



SWANSEA METROPOLITAN UNIVERSITY

PRIFYSGOL FETROPOLITAN ABERTAWE

Advanced Engine Technology

Lecture 7: Emissions Control

- General System Layout
 - Mounting for vibration
 - Materials
- What are emissions?
- Exhaust Noise
 - Resonant Chamber Silencers
 - Reactive Interference Silencers
 - Absorptive Silencers
- Emissions
 - Catalytic Converter
 - EGR system
 - Secondary Air System

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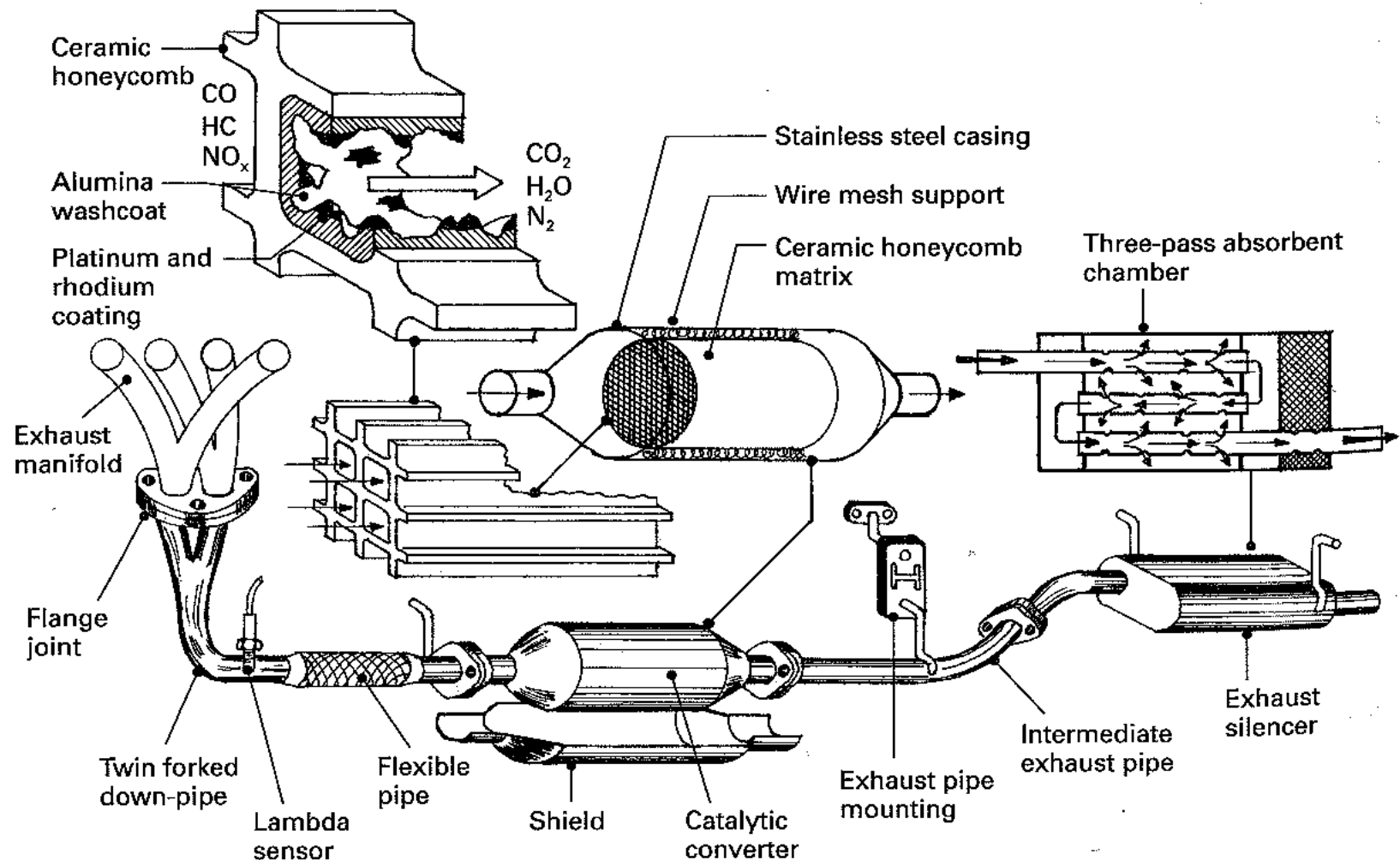
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Exhaust System Layout

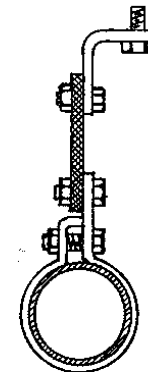
- Manifold design covered last week (overview)
- The rest of the system
 - Downpipe
 - Lambda sensor
 - Catalytic converter
 - Mountings
 - Intermediate pipes
 - Silencer
 - Tailpipe

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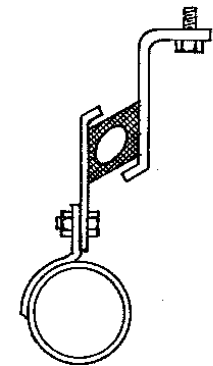
Exhaust System Layout



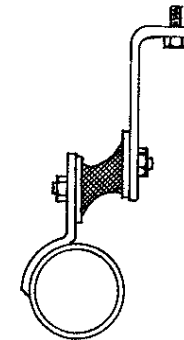
- Exhaust system can be treated as a beam hanging from the manifold and tail pipe mounts
- Engines are sources of vibration!
- This can make the exhaust vibrate
- Exhaust is flexibly mounted
 - To prevent movement between engine and body from straining exhaust joints
 - To isolate vehicle body from exhaust vibration



