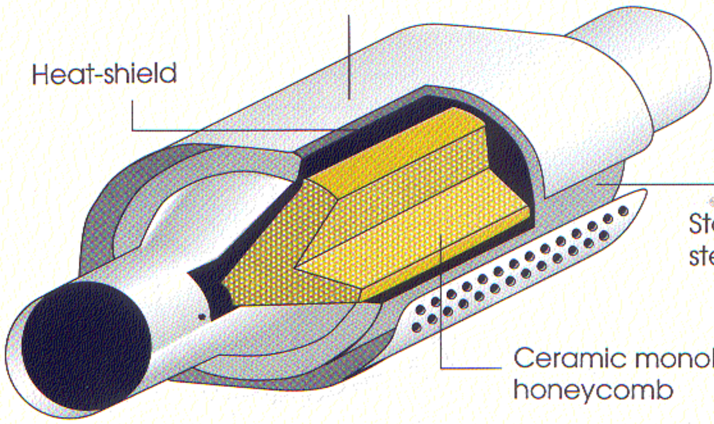
What the catalytic converter is made of

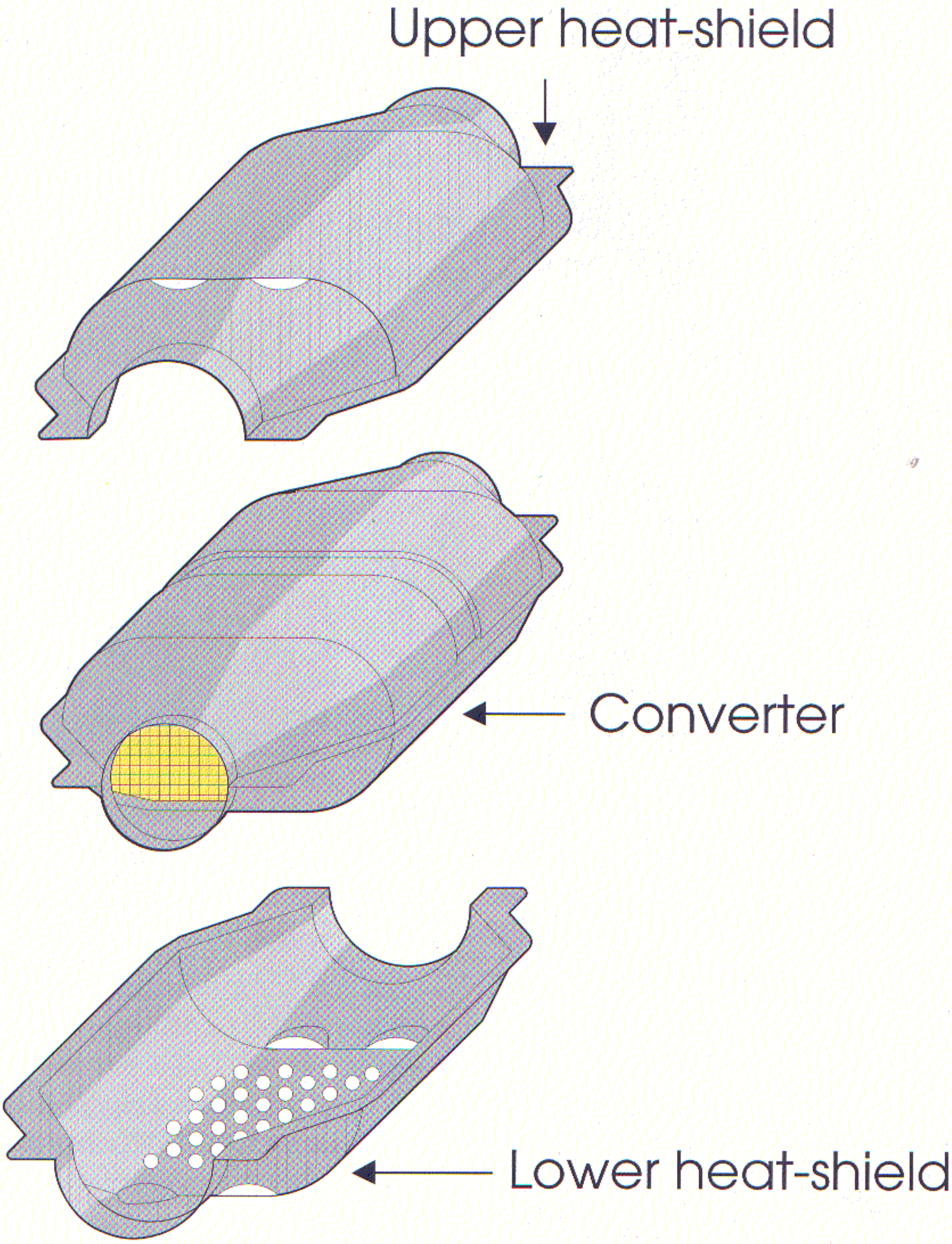
The catalytic converter is built to diminish the polluting elements in the exhaust fumes of a vehicle by catalysis. It is a device installed in the exhaust tube near the engine where the gases are still at high temperatures. This heat energy passes to the catalytic converter and increases its own temperature. This is necessary for the converter to have optimum output, reached between 400-700 degrees centigrade.



