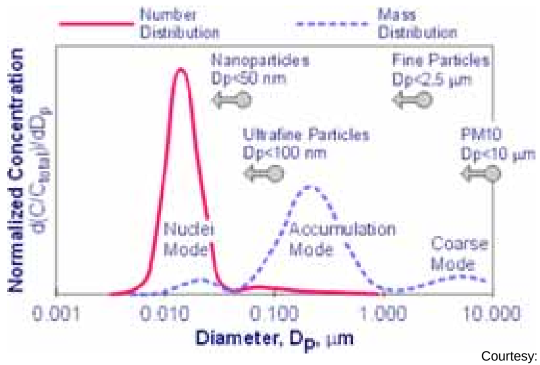
Diesel Particulate Filter
Fundamentals

Particle Size in Perspective

- **Typical DPF pore size is ~10-20 μm**
- **Typical diesel exhaust PM size distribution is:**



Courtesy: www.dieselnet.com

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Diesel Particulate Filter
Fundamentals

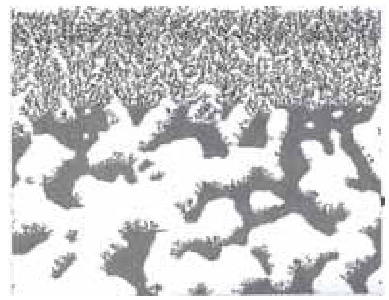
To put it in perspective

Courtesy: www.sportschrome.com

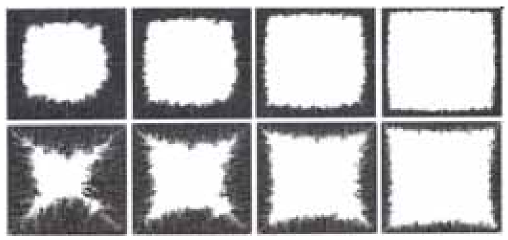
WORKSHOP
Diesel Particulate Filter
Fundamentals

Depth Bed vs. Cake Filtration

Courtesy: www.dieselnet.com



Courtesy: Konstandopoulos, A., Masoudi, M.



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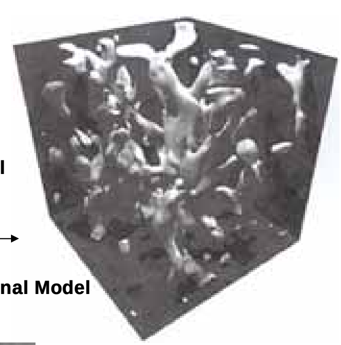
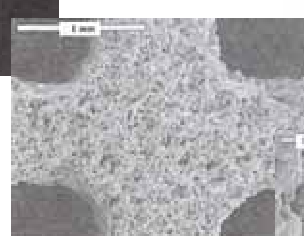
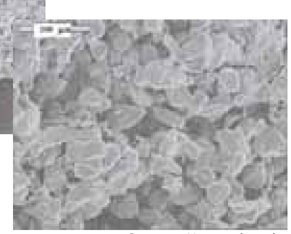
Diesel Particulate Filter
Fundamentals

Computational Model

Inverse Computational Model







Courtesy: Konstandopoulos, A., Masoudi, M.

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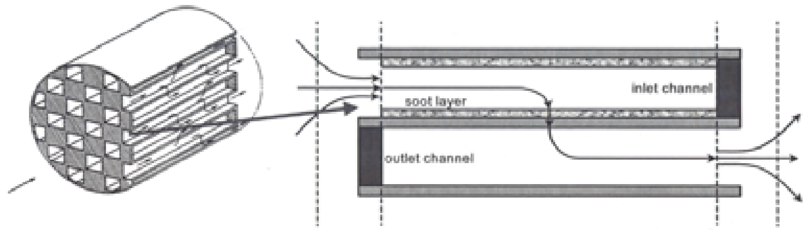
Diesel Particulate Filter
Fundamentals

What Creates Backpressure?



Courtesy: Konstandopoulos, A., Masoudi, M.

$$\Delta P_{TOTAL} = \Delta P_{Contraction} + \Delta P_{Channel} + \Delta P_{Soot} + \Delta P_{Wall} + \Delta P_{Channel} + \Delta P_{Expansion}$$

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Diesel Particulate Filter
Fundamentals

Finally .... DPFs as a System

- Idea is to integrate the substrate into a final package that is both functional in terms of installation and operation

What is available in the marketplace?

<u>To refresh your memory</u>
- Passive
- Active On-Board / Off-Board

WORKSHOP
Diesel Particulate Filter
Fundamentals

What is available in the market?

- **Passive Regeneration**
  - **Soot regeneration temperature is 550-600 deg-C but can be reduced significantly when filter block is coated with oxidation catalyst**
  - **Soot regeneration rate is enhanced by adding special ingredient to wash-coat composition - promoters**
  - **Two oxidation mechanisms;**
    - **NO_2 Oxidation**
      - **High loading DOC is upstream the DPF to produce NO_2 from the ~90% engine out NO**
      - **NO_2 oxidizes soot at low temperatures: 270-320 deg-C**
      - **NO_2 consumption depends on soot load and that makes tailpipe NO_2 emissions uncontrolled**
    - **O_2 Oxidation**
      - **Two catalyst families;**
        - **Precious Metal Catalyst: reduce BPT to 280-350 deg-C**
        - **Base Metal Catalyst: reduce BPT to 375-420 deg-C**
      - **Fuel Born Catalyst (Additives)**

