

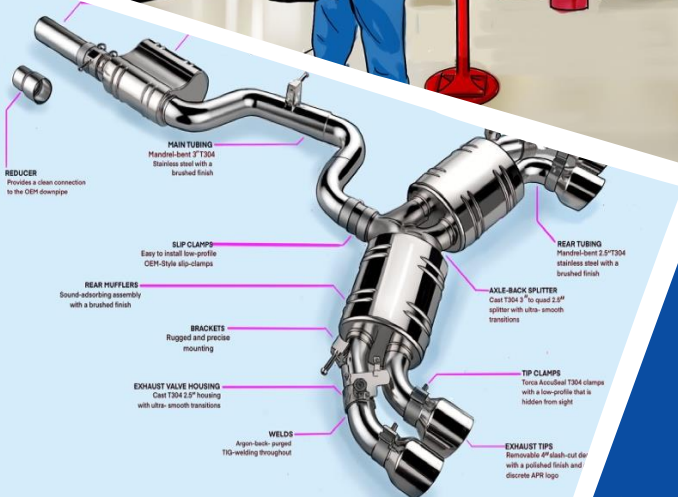


RQF LEVEL 3



AUTES301 AUTOMOBILE TECHNOLOGY

Engine Exhaust System Repairing



TRAINEE'S MANUAL

December 2023



ENGINE EXHAUST SYSTEM REPAIRING



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Under Rwanda TVET Board (RTB) guiding policies and directives



Under Swisscontact supervision and involvement

COORDINATION TEAM

Aimable Rwamasirabo

Sosthene Kazima

Production Team

Authoring and Review

Elyse Hagenimana

Tumaini Manimbi

Conception, Adaptation and Editorial works

Jean Marie Vianney Muhire

Vincent Havugimana

John Paul Kanyike

Jean Damascene Rikunze

Formatting, Graphics, Illustrations, and infographics

Albert Ngarambe

Jean Claude Asoka Niyonsaba

Coordination and Technical support

Suisscontact Rwanda and RTB

Project Implementation

MCT Global Ltd

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LIST OF ABBREVIATIONS AND ACRONYMS

CBET:	Competency-Based Education and Training.
RQF:	Rwanda Qualification Framework
RTB:	Rwanda TVET Board
TVET:	Technical and Vocational Education and Training
%:	Percentages
Kg:	Kilograms
cm:	Centimeter
M:	Meter
G:	Gram
Kg:	Kilogram
mm:	Millimeter
PPE:	Personal Protective Equipment
SCEB:	Stabilized Compressed Earth Blocks
hp:	Horsepower
RS:	Rwandan Standard
RSB:	Rwanda Standards Board
KPa:	Kilopascal
N:	Newton
mm²:	Millimeter squared
MPa:	Megapascal
TSB:	Technical Service Bulletins.
PCM:	Power-train Control Module
EGR:	Exhaust Gas Recirculation.
DEF:	Diesel Exhaust Fluid.
DTC:	Diagnostic Trouble Code.
mV:	Millivolt
MIL:	Malfunction Indicator Lamp

°F:	Degree Fahrenheit
°C:	Degree Celsius
Psi:	Pressure per Square Inch
Rpm:	Revolution Per Minute
V6:	Engine with six cylinders in form of “V”
V8:	Engine with eight cylinders in form of “V”
CO:	Carbon Monoxide
CO₂:	Carbon Dioxide
H₂O:	Water Vapor
NO_x:	Nitrogen Oxides
H₂SO₄:	Sulfuric acid
HO₂S:	Heater control/Oxygen Sensor
A/F:	Air Fuel Ratio
HC:	Hydrocarbons
COVID-19:	Coronavirus Disease of 2019
OBD II:	On-Board Diagnostic II
MIG:	Metal Inert Gas
TIG:	Tungsten Inert Gas
PPM:	Parts Per Million.
G/MI:	Grams Per Mile.

INTRODUCTION

This trainee manual encompasses all necessary skills, knowledge and attitudes required to repair engine exhaust system. Students undertaking this module shall be exposed with practical activities that will develop and nurture their competences. The writing process of this training manual embraced competency-based education and training (CBT) philosophy by providing enough practical opportunities reflecting real life situations.

The trainee manual is subdivided into units, each unit has various topics, trainee will start with a self-assessment exercise to help trainee rate him/herself on the level of skills, knowledge and attitudes about the unit.

A discovery activity is followed to help trainee discover what he/she already know about the unit.

After these activities trainee will learn more about the topics by doing different activities, reading the required knowledge, techniques, steps, procedures and other requirements under the key facts section, trainee may also get assistance from the trainer. The activities in this training manual are prepared such that they give opportunities to students to work individually and in groups.

After going through all activities, trainee shall undertake progressive assessments known as formative and finally conclude with his/her own self-reflection to identify his/her strengths, weaknesses and areas for improvements.

Do not forget to read the point to remember section which provides the overall key points and takeaways of the unit.

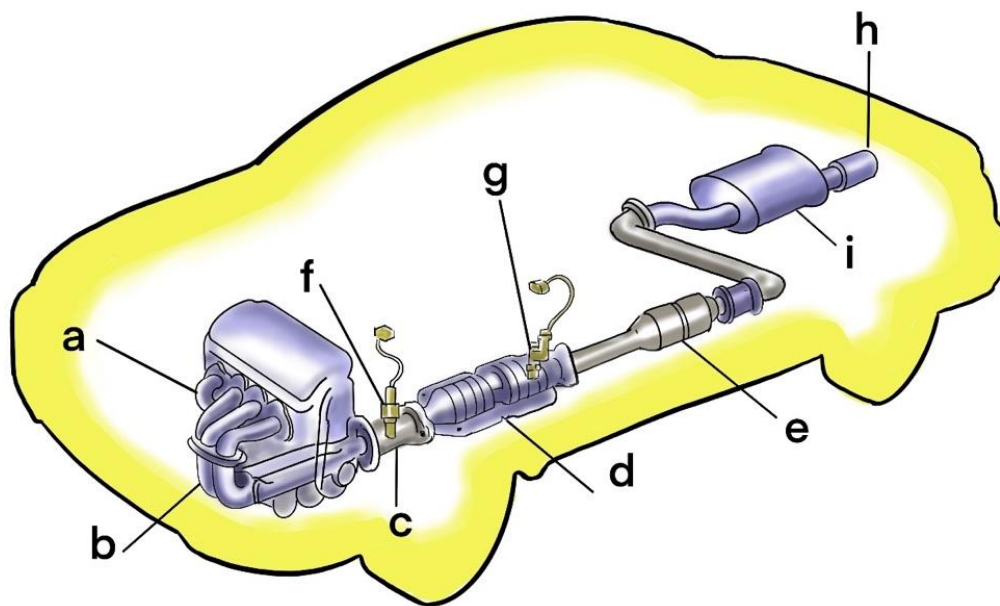
Module Units:

Unit 1: Describe engine exhaust system

Unit 2: Prepare workplace

Unit 3: Repair engine exhaust system

UNIT 1: DESCRIBE ENGINE EXHAUST SYSTEM



Unit summary:

This unit provides you with the knowledge, skills and attitudes to describe the engine exhaust system. It covers the identification of exhaust system exit pipe types, identification of exhaust system components, description of functions, constructions and operating principles of exhaust system components.

Self-Assessment: Unit 1

1. Study the unit illustration above and answer the following questions.
 - a. What do you see in the illustration?
 - b. What topics do you think will be covered under this unit based on the illustration?
2. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.
 - a. There are no right or wrong ways to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?
 - c. Read the statements across the top. Put a tick in a column that best represents your level of knowledge, skills and attitudes.
 - d. At the end of this unit, you will assess yourself again.

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Identify different types of exhaust system according to exit pipes					
Identify all the components of exhaust system					
Explain the functions of all the components of exhaust system					
Describe the constructions materials of all the components of exhaust system					

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Describe operating principle of all the components of exhaust system					



Key Competencies:

Knowledge	Skills	Attitudes
1. Identify the type of exhaust system exit pipes	1. Describe the operating principle of exhaust system components	1. Pay attention to details while describing the engine exhaust system
2. Explain the function of exhaust system	2. Describe the function of exhaust system components	2. Demonstrate team spirit while working with others
3. Name the components of exhaust system	3. Describe the construction materials of exhaust system components	3. Comply with national and international standards at the workplace
4. Explain the construction materials of exhaust system components	4. Select exhaust system components	4. Time management



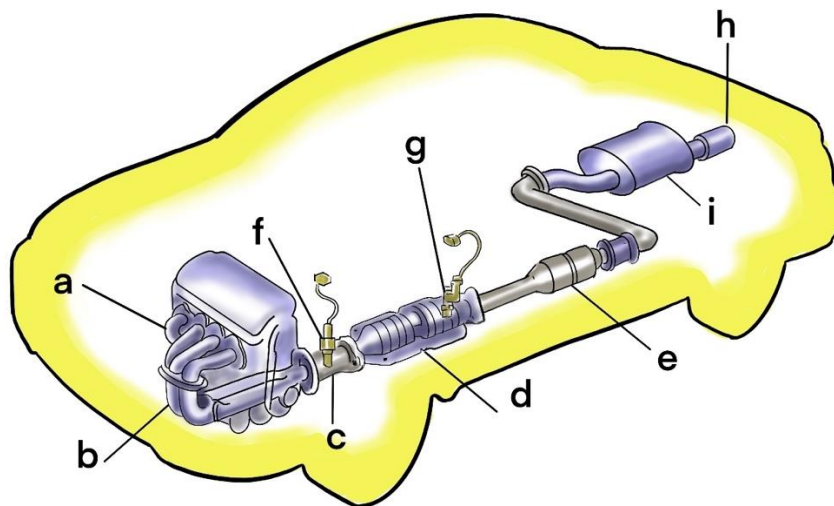
Discovery activity



Task 1:

1. Analyse the figure below and answer the following questions:
 - a. What are the types of exhaust system due to exit pipe?
 - b. Explain the function of exhaust system.

- c. Rename the components of exhaust system from a to j.
- d. Explain the function of exhaust system components a to j.
- e. Describe the construction materials of exhaust system components a to j.
- f. Describe the operating principle of exhaust system components a to j.



Topic 1.1: Identification of exhaust system.