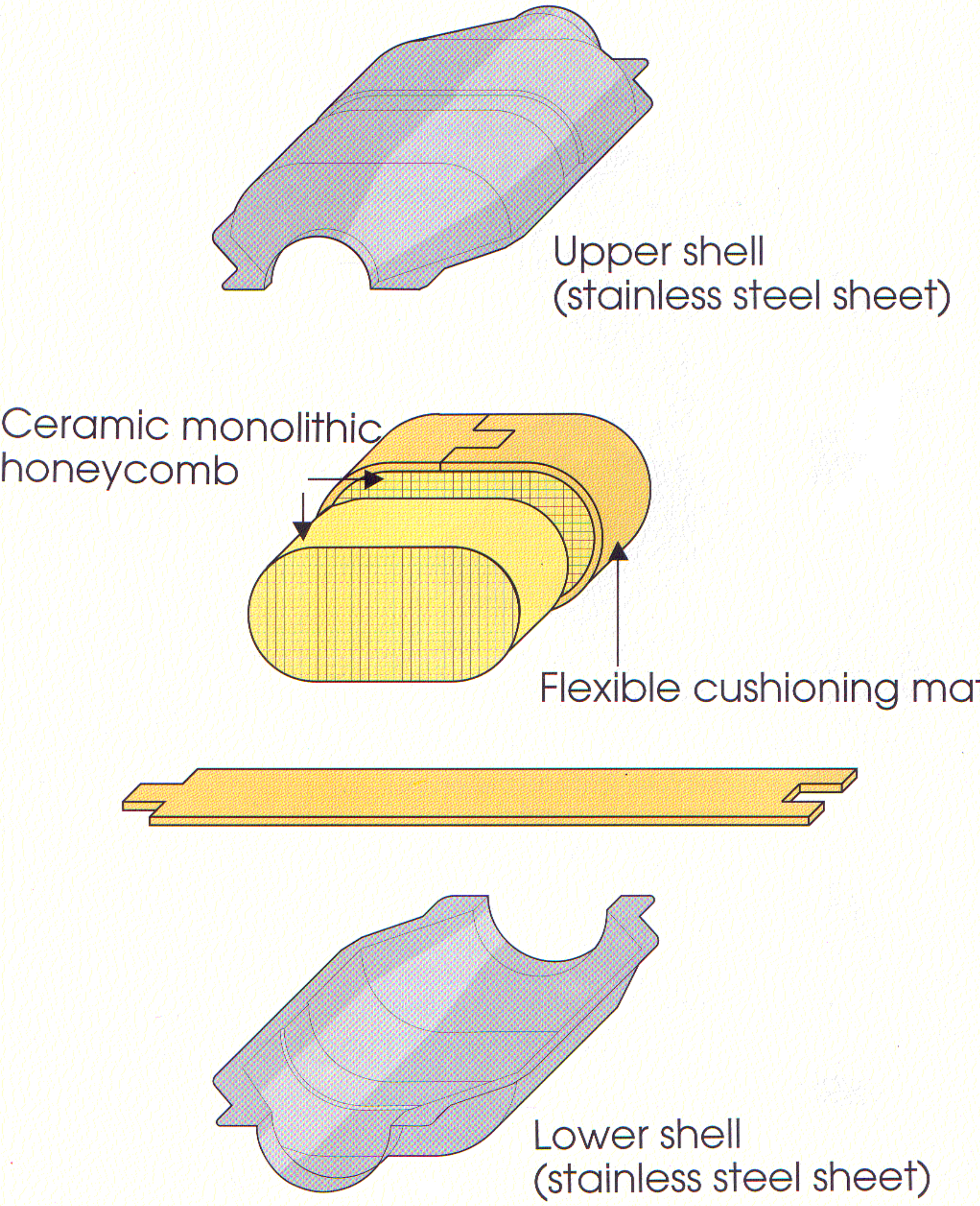
On the outside, the catalytic converter is a stainless steel recipient frequently covered with a metallic anti-thermal shield, also stainless, that protects the lower parts of the vehicle from the high temperatures reached.

Inside, there is a ceramic support or monolith of oval or cylindrical shape with a structure made up of multiple cells in a panel with a density of approximately 450 cells per square inch (70 per square centimetre). Its surface is coated with a resin that contains Noble metals like Platinum (Pt) and Palladium (Pd) that allow oxidation and Rhodium (Rh) that is used in reduction. These precious metals behave as active catalytic converters, that is, they initiate and accelerate the chemical reactions between other substances with which they come into contact, without participating in these reactions. The contaminating exhaust fumes generated by the engine are partially transformed into innocuous elements once they come into contact with the active surface of the catalytic converter.

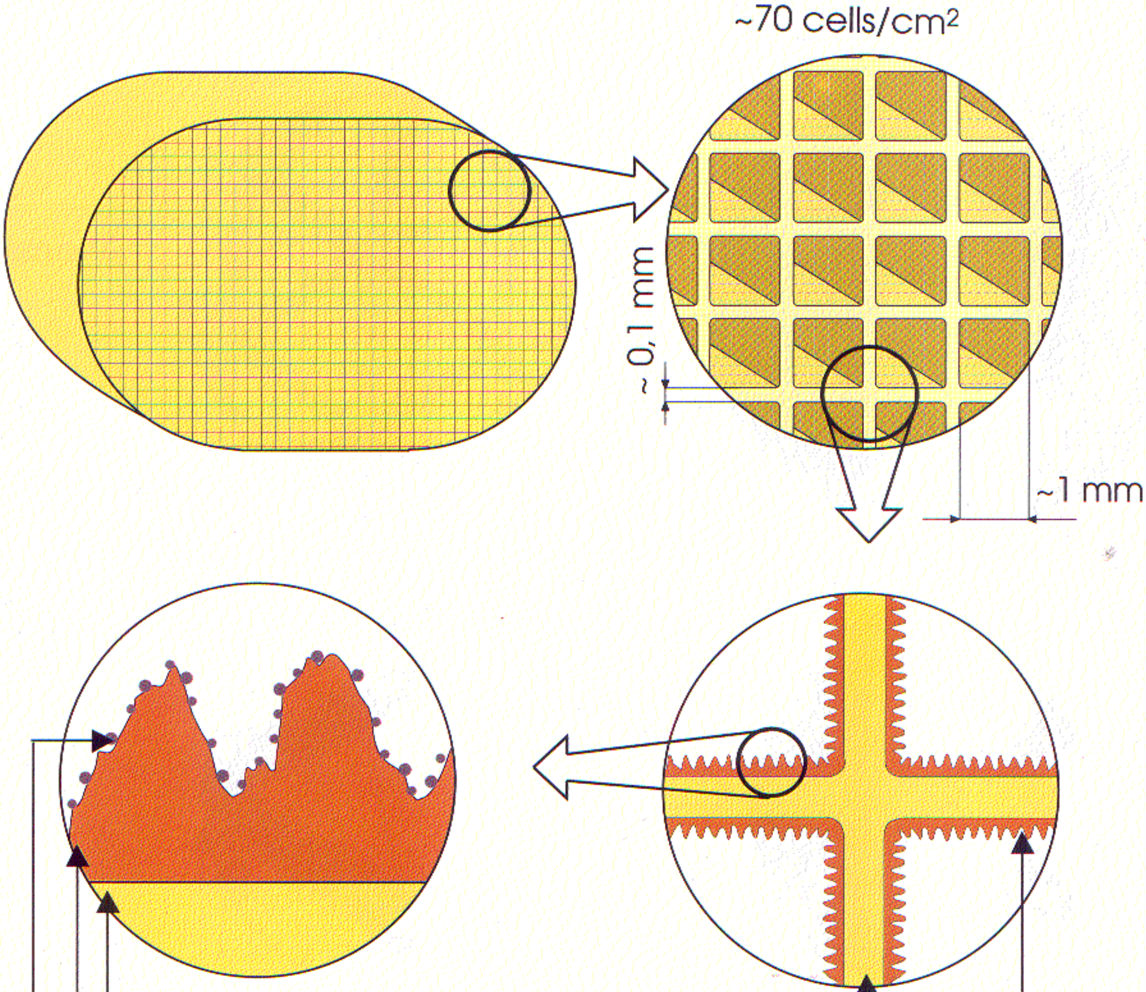
Catalytic converter and optional components