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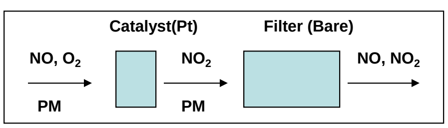
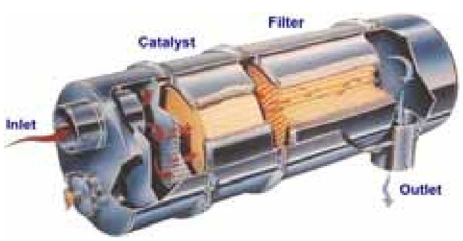
Diesel Particulate Filter
Fundamentals



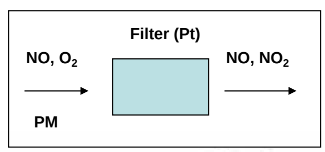


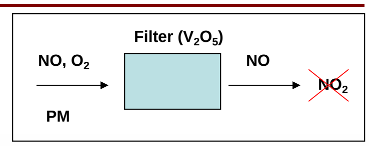
Courtesy www.ect.jmcatalysts.com

Unpredictable in NO2 output

→Generally high

→Higher in CCRT





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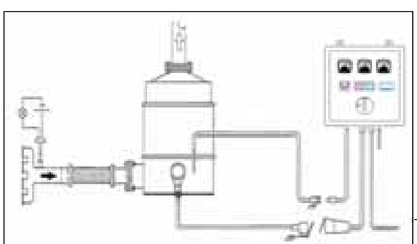
Diesel Particulate Filter
Fundamentals

What is available in the market?

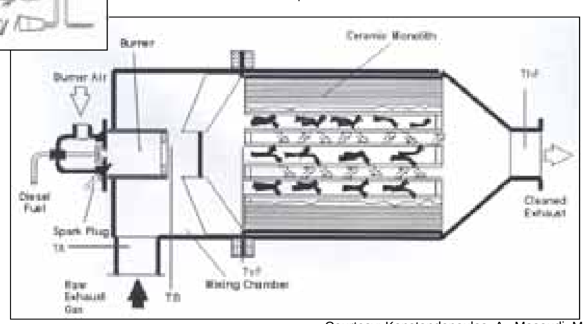
- **Active Regeneration**
  - **On-board automated active (passive forced regeneration)**
    - **Diesel burner is triggered by DPF differential pressure at target engine modes**
    - **Diesel fuel post injection (manifold) to produce exothermic condition over heavy loaded DOC to force the DPF regeneration**
  - **Off-board manual active – Shift End**
    - **Diesel Burner is triggered manually at the end of each shift**
    - **Electrical Heater is triggered manually at the end of each shift**

WORKSHOP
Diesel Particulate Filter
Fundamentals



Active On-Board

Active Off-Board



Courtesy: Konstandopoulos, A., Masoudi, M.

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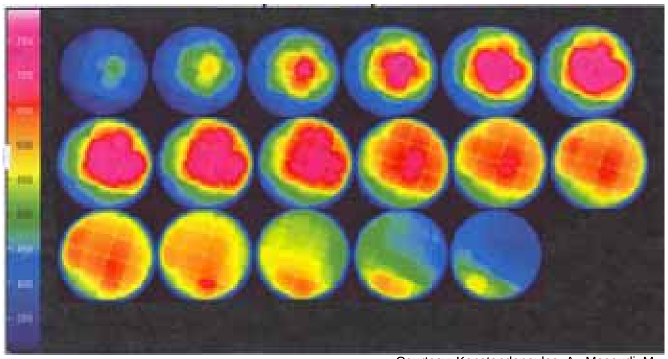
Diesel Particulate Filter
Fundamentals

Regeneration

- **In itself most important aspect of a functional DPF system**



Courtesy: Konstandopoulos, A., Masoudi, M.

MDEC

Mining Diesel Emissions Council
October 1st – 5th, 2007

WORKSHOP

Diesel Particulate Filter

Fundamentals

Selection & Sizing

Retrofit & Operation

Maintenance

Presented By Ted N Tadrous
Engine Control Systems Limited

WORKSHOP

Diesel Particulate Filter

Selection & Sizing

So you've determined you need a DPF!

To qualify your application for DPF retrofit – you need to determine;

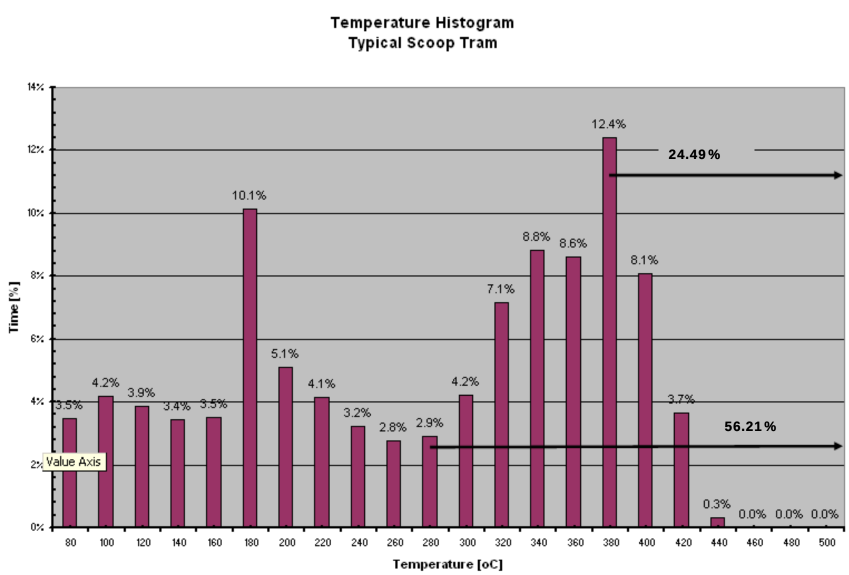
- **Duty cycle**
  - **Exhaust temperature profile**
  - **Shift pattern & duration**
- **Certified engine out PM level**
- **Available space envelope**
- **Sulfur level in diesel fuel**
- **Emission contribution of application as part of a fleet/shift**
- **Operation sensitivity to NO_2 formation and/or ambient levels**
- **NOx / PM Ration [>20 is desired]**