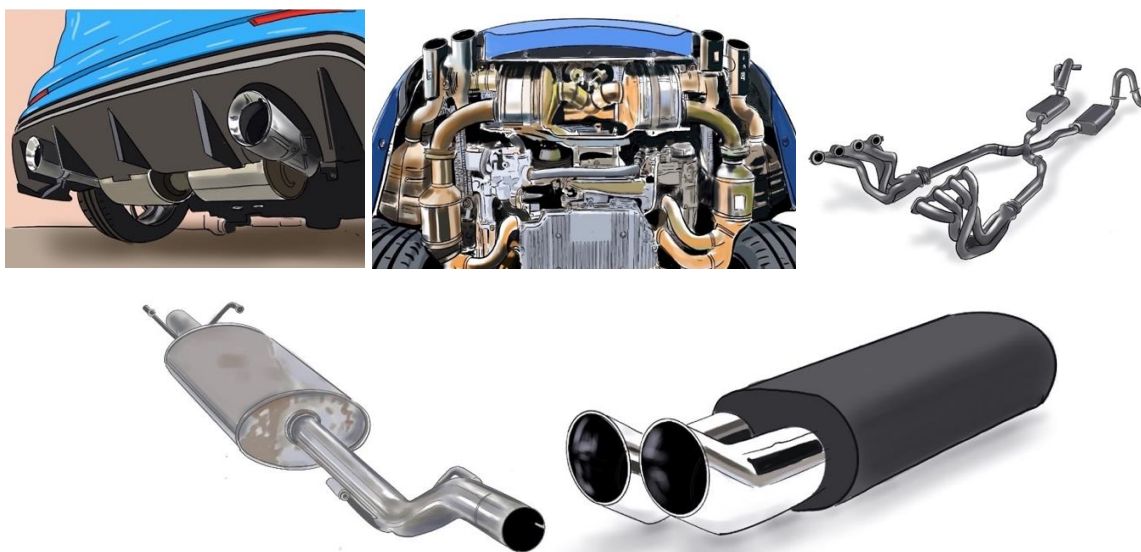


Activity 1: Problem Solving



Task 2:

1. Discuss the pictures below and answer the questions that follow:



Questions:

- What are the types of the exhaust system due to exit pipe?
- Explain the advantage and the disadvantage of each exhaust system types.
- Describe the construction materials of each exhaust system.

Key Facts 1.1a: Identification of exhaust system

- Introduction to engine exhaust system**

The exhaust system serves to collect the exhaust gases from the cylinders, removes harmful substances, reduces the level of noise and discharges the purified exhaust gases at a suitable point of the vehicle away from its occupants.

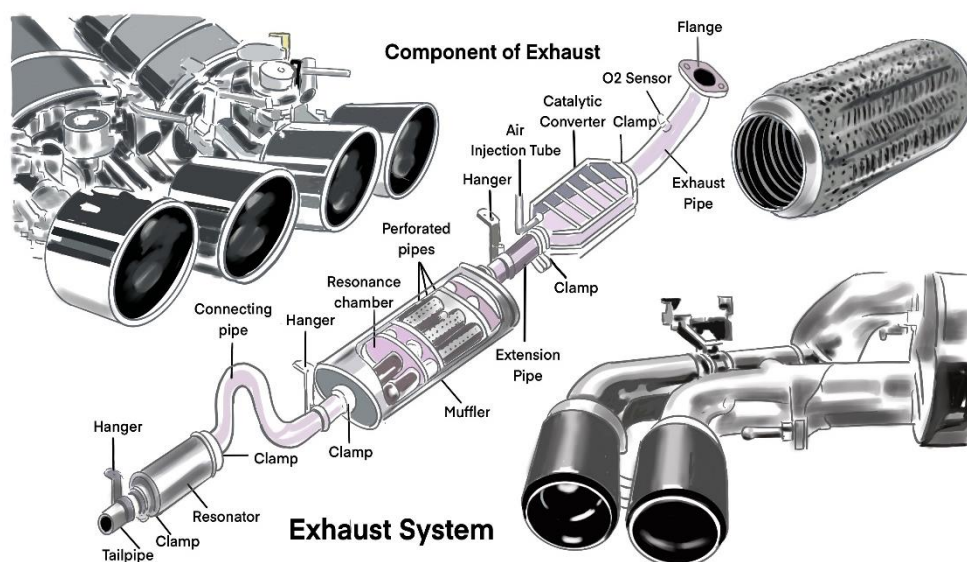


Figure 1 Detailed components of exhaust system

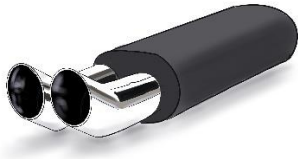
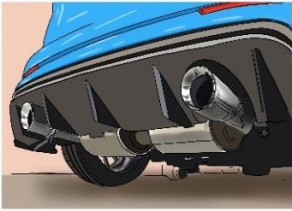
Key Facts 1.1. b: Identification of exhaust system

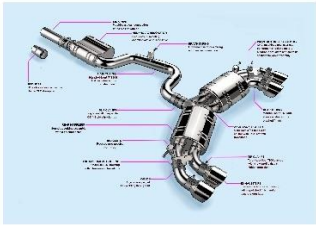
- Identification of exhaust system types**

The exhaust system can consist of one or two channels depending on the engine.

The flow resistance must be selected so that the exhaust backpressure affects engine performance as little as possible. To ensure that the exhaust system functions perfectly, it must be viewed as a whole and developed accordingly. This means that its components must be coordinated by the design engineers in line with the specific vehicle and engine.

Type	Description	Advantages	Disadvantage
✓ Single Exit Exhaust 	This is a type of car exhaust system that utilizes a single pipe to direct the flow of exhaust gases out of a vehicle. This type of exhaust setup is commonly found as a factory-equipped option in many cars. Single exhaust systems commonly feature a Y-pipe design, which gathers the exhaust gases from the manifold and channels through the muffler before exiting the vehicle. It allows for smoother airflow, contributing to more efficient engine operation.	The single exit exhaust is lighter in weight. Has a lower cost compared to other exhaust systems? Its smaller diameter also results in increased exhaust gas velocity.	The only drawback of this exhaust system is its limited absolute flow, as it is restricted to the diameter of a single tubing.
✓ High Performance Exhaust 	High-performance exhaust systems are comparatively more expensive which is found doing a highly efficient job of filtering out the gases. Whereas, these are not the standard and should not be fitted to the vehicle aftermarket but in some cases the high-performance exhaust	Added Performance It Sounds as Good as it Looks Added Style	More Fuel Usage May Void Some Manufacturer Warranties

	system is found increasing the efficiency of a car and also the performance of the engine.		
Types of high-performance exhaust system			
✓ Dual Exit Exhaust 	The dual-exit exhaust system uses two separate pipes to pass the exhaust gas. In a dual exhaust system, the process of gas expulsion is much faster and more effective than in single-exit exhausts. This is the reason a dual exhaust system is typically found on vehicles with six-cylinder V6, V8 engines or larger ones. Since dual exit exhaust lowers the energy burden on the engine, it improves a car's performance and fuel efficiency.	Dual-exit exhaust systems are designed to provide additional performance gains. They get gases out faster allowing the engine to suck more air in, which creates horsepower.	These types of exhaust systems are often more expensive. Heavier than single-exit ones. They can also be louder; however, it depends on the arrangements of the exhaust piping.
✓ Opposite Dual Exhaust 	These types of exhausts are used where the dual rear exhaust systems cannot bend. Opposite dual exhaust systems are installed	Increased Power Improved Sound Improved Fuel	Increased Cost Increased Maintenance Potential for Excessive

	as they work a bit differently as compared to the other exhausts. These are wrapped around the wheel with the bend to add a filtering process. These types of exhausts will be seen more on vehicles which are used for towing large loads.	Efficiency Better Exhaust Flow Increased Towing Capacity Improved Engine Longevity Increased Resale Value	Noise Reduced Ground Clearance Potential for Exhaust Leaks Potential for Heat Damage Reduced Cargo Space Difficulty in Finding Replacement Parts Reduced Fuel Efficiency	
✓ Dual Side Exhaust 	A dual side exhaust system refers to as that system which has two pipes next to each other on one side. These two pipes are used to expel gasses more efficiently as compared to the single exit pipes.	Enhanced Styling		



Activity 2: Guided Practice



Task 3:

1. Visit the workshop, analyse the vehicle parked on service bay then answer the following questions:
 - a. Identify the exhaust system types according to exit pipe of the vehicle.
 - b. Describe the difference between exhaust system types according to exit pipe of the above vehicle.



Activity 3: Application



Task 4:

1. Take a field visit on nearest garage, observe the vehicles in the garage, then using your notebook, describe all the types of exhaust system and their components you have observed.

Topic 1.2 Description of exhaust system components



Activity 1: Problem Solving



Task 5:

1. In groups, conduct research from Internet or reference books on:
 - a. The components of exhaust system.
 - b. The function of exhaust system.
 - c. Find out the arrangement of exhaust system components.
 - d. Find out the construction materials of exhaust system components.
2. Refer to the key facts for further information

Key Facts 1.2.a: Description of exhaust system components

- Identification of exhaust system components

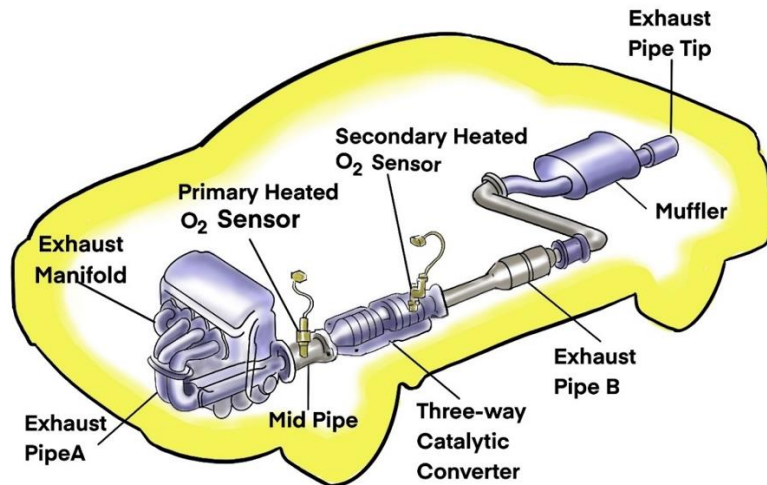


Figure 2 exhaust system components of vehicles

Parts of a typical exhaust system include the exhaust manifold, the exhaust pipe and seals, the catalytic converter, exhaust gas oxygen sensors, the muffler (and sometimes a resonator), Heat shields, the tailpipe, clamps, brackets, and hangers. An exhaust system serves three functions:

- ✓ It carries burned exhaust gases away from the passenger compartment of the car.
- ✓ It quiets the engine.
- ✓ One or more catalytic converters control exhaust emissions.

Backpressure

It would do no good to have a large intake system, with large valves and ports, if the exhaust system were restricted. In four-stroke engines, restrictions in the exhaust can cause backpressure, especially at higher speeds. Excessive backpressure reduces performance and fuel economy. A small amount of backpressure from the exhaust system is needed to keep the combustion chambers hot enough for more complete combustion. Only a small amount of backpressure (about 2 pounds) will prevent the air-fuel mixture from going out the exhaust during valve overlap and result in a denser air-fuel charge in the cylinder. Exhaust system restrictions also keep the exhaust system hot after the engine is shut off, preventing cold air from coming back into the cylinder, where it would warp an exhaust valve. Exhaust system flow is not affected in a major way by bends in the pipe as long as the cross-sectional area of the pipe is not diminished. Special bending machines are capable of providing a true radius to exhaust pipe.

