What Happens When You Run Out of Injector?

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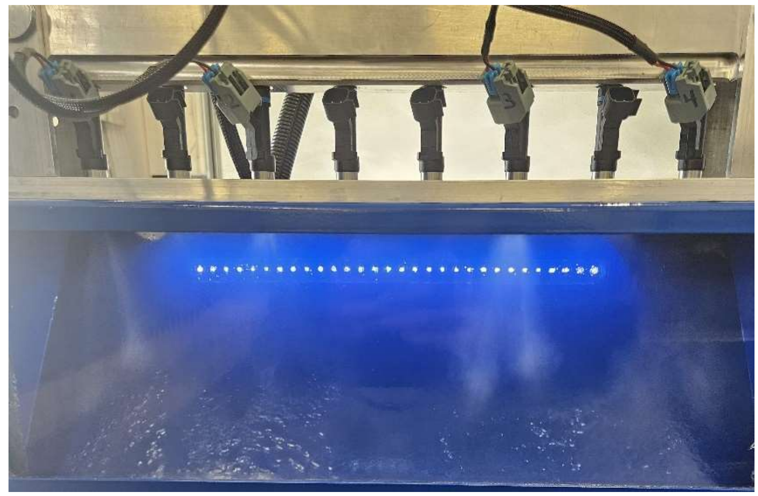
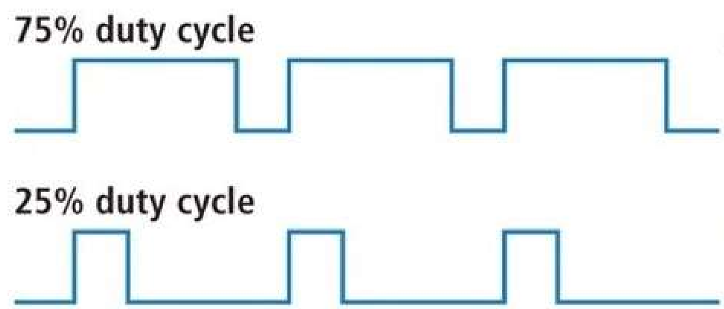




Any nozzle can only flow so much when left wide open. This flow rate moves with pressure, but it represents the maximum possible delivery when open 100% of the time. Since we pulse fuel injectors in an engine intermittently, we often speak in terms of “Duty Cycle” (DC) as a percentage of the maximum flow. 75% duty cycle would mean that the injector is pulsed such that it is open three quarters of the possible time. If we keep increasing the duty cycle, we eventually hit a point where the tail end of one event runs into the beginning of the next around 100% DC. Due to the inherent opening and closing delays in solenoid fuel injectors, this practical limit is actually less than that. The inductance and inertia effects can blur the line between close events, so we want to avoid that if we are to stay in precise control of our fuel delivery.

In short, there’s some practical limit to how long we can leave the injector open on each shot.

Another important point: there is no such thing as 101% (or higher) duty cycle. You can ask for it, but you won’t get it. Fully open is fully open. If the ECU calculations result in a requested pulse width that’s longer than the available cycle time at that RPM, we end up with an injector that just doesn’t close between events. Worse, each event is limited by the engine’s cycle time (time for two complete revolutions in a 4-stroke engine). This means the maximum delivered fuel mass can be no greater than the static flow rate multiplied by this cycle time. If we have more airflow and we are limited in fuel mass delivered, the combustion goes leaner than expected. No amount of longer injection time request can overcome these physics. We must either find a way to increase the injector’s flow rate (different injectors, increased working pressure) or accept this limit and dial back our airflow (horsepower) to keep the AFR safe.