WORKSHOP
Diesel Particulate Filter
Selection & Sizing

- Selection is based on duty cycle & operation logistics
  - Shift duration & pattern
  - Exhaust temperature traces for at least 3 days to determine repeated duty cycle.
  - Analysis of exhaust temperature trace & histogram
  - Duration of idling & low load condition

Bare DPF	Base Metal	Precious Metal	Active
>550ºC	380-420ºC	280-320ºC	NA

WORKSHOP
Diesel Particulate Filter
Selection & Sizing



Court

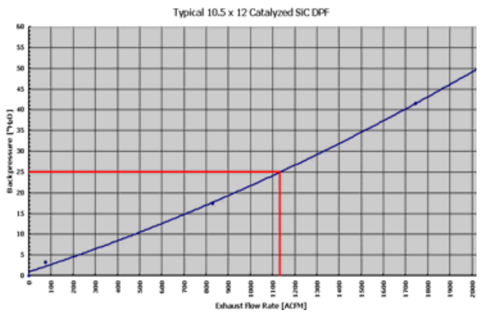
WORKSHOP

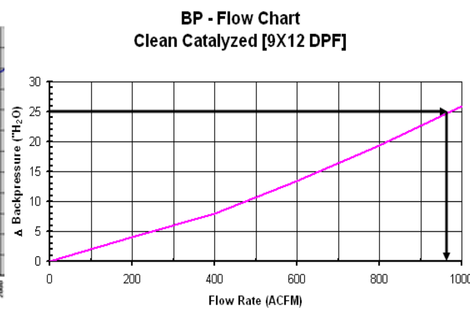
Diesel Particulate Filter

Selection & Sizing

Sizing is based on engine parameters & PM emission level

- PDF capacity to accommodate max exhaust flow causing minimum restriction leaving room for soot accumulation
- More soot accumulation > > > > Larger DPF volume
- SiC has slightly more soot capacity than Cordierite



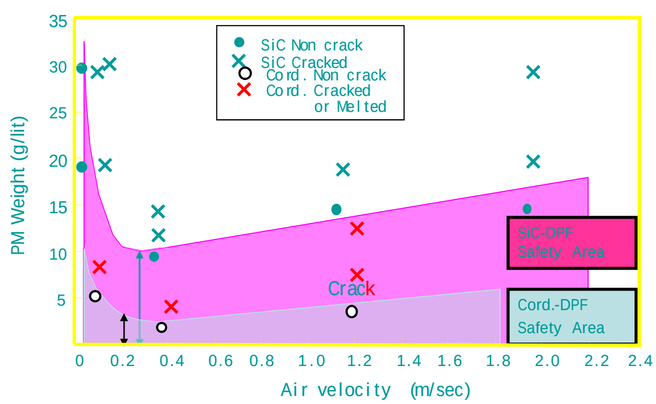


Courtesy of ECS

WORKSHOP

Diesel Particulate Filter

Selection & Sizing

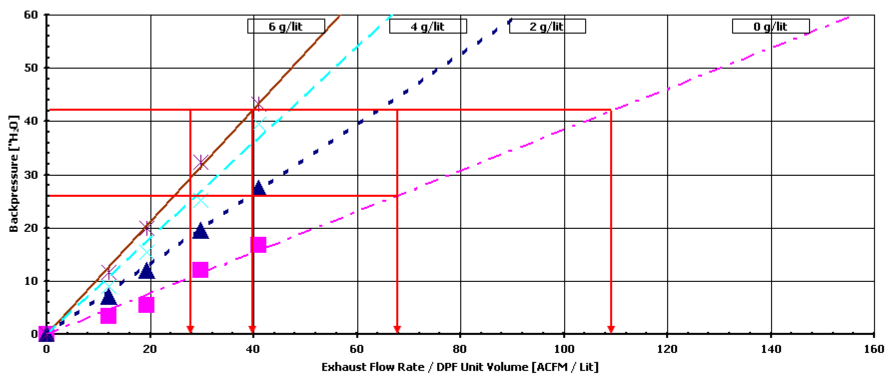


Courtesy of Ibiden

SiC limit is 8 g/lit soot loading while Cordierite has 6 g/lit capacity

WORKSHOP
Diesel Particulate Filter
Selection & Sizing

Effect of Soot Loading on Backpressure - Cordierite DPF



+ Max safe soot loading is 6 g/lit for Cordierite DPF material
+ For 27" WG BP Engines, Use 20 - 28 ACFM/Lit ratio for soot loading range 2 - 4 g/lit
+ For 42" WG BP Engines, Use 28 - 40 ACFM/Lit ratio for soot loading range 2 - 4 g/lit

Courtesy of ECS

DPF System Supplier is Responsible for Sizing

- Using engine data sheet, obtain;
  - Exhaust flow rate @ rated power,

$$\text{ExhaustFlowRate[ACFM]} = \frac{\text{EngineDisp[CID]}}{1728} \times \frac{\text{RPM}}{2} \times \eta_{vol} \times \frac{Exh.Temp[oK]}{AmbTemp[oK]} \times \frac{P_{atm}}{P_{exh}}$$

  - Maximum allowable backpressure
  - Specific PM emission

- Using DPF System Sizing Guidelines / Tool;
  - Enter exhaust flow @ rated power, and
  - PM specific emission [g/bhp-hr]
  - Select the model corresponding to max allowable BP

