Driving Automotive Innovation – Cylinder Deactivation

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902 Senate Hart Building, Washington, D.C.

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Challenge: Move Peak Efficiency Islands to the Driver Operating Zone

CITY AND HIGHWAY DRIVING (gasoline)

Moving the high-efficiency island down:

- ***Downsize + Boosting***: Retains power and improves low-load efficiency
- **Cylinder Deactivation**: Fewer cylinders at better efficiency
- ***Variable Valve Lift***: Reduces throttle losses at low loads

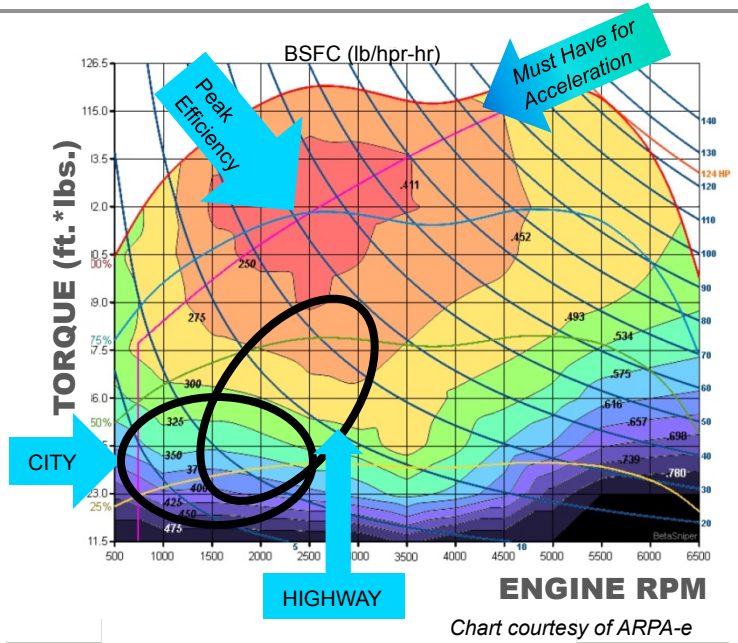
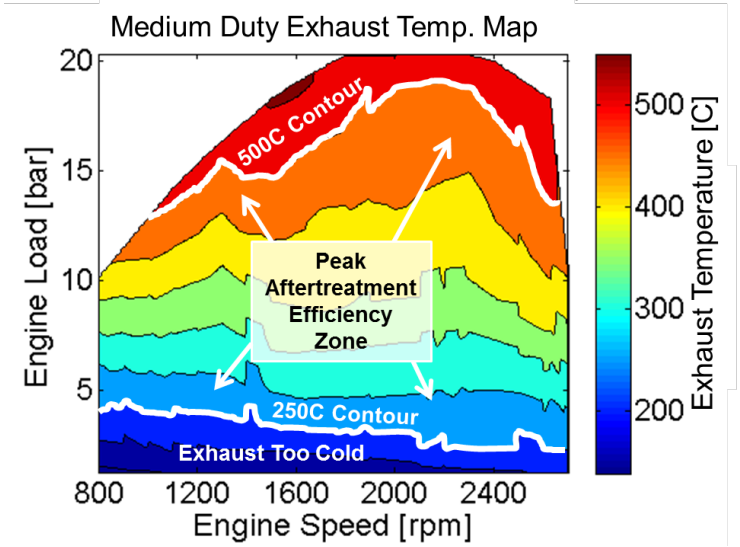


Chart courtesy of ARPA-e

LOW LOAD OPERATION (diesel below 250C)

Raising diesel exhaust temperature to the peak aftertreatment efficiency island:

- *Internal EGR*
- *Early Exhaust Valve Opening*
- **Cylinder Deactivation**



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Cylinder Deactivation (CDA) & Benefits

