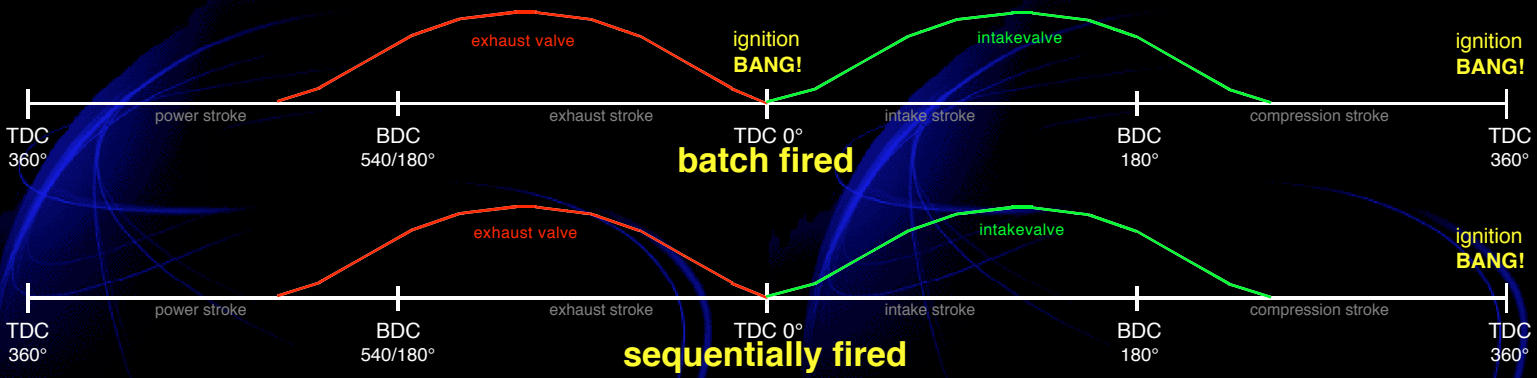
Sequential Fuel Injection vs. Batch-Fired Injection

ABSTRACT

Having watched with interest a heated discussion on the RennList email list (Oct. 1/01) on full sequential fuel-injection(paired) vs. batch-fired injectors (all at once), it appears that pictures can save thousands of words slung around in vain. This comparison must separate the two components of electronic engine-management, ignition and fuel-delivery. I will clarify each aspect as it relates to sequential vs. batch fuel-injection and illustrate that the differences between the two methods are minimal and the resultant power-differences to be negligible.

IGNITION CONSIDERATIONS

This is fairly simple to show. The sequential arrangement fires a spark every 720-degrees of crank rotation, semi-batch fires twice as often (every 360-degrees). As Scott Gomes indicated, on a Turbo, the little extra boost of combustion during the overlap period can actually add exhaust energy to help spool up the turbo at low-RPMs.