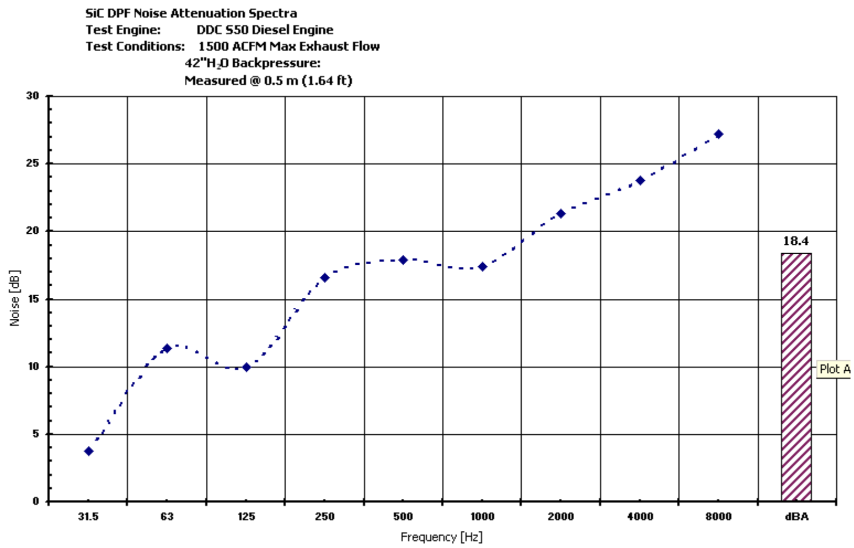
WORKSHOP
Diesel Particulate Filter
Selection & Sizing
Snapshot of a typical engine data sheet

Gaseous Emissions per 13 mode steady state test (ECE 49 and 88/77/EEC). The levels of exhaust emissions have been designed, and demonstrated on one or more engines in a test cell, to be equal or below the following figures:

—Weight-Specific NOx	— g/kW-hr (g/bhp-hr.)	.46	(6.31)
—Weight-Specific HC	— g/kW-hr (g/bhp-hr.)	0.42	(0.31)
—Weight-Specific CO	— g/kW-hr (g/bhp-hr.)	0.6	(0.45)
—Weight-Specific Particulates	— g/kW-hr (g/bhp-hr.)	0.174	(0.13)

INTERMITTENT		RATED	POWER POINT	PEAK TORQUE
Fuel Rating Option used for this data: FR-90001				
Engine Speed	— rpm	2500		1500
Gross Power Output	— kW (bhp)	149 (200)		128 (171)
Torque	— N•m (lb.-ft.)	570 (420)		814 (600)
Intake Manifold Pressure.	— mm Hg (in. Hg)	1320 (52)		940 (37)
Motoring Friction Horsepower	— kW (hp)	28 (37)		9 (12)
(1) Turbocharger Compressor Outlet Pressure	— mm Hg (in. Hg)	N/A		N/A
Intake Air Flow	— litre/sec. (cfm)	240 (509)		126 (268)
(1) Charge Air Flow	— kg/min. (lb./min.)	N/A		N/A
Exhaust Gas Flow	— litre/sec. (cfm)	609 (1292)		356 (755)
(1) Turbocharger Compressor Outlet Temperature	— °C (°F)	N/A		N/A
Exhaust Gas Temperature - Dry Stack	— °C (°F)	520 (968)		550 (1022)
Heat Rejection to Ambient (Dry Manifold)	— kW (BTU/min.)	20.9 (1190)		12.0 (680)
Heat Rejection to Coolant (Dry Manifold).	— kW (BTU/min.)*	101.2 (5756)		68.4 (3888)
Heat Rejection to Fuel	— kW (BTU/min.)	0.8 (45)		0.3 (15)
Engine Coolant Flow @ 35 kPa (5.0 psi) ΔP External Cooling Circuit Resistance	— litre/sec. (U.S. gpm)*	3.4 (54)		2.0 (32)
(2) Min. Aftercooler Radiator Coolant Flow:				
—with Open Thermostat at Max. Engine Coolant Out. Temp.	— litre/min. (U.S. gpm)	TBD		TBD
—@ 25°C (77 °F) Ambient	— litre/min. (U.S. gpm)	TBD		TBD
(2) Max. Coolant Temperature from Aftercooler Radiator @ 25°C (77 °F) Ambient	°C(°F)	TBD		TBD
Altitude Limitations:				
— Intermittent	— m (ft.)	3048 (10,000)		3048 (10,000)
— Continuous	— m (ft.)	2255 (7400)		2255 (7400)

