

The Effect of Cylinder Deactivation on Engine Efficiency and Emissions

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Abstract: Cylinder deactivation (CDA) works by shutting off fuel, spark, and valves in an engine's cylinders while it is under low load, which lets the other cylinders run more efficiently. This paper will go through the aspects of technology from the 1981 Cadillac V8-6-4, through General Motors' modern Active Fuel Management and Dynamic Fuel Management systems, to the controlled Dynamic Skip Fire developed by Tula Technology. Pulling information from SAE test data and other research, this paper discusses cylinder deactivation's fuel-efficiency benefit and how it affects emissions. It then reviews the durability concerns that followed after widespread adoption of the system and finishes by looking at how the shift led to improvements in technology and in performance.

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I. INTRODUCTION

A normal gasoline- or diesel-engine-powered car spends the majority of its life doing far less work than it is capable of. Highway cruising typically requires only a fraction of an engine's overall output, and a conventional engine meets this demand inefficiently. It wastes more energy simply keeping all of its cylinders running at light and inefficient loads (Clemson VEL, n.d.). Cylinder deactivation mitigates this by removing some cylinders from producing power altogether, with fuel injection, spark, and valve movement suspended. The remaining cylinders work harder to produce the same output, which is essentially more efficient. Manufacturers prefer this idea because it promises real fuel savings without the need for a smaller engine or a hybrid powertrain. This paper explains how cylinder deactivation works, reviews its fuel-efficiency and emissions performance, and looks at reliability problems that have arisen from its first development to the present.

➤ How Cylinder Deactivation Works

When an engine is under a lighter load, it wastes energy overcoming its own pumping losses and needs extra effort to pull air through a partially closed throttle (Clemson CVEL, n.d.). Cylinder deactivation reduces this by concentrating the same total demand onto fewer cylinders so that each of the active cylinders works with a slightly more open throttle and a more efficient load, while the deactivated ones sit idle with closed valves and no supply of fuel. On pushrod engines like the ones found in GM's and Chrysler's V8s, this is done with hydraulic lifters that collapse under oil pressure to stop the valves from lifting. Other manufacturers like Honda, Mercedes-Benz, and Volkswagen use an overhead cam, which works by using locking rocker arms, or a sliding multi-lobe camshaft in Volkswagens, to achieve the same result

(Clemson CVEL, n.d.). The same works for diesel engines too, but not for the same reasons. Fewer cylinders under the same airflow means that the exhaust that is produced is hotter, which allows the emissions control catalyst to operate at its most effective operating temperature (Ramesh et al., 2018).

➤ The 1981 Cadillac V8-6-4

The first mass-produced engine that adopted the cylinder deactivation system showed that, at the time, the technology was stronger than the engineering available to build it. In 1981, Cadillac introduced the L62 "V8-6-4" engine that was developed with Eaton Corporation. It used solenoids on the rocker arms of the 4 cylinders to disable the valvetrain and valves and turned the 6.0-liter V8 into a V6 or V4 under lighter loads (Severson, 2025). Cadillac's chief engineer, Robert Templin, claimed that the system was worth an extra 4 to 5 mpg on the highway. However, the Environmental Protection Agency (EPA) tested it and showed that the actual combined mileage improvement over the non-deactivated 1980 engine was less than one percent for most models and even negative for some (Severson, 2025). In practice, the engine's throttle-body fuel injection could not selectively cut fuel to individual cylinders, and the computer could not keep up with the rapid changes in driving conditions, so the car experienced lurching, hesitation, or even stalls as the cylinders would cut in and out (Severson, 2025). Despite many updates, the system was never corrected, and GM faced many class-action lawsuits in more than a dozen states. Eventually, owners and dealerships entirely disabled the system and restored the full eight-cylinder operation. The V8-6-4 was discontinued from most models only after a single year of production, and it led to a reputation that followed cylinder deactivation that would take 2 decades to fix.