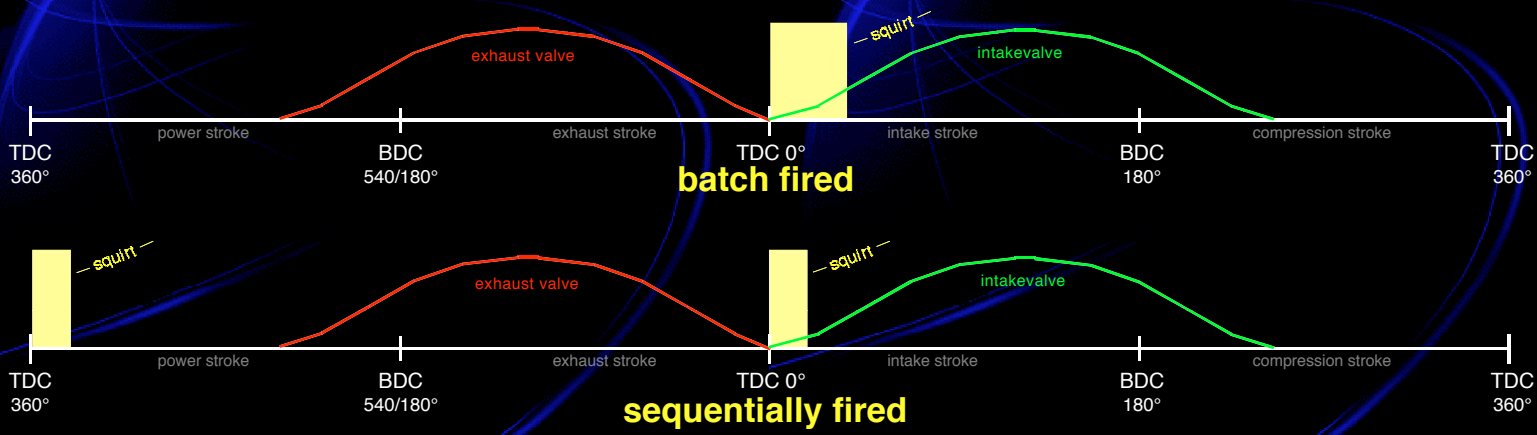


STANDARD CONFIGURATION

In these examples, let's assume we're going to use the standard equations to limit fuel-injector duty-cycle to no more than 80% at redline. Both systems of fuel-delivery can use the same size injectors and fuel-pumps. It's also assumed that both systems will start fuel-delivery at TDC, whereas we know from empirical data and testing that it's better to start well before that point.

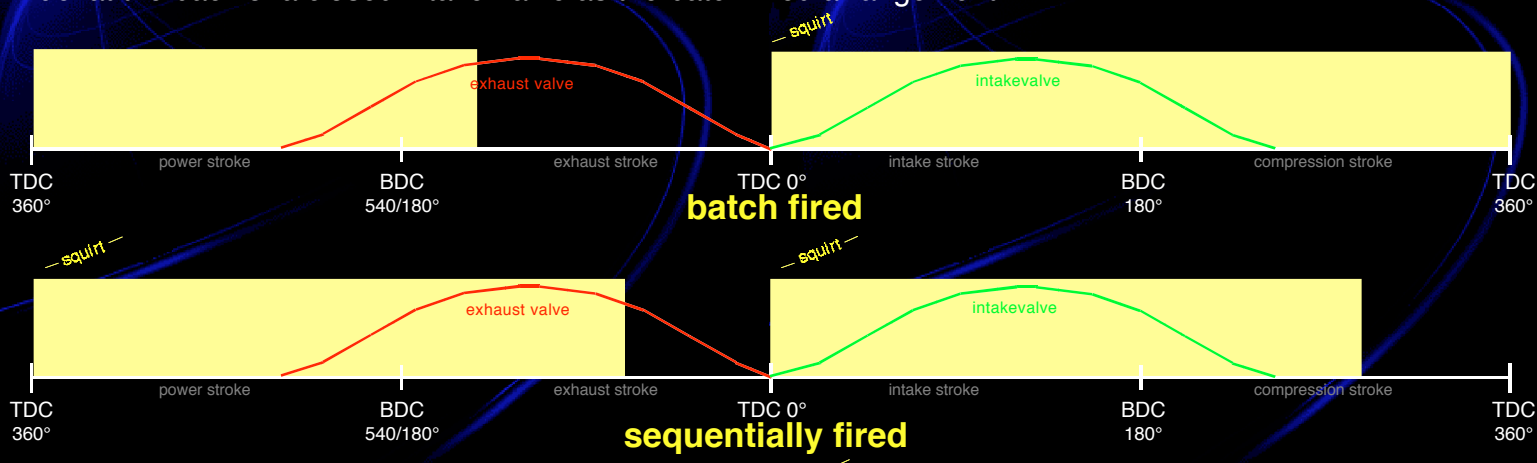
FUEL-DELIVERY AT LOW-RPM

Low-RPM operation is an area where sequential vs. batch-fired injectors can cleary be contrasted. This shows a maximum of 50% difference in fuel-delivery timing (delivered volume is the same). However, due to the large amount of time available for vaporization and getting the mixture into the combustion chamber, there's probably negligible performance differences between the two methods.