WORKSHOP
Diesel Particulate Filter
Selection & Sizing

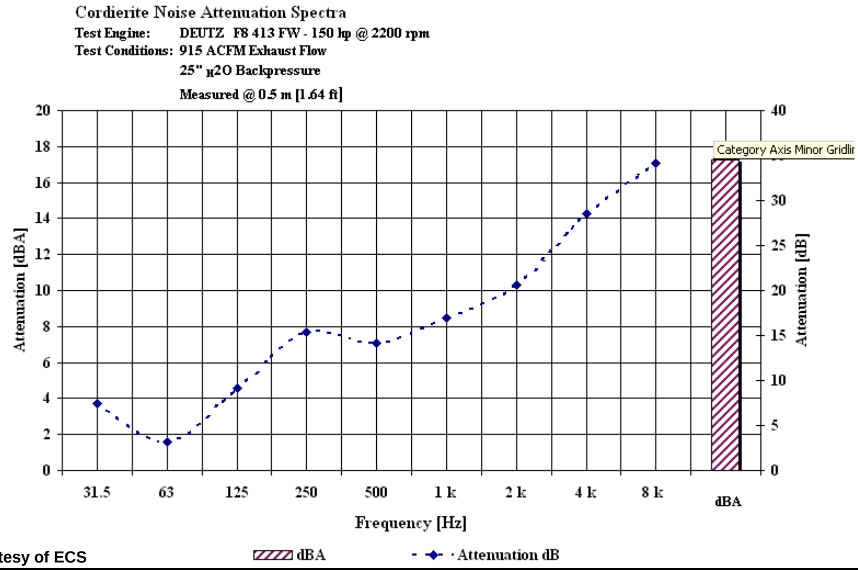


Courtesy of ECS

WORKSHOP

Diesel Particulate Filter

Selection & Sizing



Courtesy of ECS

MDEC

Mining Diesel Emissions Council
October 1st – 5th, 2007

WORKSHOP

Diesel Particulate Filter

Fundamentals

Selection & Sizing

Retrofit & Operation

Maintenance

Presented By Don Malgast
Engine Control Systems Limited

WORKSHOP

Diesel Particulate Filter

Retrofit & Operation of your DPF System:

- **Application specific requirements such as surface temperature, ...etc.**
- **Vertical or horizontal orientation may be critical from a DPF system design or application vibration view point**
- **Following the manufacturer installation guidelines is critical**
- **Opacity baseline for tuned engine prior retrofit is important**
- **DPF system must include performance diagnostic kit including alarms**
- **Operator Training**

WORKSHOP

Diesel Particulate Filter

Retrofit & Operation of your DPF System:

Vertical Mount (Stack)

•Locate best position for the DPF assembly. This usually is in the location of the existing silencer/muffler.

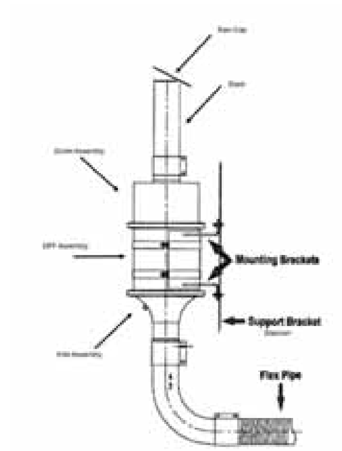
•Remove the existing silencer/muffler.

•Support the DPF assembly at the filter center body using mounting brackets.

• Mount support brackets securely to frame or cab stanchion.

• Install exhaust flex pipe between inlet of DPF and exhaust pipe 24” from engine, to absorb vibration and cab movement.

•Install a Backpressure Monitor Kit as per manufacturer recommendation.



WORKSHOP

Diesel Particulate Filter

Retrofit & Operation of your DPF System:

Under Chassis Mounting

•Locate the best position for the DPF assembly. This is in the location of the existing silencer/muffler.

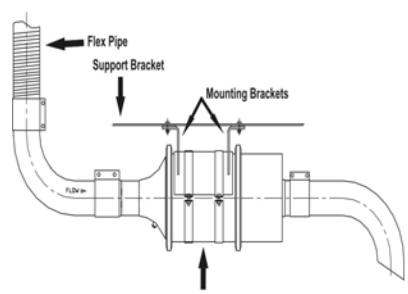
•Remove the existing silencer/muffler.

•Support the DPF assembly at the filter center body using mounting brackets.

•Mount support brackets securely to chassis.

•Install exhaust flex pipe between inlet of DPF and exhaust pipe 24” from engine to absorb vibration.

•Install a Backpressure Monitor Kit as recommended by manufacturer.



WORKSHOP
Diesel Particulate Filter
Retrofit & Operation of your DPF System:

Horizontal Mounting

•Locate the best position for the DPF assembly. This is in the location of the existing silencer/muffler.

•Remove the existing silencer/muffler.

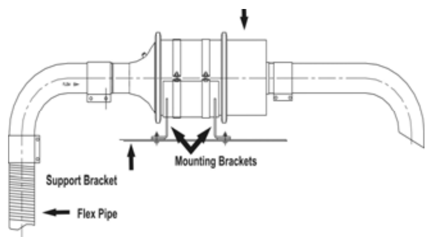
•Install DPF in place of the original muffler.

•Support the DPF assembly at the filter center body using mounting brackets.

•Mount support brackets securely to deck or fender

•Install exhaust flex between inlet of DPF and exhaust pipe 24” from engine to absorb vibration.

•Install a Backpressure Monitor Kit as recommended by manufacturer.



WORKSHOP
Diesel Particulate Filter
Retrofit & Operation of your DPF System:

Vertical Dual Mounting

•Locate the best position for the DPF assembly. This is in the location of the existing silencer/muffler.

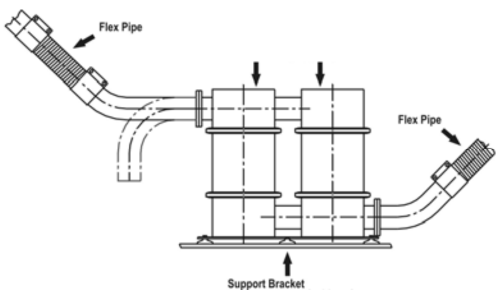
•Remove the existing silencer/muffler.

• Install DPF in place of the original muffler

• Mount support brackets securely to deck

• Install exhaust flex between inlet of DPF and exhaust pipe 24” from engine to absorb vibration.