Key Facts 1.2.b:

- Description of exhaust system components

- ✓ Exhaust Manifold

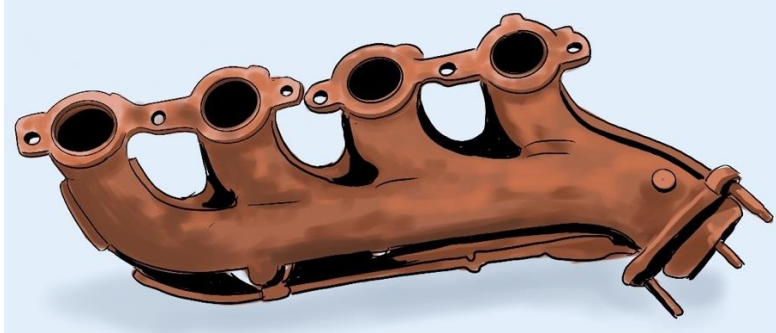


Figure 3 An exhaust manifold for a four-cylinder engine.

The exhaust manifold collects the burnt gases as they are expelled from the cylinders and directs them to the exhaust pipe. Exhaust manifolds for most vehicles are made of cast or nodular iron.

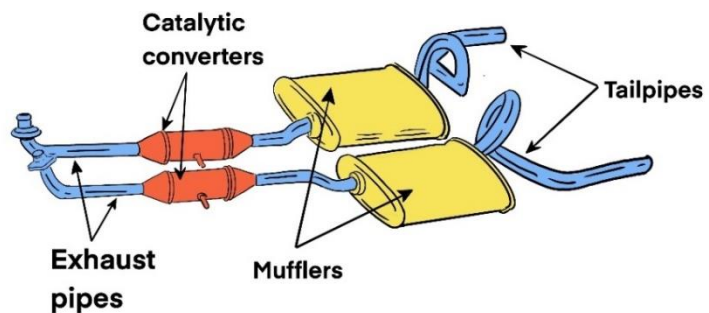


Figure 4 A dual exhaust system.

In-line engines have one exhaust manifold. V-type engines have an exhaust manifold on each side

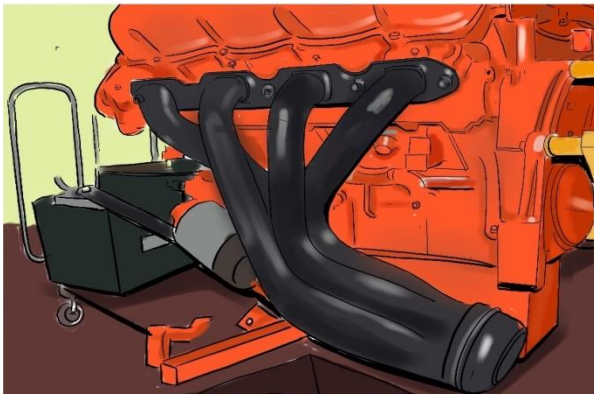


Figure 5 A tuned exhaust manifold header.

of the engine. An exhaust manifold will have three, four, or six passages, depending on the type of engine. These passages blend into a single passage at the other end, which connects to an exhaust pipe. From that point, the flow of exhaust gases continues to the catalytic converter, muffler, and tailpipe, and then exits at the rear of the car.

V-type engines may be equipped with a dual exhaust system that consists of two almost identical, but individual, systems in the same vehicle. Exhaust systems are designed for particular engine–chassis combinations. Exhaust system length, pipe size, and silencer size are used to tune the flow of gases within the exhaust system. Proper tuning of the exhaust manifold tubes can actually create a partial vacuum that helps draw exhaust gases out of the cylinder, improving volumetric efficiency.

Separate, tuned exhaust headers (Figure 10) can also improve efficiency by preventing the exhaust flow of one cylinder from interfering with the exhaust flow of another cylinder. Cylinders next to one another may release exhaust gas at about the same time. When this happens, the pressure of the exhaust gas from one cylinder can interfere with the flow

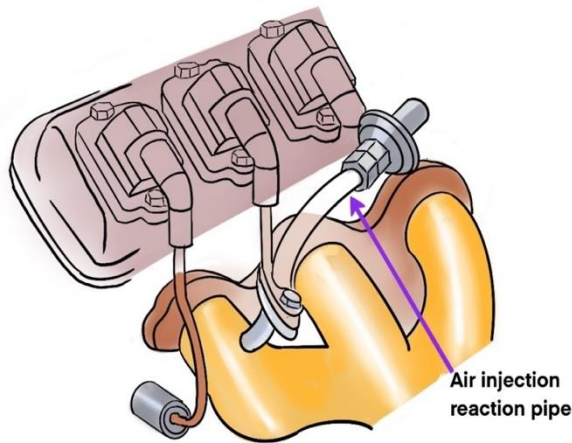


Figure 6 An air pipe mounting on an exhaust manifold

from the other cylinder. With separate headers, the cylinders are isolated from one another, interference is eliminated, and the engine breathes better. The problem of interference is especially common with V-8 engines. However, exhaust headers tend to improve the performance of all engines.

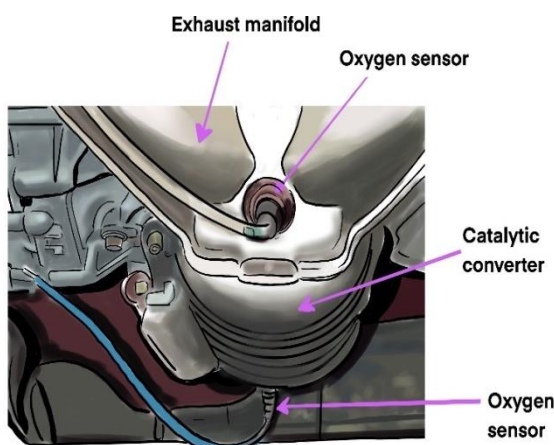


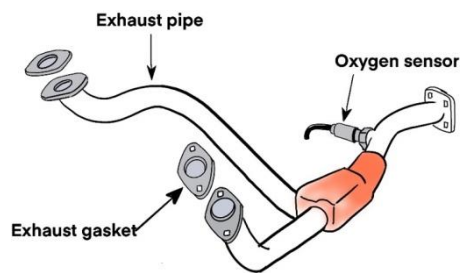
Figure 7 An oxygen sensor sits in this exhaust manifold

Exhaust manifolds may also be the attaching point for the air injection reaction (AIR) pipe (Figure 6). This pipe introduces cool air from the AIR system into the exhaust stream. The added air in the exhaust stream during engine warm-up helps burn excess fuel in the exhaust and heat up the catalytic converter faster.

The catalytic converter mounts onto the exhaust manifold, and another oxygen sensor fits into the exhaust pipe.

Some exhaust manifolds have provisions for the exhaust gas recirculation (EGR) pipe. This pipe takes a sample of the exhaust gases and delivers it to the EGR valve. Also, some exhaust manifolds have a tapped bore that retains the oxygen sensor (Figure 7)

✓ Exhaust Pipe and Seal



The exhaust pipe is metal pipe, made of aluminized steel, stainless steel, or zinc-plated heavy gauge steel, that runs under the vehicle between the exhaust manifold and the catalytic converter (Figure 8). Exhaust gaskets are generally

designed in the form of composite graphite - cemjo, crush ring, spiral wound gasket, wire mesh gasket and steel embossed gaskets.



Figure 8 Different types of exhaust gaskets

✓ Exhaust flex pipe



An exhaust flex pipe is a flexible tube and a part of the car's exhaust system. Usually, flex pipes are made of stainless steel to give the exhaust line the required flexibility during the movement of the vehicle. The pipe must be flexible as this helps to limit cracks that could otherwise appear in the exhaust system.

Figure 9 An exhaust flex pipe

✓ Catalytic Converters

A catalytic converter is part of the exhaust system and a very important part of the emission control system. Because it is part of both systems, it has a role in both. As an emission control device, **it is responsible for converting undesirable exhaust gases into harmless gases.** As part of the exhaust system, **it helps reduce the noise level of the exhaust.** A catalytic converter contains a ceramic element coated with a catalyst.

A catalyst is a substance that causes a chemical reaction in other elements without actually becoming part of the chemical change and without being used up or consumed in

the process. Catalytic converters may be pellet type or monolithic type.

A pellet-type converter contains a bed made from hundreds of small beads and is mostly used on older vehicles. Exhaust gases pass over this bed. In a monolithic-type converter, the exhaust gases pass through a honeycomb ceramic block.

The converter beads or ceramic block are coated with a thin coating of cerium, platinum, palladium, rhodium, or any combination of these and are held in a stainless-steel container.

Modern vehicles are equipped with three-way catalytic converters, which means the converter reduces the three major exhaust emissions, hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx). The converter oxidizes HC and CO into water vapor and carbon dioxide (CO₂) and reduces NOx to oxygen and nitrogen.

Many vehicles are equipped with a mini-catalytic converter that either is built into the exhaust manifold or is located next to it (Figure 13). These converters are used to clean the exhaust during engine warm-up and are commonly called warm-up converters. Some older catalytic converters have an air hose connected from the AIR system to the oxidizing catalyst. This air helps the converter work by making extra oxygen available. The air from the AIR system is not always forced into the converter; rather, it is controlled by the vehicle's PCM. Fresh air added to the exhaust at the wrong time could overheat the converter and produce NOx, something the converter is trying to destroy.

OBD II regulations call for a way to inform the driver that the vehicle's converter has a problem and may be ineffective. The PCM monitors the activity of the converter by comparing the signals of an HO S2 located at the front of the converter with the signals

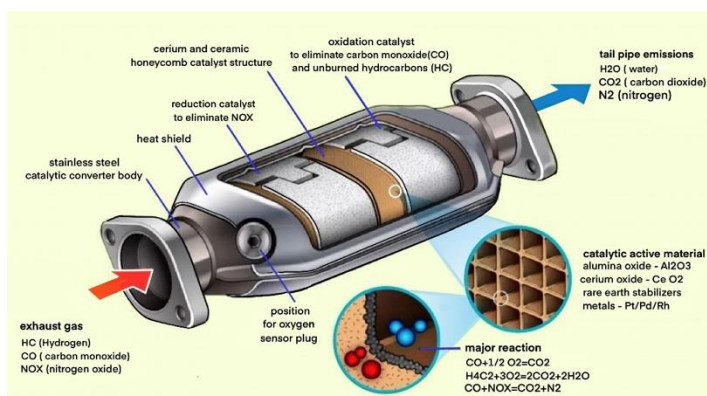
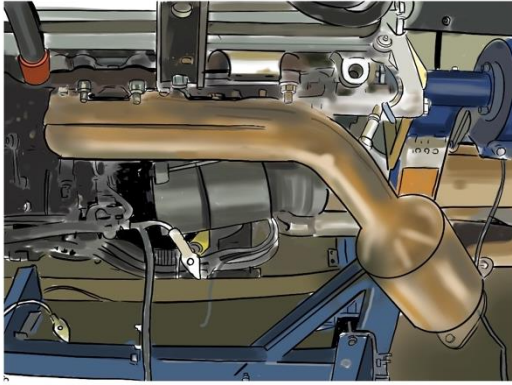


Figure 10 monolithic-type catalytic converter

from an HO S2 located at the rear. If the sensor outputs are the same, the converter is not working properly and the malfunction indicator lamp (MIL) on the dash will light.