Main components of the converter



Details of the ceramic type catalytic converter



Refractive ceramic support made of aluminium and magnesium silicates

Rough layer of aluminium oxide (corundum) to increase the surface area exposed to the gases

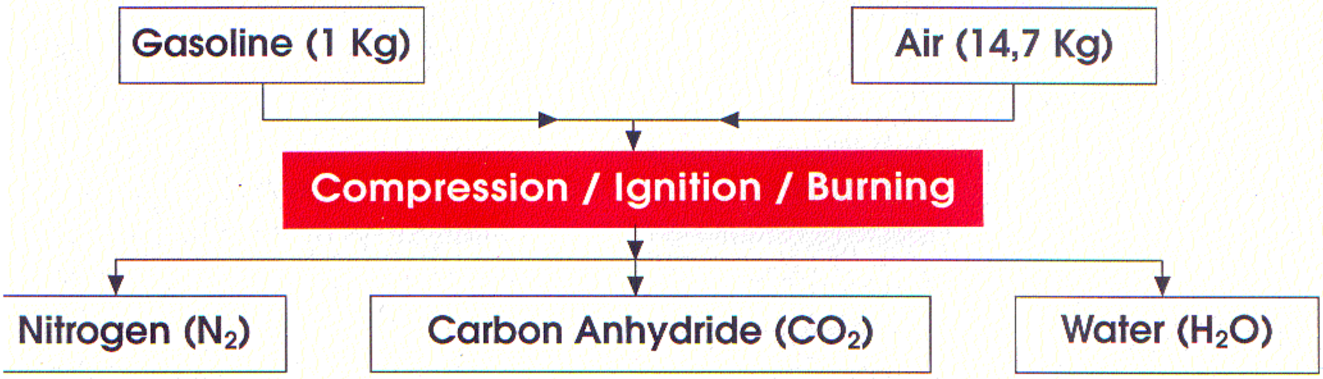
Active metals (Platinum, Rhodium, Palladium)

Useful area for the passage of gases 70% of the total
Softening temperature ~ 1000°C