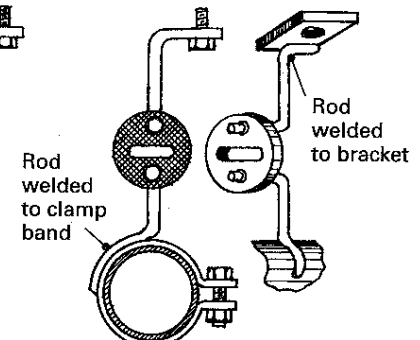
a) Rubberised fabric strap mount



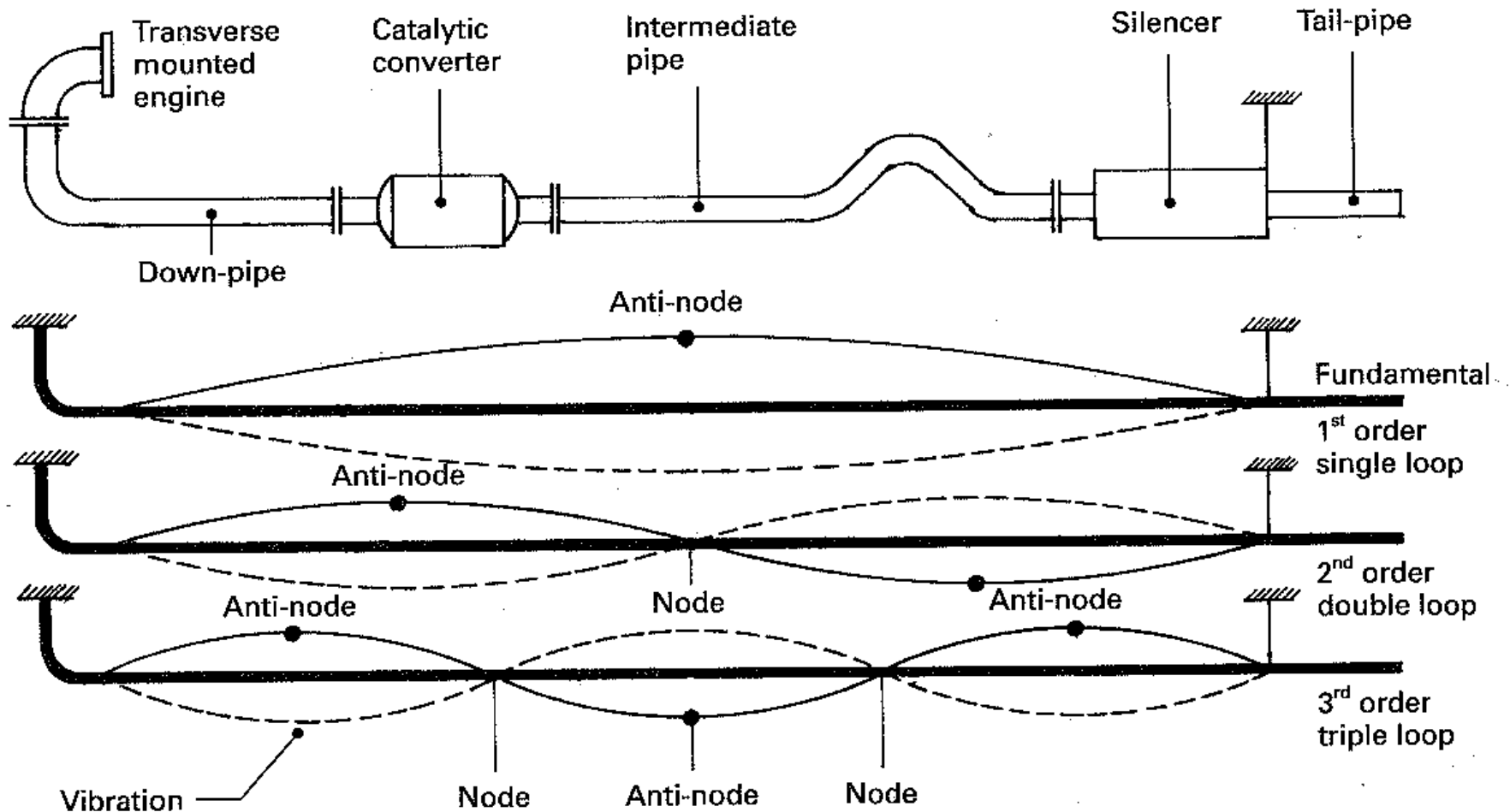
b) Bonded rubber hollow block mount



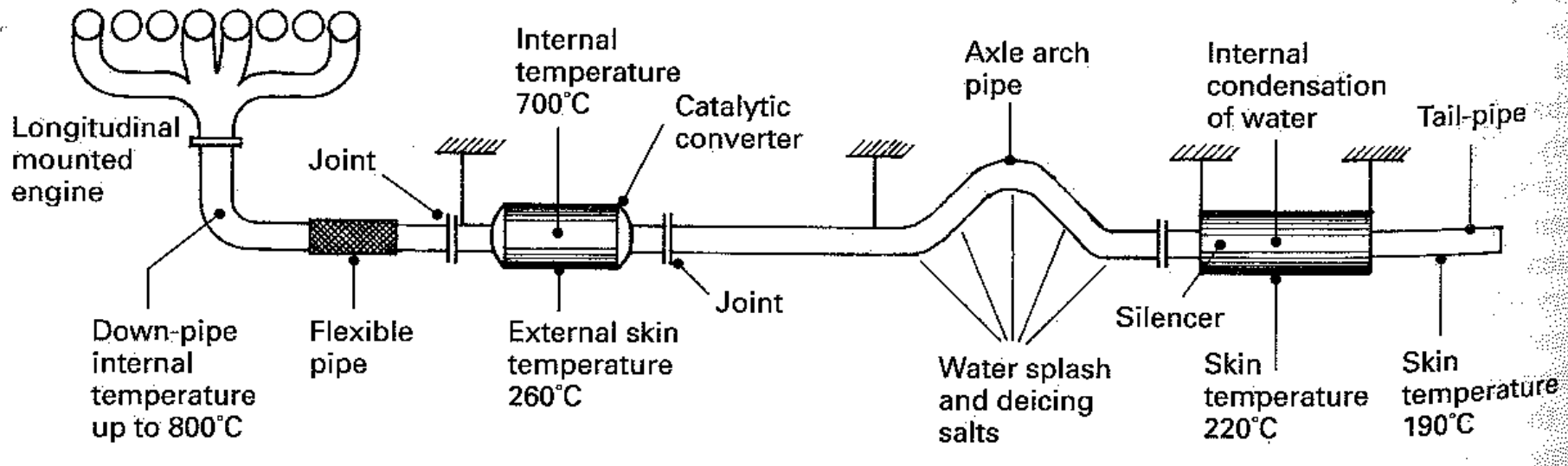
c) Bonded rubber cylindrical block mount