But what really happens when we go too far? Stories are everywhere online. Countless internet "experts" regurgitate the same lines about maxing out fuel injectors:

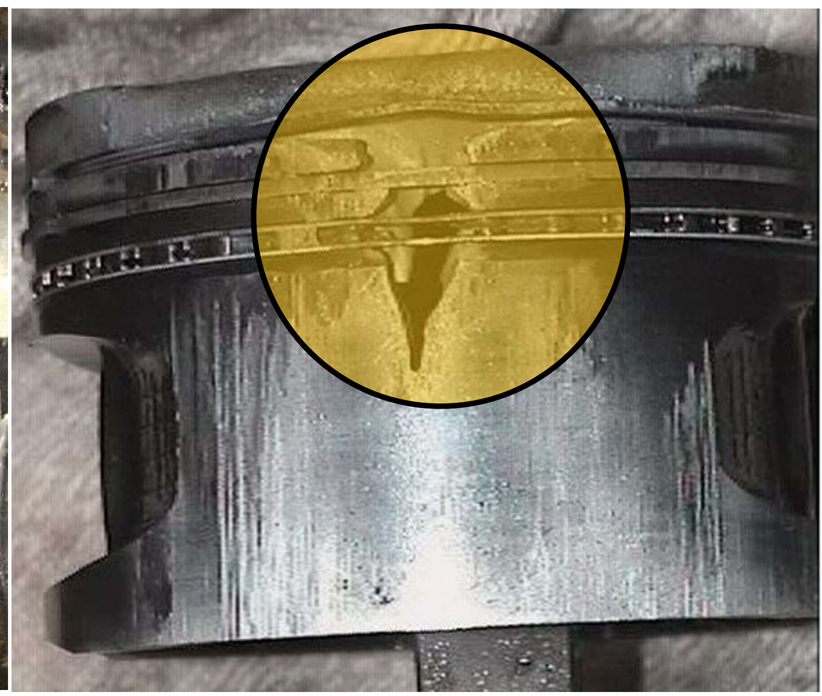
"Don't run more than 80% injector duty cycle."

"90% will probably work."

"I saw 110% and I'm fine."

"You might as well get giant injectors right from the start. 2200's aren't that bad."

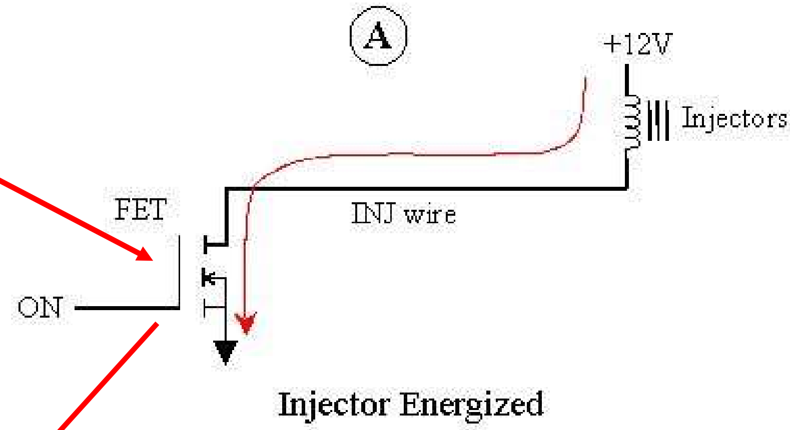
High performance engines are literally playing with fire. The trick is to have just enough fire. Ironically, not enough fire can be just as destructive as too much. This happens whenever we are attempting to make a bunch of power, but don't quite have enough fuel to go along with the air we are moving through the engine. If our fuel injectors are not capable of flowing enough, the result can be a leaner than intended mixture in the cylinder. This leaner mixture can burn at a hotter temperature, hot enough to **melt aluminum** as it turns out. We keep combustion temps inside the cylinder in check by adding that extra bit of fuel, which also tends to help avoid spark knock as well.