The oxygen sensor is an instrument for managing the exhaust emissions of petrol, diesel and gas engines. It is an oxygen concentration sensor which measures the residual oxygen content of the exhaust gases and then transmits a signal to the engine management system in the form of an electric voltage.

Figure 11 A warm-up converter may be used before the primary converter.

The oxygen sensor voltage allows the control unit to detect whether the mixture is too lean or rich. The control unit reduces the quantity of fuel in the A/F ratio if it is too rich, and increases it if it is too lean.

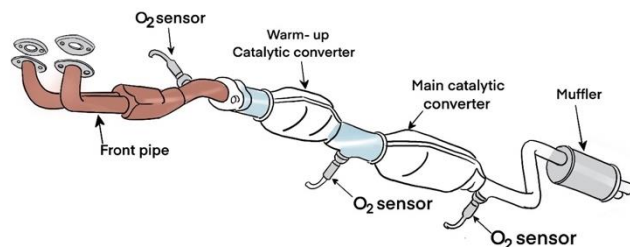


Figure 12 Exhaust system for an OBD II vehicle.

✓ Mufflers

The muffler is a cylindrical or oval-shaped component, generally about 2 feet (0.6 meters) long, mounted in the exhaust system about midway or toward the rear of the car.

Inside the muffler is a series of baffles, chambers, tubes, and holes to break up, cancel out, or silence the pressure pulsations that occur each time an exhaust valve opens.

Two types of mufflers are commonly used on passenger vehicles. Reverse-flow mufflers change the direction of the exhaust gas flow through the inside of the unit. This is the most common type of automotive muffler. Straight-through mufflers permit exhaust gases to pass through a single tube. The tube has perforations that tend to break up pressure pulsations. They are not as quiet as the reverse-flow type. There have been several important changes in recent years in the design of mufflers. Most of these changes have been centered at reducing weight and emissions, improving fuel economy, and simplifying assembly.

These changes include the following:

✚ **New materials.** More and more mufflers are being made of aluminized and stainless steel. Using these materials reduces the weight of the units as well as extends their lives.

✚ **Double-wall design.** Retarded engine ignition timing that is used on many small cars tends to make the exhaust pulses sharper. Many cars use a double-wall exhaust pipe to better contain the sound and reduce pipe ring.

✚ **Rear-mounted muffler.** More and more often, the only space left under the car for the muffler is at the very rear. This means the muffler runs cooler than before

and is more easily damaged by condensation in the exhaust system. This moisture, combined with nitrogen and sulfur oxides in the exhaust gas, forms acids that rot the muffler from the inside out. Many mufflers are being produced with drain holes drilled into them.

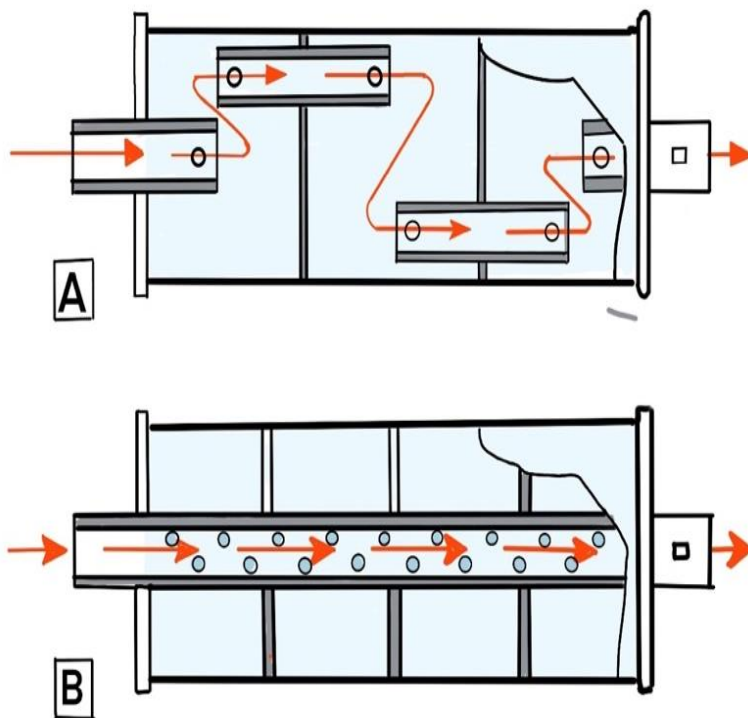


Figure 13 Internal construction of muffler (A is reverse flow muffler then B is straight through muffler)

✚ **Back pressure.** Even a well-designed muffler will produce some back pressure in the system. Back pressure reduces an engine's volumetric efficiency, or ability to breathe. Excessive back pressure caused by defects in a muffler or other exhaust system part can slow or stop the engine. However, a small amount of back pressure can be used intentionally to allow a slower passage of exhaust gases through the catalytic converter. This slower passage results in more complete conversion to less harmful gases. Also, no back pressure may allow intake gases to enter the exhaust.

✓ **Resonator**

On some older vehicles, there is an additional muffler, known as a resonator or silencer. This unit is designed to further reduce or change the sound level of the exhaust. It is located toward the end of the system and generally looks like a smaller, rounder version of a muffler.

✓ Tailpipe

The tailpipe is the last pipe in the exhaust system. It releases the exhaust fumes into the atmosphere beyond the back end of the car.

✓ Heat Shields

Heat shields are used to protect other parts from the heat of the exhaust system and the catalytic converter. They are usually made of pressed or perforated sheet metal. Heat shields trap the heat in the exhaust system, which has a direct effect on maintaining exhaust gas velocity.

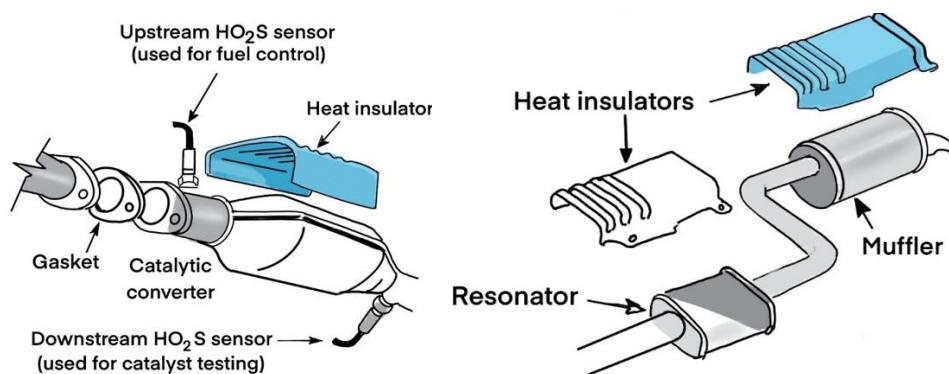
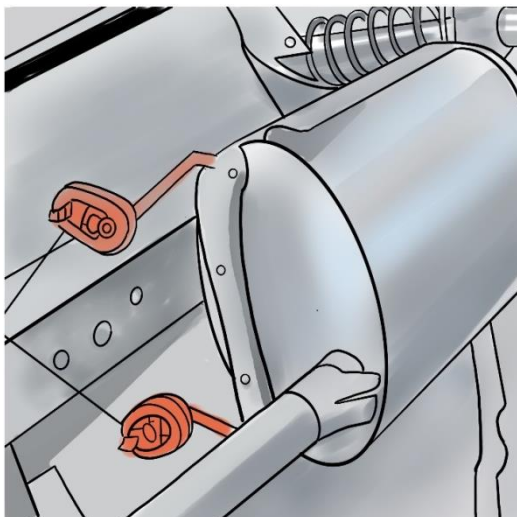


Figure 14 Typical locations of heat shields in an exhaust system.

✓ Clamps, Brackets, and Hangers

Clamps, brackets, and hangers are used to properly join and support the various parts of



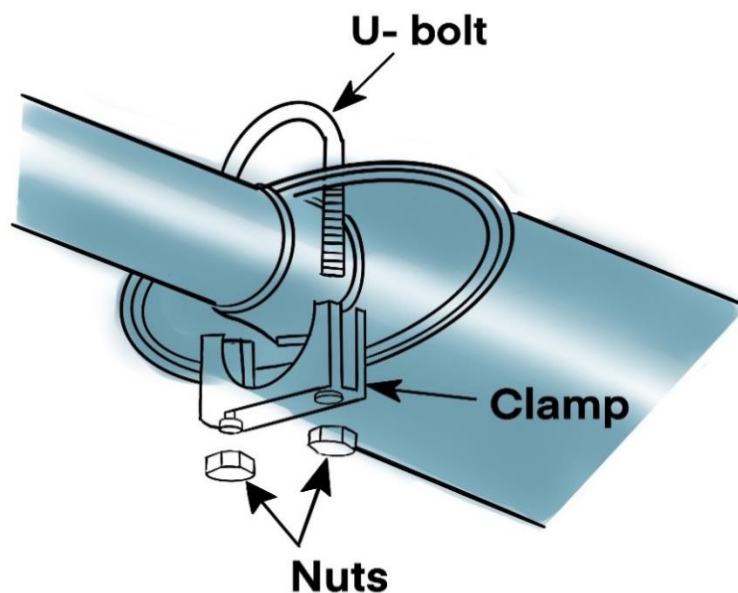
the exhaust system. These parts also help isolate exhaust noise by preventing its transfer through the frame (Figure 21) or body to the passenger compartment. Clamps help secure exhaust system parts to one another. The pipes are formed in such a way that one slips inside the other. This design makes a close fit.

A U-type clamp usually holds this connection

tight. Another important job of clamps and brackets is to hold pipes to the bottom of the vehicle.

Clamps and brackets must be designed to allow the exhaust system to vibrate without transferring the vibrations through the car.

Many different types of flexible hangers are available. Each is designed for a particular application. Some exhaust systems are supported by doughnut-shaped rubber rings between hooks on the exhaust component and on the frame or car body. Others are supported at the exhaust pipe and tailpipe connections by a combination of metal and reinforced fabric hanger. Both the doughnuts and the reinforced fabric allow the exhaust system to vibrate or move without breakage that could be caused by direct physical



connection to the vehicle's frame.