d) Slotted rubber disc mount



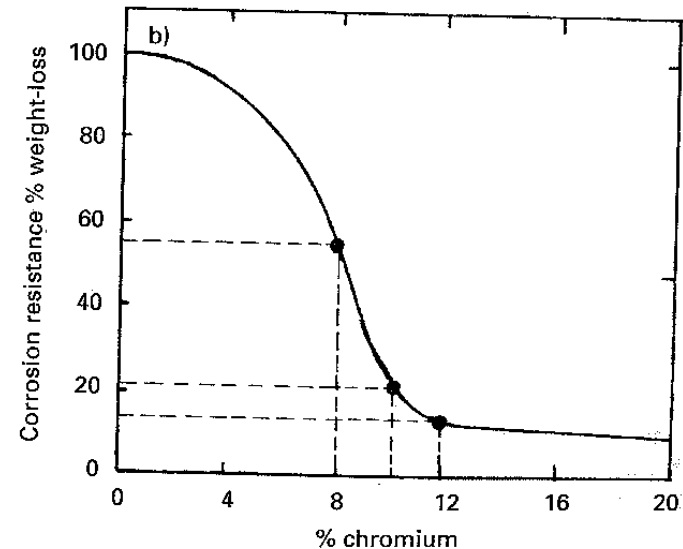
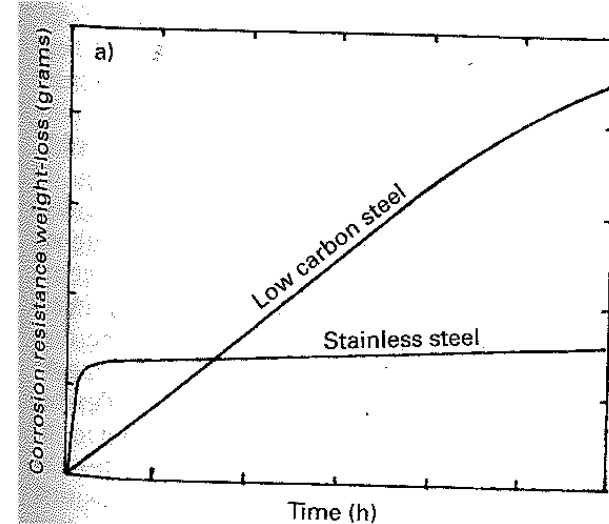
- The exhaust system is a harsh environment!
- This makes it susceptible to corrosion and fatigue



- Hot metal subject to continual quenching and reheating in wet weather
- Thermal shock
- Corrosion from acidic condensation – dew-point of exhaust gas is 95°C and so tail pipe is more likely to corrode as it is cooler
- Vibration (fatigue)



- 2 main materials
 - Aluminised mild steel
 - 0.2mm coating of aluminium oxide in mild steel
 - Doubles service life – withstands oxidation at up to 900°C for long periods
 - Stainless steel
 - Much longer service life
 - Particular grades of stainless designed for exhausts – high formability, good weldability



