Hybrid EGR

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Emissions is becoming an increasingly dirty word and internal-combustion engines now have the finger pointed squarely at them by law makers.

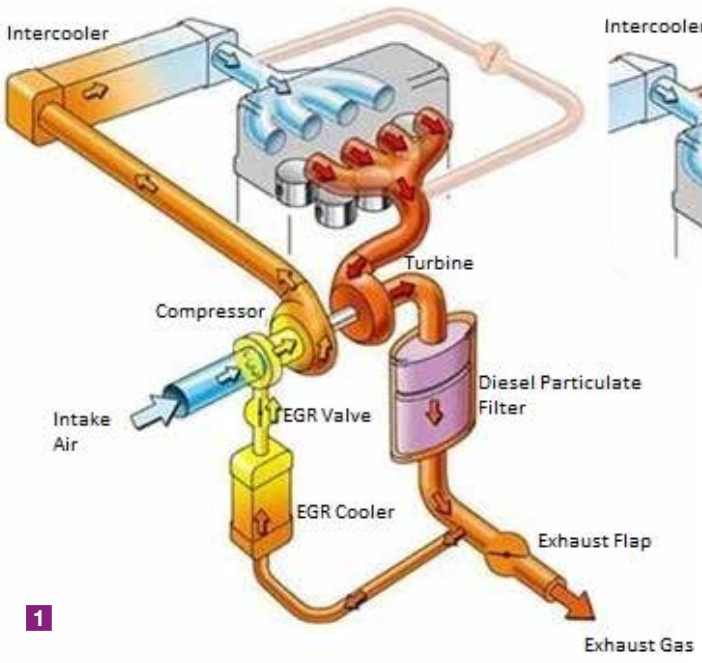
Diesels are near the top of the hit list. Although a modern diesel engine is still relatively simple in design, the emissions management and after-treatment systems bolted onto it can resemble something from the Mars rover.

One such system, perhaps with the worst rap sheet of them all, is exhaust gas recirculation (EGR), or as many forum goers prefer to call it, the 'anti-performance valve'. A valve that has entire online shops dedicated to banishing it from existence with blanking plates and voltage modifiers.

Such banter aside, the once primitive EGR system has gone through changes and now leads the way as one of the cheapest, most effective ways of reducing nitrogen oxide (NOx) emissions.

This is good for anyone with a vested interest in diesel because it is my belief that expensive after-treatment systems will be what ultimately forces the market away from it.

High Pressure EGR System



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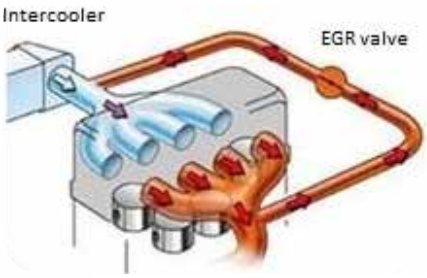
Low Pressure EGR System



The after-treatment list grows by the day, with even the lowest of base models utilising expensive items such as the diesel oxidisation catalyst (DOC), NOx storage catalyst (NSC), diesel particulate filter (DPF) and selective catalytic reduction (SCR, or exhaust fluid injection).

So how is EGR – our soot-depositing, intake-blocking, code-setting enemy – improving to help keep diesel vehicles reasonably priced for consumers?

EGR advancements

The regular EGR system we are all used to is known as high-pressure EGR (HP EGR) or, sometimes, short-route EGR. In this sytem, exhaust gas in the exhaust manifold, before the turbine, is routed into the intake manifold, after the turbo compressor.

Hybrid EGR systems, however, are increasingly becoming the norm. These keep the benefits of high-pressure EGR while adding in a low-pressure EGR (LP EGR) system, sometimes referred to as long-route EGR (pic 1).

Low-pressure EGR takes exhaust gas from further downstream of the turbine, often after a DPF, then routes it into the intake stream, before the turbo compressor.

HP EGR and LP EGR systems each have different pros and cons, so each is operated during different load situations in a Hybrid EGR system. Sometimes both operate at the same time (table 1).

Let's take a closer look at some of these points.

Response time

This is best thought of as 'EGR lag'. HP EGR can have a valve mounted directly on the intake manifold, so exhaust gas reaches the cylinders quickly when it opens. LP EGR requires exhaust gas to travel the entire length of intake plumbing before its result is achieved. This long path does, however, improve equal cylinder distribution in the LP EGR system.

Soot deposits

We are all well aware of the intake-restricting carbon build-up that HP EGR can create. Fitting a quality crankcase-breather-filter assembly (i.e. a catch can) can reduce this and be a great investment.