Some exhaust systems are a single unit in which the pieces are welded together by the factory. By welding instead of clamping the assembly together, car makers save the weight of overlapping joints as well as that of clamps.

Figure 15 U-clamp is often used to secure two pipes that slip together.



Activity 2: Guided Practice



Task 6:

1. Visit the school workshop analyse the vehicle parked on service bay then answer the following questions:
 - a. identify the exhaust system components of the vehicle
 - b. describe the exhaust system components of the vehicle



Activity 3: Application



Task 7:

1. Take a field visit on nearest garage then observe the vehicles in the garage then compile a report describing all the components of exhaust system you have observed by focusing on the:
 - a. Engine exhaust components,
 - b. Functions of engine exhaust system components,
 - c. Construction materials of engine exhaust system



Formative Assessment

1. What are the types of exhaust system due to exit pipe
2. Differentiate the type the exhaust system due to exit pipe
3. Explain the function of exhaust system
4. Explain the function of the following exhaust system components
 - a) Exhaust manifold
 - b) Exhaust pipe
 - c) Exhaust gasket
 - d) Catalytic converter
 - e) Muffler
 - f) Resonator
 - g) Tailpipe
 - h) Heat shields
 - i) Clamps, Brackets and Hangers
 - j) Exhaust gas oxygen sensors
5. Describe the construction materials of the following exhaust system components
 - a) Exhaust manifold
 - b) Exhaust pipe
 - c) Exhaust gasket
 - d) Catalytic converter

- e) Muffler
- f) Resonator
- g) Tailpipe
- h) Heat shields

6. Describe the operating principle of the following exhaust system components

- a) Exhaust manifold
- b) Catalytic converter
- c) Muffler



Points to Remember

- Single exhaust systems commonly feature a Y-pipe design, which gathers the exhaust gases from the manifold and channels them into a singular pipe.
- A single exhaust is lighter in weight and has a lower cost compared to other exhaust systems.
- High-performance exhaust systems are comparatively more expensive which is found doing a highly efficient job of filtering out the gasses.
- High performance dual exhaust system comes in different ways including dual exit pipe, opposite dual exhaust system and dual Side Exhaust
- A vehicle's exhaust system carries away gases from the passenger compartment, cleans the exhaust emissions, and muffles the sound of the engine. Its components include the exhaust manifold, exhaust pipe, catalytic converter, muffler, resonator, tailpipe, heat shields, clamps, brackets, and hangers.
- The exhaust manifold is a bank of pipes that collects the burned gases as they are expelled from the cylinders and directs them to the exhaust pipe. Exhaust manifolds for most vehicles are made of cast or nodular iron.
- The catalytic converter reduces HC, CO, and NOx emissions.
- The muffler consists of a series of baffles, chambers, tubes, and holes to break up, cancel out, and silence pressure pulsations.
- In four-stroke engines, restrictions in the exhaust can cause backpressure, especially at higher speeds. Excessive backpressure reduces performance and fuel economy.

- The oxygen sensor is an instrument for managing the exhaust emissions of petrol, diesel and gas engines.
- Heat shields are used to protect other parts from the heat of the exhaust system and the catalytic converter.
- Clamps, brackets, and hangers are used to properly join and support the various parts of the exhaust system.
- A resonator is designed to further reduce or change the sound level of the exhaust.
- The tailpipe is the last pipe in the exhaust system. It releases the exhaust fumes into the atmosphere beyond the back end of the car.



Self-Reflection

1. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.
 - a. There are no right or wrong ways to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?
 - c. Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.

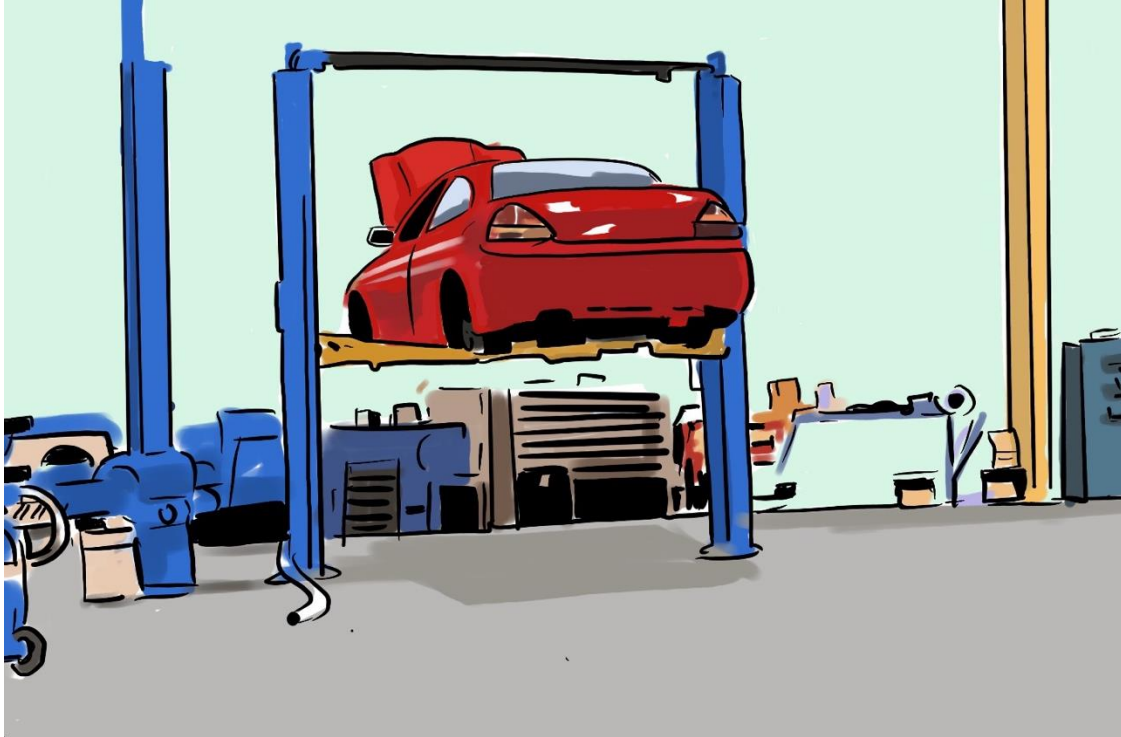
My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Identify different types of exhaust system according to exit pipes					
Identify all the components of exhaust system					
Explain the functions of all					

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
the components of exhaust system					
Describe the constructions materials of all the components of exhaust system					
Describe operating principle of all the components of exhaust system					

Fill in the table above and share results with the trainer for further guidance.

Areas of strength	Areas for improvement	Actions to be taken to improve
1.	1.	1.
2.	2.	2.

UNIT 2: PREPARE WORKPLACE



Unit summary:

This unit provides you with the knowledge, skills and attitudes to prepare workplace. It covers the identification of Safety precautions at workplace, Selection of personal protective equipment (PPE), Cleaning and arrangement of the workplace.

Self-Assessment: Unit 2

1. Study the unit illustration above and answer the following questions:
 - a. What do you see in the illustration?
 - b. What topics do you think will be covered under this unit based on the illustration?
2. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.
 - a. There are no right or wrong ways to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?
 - c. Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.
 - d. At the end of this unit, you will assess yourself again.

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Identify personal safety at workplace					
Describe the work area safety at workplace					
Describe the tools and equipment safety					
Classify personal protective equipment (PPE)					

My experience	I don't	I know	I have	I have a lot	I am
Knowledge, skills and attitudes	have any experience doing this.	a little about this.	some experience doing this.	of experience with this.	confident in my ability to do this.
Use of personal protective equipment (PPE)					
Identify types of cleaning method at workplace					
Describe the procedures for cleaning the workplace, tools and equipment					



Key Competencies:

Knowledge	Skills	Attitudes
1. Identify the safety precautions at workplace	1. Describe the Safety precautions at workplace	1. Pay attention to details while describing the procedures for cleaning the workplace, tools and equipment
2. Identify personal protective equipment (PPE)	2. Select personal protective equipment (PPE)	2. Demonstrate team spirit while working with others
3. Identify types of cleaning method at workplace	3. Describe the procedures for cleaning the workplace, tools and equipment	3. Pay attention to details while using personal protective equipment (PPE)
	4. Apply cleaning techniques	



- What do you see on the picture?
- Explain the personal protective equipment you see on the picture.
- In the picture below explain the types of hazards an employee must prevent at workplace.
- Describe the type of cleaning that person is performing in the picture. Are there others that are not shown on the picture?



-
- An illustration of various personal protective equipment (PPE) items. On the left, there is a blue and grey hood, a pair of yellow gloves, and two pairs of safety goggles. On the right, there are two earplugs and a pair of safety goggles.

2. Questions:

- a. Explain the personal protective equipment you see on the picture above.
- b. Explain the types of hazards in the workplace.
- c. Describe the personal safety, cleaning safety and work area safety.
- d. Describe safety tools and equipment.

3. Refer to the key facts 2.1a &b for further information

Key Facts 2.1a: Application of safety precautions at workplace

- **Safety precautions at workplace**

- ✓ **Introduction**

Working on vehicles in automotive repair shops requires safety measures. Everyone involved in such businesses needs to ensure that proper safety precautions are followed always for everyone's protection.

- ✓ **Personal, tools and equipment safety**

Safety measures protect workers and visitors from injuries. As accidents happen more frequently when someone slips on an oily floor, falling off ladders with tools clutched tightly by slippery fingers. Therefore, it is essential to know how to safeguard yourself and your co-workers and even customers because accidents happen.

- ✓ **Common injuries in automotive repair shops**

Auto mechanic work involves dangerous machinery, chemicals, and tools which put employees at a greater risk of accidents. These lead staff to lose their lives, level of productivity and incur higher medical costs. Below are some of the injuries in automotive shops.

- **Cuts and Burns**

In an automotive shop, chances are your job involves using tools and handling automobile parts. These are things that can be sharp or heavy enough to injure anyone if something goes wrong. A 2011 study published in Industrial Health found mechanics reporting cuts as the most common type of accident experienced in place of work. In addition, mechanics and other workers in the automotive industry are also injured due to falls or equipment tip-over, leading to severe cuts or burn accidents.

Trauma

Employees in automotive shops like mechanics are at risk of all sorts of injuries. For example, they need to lift heavy objects, leading to straining their muscles. In addition, they often work for hours with poor posture, which can lead to repetitive stress injury or cumulative trauma disorder such as muscle pulls, spinal and wrist injuries. Slips and trips could cause trauma even without falling, and they are common in the automotive workplace.

According to the BSL, in 2005, heavy lifting accounted for more than 50% of all overexertion injuries. Using advanced tools and utilizing proper techniques while performing any physical task could prevent such injuries. Unfortunately, some of these musculoskeletal injuries cannot always be avoided despite your best efforts.

Eye injuries

Eye injuries among auto mechanics are nothing new. However, studies have shown that most eye injuries occur with workers who aren't wearing safety equipment due to the unavailability of safety gear like goggles or inadequate training on how important they are to protect their eyes. As a result, every day in America alone, 1,000 people suffer from work-related eye injuries. In addition, the prevalence of workplace accidents involving an injured worker's eye is widespread.