How It Works

Fuel cut off

↓

Intake and exhaust valves stop opening

↓

Charge trapped

↓

Cylinder = Air Spring

Gasoline Benefits

↑ Fuel Economy

Diesel Benefits

↑ Exhaust Temperature

↑ Fuel Economy

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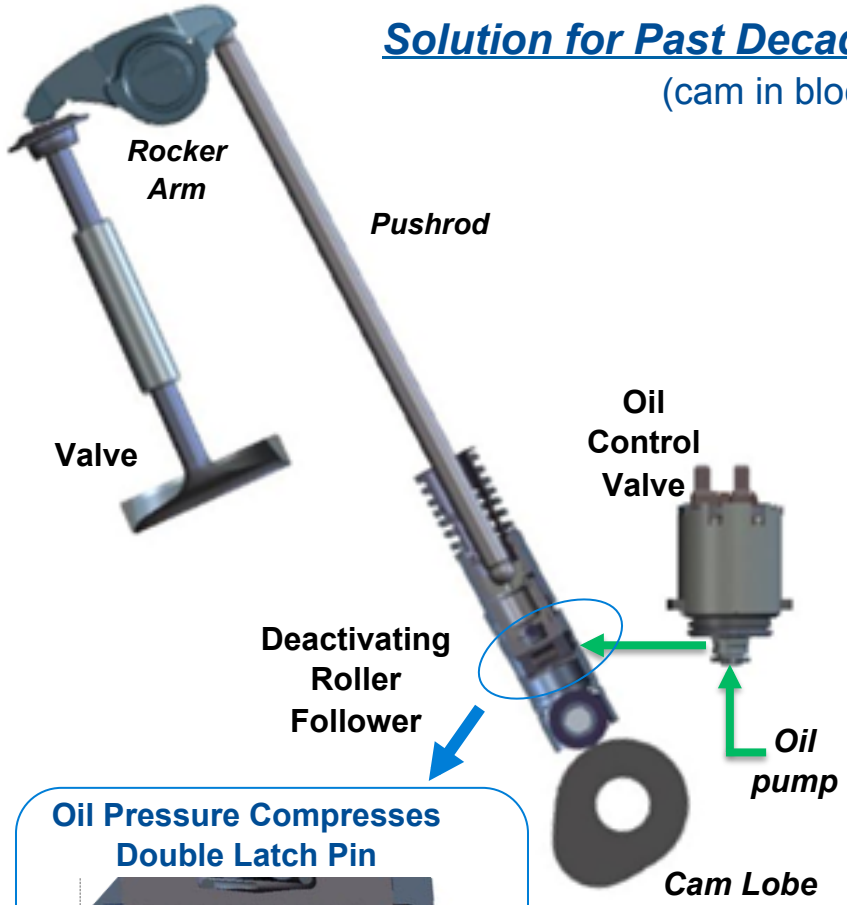
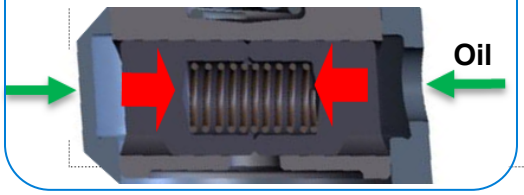
Various Methods For Cylinder Deactivation (CDA)

Solution for Past Decade

(cam in block)

