



The Catalytic Converter
Programme

**Student Content -
Training Programme
Handbook**

Module 2 - Catalytic Converters

Klarius™ Continuing
Professional Development

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Programme Details

This training programme provides an introduction to Catalytic Converters, the technology used in them, aspects of component servicing and replacement and their requirement as part of the overall UK legal emissions and MOT vehicle standards.

Programme Aims and Objectives

Programme Aims:

- To provide the student with an up to date understanding of the function of a Catalytic Converter
- To provide the student with an understanding of the operational life of a Catalytic Converter
- To provide the student with an understanding of how a Catalytic Converter affects vehicle performance and therefore impacts on customer satisfaction



Programme Objectives:

- That the student understands how a Catalytic Converter works
- That the student can identify the components of a Catalytic Converter
- That the student understands the likely causes for Catalytic Converter failure
- That the student can identify when it is appropriate to replace a Catalytic Converter
- That the student understands the legal responsibilities associated with Catalytic Converter fitment and correct functioning



Overview of the Programme Content

Module 2 - Catalytic Converters

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Programme Aims and Objectives

Programme Learning Outcomes

On completion of the programme the student will be able to understand and identify the following:

- What a Catalytic Converter is and it's function
- What the difference between a Catalytic Converter and a DPF is
- The technical structure of a Catalytic Converter and how it relates to it's function
- Reasons for Catalytic Converter failure and how to assess them
- Catalytic Converter diagnostic protocols and how to assess Catalytic Converter and vehicle performance
- How to recommend when either a Catalytic Converter service or replacement is appropriate
- The legislative requirements for exhaust emissions in relation to Catalytic Converters and how these relate to both garage and customer MOT and service responsibilities

Programme Assessment

On completion of the programme the student will demonstrate their understanding of the programme content by completing an assessment.

- The course is a 3 hour continuing professional development programme that consists of delivery of both theory and practical knowledge by a programme tutor
- The theory, practical knowledge and it's application are assessed via a 20 question multiple choice assessment based on the contents of the student manual and tutor presentation given during the 3 hour training session – It will take place at the end of the training session and will require the candidate to achieve a minimum of 70% to pass. The student assessments will last 30 minutes.
- Students who have not achieved the minimum pass mark will not receive the programme certificate and will need to retake the test at a later date.



Overview of the Programme Content

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Programme Aims and Objectives

Programme knowledge

The training programme will provide the student with current industry standard and legislative knowledge relating to the following aspects of Catalytic Converters (CATs)

CATs – Their Function and how they work

- Introduction to CATs and their components
- CAT technical requirements and performance

CATs - Failure modes

- Introduction to failure types
- Causes of failure types

CATs – Understanding and applying diagnostics

- Assessing and understanding CAT issues
- Diagnosing the correct issues
- Knowing when to replace

CATs - Fitting advice / Quality / Type Approval

- The differences between OEM and After Market CATs
- Understanding the implications to the customer of poor choice
- Advantages to fitting fully Type Approved CATs

CATs - Legislation & MOT requirements

- Understanding UK legal and EU emissions requirements
- CAT use in relation to vehicle insurance



Overview of the Programme Content

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The Catalytic Converter Programme

Catalytic Converters – Their Function and how they work

- Introduction to Catalytic Converters (CATs) and their components
- CAT technical requirements and performance

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EU Emissions Regulations

Emission standards for passenger cars and light commercial vehicles are governed by EU legislation under a number of EU Emissions Regulations. Since the Euro II stage, **EU regulations introduced different emission limits for diesel and petrol vehicles.** Diesels have tighter CO standards but are (currently) allowed higher NOx emissions. Petrol-powered vehicles are exempted from particulate matter (PM) standards up to the Euro IV stage, but vehicles with direct injection engines are subject to a limit of 0.005ppm for Euro V and Euro VI. Particulate matter for petrol engines was controlled from 2009 (Euro IV), with a limit of 0.01ppm.