Chemical burns

Mechanics and other technicians are faced with danger when they are overexposed to harmful chemicals and sharp tools. However, even with all the precautions in place, incidents sometimes still happen. Breathing in fumes or coming into contact are the two most common ways of exposure to harmful chemicals.

Similarly, auto mechanics are also exposed to these dangerous substances when the engine parts start to wear off, and they contain these chemicals. For instance, toxic chemical additives could be present in the oil.

Automotive gas is highly flammable, and if not handled properly, it could lead to severe burns if they come into contact with sparks, high temperatures of fire.

Loss of body parties

Working with power tools and equipment in an automotive workshop is dangerous. For example, the use of grinders, electric metal shears, etc., present the danger that you could lose a body part if not careful enough. Some of these injuries can be prevented by following practices to keep yourself safe while working:

- Make sure that all power cords are unplugged before moving any machine
- Wear grounding straps when using grinders both on your body and around loose clothing items like sleeves;
- Use only one hand at a time with electric shears, so you don't get caught by blades while cutting metal sheets, etc.; and finally
- Never push heavy objects without assistance from another individual.

Slips, Trips, and Falls

The auto garage is one of the most dangerous places to work. The constant presence of fluids and cables on the floor creates a slippery surface, leading to accidents such as slips, trips, or falls. In addition, some chemicals may be stored next to regular foot traffic in areas where they should not be stored.

Strains, Sprains

Working in the automotive repair shop can cause injuries like over-work oneself by lifting heavy objects or being forced to repeat tasks without breaks. If left untreated, the strains could lead to severe injuries for those working on vehicles all day long. Therefore, it is recommended to implement safe practices that will help reduce stress-type strain exposures like improper lifting techniques.

To be effective, safety guidelines should comprise the personal safety, safety of tools and equipment, and work area safety.

✓ **Prevention of common injuries**

Mechanics and employees in the automotive industry often conduct some of the most difficult and daunting tasks. They are tasked with some of the most challenging repairs that stretch them mentally, physically, and emotionally too.

Their jobs come with a significant risk of injuries with the thousands of metal hanging above them with sharp tools around. In addition, the repetitive nature of the operations can potentially be a source of risks to injury. However, safety precautions can be put in place to prevent some foreseeable incidents before they happen. For that reason, some injuries can be avoided by watching out and taking preventive measures. The following are some of the measures.

In electrical Hazard

In the event of an electrical shock, time is crucial. The severity and effects depend on several factors such as whether or not you are wet (because water conducts electricity), how much current was passed through your body, what pathway it took throughout, and how long, but most importantly- you need to do something fast.

To avoid any issues at hand, always make sure you have protection against these dangers.

- Always ensure all tools are cleared away before you start any work near the source of power like the motors or generators because they pose an increased risk.
- Children should be kept out of repair areas, especially when you're working.
- Always make sure you maintain good housekeeping practices by keeping floors clean.

Strain and Sprain

Strains and sprains are some of the most common injuries in automotive repair shops. You can help prevent or minimize these painful accidents by ensuring you have good physical fitness, maintaining a healthy weight, avoiding smoking or drinking too much alcohol (as this will lead to weariness), practicing proper posture while at work, or keeping alert. Always have an adequate sleep and rest when needed. As for workplace safety measures that contribute to an increased risk of injury, always know how equipment is designed and do not overload them.

Workers should be encouraged to take a few minutes in the morning for a warm-up exercise or a stretch and flex program as they will reduce sprains, tears, and strains.

Proper safety gear

Machines are a great way to automate tasks that would otherwise be very difficult for humans. However, even with the help of safety equipment, workers need to take care when operating machinery not to hurt themselves or others around them.

Workers need to wear personal safety equipment (PPE). Some standard PPE includes closed-toe shoes, helmets, gloves, and many others. These safety gears are available in many different varieties, depending on what you are doing. For instance, full wrap goggles can prevent debris from reaching your eyes while operating machinery. Similarly, cut-resistant gloves are suitable for those working with sharp tools or pointed edges that could potentially cause injury.

Machine Injuries

Many ways can be used to reduce the risk of workplace injuries when using work equipment or handling tools—by taking adequate steps. Employers have a responsibility to ensure the safety of the workplace for all employees. Therefore, they should take every action possible to protect their employees from injury.

Some of the appropriate measures to reduce machine injuries include the following:

- **Risk assessment** - Never invest in work equipment without first doing a thorough risk assessment. The process of assessing risks is crucial because knowing your liabilities can allow you to avoid accidents and injuries before they happen.
- **Getting rid of the hazards** - The best way to avoid injury when on the job is to plan and work around hazardous equipment. If this cannot be done, other forms of protecting yourself from injury should be considered.

Emergency response for workplace accidents

Businesses should always prepare in advance for disaster. This includes developing an emergency response plan that trains all employees on how to deal with potential workplace injuries during a crisis.

Occupational Safety and Health team/task force's emergency action plan should be designed to protect workers from workplace emergencies. It requires employers to make an assessment of the worst-case emergencies' probable at their facilities, such as fires

and explosions. Once a potential disaster has been identified, it can be mitigated by employees following predetermined procedures for dealing with that particular situation - an example would be evacuating after hearing a fire alarm.

A well-crafted emergency action plan can save your life. It should include the preferred



method of reporting an emergency, evacuation policy and escape routes, contact information for outside agencies and personnel to be contacted during a crisis or disaster scenario inside the facility.

Figure 16 different safety gears in automotive repair shop

✓ **Safety responsibility**

A careless attitude and poor work habits invite disaster. Shop/garage accidents can cause serious injury, temporary or permanent disability, and death. Safety is not a one time or an individual effort. It takes everyone working together to notice and report any hazards to the employer. Both the employer and the employees must work together to protect the health and welfare of all who work and walk in the shop.

Key Facts 2.1b:

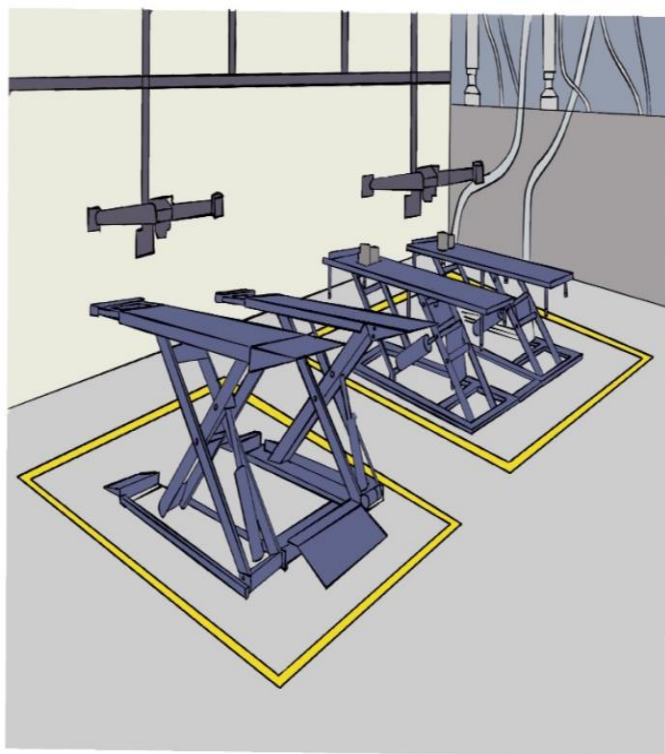
- **Work area safety**

✓ **Safety guidelines**

The work area should be kept clean and safe. These include but not limited to the following:

The floor and bench

The floor and bench tops should be kept clean, dry, and orderly. Any oil, coolant, or grease on the floor can make it slippery. Slips can result in serious injuries. To clean up oil, use a commercial oil absorbent. Keep water off the floor. Water is slippery on smooth floors, and electricity flows well through water. Aisles and walkways should be kept clean and wide enough to move through easily.



Make sure the work areas around machines are large enough to operate the machine safely.

Ventilation

Proper ventilation of space heaters, used in some shops, is necessary to reduce the CO levels in the shop. Also, proper ventilation is very important in areas where volatile solvents and chemicals are used. (A volatile liquid is one that vaporizes very quickly.) Keep an up-to-date list of emergency telephone numbers

clearly posted next to the telephone. These numbers should include a doctor, hospital, and fire and police departments.

First-Aid kit availability

Also, the work area should have a first-aid kit for treating minor injuries. There should also be eye flushing kits readily available. Gasoline is a highly flammable volatile liquid. Always keep gasoline or diesel fuel in an approved safety can, and never use it to clean your hands or tools. Oily rags should also be stored in an approved metal container. When these oily, greasy, or paint-soaked rags are left lying about or are not stored properly, they can cause spontaneous combustion.

Fire extinguishers and blanket availability

Car repair shops pose a range of fire risks, from flammable liquids to high tech equipment, plus a potentially combustible mix of dust, swarf and lubricants.

Therefore, the shops should always equip themselves with at least two different types of fire extinguisher. As spontaneous combustion results in a fire that starts by itself, without a match. Make sure that all drain covers are snugly in place.

Open drains or covers that are not flush to the floor can cause toe, ankle, and leg injuries. Know where the fire extinguishers are and what types of fires they put out.

A multipurpose dry chemical fire extinguisher will put out ordinary combustibles, flammable liquids, and electrical fires. Never put water on a gasoline fire. The water will just spread the fire. Use a fire extinguisher to smother the flames. Remember, during a fire, never open doors or windows unless it is absolutely necessary; the extra draft will only make the fire worse.

A good rule is to call the fire department first and then attempt to extinguish the fire. To extinguish a fire, stand 6–10 feet from the fire. Hold the extinguisher firmly in an upright position. Aim the nozzle at the base and use a side-to-side motion, sweeping the entire width of the fire. Stay low to avoid inhaling the smoke. If it gets too hot or too smoky, get out. Remember, never go back into a burning building for anything.

	Class of Fire	Typical Fuel Involved	Type of Extinguisher
Class  A Fires (green)	For Ordinary Combustibles Put out a Class A fire by lowering its temperature or by coating the burning combustibles	Wood Paper Cloth Rubber plastics Rubbish Upholstery	Water*1 Foam* Multipurpose dry chemical*
Class  B Fires (red)	For Flammable Liquids Put out a Class B fire by smothering it. Use an extinguisher that gives a blanketing, flame-interrupting effect, cover whole flaming liquid surface.	Gasoline Oil Grease Paint Lighter fluid	Foam* Carbon dioxide ² Halogenated agent ² Standard dry chemical ² Purple K dry chemical ² Multipurpose dry chemical*
Class  C Fires (blue)	For Electrical Equipment Put out a class C by shutting off power as quickly as possible and always using a nonconducting extinguisher agent to prevent electric shock	Motors Appliances Wiring Fuse boxes Switchboards	Carbon dioxide ² Halogenated agent ² Standard dry chemical ² Purple K dry chemical ² Multipurpose dry chemical*
Class  D Fires (yellow)	For Combustible Metals Put out class D fire of metal chips, turnings, or shavings by smothering or coating with a specially designed extinguishing agent.	Aluminium Magnesium Potassium Sodium Titanium Zirconium	Dry power extinguishers and agents only

Figure 17 Guide to fire extinguisher selection.