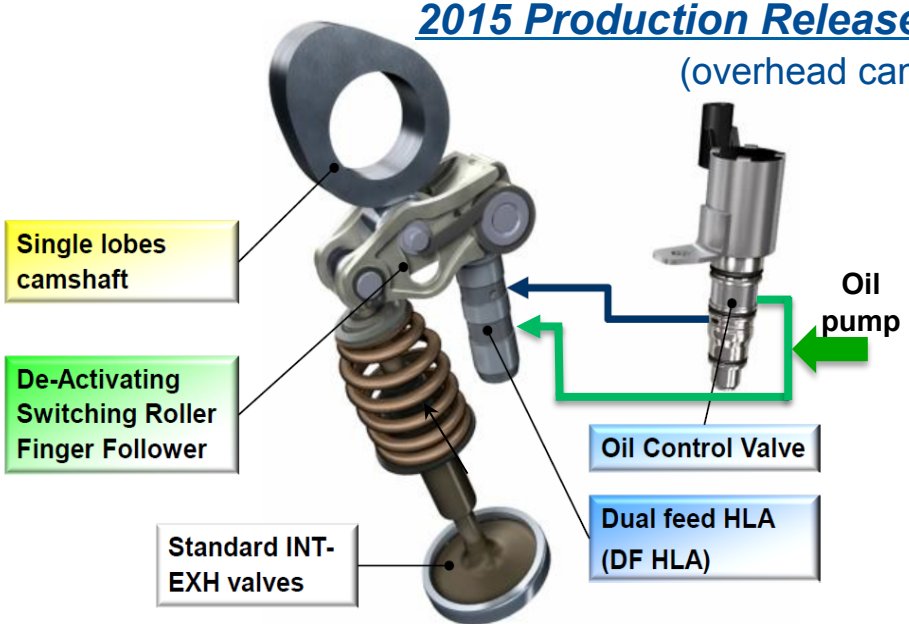


Oil Pressure Compresses Double Latch Pin

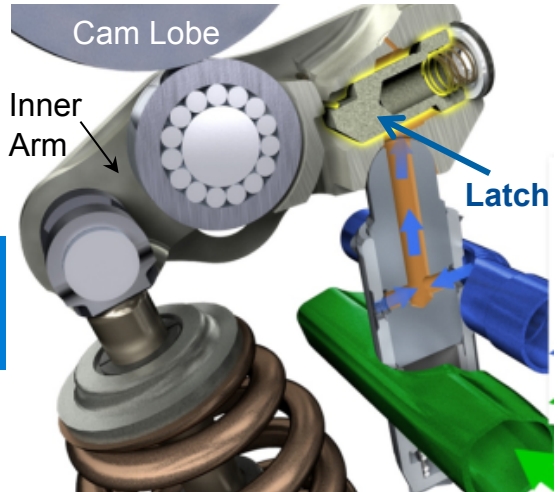


2015 Production Release

(overhead cam)



Oil Pressure Retracts Latch Pin



Cylinder Deactivation Improves Fuel Economy between 2% and 12%

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CDA Vehicles Over Past Decade

GEN 5 Engine	GM Vehicles for 2016 [1]
4.3L V-6	Silverado and Sierra
5.3L V-8	Silverado, Sierra, Suburban, Tahoe, Yukon
6.2L V-8	Silverado, Sierra, Escalade, Yukon Corvette, Camaro

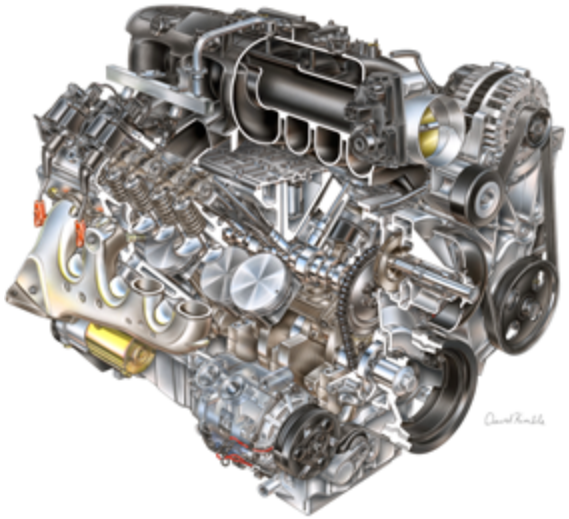

Illustration: General Motors V-8 Engine

Implemented for

Past Decade

(Cam in block engine)

Engine	More Vehicles
3.5L V-6	Honda Odyssey, Pilot, Accord, Acura
5.7L V-8	Dodge Ram, Chrysler 300 Dodge Durango, Jeep Grand Cherokee
5.5L V-8	Mercedes-Benz
4.0L V-8	Audi

Cylinder Deactivation is Proven Technology to Reduce Fuel Consumption

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Recent Implementation of CDA