With all engines, what goes in must come out. If you put in 1kg of fuel and 25kg of air and burn them, the end result will be 26kg of exhaust emissions. Because the combustion process within an engine is not completely efficient, there are a variety of by products (pollutants) from this combustion, such as CO, HC or NOx which can be harmful to people and the environment.

- EU Legislation - is driving changes for vehicle emissions.
- The EU has strict controls for each type of pollutant.
- Typically every few years, vehicle emissions are revised to a new, lower EU standard.
- These changes directly affect the emission control system and its components.

PETROL	CO	HC	NOx	HC+NOx	Part	NEFZ	Implementation
EURO I	2.72	-	-	0.97	-	40 seg	1992
EURO II	2.2	-	-	0.5	-	40 seg	1996
EURO III	2.3	0.2	0.15	-	-	0 seg	2000
EURO IV	1	0.1	0.08	-	-	0 seg	2005
EURO V	1	0.1	0.06	-	0.01	0 seg	2009
EURO VI	1	0.1	0.06	-	0.01	0 seg	2014

DIESEL	CO	HC	NOx	HC+NOx	Part	NEFZ	Implementation
EURO I	2.72	-	-	0.97	0.14	40 seg	1992
EURO II	1.06	-	-	0.71	0.08	40 seg	1996
EURO III	0.64	-	0.5	0.56	0.05	0 seg	2000
EURO IV	0.5	-	0.25	0.3	0.025	0 seg	2005
EURO V	0.5	-	0.18	0.23	0.005	0 seg	2009
EURO VI	0.5	-	0.08	0.17	0.005	0 seg	2014

EU Emissions targets



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Catalytic Converters – Their Function and how they work

- EU Emissions Regulations

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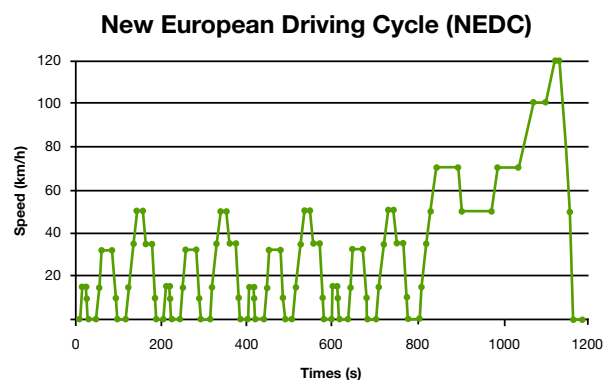
CAT Quality – Type Approval

Type approval is the **confirmation that production samples of a design will meet specified performance standards**. The specification of the product is recorded and **only that specification is approved**. Automotive EC Directives and UN Regulations **require third party approval** - testing, certification and production conformity assessment **by an independent body**. In the UK, the Vehicle Certification Agency (VCA) is both Approval Authority and Technical Service. In the UK, all **replacement catalysts for Euro III onwards (2001>), must meet the R103 standard**. R103 is tested on vehicle, with lab testing to EU drive cycles.

- Parts are approved by their shape / coating
- Tests against the OEM part / EU Limit
- Requires an 8 week program
- Involves 2 weeks of car testing
- Provides a Certificate of homologation
- Approval No. - marked clearly on body
- Klarius test in UK, Germany, Spain