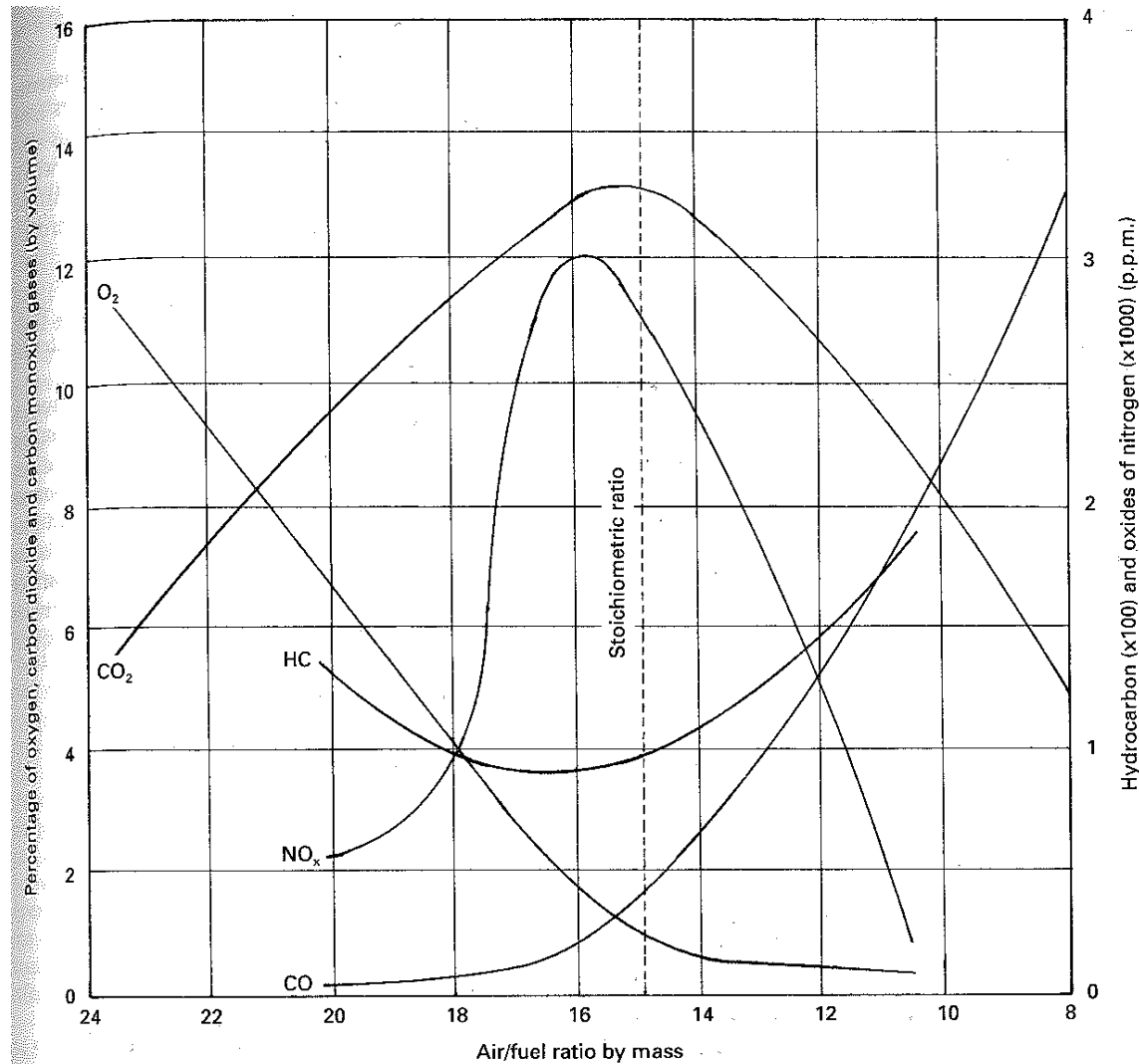
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What are emissions?

- Exhaust Gas emissions
 - CO₂ Carbon Dioxide
 - Product of combustion where carbon in fuel is completely burnt
 - Not poisonous, but contributes to global warming
 - CO Carbon Monoxide
 - Incomplete combustion
 - Rich/poorly atomised mixtures
 - Poisonous
 - Hydrocarbon (HC)
 - Incomplete combustion
 - Eye/throat irritant, can be carcinogenic
 - Oxides of nitrogen (NO_x)
 - Formed at high temperatures
 - Can be poisonous

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What are emissions?



- Exhaust Gas emissions
 - Particulates
 - Soot particles from diesel combustion
 - Hydrocarbons absorbed into soot
 - Can damage lungs
- Noise emissions
 - Pressure wave vibrations due to sudden and periodic release of gas energy via ports
 - Primary Noise is that caused directly by the release of gas
 - Fundamentally related to engine speed
 - Secondary noise is caused by flow of gas through exhaust system – crackles, rasps, harmonics etc

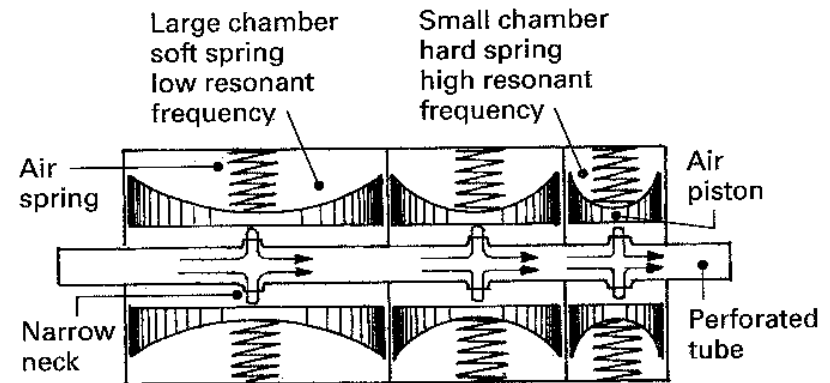
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- Three approaches to suppression
 - Resonant chamber damping
 - Reactive interference damping
 - Absorption material damping
- Real silencers use a combination of these methods
- Minimal engine power loss to achieve required sound reduction
 - maximum 4% of engine power

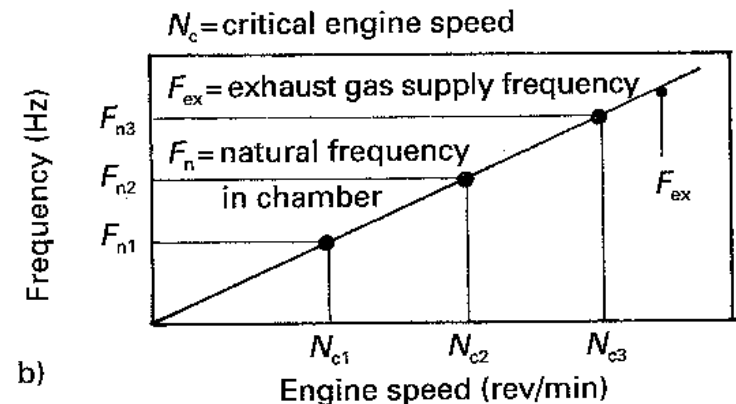
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Resonant Chamber