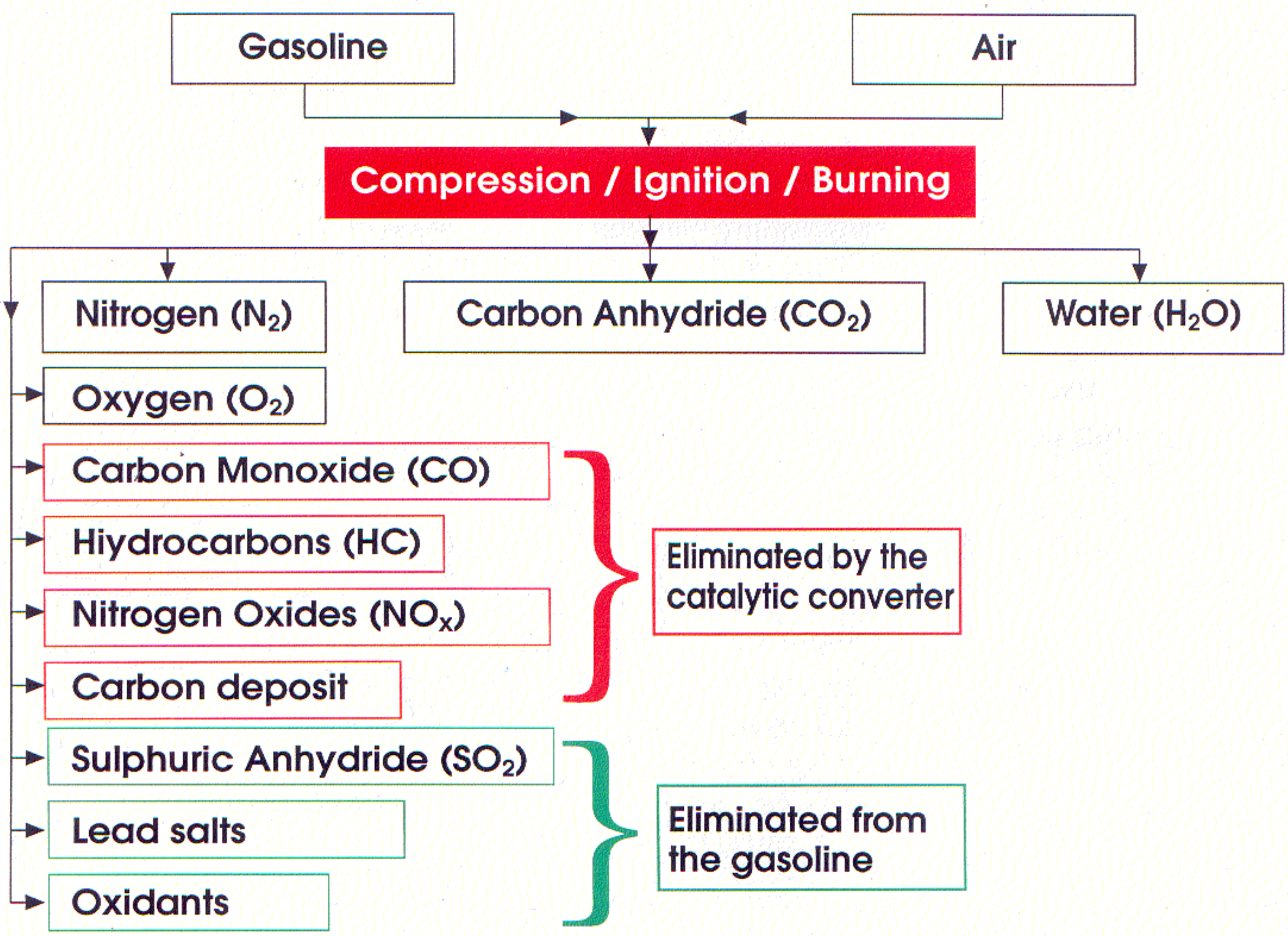
Combustion in explosion engines

uel = Gasolinemede of Hydrocarbons (HC)
omburent = Oxygen (O_2)
xygen comes from atmospheric air (with a volume of 21% O_2 and 79% N_2)

* Ideal combustion with stoichiometric mix



* Actual combustion



Types of gases produced in combustion and their consequences

The gases emitted by an internal gasoline combustion engine are mainly of two types: inoffensive and contaminants.

The first are Nitrogen, Oxygen, Carbon Dioxide, water vapour and Hydrogen. The second (contaminants) are mostly Carbon Monoxide, Hydrocarbons, Nitrogen Oxides and Lead.

Inoffensive

Nitrogen is an inert gas present in a concentration of 79% of the air we breath. Although it is an inert gas at room temperature, Nitrogen oxidises to from small quantities of Nitrogen Oxides, due to the high temperatures in the engine.

Oxygen is one of the indispensable elements for all combustion and makes up 21% of our air. If the mixture is either too high or too low in oxygen than not all of the hydrocarbon bonds will be oxidised and
it will emitted with the rest of the exhaust fumes.

Water vapour is produced as a result of the combustion by the oxidation of Hydrogen and is released with the exhaust fumes.

Carbon dioxide produced by the complete combustion of carbon is not toxic for human beings and is a source of energy for green plants thanks to photosynthesis. It is a logical product of combustion, or to put it another way, combustion improves as its concentration increases. Nonetheless, a huge increase in the concentration of carbon dioxide in the atmosphere can produce large climatic changes (the so called green house effect).

Contaminants

Carbon monoxide, in high concentrations and after long periods of exposure, can produce an irreversible transformation of Haemoglobin, the molecule used to transport oxygen from the lungs to the cells of the organism, into Carboxy-haemoglobin which cannot transport oxygen. A CO concentration of more than 0,3% volume can be deadly.

The lack of oxygen does not allow for complete combustion and carbon monoxide is formed instead of carbon dioxide. In a vehicle, the appearance of greater concentrations of CO in the exhaust indicate that the initial mixture is rich in or has a lack of oxygen.

Hydrocarbons have different toxic effects, depending on their molecular structure. Benzol, for example, is poison all by itself. Exposure to this gas causes irritation of the skin, eyes and respiratory pathways,. If in high concentrations it will provoke depression, dizziness, headaches and nausea. Benzol is one of the multiple causes of cancer. Its presence is due to the incombustible components of the mixture or to the intermediate reactions of combustion which are also, in turn, responsible for the production of Aldehydes and Phenols.

The simultaneous presence of Hydrocarbons, Nitrous oxides, ultraviolet rays and atmospheric stratification produces photochemical smog which has serious consequences on the health of living beings.

Nitrogen Oxides do not only irritate the mucous layer, but, in combination with Hydrocarbons in smog and air humidity, produce Nitrous Acids. These later fall to the earth in the form of acid rain and contaminate extensive areas, sometimes situated hundreds of kilometres away from the source of contamination.

Lead is the most dangerous metal in the combustion additives. If inhaled it can provoke the formation of coagulates or thromboses in the blood which have serious pathological consequences. It is present in gasoline in the form of Tetra-ethyl lead and is used to increase the level of octane and also, in older engines, as a lubricant of valve seats. In unleaded gas this metal has been substituted by other less contaminating components that also provide a high octane index.