Typical approval markings



The Catalytic Converter Programme

Catalytic Converters – Their Function and how they work

- CAT Quality – Type Approval

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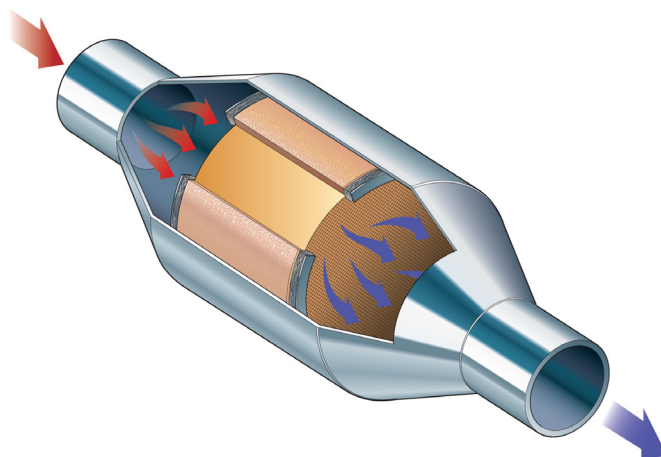
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Catalytic Converters (CATs)

Catalytic Converters are components that are integrated within the overall exhaust system to help meet **European Union exhaust gas emissions standards**. They can be both separate from, or integrated within, a diesel particulate filter unit contained in the exhaust system. The Catalytic Converter works by a **chemical reaction** which helps to convert the **toxic exhaust gases** into **less harmful gases**.

- The principle of the Catalytic Converter (CAT) is to **convert the toxic leftover Hydrocarbons, Carbon Monoxide and Nitrogen Oxides** in the exhaust into Water, Nitrogen and Carbon Dioxide, which are a lot less harmful.
- The oxidation reduction reaction **only happens at higher gas temperatures** (350°C+) so CATs are being placed closer to the manifold, and in some cases as part of the manifold in order to increase effectiveness.
- Catalyst reaction is non-degrading (zero loss).
eg: When used in perfect operating conditions it should last the lifetime of the vehicle.



The Catalytic Converter Programme

Catalytic Converters – Their Function and how they work

- Catalytic Converters (CATs)

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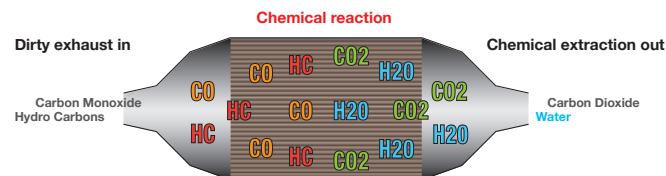


How Do They Work?

A catalyst is a **substance that speeds up (catalyses) a chemical reaction**, it promotes the reaction without requiring more energy, but is not consumed by the reaction. **Catalysts work by catalysing a redox (oxidation or reduction) reaction.** To achieve this chemical reaction heat is required. **Heat is very important to the successful operation of a CAT.** In order to achieve the required chemical reaction a minimum temperature of 350°C is needed. There are two types of catalytic converter; two way (or “oxidation”) catalysts and three way (“oxidation-reduction”, redox) catalytic converters.

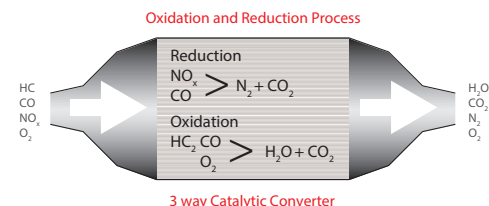
Two way catalysts:

- Two way catalysts are typically found in diesel engines and can't convert NOx
- Diesel Oxidation Catalysts (DOC) run cooler than a petrol CAT.
- Diesel catalysts can only operate in a two way mode due to the chemical structure of diesel exhaust gases.



Three way catalysts:

- Three way catalysts are typically found in petrol engines and can convert Nitrogen Oxides (NOx)
- The three way catalysts performs three simultaneous operations:
 1. Reduction of nitrogen oxides to nitrogen and oxygen
 2. Oxidation of carbon monoxide to carbon dioxide
 3. Oxidation of unburned hydrocarbons (HC) to carbon dioxide and water



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Catalytic Converters – Their Function and how they work

- How Do They Work?