Because LP EGR can use exhaust gas after the DPF, it is close to being soot-free. However, you may still find minimal soot build-up throughout the piping and intercooler. This gas does need to pass through the turbo compressor, so for safety a filter will often be incorporated in the LP EGR cooler to eliminate any possible soot particles. This is something to consider when purchasing aftermarket coolers.

Turbo compressor efficiency

LP EGR allows all exhaust gas to travel through the turbine, allowing quicker turbo response than a HP EGR system, which bleeds precious exhaust energy before the turbine.

Conversely, in an LP EGR system we now have fresh air and exhaust gas passing through the turbo inlet compressor, meaning a larger turbo is required to handle this larger amount of gas.

This larger amount of gas flow in LP EGR is particularly useful at low speeds, and high and low load points, where traditionally EGR rates are high but overall air flow is low.

The operating point of the variable-nozzle turbo (VNT) can be moved to an area of higher efficiency, increasing fuel economy and decreasing compressor surge while reducing NOx and soot.

At high speeds, and high load points, HP EGR gradually decreases the difference between exhaust and intake pressures, even lower than LP EGR, so HP EGR becomes the better option for the trade-off between fuel economy, NOx and soot.

Throughout the mid-range and steady states, a combination of HP EGR and LP EGR can be used.

Advantages	Disadvantages
High Pressure EGR	
• Fast EGR response time • Turbo compressor efficiency and durability	• Unstable EGR cylinder distribution • Soot deposits through system • Hotter EGR • Reduced turbine-wheel response
Low Pressure EGR	
• Equal EGR cylinder distribution • Clean EGR (after DPF) • Highly cooled EGR • Improved turbine-wheel response	• Slow EGR response time • Turbo compressor efficiency and durability • Increased compressor size

Turbo compressor durability

With the turbo compressor wheel living most of its life well over the 100,000RPM mark, routing exhaust gas through it is a tricky proposition. Particular attention is paid to the EGR cooler in an LP EGR system because any water droplets formed from condensation as the hot exhaust gases pass through the cooler could be disastrous. Often an EGR-cooler bypass valve will be utilised to prevent hot exhaust gas passing through a dead-cold cooler as the vehicle warms up. This EGR-cooler bypass is often even activated in standard HP EGR systems to facilitate engine and catalyst warm-up, and also when performing a DPF regeneration.

Exhaust gas can also accelerate corrosion on the compressor wheel, so a special turbo designed to resist this must be used.

Both LP and HP EGR systems require forms of throttling air to create pressure differential for the exhaust gas to find its way back into the intake stream:

- **Variable-nozzle turbo** – The variable nozzles of the turbo are a key aspect in manipulating exhaust back-pressure throughout the load range. It is able to create higher exhaust-manifold pressure than intake pressure, allowing exhaust gas to flow into the intake manifold (pic 2).
- **Intake-air throttle valve** – When load situations mean it is not reasonable to use just the VNT to create high exhaust pressure, this valve reduces the intake-manifold opening, reducing intake-manifold pressure and allowing exhaust gas to flow into the intake manifold. A secondary function of this valve is its closing on engine shutdown for smoothness and to prevent an emergency diesel runaway situation.
- **Exhaust-air throttle valve** – Usually located downstream of the DPF, this is the preferred method to create exhaust backpressure in a LP EGR system and drive exhaust gas into the intake piping.

Great effort is used to get exhaust gas back into the intake, so as ‘EGR performance’, ‘EGR flow’ and ‘NOx level exceeded’ codes become more and more common it is important to consider the whole system and how it works in unity rather than focusing on the actual EGR valve itself.

The ECM is often watching mass air flow (MAF) and manifold absolute pressure (MAP) sensor readings to set these fault codes, particularly in systems that do not utilise a position sensor on the EGR valve. Obtaining the correct manufacturer code-setting parameters can be the key to faster diagnosis.

TaT’s ‘Good scan/scope data’ section, accessed from the TaT website’s homepage, is a great resource when diagnosing EGR-flow problems. I’ll often jot out a table of RPM, MAF and EGR command so I can compare my problem vehicle with known good readings. This gives great direction for possible EGR-system blockages, so you can recommend physically pulling apart the system to the customer with confidence.

Be forewarned, though. With this method you must ensure all other parameters are equal when making your table.

As I hope I’ve demonstrated, modern EGR command is a complex dance between engine temperature, load, HP EGR and LP EGR systems, so you want to ensure you are comparing apples with apples.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