- Chambers have different volumes – linked to central pipe via perforations
- Therefore the gas within them will resonate at different engine speeds in response to the pulsating gas flow through the central pipe
- Large chambers resonate at low rpm's
- Analogy of a piston and spring



a) Helmholtz multi-resonant chamber principle

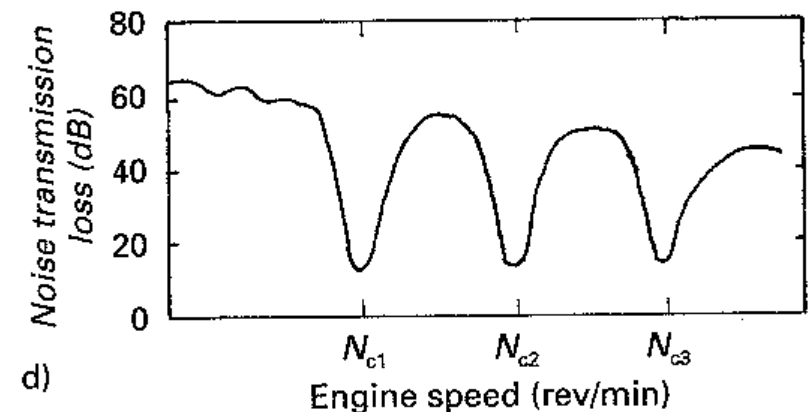
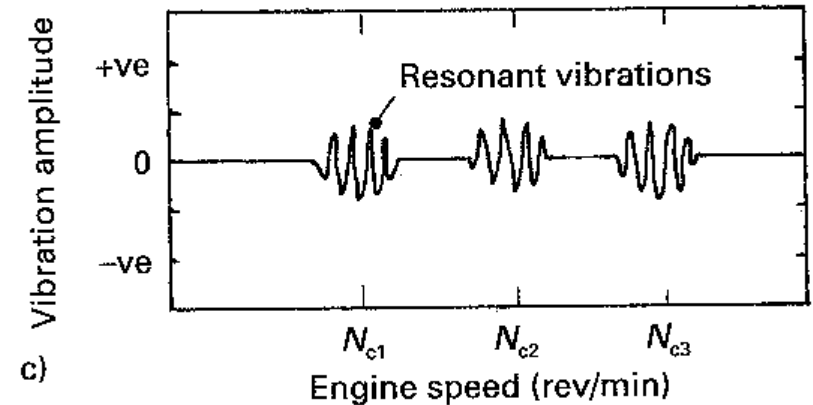


b)

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Resonant Chamber

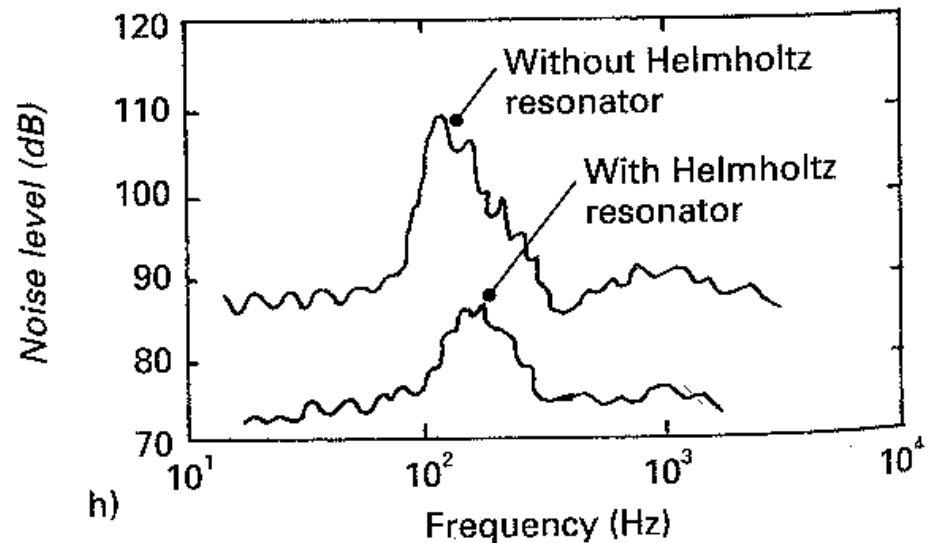
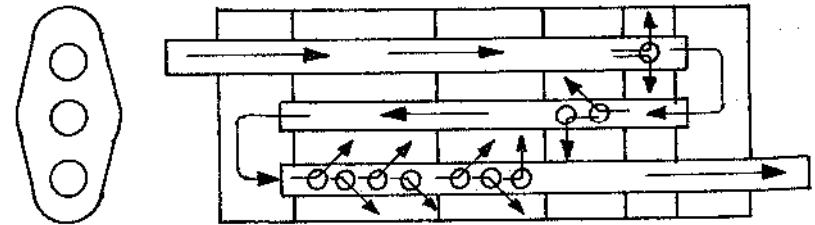
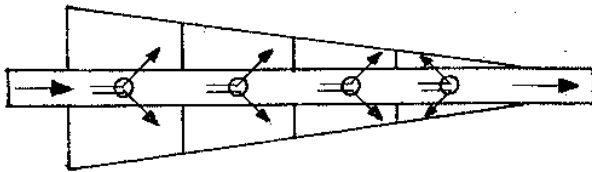
- Thus if resonant frequency of chamber coincides with exhaust gas frequency, vibrations of gas within chamber become large
- Absorbs large amounts of noise energy
- Can be tuned to eliminate particular frequencies – low “booms” are hard to eliminate by other means



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Resonant Chamber

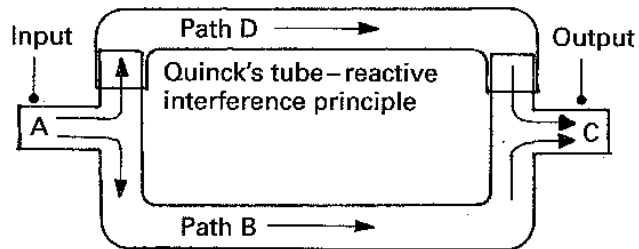
- High frequency chambers are small
- Conical designs
- Overlap of suppression bands
- Multiple-pass designs
- Low back pressure (and hence power loss)