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Catalyst Operation

A CAT is a flow through device – it converts the gasses as **they pass through the channels and react with the metal coated monolith honeycomb**

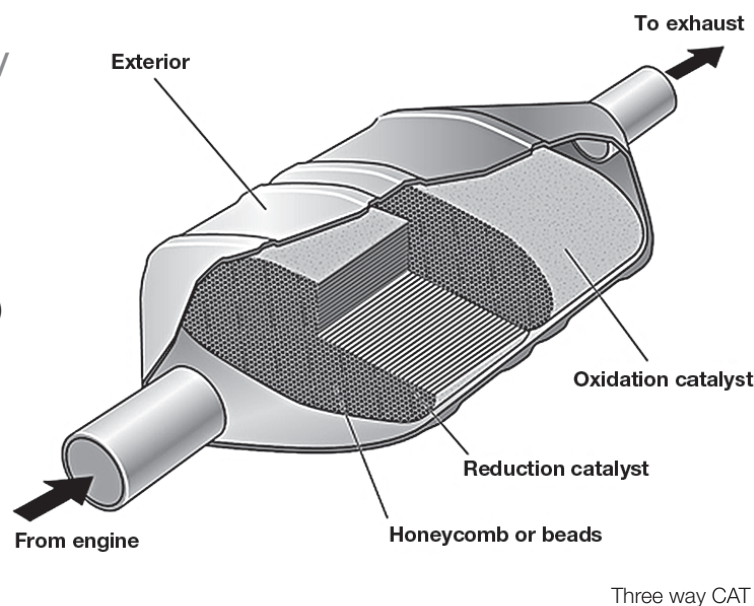
CATs are **only functional above light off temperature (>350°C)**

The use of **Platinum Group Metal (PGM) catalysts (Platinum/Palladium/Rhodium)** – allows conversion of the gases

Constructed from a Cordierite Monolith honeycomb, housed in stainless canning (inc. the support mat)

From Euro IV onwards catalysts are located nearer to engine, have a larger diameter and use more PGM

Brick size/volume as well as PGM loading is critical to performance



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Catalytic Converters – Their Function and how they work

- Catalyst Operation

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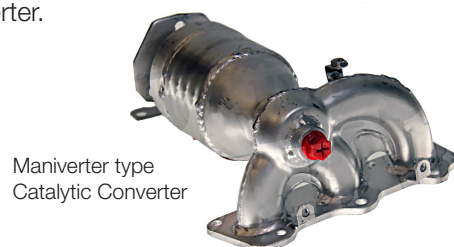
Catalytic Converter Placement

As EU regulations have become more stringent, vehicle manufacturers have continually developed CATs to make them more efficient. Some of the **key factors that CAT efficiency are temperature and the air/fuel ratio of the engine** – ideally 14.7 : 1

To optimise these factors **CATs have been placed closer to the engine and been integrated into the engine's electronic control unit (ECU).**

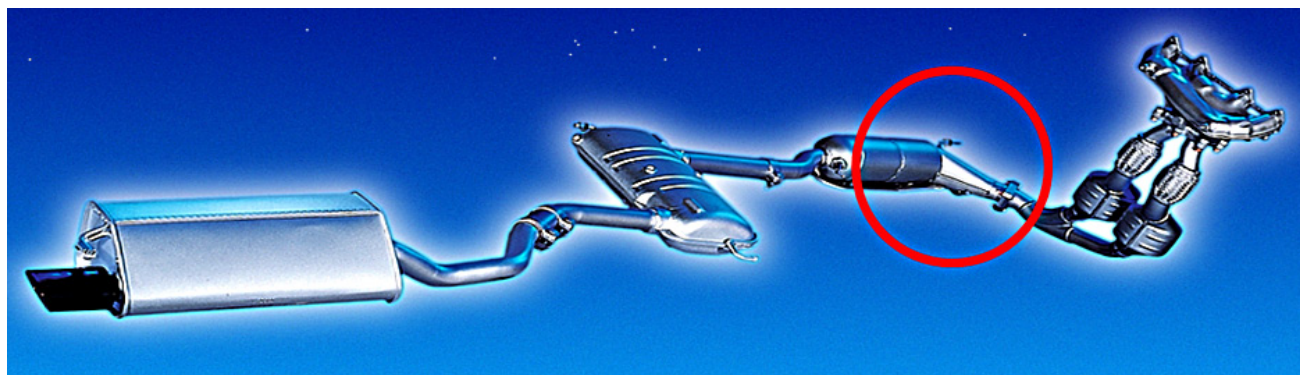
There are two key placement areas:

- 1. Underfloor CATs:** Older CATs tend to be underfloor CATs. Thus meaning there is a length of pipe between the manifold and the CAT.
- 2. Manifold Cats:** Also known as “close coupled.” These fit direct to the manifold, sometimes known as maniverter.



- The catalytic converter is the **first element of the emission control system**
- The catalytic converter is part of the **Emission Control System, integrated into the ECU and OBD systems**
- ‘Stoichiometric’ air fuel ratio

14.7 : 1
Air Fuel



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Catalytic Converters – Their Function and how they work

- Catalytic Converter Placement

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CAT Materials

The materials used in CATs have to do two main jobs; they must be able to **provide a fine mesh structure** that can support the PGM loadings and also be able to withstand and **operate within high temperature environments**, typically around 600°C - 800°C. To achieve this, **specialist materials are used**.

TYPES OF SUBSTRATES - There are **2 different types of substrates**:

1. Ceramic

These account for about 95% of CAT sales. The monolith is a ceramic brick with a honeycomb structure, held in place by matting.



2. Metallic

Constructed from a corrugated metallic matting, which is rolled to form the monolith.



Metallic catalyst coatings (PGM)

In order for CATs to function they use specific types of metals, known as the **Platinum Group of Metals (PGMs)**, to **act as catalysts** to accelerate the chemical reaction with the exhaust gases, which converts the exhaust gasses to safer basic molecules. **These metals are applied to the surface of the monolith substrate** after a wash coat. This creates a rough, irregular surface, which greatly increases the surface area compared to the smooth surface of the bare substrate, providing a greater active surface to react with the engine exhaust.

The 3 main type of PGMs are: **Platinum, Rhodium, Palladium**



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Catalytic Converters – Their Function and how they work

- CAT Materials

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Diagnosis/Fault Finding

The CAT should last the life of the vehicle, when used in normal operating conditions. Understanding **how the vehicle has been used and maintained** will have an impact on its performance; also on what approaches and **diagnostics can be undertaken** to return the emissions system, and therefore the client's car, **to its normal operating economy and performance.**

Key areas of diagnostic approach:

Overall vehicle condition

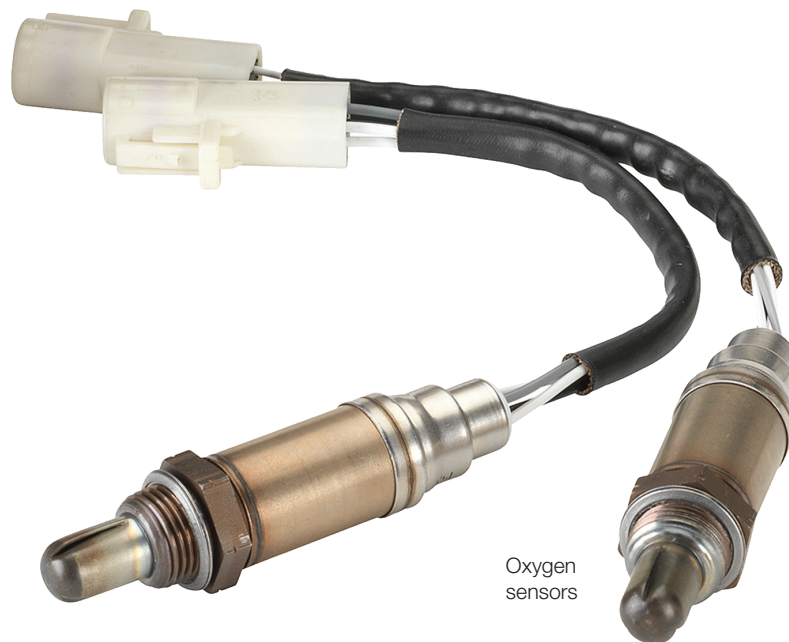
- Damaged exhaust system (low/high back pressure).
- Poor vehicle service record.
- The CAT may not function correctly if the Engine Management Light (EML) is on.

