3.8.3 CATALYTIC PURIFICATION CONVERTERS

A catalytic converter comprises:

- the catalytic converter itself;
- auxiliary devices which should be added to a conventional engine to ensure proper operation of the process (e.g. electronic fuel injection for three-way converters, or injection of additional air for one way catalysis).

We distinguish now two techniques:

- simple oxidation catalysis (one way catalysis) that can act on CO and HC;
- multi-functional catalysis, more commonly known as three-way, that allows to act on CO, HC and NOx by simultaneous chemical reactions of oxidation and reduction (Figures 3.8.5 and 3.8.6).

The catalytic converter, of size similar to that of a conventional exhaust line, is placed on the pipe near the engine in order to process hot exhaust gases.

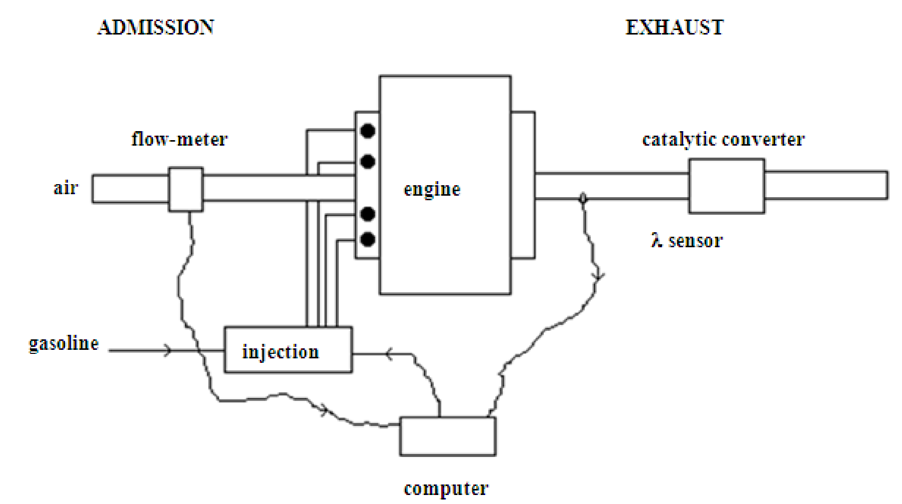

Figure 3.8.5: Three-way catalytic conversion

It contains a catalyst which is in the form of a deposit of precious metals (1 to 3 g per converter) on a porous monolithic ceramic honeycomb, to develop a large surface area.

Catalytic converters are a very effective technique of remediation: over 90% of conversion in new condition when the engine and catalyst are warm.

The one-way catalysts require oxygen in the exhaust gases, which can be achieved by an air pump fitted to the vehicle. However, this technique does not require sophisticated carburetion or injection device. Being without action on the nitrogen oxides, the oxidation catalyst must be coupled to a device for reducing such pollution. This is achieved by recycling a fraction of exhaust gases to the admission.

With three-way catalyst converters, a perfectly balanced and uniform air fuel mixture must be ensured, which can now be performed by controlled electronic fuel injection. In fact, for achieving simultaneous removal of the three pollutants, the composition of exhaust gases should remain within a very narrow range.

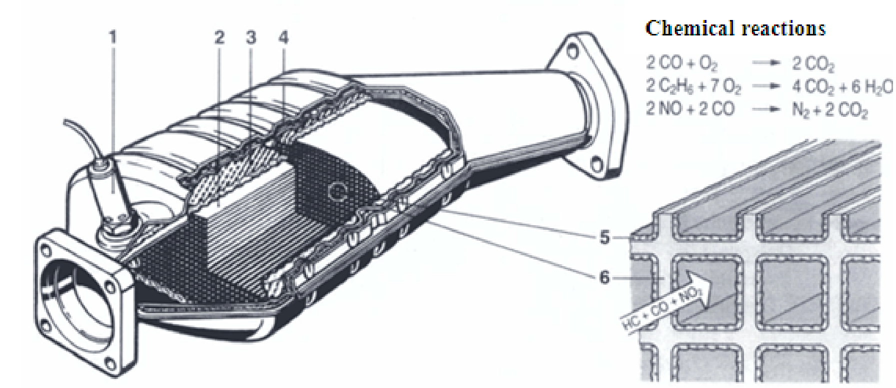

Figure 3.8.6: Three-way catalytic converter, Extrait de Cahiers Techniques Bosch

Figure 3.8.6 shows the cutaway of a catalytic converter, with the oxygen sensor (1), the ceramic monolith (2), a flexible metallic grid (3), a jacketed heat insulation (4), a platinium coating (5), and a ceramic or metal support (6).

This is only possible by controlling fuel injection by a sensor (the said Lambda sensor by reference to air ratio) that continuously doses the oxygen content of exhaust gases.