Figure 18 fire blanket.

Storage of tools and equipment

Properly store all parts and tools by putting them away in a place where people will not trip over them. This practice not only cuts down on injuries, but also reduces time wasted looking for a misplaced part or tool.

Use of warning signs

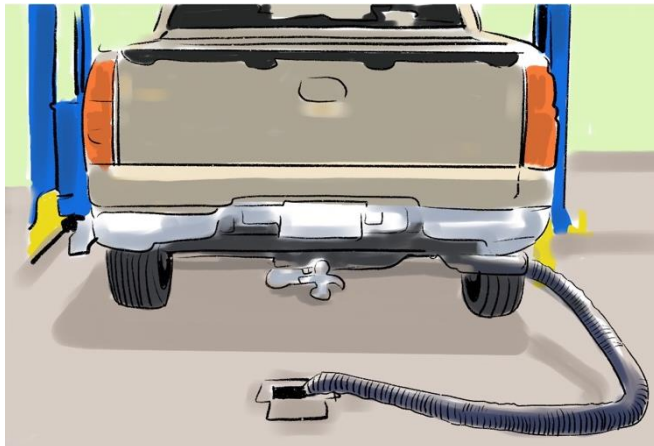
Always be familiar with evacuation routes and where to gather outside the building.

Always know the location of all safety equipment in the shop, and be familiar with the operation of this equipment.

Vehicle operation

If the engine must be running while working on the car, block the wheels to prevent the car from moving. Place the transmission into park for automatic transmissions or in neutral for manual transmissions. Set the emergency brake. Never stand directly in front

of or behind a running vehicle. Run the engine only in a well-ventilated area, to avoid the danger of poisonous carbon monoxide (CO) in the engine exhaust. If the shop is equipped



with an exhaust ventilation system (Figure 27), use it. If not, use a hose and direct the exhaust out of the building.

Figure 19 Exhaust vent hose to a tailpipe.



Activity 2: Guided Practice



Task 10:

1. Read the scenario below and perform the tasks related to it.

IPRC NGOMA has a mechanical workshop and is expecting the fall intake for short course candidates. You have been tasked to prepare the workshop by applying the safety precautions for the workplace.

- a. Ensure the work area is safe
 - b. Ensure the tools and equipment are safe
 - c. Ensure the personal safety is ready to be applied
 - d. Describe for the users how fire extinguishers are used in case of fire outbreak
2. Seek guidance from your trainer if needed.



Activity 3: Application



Task 11:

1. Visit auto repair shops neighbouring your school, participate in the application of safety precautions at the workplace.
2. Make a report on the safety measures put in place by focusing on the following:
 - a. Work area safety
 - b. Tools and equipment safety
 - c. Personal safety
 - d. Types of fire extinguishers at the place
 - e. Recommendations on what to improve for a safer environment.

Topic 2.2: Selection of Personal Protective Equipment (PPE)



Activity 1: Problem Solving



Task 12:

1. Analyse the picture below and answer the questions that follow:



Questions:

- a. What do you see on the picture?
- b. Name the types of PPE.
- c. Explain the functions of these PPE.
- d. Describe when and why to wear these

PPE.

Refer to the key facts 2.2 for further information

Key Facts 2.2: Selection of Personal Protective Equipment (PPE)

- **Selection and use of PPE**

- ✓ **Use of PPEs**

In auto repair business, employees are exposed to hazards such as falling, flying, abrasive and splashing objects, or are exposed to harmful dusts, fumes, mists, vapors, or gases, therefore they must be provided with personal protective equipment necessary to protect them from the hazard.

- ✓ **Selection**

The following considerations should be evaluated in the selection and use of PPE when working in the repair shop and using portable power tools. There are similarities in PPE used for hand and power tools however, there are also distinct differences.

- ✚ **Safety glasses or goggles** must be worn in order to protect the eyes from projectiles. A face-shield may be used in addition to safety glasses or goggles to provide additional protection. A face-shield will protect the face and neck from hot metal fragments created during such tasks as grinding;
- ✚ **Cut resistant gloves**, while capable of preventing lacerations due to hand tools, will not protect against blades and bits of power tools;
- ✚ **Safety shoes** should also be worn while working with power tools to prevent injury from dropped tools.
- ✚ **Ear protection** may be necessary due to the increased noise levels produced by power tools.
- ✚ **Respiratory protection** might be necessary when workers are exposed to dusts and fumes.

- ✓ **Function of PPEs**

Personal safety simply involves those precautions you take to protect yourself from injury. These include wearing protective gear, dressing for safety, and correctly handling tools and equipment.

▪ Safety goggles and face shields



Figure 20 (A) Safety goggles, (B) face shield, and (C) safety glasses.



Face and Eye Protection PPEs includes safety goggles and face shields and should be used for tasks that can cause eye damage or loss of vision, sprays of toxic liquids, splashes, and burns.

Eye Protection Your eyes can become infected or permanently damaged by many things in a shop.

Some repair procedures, such as grinding, result in tiny particles of metal and dust that are thrown off at very high speeds. These metal and dirt particles can easily get into your eyes, causing scratches or cuts on your eyeball.

They can also get into your lungs if you are not properly protected. Pressurized gases and liquids escaping a ruptured hose or fuel line fitting can spray a great distance.

If these chemicals get into your eye, they can cause blindness. Dirt and sharp bits of corroded metal can easily fall down into your eyes while you are working under a vehicle. Eye protection should be worn whenever you are exposed to these risks. To be safe, you should wear safety glasses whenever you are working in the shop. There are many types of eye protection available. To provide adequate eye protection, safety glasses have lenses made of safety glass.

If chemicals such as battery acid, fuel, or solvents get into your eyes, flush them continuously in an eyewash station or with sterile water from an eye wash bottle. Have someone call a doctor and get medical help immediately.

▪ **Safety overall**

PPE includes safety overall, vests and overcoat that can be used for tasks that can cause body injuries from extreme temperatures, flames and sparks, toxic chemicals, insect bites and radiation.

Your clothing should be well-fitted and comfortable and made with strong material. Loose, baggy clothing easily can get caught in moving parts and machinery. Cut-offs and short pants are not appropriate for shop work.

▪ **Safety boots**

PPE includes knee pads and safety boots and should be used for tasks that can cause serious foot and leg injuries from falling or rolling objects, hot substances, electrical hazards, and slippery surfaces.

Automotive work involves the handling of many heavy objects that can be accidentally dropped on your feet or toes. Always wear shoes made of leather or a similar material, or boots with nonslip soles. Steel-tipped safety shoes can give added protection for your feet. Sports sneakers, street shoes, and sandals are not appropriate in the shop.

▪ **Safety gloves**



PPE includes safety gloves and should be used for tasks that can cause hand and skin burns, absorption of harmful substances, cuts, fractures or amputations.

Good hand protection is often overlooked. A scrape, cut, or burn can limit your effectiveness at work for many days. A well-fitted pair of heavy work gloves should be worn during operations such as grinding and welding or when handling high-temperature components. Always wear approved rubber gloves when handling caustic chemicals. Caustic chemicals are strong and dangerous chemicals. They can easily burn your skin. Be very careful when handling this type of chemical.

Close-fitting surgical gloves that offer some protection from toxic chemicals such as engine oil, gasoline, brake fluid, and cleaning chemicals. It is important to remember that the skin is an organ and it absorbs some of the fluids that are placed on it. Close-fitting surgical gloves are very inexpensive, disposable, and come in different versions, such as latex, powdered, and nitrile.

There are thicker, padded gloves too, these gloves are a little bit thicker than the surgical gloves, but offer better protection to sharp or hot objects. Most of the higher-quality gloves of this type offer padded protection in high-wear areas, such as the palm and fingers. They are also very comfortable when you have to work on a very hot engine component and you cannot wait for it to cool down. It is a good practice to have many different types of gloves in your toolbox so you can switch to the one that fits the job.

- **Safety harnesses**

PPE includes safety harnesses and lanyards and should be strictly used for tasks that can cause falling from heights and serious injury or death.

- **Ear muffs**

PPE includes ear muffs and plugs and should be used for tasks that can cause hearing problems and loss of hearing. Exposure to very loud noise levels for extended periods of time can lead to a loss of hearing. Air wrenches, engines running under a load, and



vehicles running in enclosed areas can all generate annoying and harmful levels of noise. Simple ear plugs or earphone-type protectors should be worn in constantly noisy environments.

Figure 21 Ear muffs

- **Safety of long hair and hanging jewelry**

Long hair and loose, hanging jewelry can create the same type of hazard as loose-fitting clothing. They can become caught in moving engine parts and machinery. If you have long hair, tie it back or cover it with a cap. Never wear rings, watches, bracelets, or neck chains. These easily can get caught in moving parts and cause serious injury.

- **Face masks**



These PPE includes full-face respirators, self-contained breathing apparatus, gas masks, and surgical masks are used for a task that can cause inhalation of harmful materials to enter the

body. This includes harmful gas, chemicals, large-particle droplets, sprays, splashes, or

splatter that may contain viruses and bacteria such as COVID-19, viral infections, and more.

Technicians often work with chemicals that have toxic fumes. Air or respiratory masks should be worn whenever you will be exposed to toxic fumes. Cleaning parts with solvents and painting are the most common times when respiratory masks should be worn. Masks should also be worn when handling parts that contain asbestos or when handling hazardous materials.

- **Hard hat**

PPE includes hard hats and headgears and should be required for tasks that can cause any force or object falling to the head.

- ✓ **Importance of PPEs**

Here are some benefits of using PPEs:

- ✚ Prevent unnecessary injury in the workplace;
- ✚ Protect employees from excessive chemical exposure;
- ✚ Prevent the spread of germs and infectious diseases
- ✚ Help businesses comply with regulatory requirements
- ✚ Improve employee productivity and efficiency.

PPEs types	How to use them
✓ Face and Eye Protection	✚ Check if safety glasses comply with the eye protection standard. ✚ Ensure that there are no cracks or deformities on the lenses. ✚ Ensure the strap is in good working condition and is firmly sealed to the cheek and forehead. ✚ Clean and disinfect after use.
✓ Respiratory Protection	✚ Ensure that the equipment is fit-tested and the employee has undergone proper training before wearing one. ✚ Carefully read the instructions to determine if it is designed to help protect against the hazards you may face. ✚ Change filters on half-mask or full-mask respirators frequently.