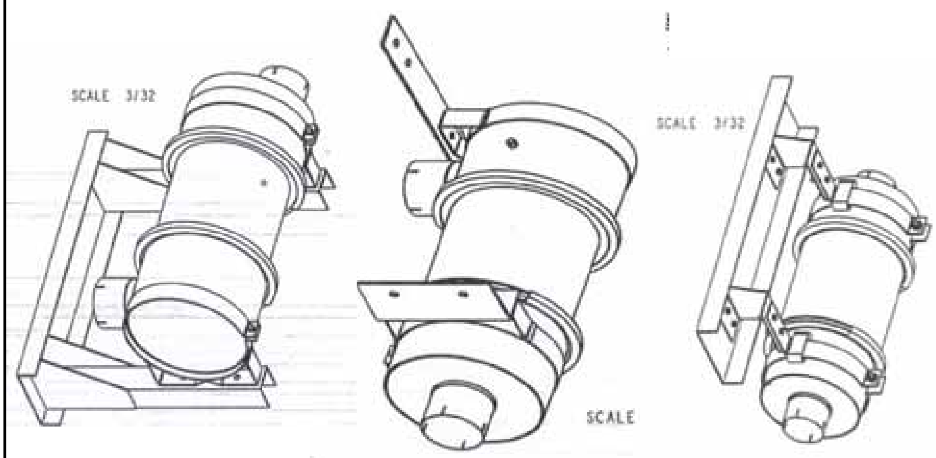
•Install the Backpressure Monitor Kit as recommended by manufacturer.



WORKSHOP

Diesel Particulate Filter

Retrofit & Operation of your DPF System:



WORKSHOP

Diesel Particulate Filter

Retrofit & Operation of your DPF System:

Performance monitoring is essential to protect both the engine and DPF;

- **Continuous monitoring for back pressure and alarming for excessive levels will help indicate cleaning requirement**

- **Continuous monitoring of duty cycle help explain DPF performance and prevent premature service and down time**

MDEC

Mining Diesel Emissions Council

October 2nd , 2007

WORKSHOP

Diesel Particulate Filter

Fundamentals

Selection & Sizing

Retrofit & Operation

Maintenance

Presented By John Stekar

Catalytic Exhaust Products Limited

WORKSHOP

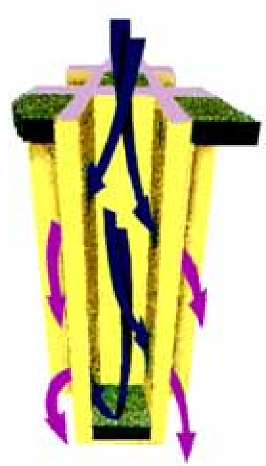
Diesel Particulate Filter

Maintenance of your DPF System:

Regardless of the regeneration strategy, DPF restriction will increase over time due to the accumulation of the ash inside the filter and compaction of un-combusted soot.

Diesel Particulate Filters (DPF) and Diesel Oxidation Catalysts (DOC) collect diesel particulate matter and inorganic based exhaust constituents. Inorganic based exhaust constituents are typically known as ash. Ash does not oxidize into a gaseous state as does diesel particulate matter. Ash forms oxides and sulphates which are stored within the DPF.

An essential component to effective use and safeguard the filter is to remove the ash occasionally to avoid sintering with DPF material under exothermic regeneration conditions.



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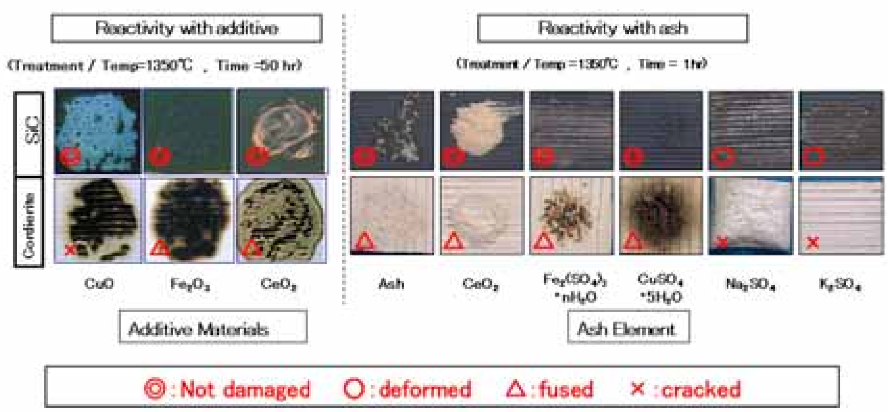
Diesel Particulate Filter

Maintenance of your DPF System:

Sources of Inorganic based Ash:

- **diesel engine exhaust system corrosion (iron)**
- **diesel engine metals and engine component wear (copper, tin, aluminum, silicon, chromium, nickel and iron)**
- **oxidized engine crankcase lubrication oil. (sulphur, calcium, zinc, magnesium and phosphorus)**
- **by-products of diesel fuel additives (cerium, platinum and iron).**

Why Clean the DPF?



It is important to implement a cleaning strategy for DPF to remove ash periodically

Courtesy of Ibiden

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Effects of Ash

- With engine usage inorganic based ash will gradually accumulate within the Diesel Particulate Filter and Diesel Oxidation Catalysts.
- The pressure drop across the DPF/DOC will increase until engine exhaust gas flow restriction exceeds engine manufacturer exhaust gas backpressure restriction recommendations.
- Excessive engine exhaust gas backpressure restriction will result in gradual degradation of diesel engine performance, increased fuel consumption, increased oil consumption, high oil temperatures, high coolant temperatures, etc….

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Effects of Phosphorus in Ash

- Ash which contains higher levels of phosphorus may increase oxidation temperatures of DPM. This may result in incomplete and/or partial regeneration of DPF. This may also result in reduced pollutant oxidation (HC, CO, SOF) performance of DPF and DOC.
- Therefore diesel engines which consume higher amounts of engine lubrication oil could prove to be problematic. Higher engine exhaust gas temperatures will be required to achieve complete DPF regeneration.
- Excessive diesel engine oil consumption will result in deactivation and irrepairable damage to precious metal catalysts which are coated onto DPF and DOC or are found in platinum based diesel fuel additives.