This sensor consists of a body in solid electrolytic ZrO_2 material (porous ceramic, allowing diffusion of oxygen). As shown in Figure 3.8.8, the 2-point lambda sensor has a very steep voltage characteristic, to detect the value 1 of the air factor λ.

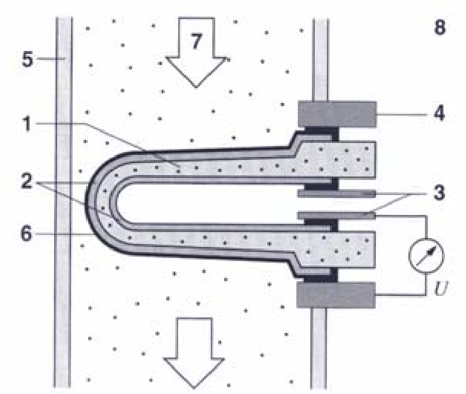

Figure 3.8.7: Lambda sensor in exhaust line, Extract from Cahiers Techniques Bosch

Figure 3.8.7 shows the configuration of tube-type lambda oxygen sensor in the exhaust pipe, with the special ceramic (1), the electrodes (2), the contact (3), the exhaust pipe (5), the porous protective layer ceramic (6), the exhaust gases (7) and air (8).

Several types of sensors are available: two-point sensors, possibly heated to better control their operating temperature and better reduce emissions, planar sensors, obtained by screen printing, which, using a special processing circuit, deliver a continuous measure of the air factor between 0.7 and 4, which allows for even finer control.

The effectiveness of catalysis is highlighted by the curves of Figure 3.8.9, which show, according to the air factor, the reductions in emissions of the various pollutants: it shows that if we want both to reduce NOx emissions and HC and CO emissions, it is imperative that the value of λ stays within a very narrow band (between 0.99 and 1 for a conversion of 90% of pollutants).

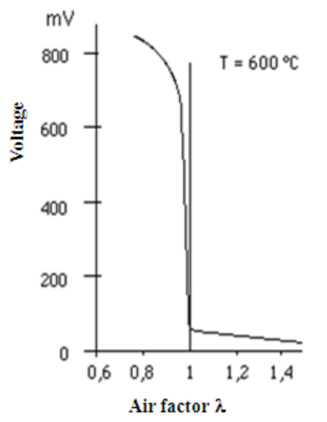

Figure 3.8.8: Lambda sensor characteristic curve

This means a slight loss of engine efficiency relative to the optimum (obtained, as we have seen, for λ ≈ 1.2).

This comes from the fact that we are pursuing two seemingly contradictory goals: on the one hand to reduce nitrogen oxides, which imposes work in the absence of oxygen, and also to further oxidize CO_2 and H_2O as well as the unburned hydrocarbons and carbon monoxide, which requires oxygen.

With the catalysts, it is possible to combine these different operations, but with the imperative of fully controlling the oxygen dosage, which can be done thanks to the Lambda sensor because of its very steep voltage characteristic for λ = 1.

If the value of λ falls below 0.99 or exceeds 1, the efficiency of catalytic converters falls rapidly: 65% for λ = 0.98 or 1.01, 40% for λ = 0.97 or 1.02.

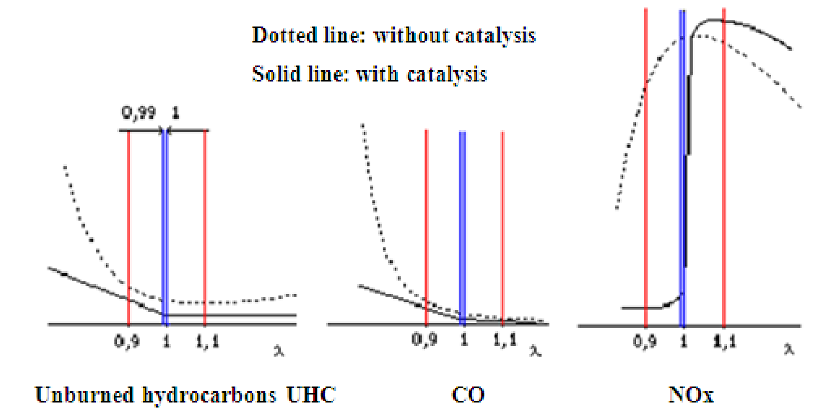

Figure 3.8.9: Catalytic conversion effectiveness

It is for this reason that the use of a "three ways" catalytic converter can only be justified with a very precise control of fuel and combustion, that is to say with injection and electronic ignition control devices of the type we presented above.

Lambda control completes the control by ignition mapping, associating it with a closed loop on the oxygen content of exhaust gases. It is thus possible to further refine the settings for the engine by maintaining λ in the desired [0.99 - 1] band. However, the Lambda sensor gives a reliable signal only above a temperature of about 350 °C. At startup, therefore, the lambda control is inoperative and the controller must operate in open loop.