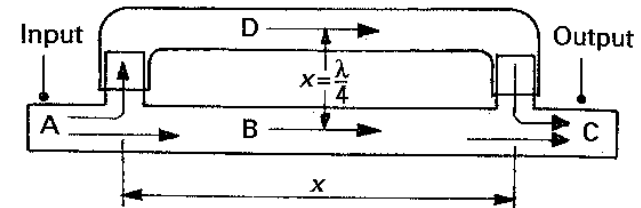
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Reactive Interference

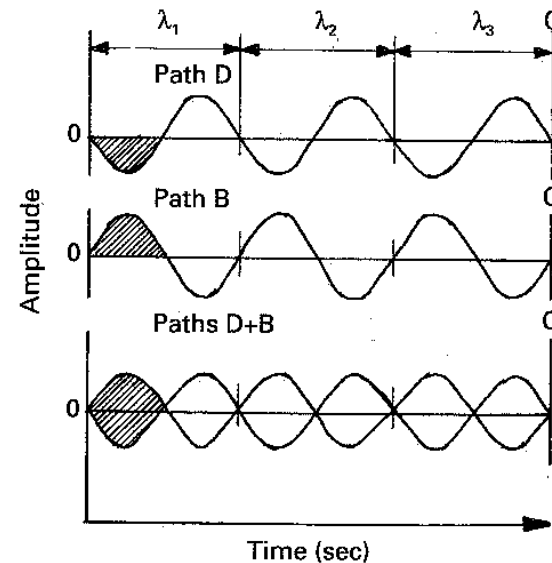
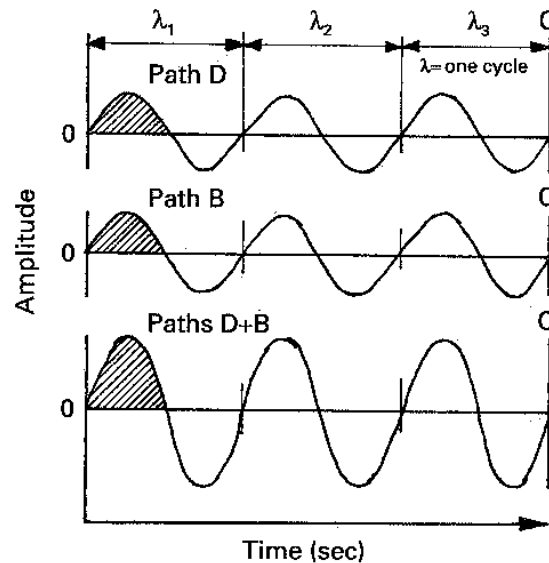
- Principle of sound cancellation by out of phase waves



a) Twin exhaust piping with equal path length



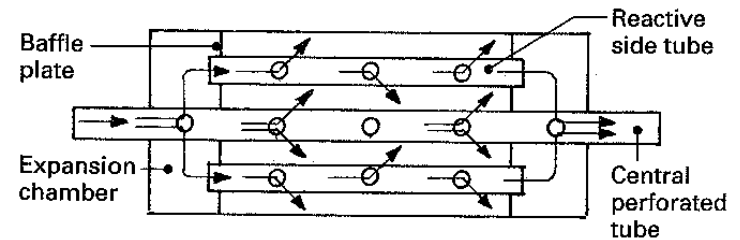
e) Twin exhaust piping with unequal path length



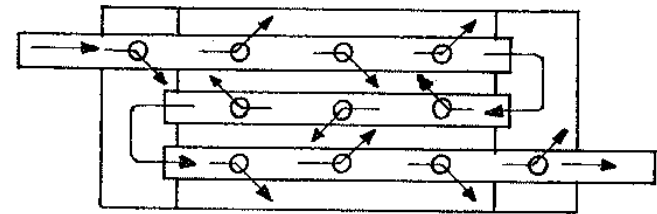
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Reactive Interference

- Simplest form of reactive silencer has central perforated tube and twin parallel side tubes
- Holes allow some gas to short circuit
- Thus the relative distance travelled by gases may be adjusted
- Thus, positive interference can occur to damp out sound waves
- Multiple pass systems extend damping range of system



c) Single-pass reactive silencer (straight through)

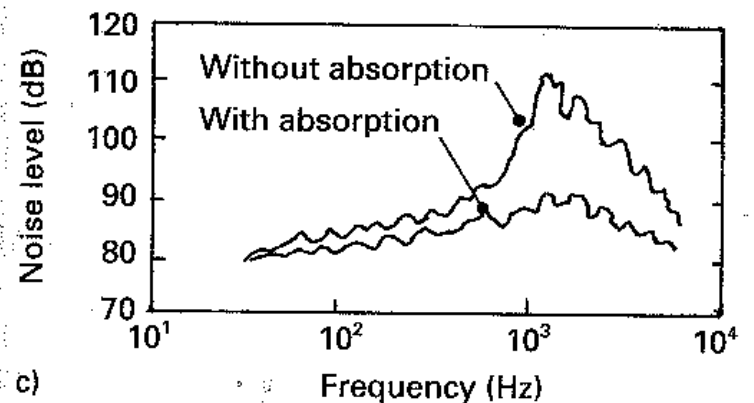
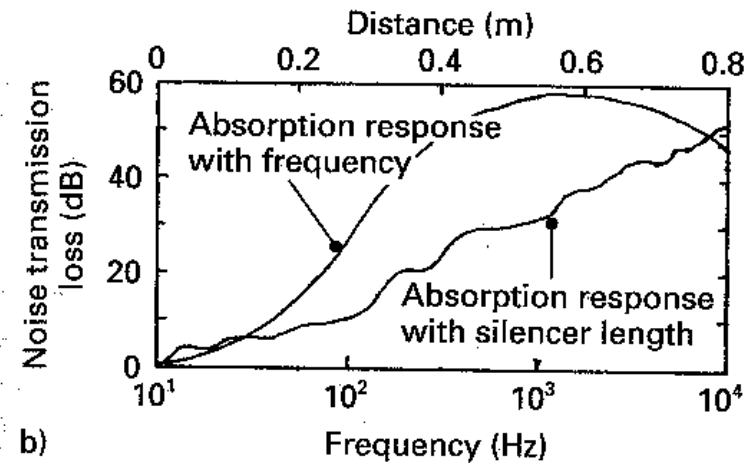