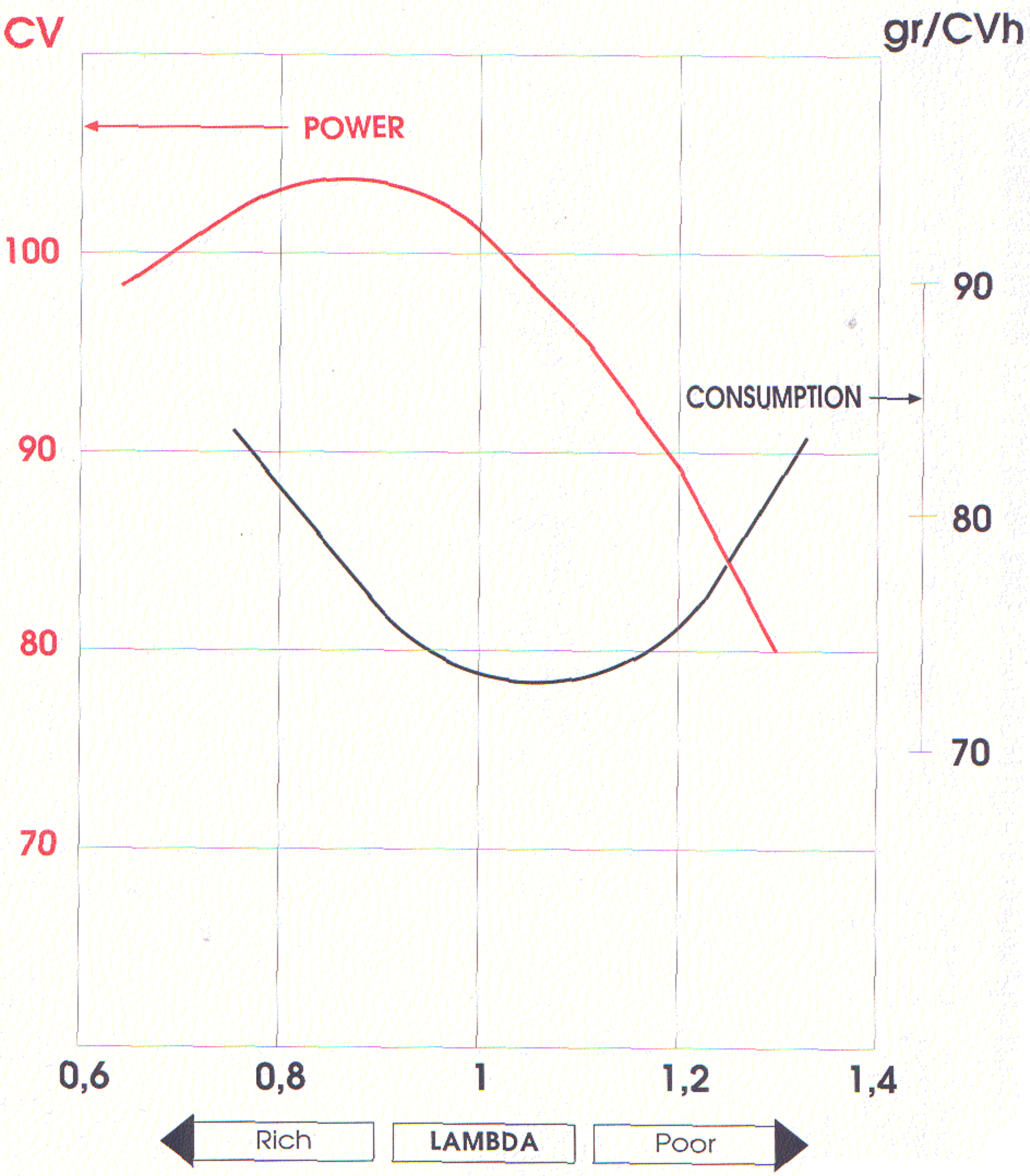
Lambda coefficient and mixture characteristics

$$\lambda = \frac{\text{Real weight to air consumed per Kg of gasolina}}{\text{Theoretical weight of air that should be consumed per Kg of gasoline}} = \frac{X}{14{,}7}$$

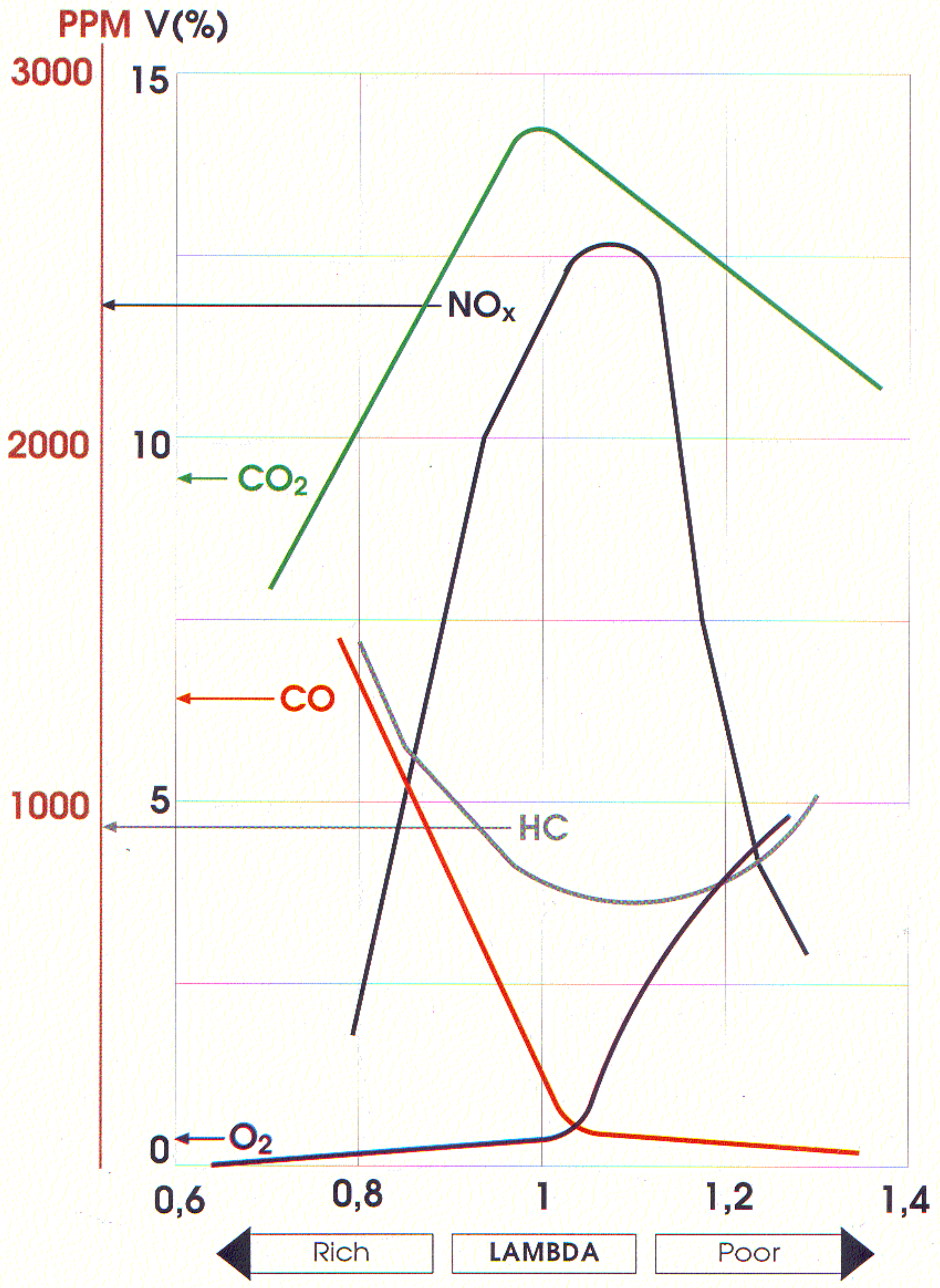
Cases according to actual mixture (x)			
X	Air	Mixture	λ
< 14,7	Defect	Rich	< 1
= 14,7	Equilibrium	Stoichiometric	= 1
> 14,7	Excess	Poor	> 1