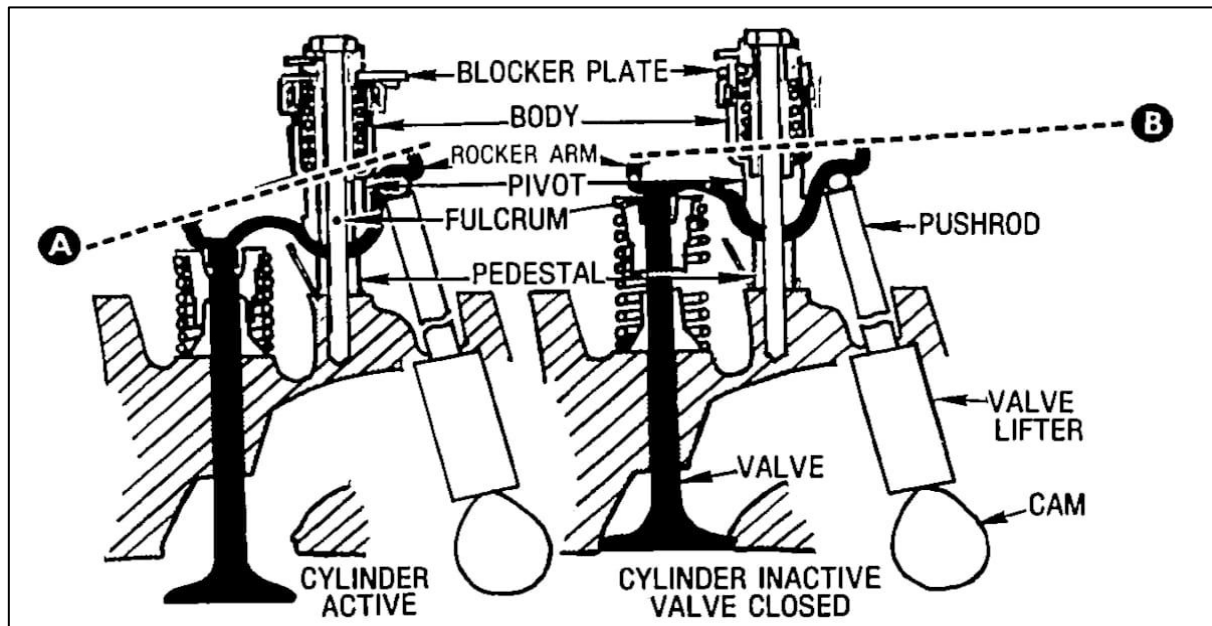


Fig 1 Cutaway Diagram of the 1981 Cadillac Modulated-Displacement (Cylinder Deactivation) System, Showing an Active Cylinder Alongside a Deactivated One.

➤ Modern Systems

Cylinder deactivation returned to production when electronic engine control and hydraulic lifter technology were developed to match the technology and allow for a better transition. Chrysler introduced their Multi-Displacement System on the Hemi V8 in 2005; General Motors introduced Active Fuel Management on its small block V8s. Both worked by deactivating 4 cylinders under lighter loads and claimed to have a fuel economy gain of about 7 to 8 percent (WardsAuto, 2015).

Tula Technology developed a Dynamic Skip Fire system that continuously varies which cylinders fire on every engine cycle rather than deactivating a fixed set (Wilcutts et al., 2013). Because the firing changes for every cylinder, DSF avoids the vibration frequencies that other systems produce, expanding the usable operating range in which the cylinders can be deactivated without impacting ride quality (Wilcutts et al., 2013). General Motors' 5.3 and 5.2-liter V8 engines fit with DSF have shown improvement in fuel economy of up to 15 to 21 percent on real world application, compared to other system that show 5 to 8 percent.

Table 1 Reported Fuel-Efficiency and Emissions Benefits of Cylinder Deactivation Across Gasoline and Diesel Applications, Drawn from Peer-Reviewed SAE and Journal Studies and Manufacturer Test Data.

Application	Technology	Reported Benefit	Source
4-cyl. gasoline, urban drive cycle	Fixed 2-cylinder deactivation	6-25% fuel consumption reduction; 19.4% lower pumping mean effective pressure; up to 5% higher thermal efficiency	SAE 2015-01-0983 (2015)
3-cyl. 1.0-L direct-injection gasoline	Single-cylinder deactivation	Up to 15% fuel economy gain at light load; NO _x emissions increased	McGhee et al. (2018)
Medium-duty diesel, loaded idle / highway cruise	Fixed-group CDA	Up to 40% efficiency improvement; 5-32% brake thermal efficiency gain	Ramesh et al. (2018)
Chrysler Hemi V8 / GM small-block V8	Multi-Displacement System / Active Fuel Management	Approximately 7-8% fuel economy improvement	WardsAuto (2015)
5.3/6.2-L V8 gasoline pickup truck	Dynamic Skip Fire (per-cylinder)	Up to 15-21% fuel economy improvement, roughly double fixed-mode systems	Wilcutts et al. (2013); Tires and Parts (n.d.)
Heavy-duty diesel highway cruise	Jacobs CDA with SCR aftertreatment	2- 2.76% highway fuel savings; up to 74% NO _x reduction via faster catalyst warm-up	Cummins Inc. (2025); Truck News (2021)