d) Three-pass reactive silencer

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Absorptive Chamber

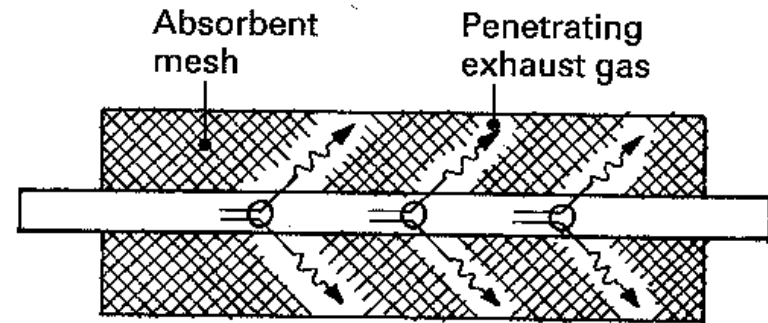
- Sound energy absorbed by acoustically dead material
- Soft/flexible fibrous materials
- Sound wave impulses cause fibres to move turning sound energy into mechanical vibration and heat
- Biased towards higher frequency (shorter wavelengths) but relatively wideband
- Silencer noise absorption increases with length



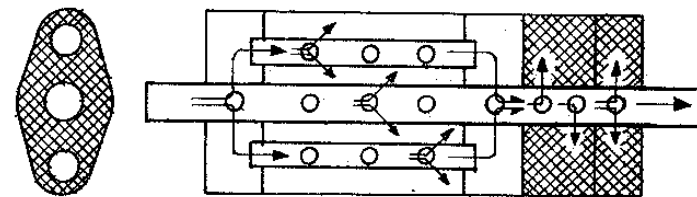
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Absorptive Chamber

- Typical construction is a perforated tube inside an annular chamber
- Chamber filled with wire wool or mineral wool
- Performance deteriorates with age so excess material included
- Often combined with a reactive chamber or expansion chambers in multiple pass designs

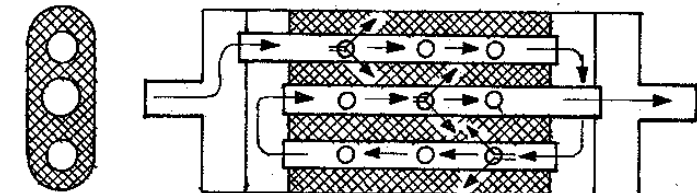


Oval section



e) Single-pass reactive section double-absorbent chamber silencer

Elongated round section



f) Three-pass absorptive section with four expansion chamber silencers

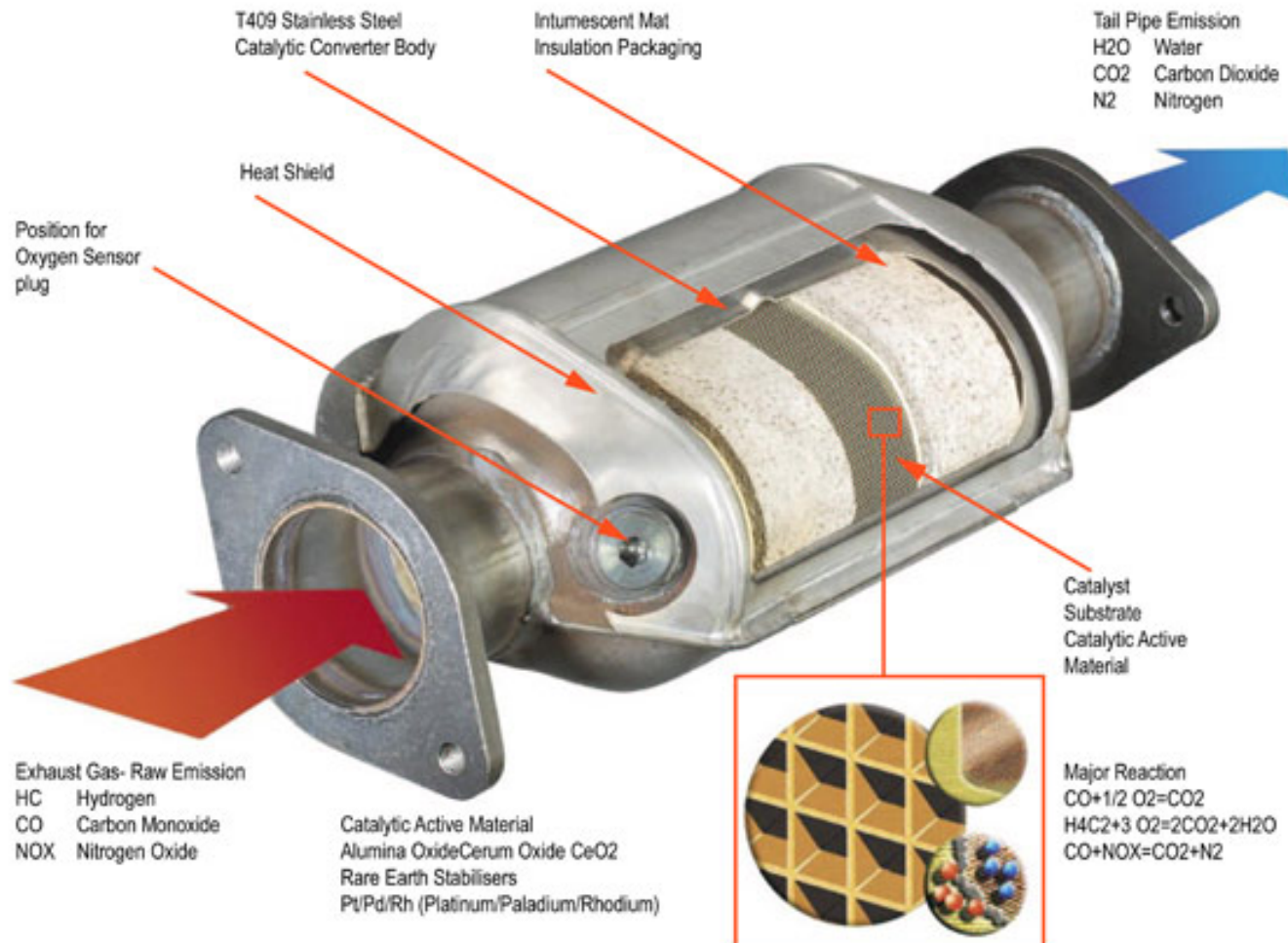
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Catalytic Converter