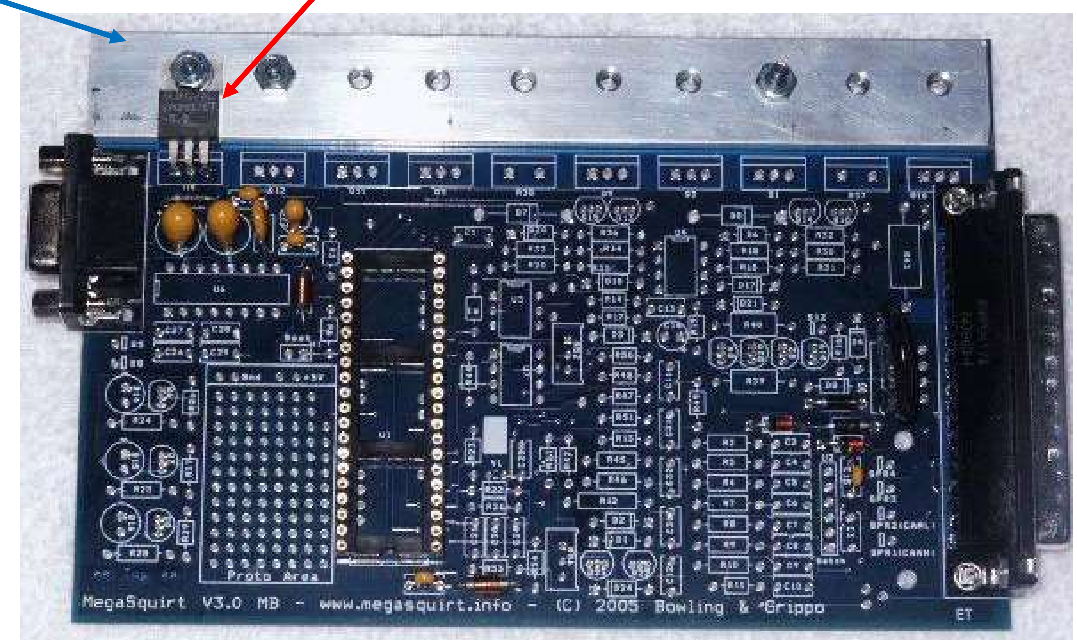
Going "too big" on injector flow rate isn't necessarily a problem at WOT. Once we're past 50% duty cycle, the question changes from "When is the injector open?" to "When *ISN'T* the injector open?" Higher flow rates drive lower injection times. The real problem there is that trying to get the relatively tiny fuel mass deliveries of idle or light throttle cruising out of a giant injector is exactly like trying to sip from the proverbial fire hose. We don't want to end up with an injector so big that we are riding the minimum stable pulse width at idle only to have 60% duty cycle up top. This is why OEMs size their injectors to be "just enough" (around 80% DC) at WOT, so they can retain good control at idle and in the drivability range.

What else can go wrong?

The pistons aren't the only part in danger when injector duty cycle approaches 100%. Inside the ECU, there are Field-Effect Transistors (**FETs**) that control the on/off switching of each injector. Whenever they are "on", current is flowing through the transistor.



For electronics, current also means HEAT. The FETs driving the injectors get warmed up proportional to the amount of current flowing through them over time. To handle this, ECUs place the FETs against a **heatsink** to absorb and redistribute this heat away from the fragile electronic components. The heatsink is often integrated with the case of the ECU with external cooling fins as well.



Higher injector duty cycle means that this current (heat) flow through the FET increases. If we never give it a rest, we can encounter a situation where we literally cook the FETs or their connections to the ECU board. It probably won't be immediate, but it can certainly happen over time. Translation: you just wrecked the ECU itself by trying to run the injectors too hard. This is one of the big reasons we try to limit injector duty cycle to 80-90% maximum.

Conclusion

Sizing injectors properly will help protect both your engine and your ECU. You want pick an injector like Goldilocks: not too big, not too small. There is usually a good bit of wiggle room in between for a few good injector choices on most applications. Just be sure to check up on your injector duty cycle when you get to your final dyno testing or track runs. Requesting 95% DC or higher can be just one cold air day away from an expensive lesson.

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