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Minimizing Effects of Ash using Correct Crankcase Oils

Recommended Diesel Engine Crankcase Lubricating Oils:

- **1) CJ-4 – contains less than 1.0% wt. sulphated ash and less than 0.12% wt. phosphorus.**
- **2) CI-4/CI-4+ – contains less than 1.5% wt. sulphated ash and less than 0.15% wt phosphorus.**

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Minimizing Effects of Ash by Minimizing Engine Oil Consumption

Ensure that the diesel engine is not consuming an inordinate amount of crankcase lubrication oil by:

- 1) analyzing engine crankcase oil on a periodic basis to determine possible engine faults.
- 2) measuring and record volume of engine crankcase oil consumed over unit engine hours.
- 3) ensuring that engine oil volume consumed is within Engine Manufacturer tolerances.
- 4) taking necessary maintenance and repair actions to minimize engine oil consumption.

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

DPF / DOC ash removal intervals:

1) for newer engines (Tier 1-3) using CJ-4 engine crankcase oil and ULSD which have minimal lubrication oil consumption rates, DPF ash removal procedures should be carried out every 1500-2000 engine operating hours or once every 12 months (whichever occurs first) or as required according to engine exhaust gas backpressure restriction levels.

2) For older engines (pre-Tier 1)using CJ-4 engine crankcase oil and ~500 ppm S which have higher lubrication oil consumption rates, DPF ash removal procedures should be carried out every 1000-1500 hours or once every 6 months (whichever occurs first) or as required according to engine exhaust gas backpressure restriction levels.

3) For diesel engines (pre and post Tier 1) using diesel fuel additives, ash collection rates will be higher and will vary according to additive dosage rates.

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Diesel Particulate Filter
Maintenance of your DPF System:

Oil Consumption and Engine Duty

Cycle / Age Variables

- light engine duty cycles may result in diesel engines which consume inordinate amount of engine crankcase oil.
- low engine speeds may result in diesel engines which consume inordinate amounts of engine crankcase oil.
- high hour diesel engines may consume inordinate amounts of engine crankcase oil.

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Manual DPF/DOC Ash Removal Field Procedure - Safety Equipment

- wear soil resistant clothing or disposable coveralls.
- leather gloves.
- 3M 5200 series respirator with 3M 6001 VOC filter and P100 particulate pre-filter/adapter.
- safety glasses with safety face shield.
- perform cleaning operation is a well ventilated area with adequate lighting.
-

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Manual DPF/DOC Ash Removal Field Procedure - Cleaning Equipment

- Compressed Air Source with adjustable pressure regulator, water separator and particle filter.
- rubber tipped air nozzle, extended tip air nozzle with flexible tube nozzle.
- Pottery Kiln with adequate internal dimensions and a programmable temperature/time/cycle controller.
- 6.5 hp+ Rigid industrial vacuum equipped with HEPA filter and vacuum hose/end cone adapters.
- Weigh scales and calibration weight.
- DPF/DOC cleaning cradle or equivalent.

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

DPF/DOC nozzle air pressure limits

- **For catalyst coated DPF/DOC recommended cleaning nozzle air pressure should be in the range of 40 to 50 psi. Nozzle air pressure in excess of 50 psi may damage or remove wash-coat and catalyst from DPF/DOC substrate surfaces.**

- **For uncoated DPF recommended cleaning nozzle air pressure should be in the range of 80 to 100 psi.**

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Manual DPF/DOC Ash Removal Procedure

Removal of DPF/DOC center body

1) Carefully support bottom of DPF/DOC with wooden blocking, etc… to prevent accidental drop damage.
2) Remove nuts from clamp bolts of V-band clamps which connect end cones to DPF/DOC. Use rubber mallet or dead blow hammer or prying tool to loosen V-band clamps. Avoid striking threaded bolt sections.
3) Separate DPF/DOC center body from the end cones.
4) Remove DPF/DOC center body from mining vehicle.
5) Place DPF/DOC on a flat surface and block DPF/DOC center body to prevent movement during cleaning procedure. Alternately use DPF/DOC cradle or steel angle mounting.
6) Remove end cone gaskets. Scrape old gasket material from end cone and center body flanges (if applicable).

WORKSHOP

Diesel Particulate Filter

Maintenance of your DPF System:

Pre-cleaning Inspection

- Check backpressure measurement system gauges, sensors, lines, filters, etc…
- With the DPF/DOC dismantled, check the condition of the end cones, end cone exhaust pipe clamps, end cone flange surfaces, test ports/plugs, end cone gasket surfaces, V-band clamps, V-band clamp bolts and nuts. Replace the end cone gaskets and replace/repair any other damaged components.
- Check the condition of DPF/DOC canning metal outer shell. Make note of any dents or other damage.
- Check the condition of the DPF/DOC end cone to center body flange surfaces. Check for corrosion, possible warp age and any other damage. If applicable sand the center body flange surfaces flat by using a small 4.5" diameter disc grinder with an 80 grit sanding disc.
- Check the DPF inlet and outlet face seals to make sure that they are not damaged, loose or missing.
- Check the DPF inlet and outlet faces for visible channel plug damage or pitting.
- Check the inlet face of the DPF/DOC inlet face for DPM plugging. Channel plugging indicates an excessive DPM loading.
- For segmented DPF check the condition of cemented seams.
- Check the DPF outlet face for DPM spotting. DPM spotting is a telltale sign of internal DPF damage.