Engine condition

- Intake air manifold leaks.
- Fuel injector problems (leaks).
- Incorrect or worn Spark Plugs.
- Ignition Timing.
- Coil Packs (misfires).
- Intake airflow.
- Running rich.

Vehicle sensors

- Faulty Oxygen sensors.
- Volume Sensors (AFM / MAP)



Oxygen sensors



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Catalytic Converters – Their Function and how they work

- Diagnosis/Fault Finding

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Common catalyst faults

The most common cause of catalytic converter failure is contamination. Examples of converter contaminants include:

- Overly rich air/fuel mixtures can cause the converter to overheat causing substrate meltdown.
- Oil contamination - Turbo / Valve seals
- Lead fuel or additives may coat the catalyst element and render the converter inoperative.
- Silicone from sealants or engine coolant that has leaked into the exhaust, may also coat the catalyst and render it inoperative.

There are other external factors that can cause the converter to degrade and require replacement. Thermal shock occurs when a hot converter is quickly exposed to cold temperature (snow, cold fuel, etc.), causing it to physically distort and eventually fail. Converters that have sustained physical damage (seam cracks, shell puncture, etc.) should be replaced as necessary.



Sealant or coolant clogging

Reasons a CAT can fail that are not the fault of the CAT itself:

- Impact / Road Damage
- Use of exhaust paste (pre cat)
- Lack of new fittings
- Plugged / Contaminated
- Poor Fitting / tension / touching
- Engine Management Light
- Misfires
- Thermal shock



Impact/
Road
Damage



Burning damage
due to over fuelling



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Catalytic Converters – Their Function and how they work

- Common catalyst faults

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Catalyst Failure modes

Catalysts may be deemed to have 'failed' for a variety of reasons, some of these may be physical, such as damage to the monolith inside of the Catalytic Converter or may be diagnostic, such as through exhaust gas emissions readings. Understanding the type of failure and its cause is key to the successful diagnosis of the problem and therefore the correct remedial action.

Monolith failures (examples)

- Due to partial or total combustion failures in one or more cylinders, this would cause the fuel to burn within the catalytic converter
- Failures of back-pressure (positive or negative) will also cause small amounts of fuel to burn in the catalytic converter.



Burning damage due to over fuelling

Emissions Failure

- To correctly **diagnose an emissions issue a four gas analyser report is required.**
- The MOT HC limit is set at 200ppm (parts per million) to prevent exhaust smoke. At 60ppm an engine fault is the most likely cause of the failure.
- High HC levels indicate over-fuelling.
- An increase in CO levels from the natural idle to the fast idle test indicates a misfire.
- It is important to **remember here that the vehicle has failed the emissions test, not the catalyst.**



Blockage due to oils or coolant



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Catalytic Converters – Their Function and how they work

- Catalyst Failure modes

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Checks before changing the Catalyst?

Think about whether or not the catalyst actually needs changing...

Why has it failed?

- Are there signs of soot (petrol) in the pipe work?
- Is the body blue in colour?
- Is there any physical damage?
- Is there a problem with the vehicle that needs to be addressed before a new catalysts is fitted - obtain an emissions report or a fault code?
- Have the Lambda sensors been checked/ changed?
- Has the correct fuel been used?