➤ Emissions

The cylinder deactivation effect on emissions is different when compared to its effect on fuel consumption. The same system that improves efficiency by running the

active cylinders at a lower throttle and heavier load leads to higher combustion temperature and pressure, which is the primary cause of nitrogen oxides (NO_x). A study of a 1.0-liter three-cylinder engine found that deactivating one cylinder

improved fuel economy by up to 15 percent at light loads but also increased NO_x emissions and friction losses in the deactivated cylinder (McGhee et al., 2018).

In diesel engines, cylinder deactivation emission benefits do not come from combustion gases but from aftertreatment thermal management. Diesel exhaust aftertreatment systems only reduce NO_x emissions effectively once their catalytic reduction catalyst reaches operating temperature, and at low engine loads, the exhaust flow is too cold to sustain that temperature. By pushing more exhaust flow into fewer and more loaded cylinders, cylinder deactivation raises the exhaust temperature and keeps the catalyst active. While testing on diesel engines under medium output, it found efficiency gains of 5 to 32 percent along with higher aftertreatment temperatures (Ramesh et al., 2018). Cummins engines equipped with Jacobs CDA technology and Tula's software reported NO_x reductions of up to 74 percent (FleetOwner, 2021; Truck News, 2021).

➤ Reliability Controversy and Litigation

Cylinder deactivation faces the controversy of whether the hardware will hold up over the life of an engine. General Motors' AFM and DFM system relies on hydraulic lifters to hold the cylinder valves closed, which many owners and repair shops have reported have failed, which can cause a cylinder to permanently stop working, misfire, or produce engine ticking that leads to repairs that require removing cylinder heads (Jalopnik, 2025), which can lead to high repair costs. Another problem faced is oil consumption. When deactivated, it can cause damage to the piston rings in the deactivated cylinders, which leads to oil burning and, in some cases, complete bottom-end engine failure. These issues led to class-action lawsuits against General Motors alleging that their systems in the Active Fuel Management and Dynamic Fuel Management V8 engines were built from substandard materials and installed out of specification (GM Authority, 2021-2024).

II. LIMITATIONS

Saying that cylinder deactivation is solely or the main contribution to a vehicle's overall fuel economy or emission production is difficult because it is typically complementary to other efficient technologies like turbocharging, direct injection, stop-start systems, each of which affects the same measurements. Fuel savings also vary with the drive cycle used to test them. The U.S. Department of Energy estimates that roughly 7.5 percent of efficiency gains sit well below manufacturers' claims of up to 20 percent. A gap that is affected by the time for a driving pattern under light-load conditions where deactivation is active (Clemson CVEL, n.d.).

III. THE FUTURE

The industry's early response to cylinder deactivation has not been forgotten but has been refined. The shift from 1981's Cadillac to the fixed group AFM, DFM, and MDS system and to the present-day Tulsa Dynamic Skip Fire shows a path of continuing development (Wilcutts et al.,

2013). By 2023, roughly 56 percent of U.S. General Motors vehicles have used cylinder deactivation (Severson, 2025). Diesel manufacturers are also pursuing per-cylinder deactivation strategies to help with nitrogen oxide standards for commercial vehicles (FleetOwner, 2021).

IV. CONCLUSION

Cylinder deactivation is the idea of an engine running fewer, more heavily loaded cylinders that wastes less energy than the same engine running all of its cylinders lightly loaded. Even though the 1981 Cadillac V8-6-4 failed to deliver the idea and faced multiple class action lawsuits, cylinder deactivation still works. Four decades of engineering, which led to fixed two-mode hydraulic systems to Tula's Dynamic Skip Fire system, have led to development in technology and reliability. While its emission effects show that the same mechanism can raise NO_x emissions even when it reduces fuel consumption, it depends on how the system is calibrated. The valve-lifter failures and limitations faced by the technology are a reminder that the engineering idea is as good as the hardware and software that is built around it.

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