Launched in 2015

- ***GM Improving Fuel Economy by 6%+ using CDA as part of the solution***

HFV6 Engine	MY	GM Vehicle [1]	Fuel Economy	Main Technology Cited
3.0L Twin Turbo	2016	Cadillac CT6	Est. **6%** Over Prior Model [2]	Twin Turbo + **CDA** + Start/Stop
3.6L		Cadillac ATS/CT6/CTS Camaro	Est. **9%** Over Prior Model [3]	**CDA** + Start/Stop
	2017	Colorado	**31** mpg Highway [4]	**CDA** + 8-speed transmission
		Acadia	**25** mpg Highway [5,6]	**CDA** + New Chassis

- ***Volkswagen and Ford Showing 6% Fuel Economy Improvement with CDA on 4 & 3 Cylinder Engines***
  - Volkswagen 1.4L 4-cyl. engine [http://www.greencarcongress.com/2013/06/vwact-20130605.html]
  - Ford 1.0L 3-cyl. demo engine [http://www.greencarcongress.com/2015/05/20150512-ford.html]

Fuel Consumption Improving by 6%+ Using CDA as Part of the Solution

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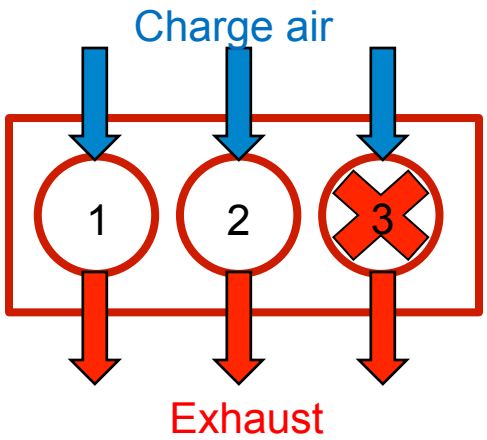
Variable Cylinder Deactivation
(3-cylinder engine example)

Standard CDA:

- Specific cylinders are deactivated, keeping these continuously inactive for the deactivation period
- Switch from 3 to 2 active cylinders



firing order:

1,3,2,1,3,2,1,3,2,1,3,2…

with standard CDA:

1,x,2,1,x,2,1,x,2,1,x,2…

Dynamic or Rolling CDA:

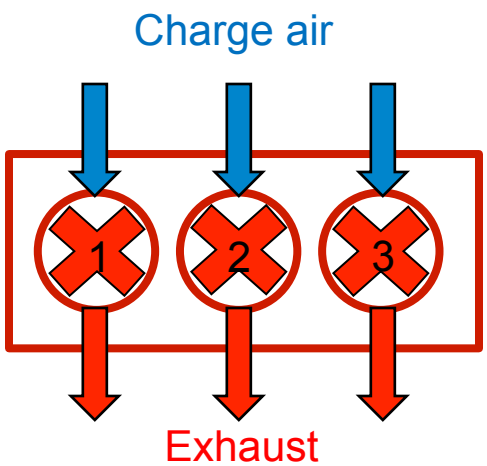
- Each cylinder is continuously changing from active to de-active each cycle.
- Switch from 3 to 1.5 active cylinders

firing order:

1,3,2,1,3,2,1,3,2,1,3,2…

with dynamic CDA:

1,x,2,x,3,x,1,x,2,x,3,x…



Next Steps for CDA include

- Electrically Actuated CDA and Deactivating Lash Adjuster

Fuel Savings Can Be Increased By Deactivating More Cylinders

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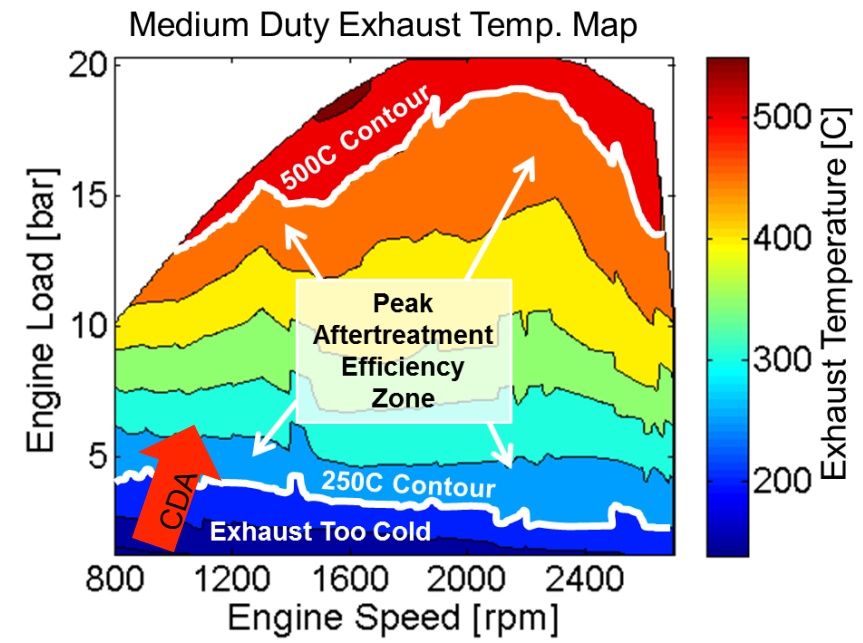
Diesel Cylinder Deactivation Benefits

- Diesel CDA improves Aftertreatment temperatures/efficiencies and yields fuel economy benefits



- CDA at low load operation for Medium-Duty Diesel
  - Adds ~100C to exhaust temperature
  - Shifts Aftertreatment from “Too Cold” to “Peak Efficiency” Zone (NOx removal)
  - Fuel savings of up to 25%

- Drive cycle fuel savings depends on time spent in low load operation

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SAE Webinar Audience Poll Results

SAE Webinar on August 4, 2016

Title: Next-Generation Advanced Combustion / Aftertreatment

Attendees: 277 Attendees in Live Audience

Poll Question: What percentage of the three markets will require variable valve actuation (as defined by variable lift, deactivation or duration) by 2025?

	Gasoline		Light Duty Diesel		Medium Duty Diesel
0%	<10%	*4.7%*	<5%	*5.2%*	<5%
10.5%	10-30%	*14.1%*	5-15%	*18.8%*	5-15%
24.6%	30-60%	*34.0%*	15-50%	*32.8%*	15-50%
53.9%	60%-100%	*30.2%*	50%-100%	*25.5%*	50%-100%
11.0%	No opinion	*16.7%*	No opinion	*17.7%*	No opinion

Poll Answers in Blue

Technical Audience is Bullish for Variable Valve Actuation Implementation for Multiple Markets by 2025

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https://event.webcasts.com/starthere.jsp?ei=1109742

Summary
Cylinder Deactivation Solutions

- Implemented over Past Decade
  - GM V-6 and V-8 Engines

  - Honda, Chrysler, Mercedes-Benz, Audi
- Recent Implementations
  - GM V-6, Part of 6%+ fuel economy solution

  - Volkswagen I-4 & Ford I-3 Demo with 6% Fuel Economy
- Medium-Duty Diesel Research with CDA at low load operation
  - Improves Exhaust Temperature for Improved Aftertreatment
  - Improves Fuel Economy

Cylinder Deactivation Hardware Proven, Durable and Ready to be Implemented on More Engines

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Thank You

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9) Diesel CDA: Int'l Journal Eng. Research 8/12/15: Fuel Efficient Exhaust Thermal Management for Compression Ignition Engines During Idle via Cylinder Deactivation and Flexible Valve Actuation
10) SAE Webinar: https://event.webcasts.com/starthere.jsp?ei=1109742

Biography
James McCarthy, Jr.

Jim McCarthy is the Engineering Manager for Eaton's Advanced Valvetrain Actuation focused on North American and Asian markets and is located in Marshall, Michigan. His previous role at Eaton focused on development of Exhaust Aftertreatment Solutions. Prior to joining Eaton, Jim worked on diesel engine technologies at Detroit Diesel.

Jim has focused his engineering career on product innovation and growth to develop and integrate serial production solutions for engine technologies while optimizing power generation to conserve fossil fuels and reduce emissions.

McCarthy received his Ph.D., Masters of Science and Bachelors of Science in Mechanical Engineering from Purdue University.

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