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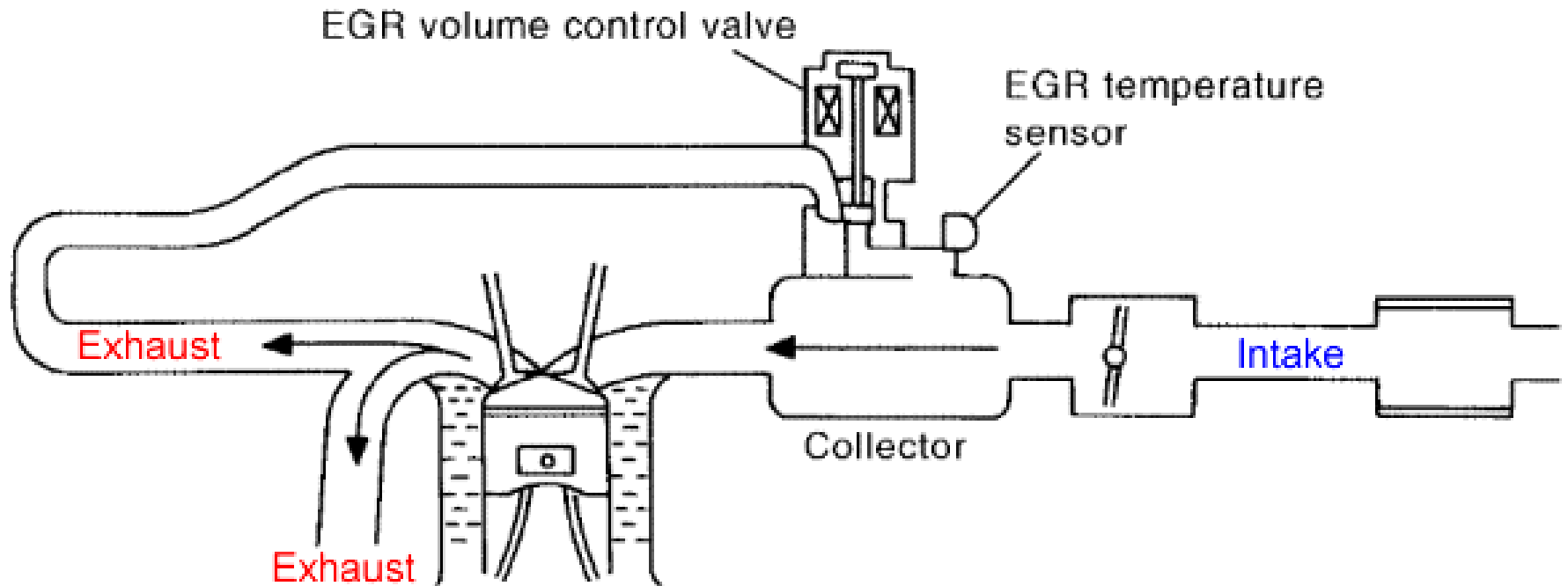


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Catalytic Converter

- Honeycomb ceramic core
 - Magnesium silicate
 - Stable at high temperatures
- Alumina washcoat applied to matrix
 - Very porous
 - Increases surface area up to 700x
- Washcoat impregnated with Platinum and Rhodium
- These speed up (catalyse) the oxidation process which turns CO, HC and NO_x into CO₂, H₂O (steam) and N₂

- Exhaust Gas recirculation
- NO_x formed at temperatures above 1370°C in the combustion process
- EGR recirculates a proportion of exhaust gas back into cylinders
 - Dilutes mixture
 - Reduces peak combustion temperatures
 - Reduces NO_x formation
- System designed to cut off exhaust supply to inlet manifold at low speed (to prevent unstable running) and at very high speed (to prevent excessive loss of power)



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Secondary Air System

- Additional air may be injected into the exhaust system
- This mixes with the burnt and partially burnt exhaust gases
- CO and HC are able to react with the oxygen, turning to CO₂ and H₂O and leading to nearly complete combustion
- Increases exhaust temperatures and thus can reduce the “warm up” period during which the CAT is inactive