Mixture	%	Consequences
Rich	< 0,75	The engine is flooded and the mixture does not light so the engine stops working
	0,75 ÷ 0,85	Mixture too rich for instantaneous use, provide power increase
	0,85 ÷ 0,95	Maximum power at continuous rate (slope, passing, etc.)
Normal	0,95 ÷ 1,05	Normal driving (Cruise rate)
Poor	1,05 ÷ 1,15	Minimum consumption with slight loss of power
	1,15 ÷ 1,30	Considerable loss of power with an increase in consumption but lower output
	> 1,30	The engine does not work, the flame is not being propagated

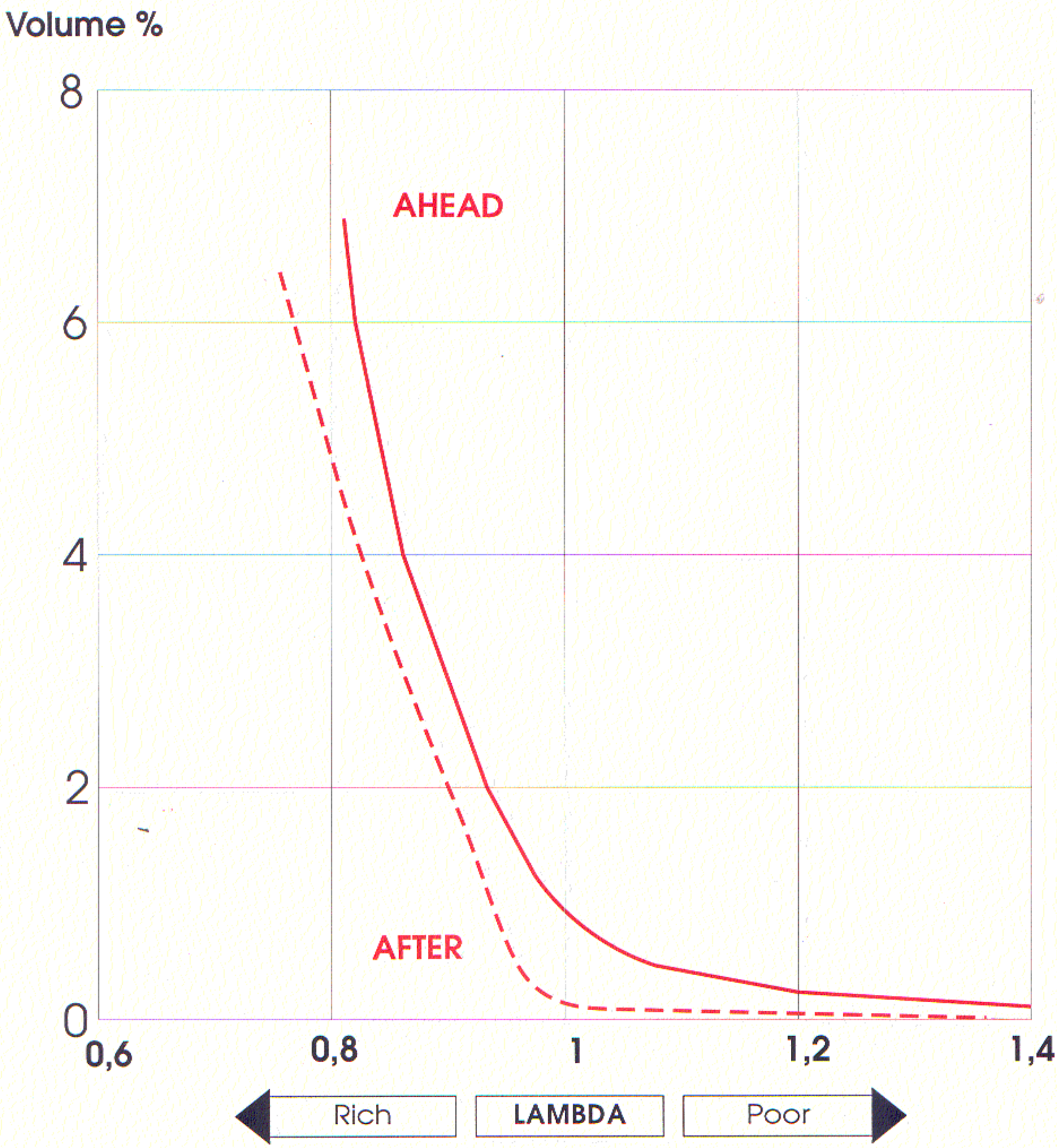
Power and fuel consumption according to Lambda variation for a general gasoline engin