Fitting Advice 1

	Good Values	
CO	Less than 0.2%	0.35%
HC	Less than 15ppm	75ppm
CO ₂	More than 13.5%	11%
O ₂	Less than 0.2%	1.5%
λ	0.97 - 1.01	1.2
R.P.M.	2500 rpm	2500

Minor air leakage before the Lambda sensor.

Fitting Advice 2

	Good Values	
CO	Less than 0.2%	4.6%
HC	Less than 15ppm	448ppm
CO ₂	More than 13.5%	7.6%
O ₂	Less than 0.2%	0.00%
λ	Btw 0.97 - 1.01	0.81
R.P.M.	2500 rpm	2500

Incomplete Combustion, lack of air (Oxygen).



The Catalytic Converter Programme

Catalytic Converters – Their Function and how they work

- Checks before changing the Catalyst?

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Fault codes – PO420

On board diagnostic (OBD) codes can be a helpful way of determining faults that lie within the vehicle. However some codes are quite general in their description and can therefore sometime be misleading as to how they can be interpreted. The PO420 code states that the 'Catalyst System' is operating inefficiently. **The key word here is 'system' not 'catalyst'.** The code relates to **issues with the overall emissions system, not just the CAT itself.**

PO420 – Catalyst System Efficiency Below Threshold

Codes can be generated by a variety of engine problems that are not related to the Catalyst.

Check through these before deciding to replace the CAT:

- Intake air manifold leaks
- Fuel injector problems (leaks)
- Incorrect or damaged spark plugs
- Ignition timing
- EGR problems
- Oil / Antifreeze entering exhaust
- O₂ sensor not operating correctly
- Road damage to the converter
- Paste / Silicone - contamination
- Misfires (Coil pack / leads)



The Catalytic Converter Programme

Catalytic Converters – Their Function and how they work

- Fault codes – PO420

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Training Programme Recap

During this training programme we have covered the following aspects of Catalytic Converters, how they work and their affect on car performance:

- The Product – what a CAT is and why it is required
- The Function – what a CAT does and how it achieves this
- The Technology – different types of CAT and their materials
- The Failure modes – why CATs may fail and common causes
- The Diagnostics – how to assess CAT condition and diagnose likely issues
- The Product quality - Fitting advice / Quality issues / Type Approval
- The Legal requirements – European Legislation & UK MOT criteria

Now please complete the training assessment multiple choice questionnaire shown overleaf



The Catalytic Converter Programme

Training Programme Recap

Module 2 - Catalytic Converters

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Student Assessment

On completion of the programme the student will demonstrate their understanding of the training programme content by completing the following multiple choice assessment.

All answers must be the student's own; any conferring with other students during the assessment will result in disqualification. The assessment will take place within a set time of 30 minutes. All completed assessments will be submitted to the tutor for marking at the end.

Please select (tick) one of the four answer options for each of the 20 questions below.

1. What is a CAT?

- ☐ a particulate container
- ☐ a silencer
- ☐ an exhaust emission control device
- ☐ a fuel filter

2. What engines can CATs be used with?

- ☐ diesel only
- ☐ petrol only
- ☐ both petrol and diesel
- ☐ only fuel injected engines

3. Is a CAT a regular service item?

- ☐ yes
- ☐ no
- ☐ it depends on the service schedule
- ☐ it depends on the vehicle manufacturer

4. Ideally, how long should a CAT last for?

- ☐ 20,000 miles
- ☐ 75,000 miles
- ☐ the life of the vehicle
- ☐ until the next major service

5. Which of the following can a CAT be integrated with?

- ☐ exhaust manifold
- ☐ the fuel injection system
- ☐ EGR valve
- ☐ the suspension mounts

6. What is the CAT Monolith?

- ☐ the structure supporting the catalytic metals
- ☐ an exhaust muffler
- ☐ an unused fuel filter
- ☐ DPF mounting bracket

please turn over the page



The Catalytic Converter Programme

Student Assessment

Module 2 - Catalytic Converters

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Student Assessment

Please select (tick) one of the four answer options for each of the questions below.