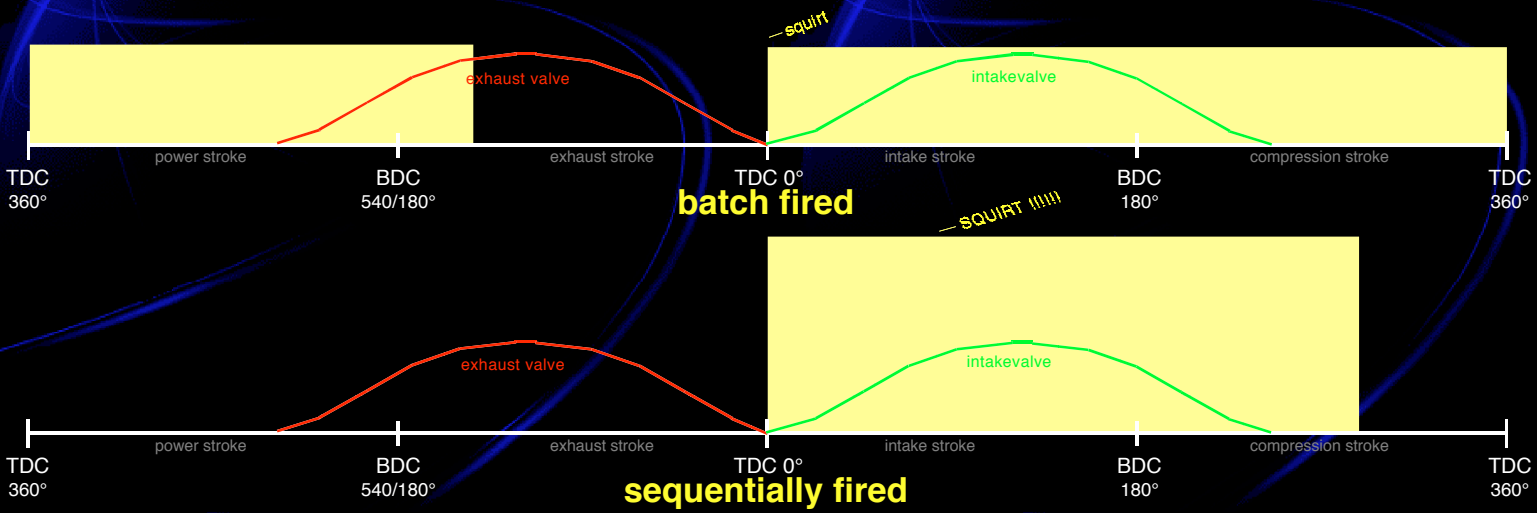
FUEL-DELIVERY AT HIGH-RPM

Under high-RPM operation, the fuel-injectors have longer duty-cycle periods. At redline, they're close to their maximum capacity and the differences in fuel-delivery is only 20% for a complete 720-degree 4-stroke engine cycle . Another interesting tidbit is that the sequentially-fired injectors spend just as much time firing fuel at the back of a closed intake-valve as the batch-fired arrangement.



VARIATION 1: DOUBLE FUEL OUTPUT ON SEQUENTIAL SYSTEM

Another scheme for sequential fuel-injection is to dump in twice as much fuel during a single 360-degree cycle of the batch-fired system. This requires using injectors that are TWICE as large and a fuel-pump that can deliver TWICE the volume at the same pressure. With this arrangement, the difference in fuel-delivery between the two methods is again 50%.



CONCLUSION AND DISCUSSION

Upon viewing a graphical display of the fuel-injector duty-cycles, one can see that the two methods of fuel-delivery are not all that different. At low-RPM operation, the volume of fuel metered is minimal given the time available that these two systems have identical performance. At high-RPM operation near redline (where maximum-power is generated), the two systems are even more similar in fuel-delivery characteristics. The only difference is really at which time during the closed-intake period to squirt fuel at the back of the intake-valve. Therefore, we can conclude that the differences in maximum power output is similar as well. This is supported in real-world cases of minimal differences.

The last scenario is not often used due inefficiencies in controlling the injectors at idle and low-RPM operations (because of minimum injector duty-cycle). High-RPM operation is also compromized because double the fuel has to mix with the same volume of air flowed making atomization difficult. Race cars that employ this configuration have resorted to pre-heating the fuel prior to injection and some even aim the injectors upstream to face the full brunt force of the incoming air for violent turbulence and maximum vaoprization.

These factors (and others) are probably the reason the majority of fuel-injection systems use batch-fired or semi-batch-fired fuel-injection(pairs staggered 360-degrees).