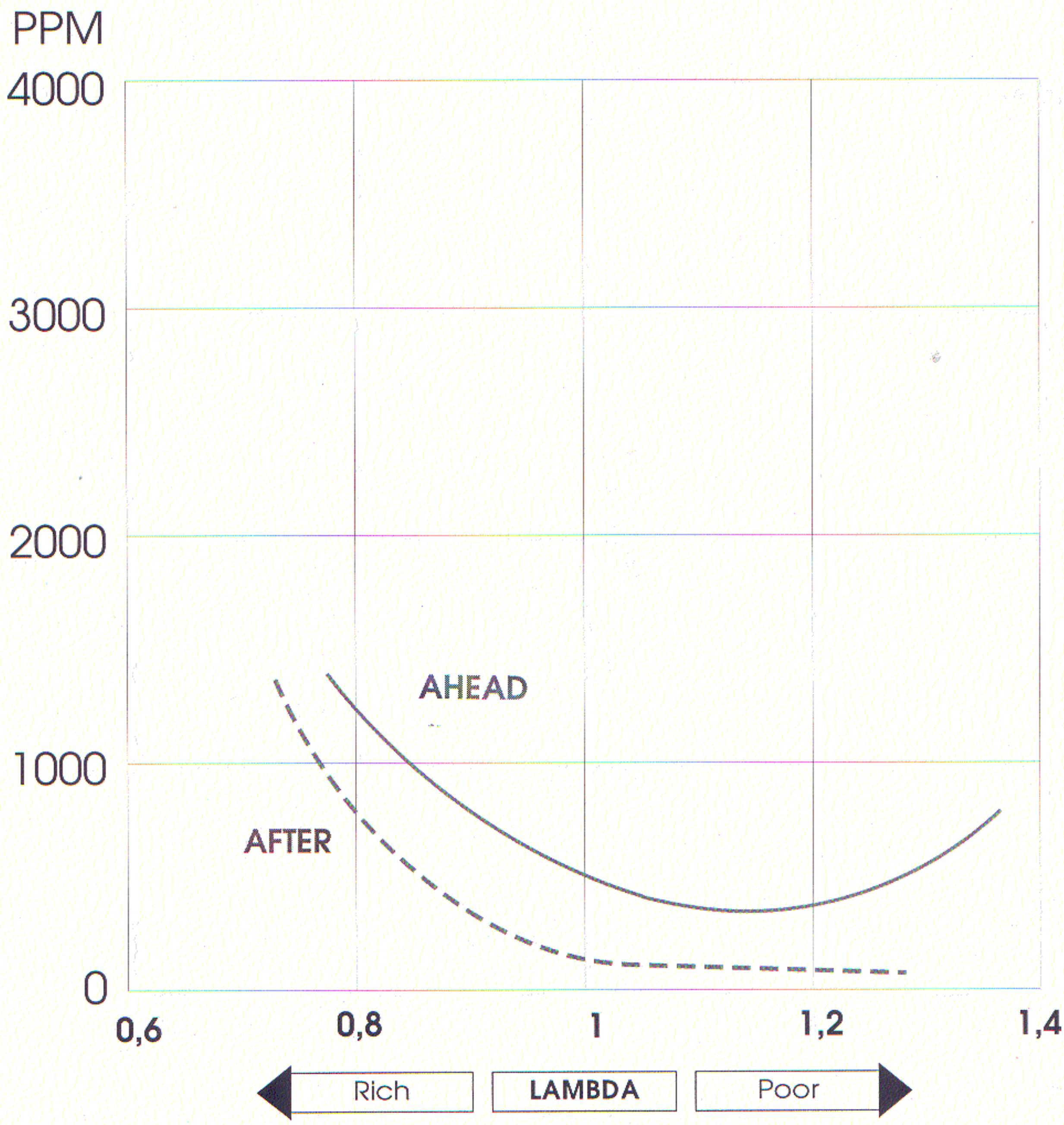
Exhaust gases according to Lambda variation for a general gasoline engine, ahead of the catalytic coverter