7. What is a CAT monolith typically made from?

- ☐ stainless steel
- ☐ platinum
- ☐ metal coated ceramic honeycomb
- ☐ flexible polymers

8. What is a key component of CAT efficient operation?

- ☐ returning unburned fuel to the engine
- ☐ recirculating exhaust gases
- ☐ high exhaust temperatures
- ☐ re-circulating exhaust gases to reduce exhaust noise

9. What materials are used to change exhaust gas in a CAT?

- ☐ flexible heat resistant polymers
- ☐ zinc coated steel
- ☐ a mixture of platinum, palladium and rhodium
- ☐ carbon fibre filters

10. What is the minimum temperature for a CAT to work?

- ☐ 100 degrees
- ☐ 350 degrees
- ☐ 750 degrees
- ☐ 1500 degrees

11. Which vehicles are 3 way CATs used on?

- ☐ petrol engine vehicles
- ☐ diesel engine vehicles
- ☐ vehicles with a DPF fitted
- ☐ Euro II regulation vehicles

12. Which of the following is a likely cause for CAT failure?

- ☐ the exhaust emissions are high
- ☐ using cheaper fuel
- ☐ the monolith is damaged
- ☐ it doesn't fail, the process is chemical

13. Which of the following methods can assess the emissions?

- ☐ visual inspection
- ☐ PO420 diagnostic
- ☐ 4 part gas analysis
- ☐ the exhaust colour

please turn over the page



The Catalytic Converter Programme

Student Assessment

Module 2 - Catalytic Converters

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Student Assessment

Please select (tick) one of the four answer options for each of the questions below.

14. What is the key aspect of a P0420 diagnostic?

- ☐ the condition of the CAT
- ☐ the efficiency of the emissions system
- ☐ the exhaust noise
- ☐ the service intervals

15. Which of the following will prevent the CAT from working?

- ☐ the monolith is damaged
- ☐ the engine is low on coolant
- ☐ the engine management light is on
- ☐ the outside temperature is below 10 degrees

16. When is the customer most likely to know the CAT isn't working?

- ☐ at an MoT test
- ☐ during cold weather
- ☐ when the oil level is low
- ☐ when the exhaust is noisy

17. What aspect of the CAT does Type Approval cover?

- ☐ the capacity of the CAT
- ☐ CATs don't require type approval
- ☐ the emissions of the CAT
- ☐ the exhaust noise levels

18. Which type of CAT does the Euro V standard cover?

- ☐ just diesel fitments
- ☐ just combined DPF units
- ☐ both petrol and diesel fitments
- ☐ older carburettor fitted vehicles

19. Will removing the CAT cause an MOT fail?

- ☐ only for vehicles made after 2003
- ☐ not if it is separate from the DPF
- ☐ if the vehicle was fitted with one as standard, yes it will
- ☐ no it is an exempt item from the test

20. Can the CAT affect your insurance?

- ☐ yes, but only for high performance cars
- ☐ yes if it is removed and the insurer isn't informed
- ☐ no, it is not an insurance policy concern
- ☐ no, all CATs work the same way



The Catalytic Converter Programme Student Assessment

Module 2 - Catalytic Converters

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Training programme close

Thank you for attending, we look forward to seeing you at further training events as you continue to develop your career and professional knowledge.

This training programme has been supported and accredited by The Institute of the Motor Industry www.theimi.org.uk



Additional training and continuing professional development support materials and videos are available at the following website:

www.klarius.eu/onlinetraining

Login details

User name: dpftraining

Password: Student_ID

Additional information about Klarius' complete range of type approved aftermarket vehicle products can be found at: www.klarius.eu

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Training programme close

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