WORKSHOP

Diesel Particulate Filter

Maintenance of your DPF System:

Manual DPF/DOC Ash Removal Procedure Step 1

Initial Cleaning of DPF/DOC center body

- Using a weigh scale measure DPF/DOC center body weight only and record weight/model number/serial number of DPF/DOC.
- Install end cone and V-band clamp onto inlet end of DPF/DOC.
- Install vacuum cleaner hose onto inlet end cone.
- Using a fine tip sharpie marker or thin masking tape mark and divide the outlet face into quadrants.
- Working one quadrant at a time (using rubber tipped or flexible tube air nozzle) blow compressed air into each open channel of the DPF/DOC outlet face. Pulse the rubber tipped air nozzle on/off when directed into each individual channel as required to clear the channel of particulate matter and as required.
- Channels located at the periphery of DPF/DOC outlet face may require additional effort due to probable higher DPM/Ash mass.
- Channels located at the center of the DPF/DOC outlet face may require less effort due to probable lower DPM/Ash mass.
- After initial cleaning, remove inlet end cone and vacuum hose from inlet face and inspect inlet face with flashlight. If compacted DPM "straws" are observed emitting from channels repeat cleaning procedure. Concentrate air flow into channels where DPM "straws" are observed.
- The accumulated DPM mass must be removed from DPF/DOC center body to minimize potential of "runaway" uncontrolled regeneration during DPF/DOC heating cycle.
- Larger DPF/DOC may require extended cleaning efforts.
- Using weigh scale measure DPF/DOC center body weight after initial cleaning. Record weight/model number/serial number of DPF/DOC.

WORKSHOP

Diesel Particulate Filter

Maintenance of your DPF System:

Manual DPF/DOC Ash Removal

Procedure Step 2

Thermal Kiln Heating of DPF/DOC Center Body

1) Install 4 metal or ceramic spacers (2.0" high by 2.0" long) oriented to allow DPF/DOC center body to be situated above the kiln floor. This will allow upward air flow through the DPF/DOC substrate.
2) Install DPF/DOC center body into pottery kiln outlet face down.
3) Open air vent holes located in the kiln body.
4) Heating cycle should consist of a 2 to 4 hour minimum "ramp up" segment which will gradually raise the kiln temperature to approximately 650 C to 700 C maximum.
5) Ramp up segment to be followed by a "constant heat" segment where kiln temperature is held constant at approximately 650 C to 700 C degrees maximum for a 2 to 4 hour minimum time period.
6) Constant heat segment to be followed by "cooling" segment where kiln temperature is gradually reduced from 700 C maximum to ambient for a minimum 4+ hour time period. It is best to allow the DPF/DOC to fully cool down to ambient temperatures naturally in the kiln. Do not attempt to speed the cooling segment.
7) Remove DPF/DOC from kiln.
8) Using weigh scale measure DPF/DOC center body weight and record weight/model number/serial number of DPF/DOC.

WORKSHOP

Diesel Particulate Filter

Maintenance of your DPF System:

Manual DPF/DOC Ash Removal

Procedure Step 3

Final Cleaning of DPF/DOC center body

1) Install end cone and V-band clamp onto inlet end of DPF/DOC.

- 2) Install vacuum cleaner hose onto inlet end cone.
- 3) Using a fine tip sharpie marker or thin masking tape mark and divide the outlet face into quadrants.
- 4) Working one quadrant at a time (using rubber tipped or flexible tube air nozzle) blow compressed air into each open channel of the DPF/DOC outlet face. Pulse the rubber tipped air nozzle on/off when directed into each individual channel as required to clear the channel of particulate matter and as required.
- 5) Channels located at the periphery of DPF/DOC outlet face may require additional effort due to probable higher DPM/Ash mass.
- 6) Channels located at the center of the DPF/DOC outlet face may require less effort due to probable lower DPM/Ash mass.
- 7) After initial cleaning, remove inlet end cone and vacuum hose from inlet face and inspect inlet face with flashlight. If DPM "straws" are observed emitting from channels repeat cleaning procedure. Concentrate air flow into channels where DPM "straws" are observed.
- 8) The accumulated DPM mass must be removed from DPF/DOC center body to minimize potential of "runaway" uncontrolled regeneration during DPF/DOC heating cycle.
- 9) Larger DPF/DOC may require extended cleaning efforts.
- 10) Using weigh scale measure DPF/DOC center body weight after initial cleaning. Record weight/model number/serial number of DPF/DOC.

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Post-cleaning DPF/DOC Inspection Tools

- 0.060” and .045” probing rods for 100 cell and 200 cell DPF densities.
- High intensity spot light (15,000,000 candlepower +).
- Bore scope with flexible .045” probe.
- Contract X-ray inspection services.
- Contract ultra sound inspection services.
- Portable CO analyzer (0 – 2000 ppm)

WORKSHOP
Diesel Particulate Filter
Maintenance of your DPF System:

Post-cleaning DPF Inspection Methods

- **if DPM spotting on the outlet face was found earlier during pre-cleaning inspection, the DPF should be internally inspected. DPM spotting is indicative of internal DPF damage. Low engine exhaust gas restriction, visible PM on exhaust tailpipe and poor engine performance are other telltale signs.**
- **gently use the .060”/040” probing rods in the area of DPM spotting. The probing rod should be able to easily slide the entire depth of the filter inlet/outlet channel without restriction.**
- **place a high intensity spotlight in close proximity to the filter inlet/outlet face. Visually inspect the opposite face for any leakage of bright light indicative of channel damage.**
- **alternately the DPF core may have to be inspected by use of bore scopes, endoscopes, x-ray and airflow testing to determine channel damage.**
- **measurement of CO % reduction efficiencies on a periodic basis (in the case of catalyzed DPF) will determine condition of precious metal coating.**

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Mining Diesel Emissions Council

October 2nd, 2007

WORKSHOP

Diesel Particulate Filter

Discussion

- Questions
- Comments
- Suggestions