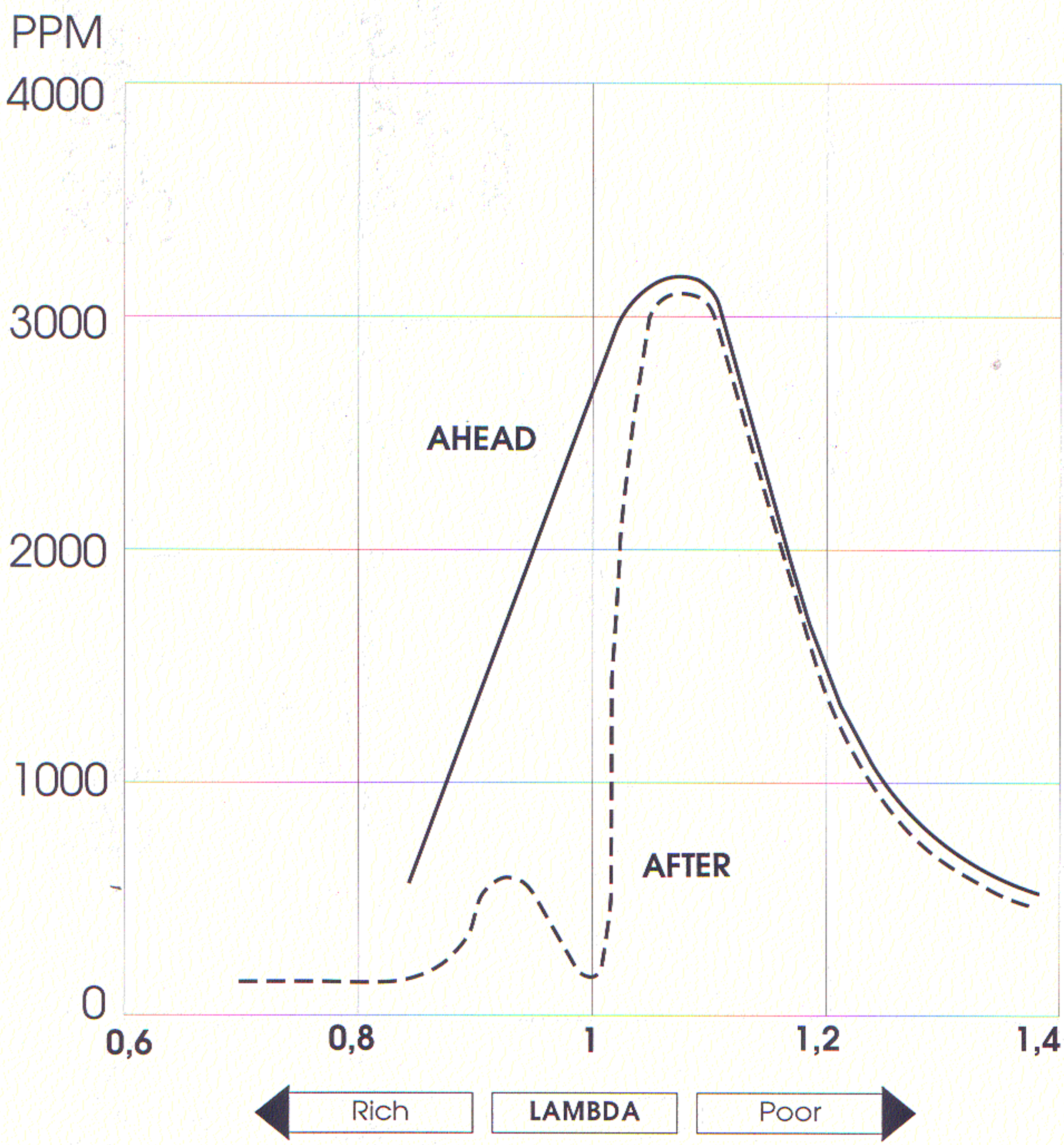
CO emissions
(gasoline partially burned)
ahead and after the catalytic coverter



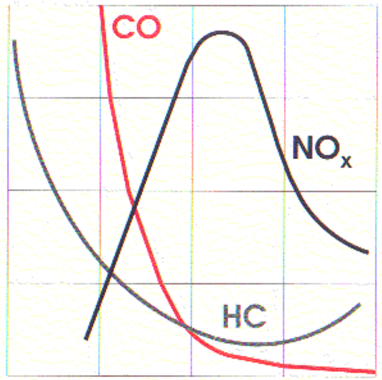
HC emissions (gasoline unburned) ahead and after the catalytic coverter

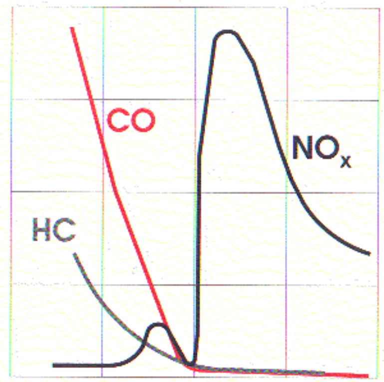


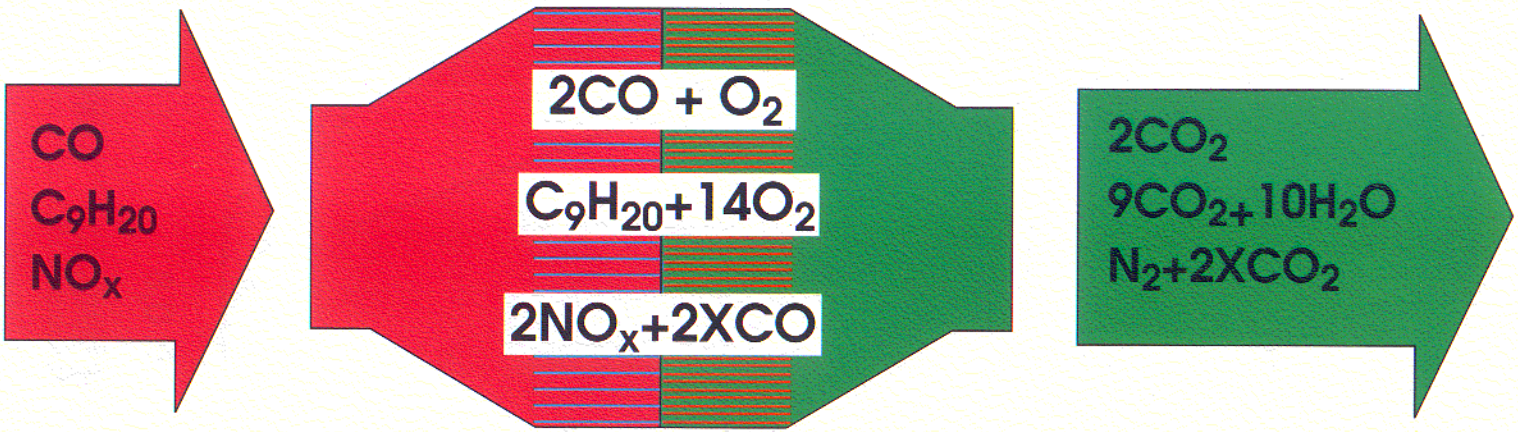
NOx emissions (Nitrogen Oxide) ahead and after the catalytic coverter



Chemical process inside a catalytic converter







PROCESS	INLET	COMBINATION	RESULT
Oxidation	CO	O_2	CO_2
Oxidation	Gasoline	O_2	CO_2 + Water
Reduction	NO_x	CO	CO_2 + Nitrogen