	✚ Replace disposable respirators with every use. ✚ Surgical masks are not to be shared with anyone. ✚ Avoid touching the surgical mask after wearing it. ✚ Change surgical mask timely and should be disposed of after use. ✚ Replace the mask immediately if it is damaged or soiled.	
✓ Skin and Body Protection	These PPE includes the following categories to protect employees from physical hazards: head, body and hand protection. i. Head ✚ Ensure that there are no dents or deformities on the shell and connections are tightened inside. ✚ Do not store in direct sunlight as extreme heat can cause damage. ✚ Choose appropriate cleaning agents as it can weaken the shells of hard hats and may eliminate electrical resistance. ✚ Always replace a hard hat if it was used for any kind of impact, even if the damage is unnoticeable. ii. Body protection ✚ Ensure that they are clean and free from cuts and burns. ✚ Always get a good fit to ensure full body protection. ✚ Ensure bodysuit is heat-resistant clothing when working with high-temperature hazards. iii. Hand protection ✚ Ensure hand protection fits perfectly with no spaces and is free from cuts, burns and chemical residue. ✚ Always replace them if any sign of contamination was observed.	

	- Use rubber gloves when working with heat and electricity to reduce the risk of burn or electrical shock. iv. Foot Protection - Ensure boots have slip-resistant soles that can protect against compression and impact. - Ensure the sole plate is in good condition to prevent punctures. v. Fall Protection - Ensure that the straps are free from tears, deformities and burn marks. - Check the buckles if connected securely and tightly. - Dispose of the equipment if used after a falling incident.
✓ Hearing protection	- Ensure the equipment fit the ear canal perfectly. - It is recommended to use formable earplugs to fit on different sizes of ear canals. - Use protectors that reduce noise exposure to an acceptable level to have a room for communication. - Ensure earplugs are clean and in good condition.

Be familiar with the location of all safety equipment when you enter a new shop.



Activity 2: Guided Practice



Task 13:

- Discuss on the workshop hazards listed below and identify PPEs needed for it.
 - Slips, trips, and falls
 - Electrical
 - Fire
 - Working in confined spaces
 - Physical hazards (potential)
 - Chemical hazards
 - Biological hazards

- h. Asbestos
- i. Noise
- j. Lack of guards or screens on equipment or around dangerous areas.



Activity 3: Application



Task 14:

1. Visit Mr.MUHIRE's garage where there is a vehicle TOYOTA Carina-E for the exhaust system leaking repair. You as a mechanic for exhaust system repair, prepare needed PPEs for the interns and demonstrate how to use them properly.
2. Compile a report on what was done and how you have proceeded

Topic 2.3: Cleaning and Arrangement of the Workplace



Activity 1: Problem Solving



Task 15:

1. Analyse the picture below and answer the questions that follow:



Questions:

- a. What is happening in the picture aside?
- b. What types of cleaning method is this employee using?
- c. Explain the benefits of workplace cleaning and arrangement.

Key Facts 2.3: Cleaning and Arrangement of the Workplace

- **Cleaning and arrangement of the workplace**

- ✓ **The benefits of cleaning the workplace**

The following benefits will explain why cleanliness is important for workplaces:

- ✚ **Well-being:** Providing a clean work environment helps in maintaining the well-being of employees. In a workplace where litter and waste are disposed correctly and surfaces are cleaned regularly, employees take fewer days of sick leave, which results in improved overall productivity.
- ✚ **Productivity:** Provisions for a clean environment can increase the productivity of employees. Cleanliness can help drive motivation and boost the morale of employees thereby creating a feeling of belonging within their organization.
- ✚ **Impression:** A clean and tidy business space leaves a good impression on both its employees and its visitors.
- ✚ **Cost saving:** By maintaining good levels of cleanliness in the workplace, companies can save on cleaning costs and refurbishments, which may become necessary if the premises are not properly maintained.

- ✓ **Types of cleaning methods**

Several categories of automotive materials call for different cleaning methods, including water-soluble deposits (dirt), organic soils, scale, and rust. Cleaning methods include:

- ✚ **Wet cleaning or chemical cleaning:** with petroleum solvents or water based chemical solutions like Alkaline (base), and Acid.
- ✚ **Abrasive cleaning:** Materials to be cleaned by abrasive cleaning methods must be free of oil and grease, which can interfere with the proper operation of an abrasive cleaning machine. Following preclearing, two types of abrasive blasting are used for various cleaning applications. Shot is round and grit is sharp and angular. Several blast materials are used by rebuilders for cleaning parts. Steel shot and glass beads are used for automotive part cleaning when removal of the surface of the material being cleaned is not desired. Beads and shot come in various sizes,

depending on the application

 **Thermal cleaning:** Many rebuilders use thermal cleaning, a cleaning procedure in which a high-temperature pyrolytic oven cooks oil and grease, turning them to ash. The hard, dry deposit that remains on the part is removed by shot blasting or jet washing.

There are two types of thermal ovens: **convection** and **open flame**. A convection oven is a flameless, insulated oven that is heated by burners from the bottom. Parts are not exposed to flame and are warmed up gradually as the oven heats up. Gradually heating parts allows less chance of warpage. An open flame oven is like a rotisserie. Parts are mounted in a cage that avoids hot spots by slowly rotating the parts directly over a flame.

✓ **Procedures for cleaning workplace, tools and equipment**

 Shop Floors

Cleaning the floor of a repair shop is essential for maintaining a safe and organized work environment. The specific procedure may vary depending on the type of repair shop and the extent of dirt, grease, and debris present. However, here is a general procedure you can follow:

1. **Safety Precautions:** Before you start, ensure that all equipment is turned off, and any hazardous materials are properly stored. Wear appropriate personal protective equipment (PPE) such as safety glasses, gloves, and non-slip footwear.
2. **Clear the Area:** Remove all vehicles, equipment, tools, and obstacles from the floor area to be cleaned. This includes jacks, lifts, and any other machinery.
3. **Sweep and Dry Debris Removal:** Begin by sweeping the entire floor to remove loose dirt, dust, and debris. Use a stiff-bristle broom or a floor sweeper. Dispose of the collected debris in designated waste containers or trash bins.
4. **Grease and Oil Spill Cleanup:** For automotive repair shops or other similar establishments, you may encounter grease and oil spills. Use absorbent materials like oil-absorbent pads or granules to soak up these spills. After the spills are absorbed, properly dispose of the absorbent materials as hazardous waste, if applicable.
5. **Scrubbing:** Use a suitable floor cleaning solution, diluted according to the

manufacturer's recommendations. This solution may be a commercial floor cleaner or a mixture of water and mild detergent. Apply the cleaning solution to the floor and use a mop, scrub brush, or a floor scrubber machine to scrub the entire area. Pay extra attention to areas with heavy stains or grease buildup.

6. **Rinse:** After scrubbing, rinse the floor thoroughly with clean water to remove any remaining cleaning solution or residue.
7. **Drying:** Allow the floor to air dry or use a mop or squeegee to speed up the drying process. Ensure the floor is completely dry to prevent slip hazards.
8. **Inspect and Touch-up:** Inspect the floor for any remaining stains, marks, or areas that may need additional cleaning. Address any stubborn stains or spots with spot cleaning and scrubbing.
9. **Return Equipment:** Once the floor is clean and dry, return all equipment, tools, and vehicles to their designated locations.
10. **Regular Maintenance:** Implement a regular cleaning and maintenance schedule to prevent excessive buildup of dirt, grease, or debris. This will make future cleaning tasks easier and ensure a safer working environment. It's essential to follow any specific guidelines or regulations relevant to your industry or location, especially if you work in a specialized repair shop, as there may be additional safety and environmental requirements. Always use appropriate cleaning products and equipment for the type of flooring in your repair shop, whether it's concrete, tile, or another material.

Tools and Equipment

Cleaning tools and equipment in a repair shop is crucial for maintaining their functionality, longevity, and ensuring safety. Here's a general procedure for cleaning tools and equipment:

1. **Safety Precautions:** Before starting the cleaning process, ensure all power tools are turned off and unplugged. Wear appropriate personal protective equipment (PPE), such as gloves and safety glasses, to protect yourself from dirt, debris, and any chemicals used in the cleaning process.
2. **Gather Your Supplies:** Collect the necessary cleaning supplies, which may include: Soap or a mild detergent, Water, A bucket or sink, Brushes and

scrubbers, Solvents or degreasers (if needed), Lubricants (for certain tools), Rags or paper towels

3. **Disassembly:** If applicable, disassemble tools or equipment as per the manufacturer's instructions. This allows for a more thorough cleaning and inspection of individual components.
4. **Dry Cleaning:** Begin by removing loose dirt, dust, and debris from the tools and equipment. You can use a brush, air compressor, or a vacuum cleaner to help with this step.
5. **Wet Cleaning:** Fill a bucket or sink with warm water and add soap or a mild detergent. You may also use a suitable cleaning solvent for more stubborn residues. Immerse the tool or equipment in the soapy water or solvent and use a brush or scrubber to gently scrub away grease, dirt, and grime.

Pay special attention to areas with heavy buildup. For delicate or electronic equipment, use a damp cloth or sponge instead of immersing the item.

6. **Rinse:** Rinse the tools and equipment thoroughly with clean water to remove any soap or solvent residues. Ensure that all cleaning agents are completely washed away.
7. **Drying:** Allow the tools and equipment to air dry completely. You can use compressed air or a clean cloth to speed up the drying process. Ensure that all components are dry, as moisture can lead to corrosion.
8. **Reassembly:** If you disassembled any tools or equipment, reassemble them according to the manufacturer's instructions.
9. **Lubrication:** Some tools and equipment may require lubrication after cleaning to ensure they function properly. Apply appropriate lubricants as recommended in the user manual or by the manufacturer.
10. **Inspection:** Examine the tools and equipment for any signs of wear, damage, or malfunction. Address any issues before returning the items to service.
11. **Storage:** Store cleaned and inspected tools and equipment in a clean and dry environment. Use appropriate storage solutions, such as toolboxes, cabinets, or racks, to prevent dust and moisture buildup.

12. Regular Maintenance: Implement a regular maintenance schedule for cleaning and inspecting tools and equipment to prevent excessive wear and damage.

By following this procedure, you can ensure that your tools and equipment are clean, safe to use, and in good working condition, which is essential for any repair shop or workshop.

Waiting Areas & Restrooms

Staff can track dirt and debris into these spaces. Scouring surfaces and mopping floors keep bathrooms and waiting rooms clean and tidy.

Sanitize and clean restrooms

Both customers and employees need a clean bathroom, including plenty of soap, toilet paper, and paper towels. It is advisable to have extra supplies on hand, so you don't run out unexpectedly. Also, set up a daily reminder to sanitize and disinfect all surfaces.

Air fresheners are essential in public restrooms, they reduce any unpleasant odors and keep bathrooms smelling fresh.

Schedule deep cleanings

Daily cleaning is essential but does not remove all automotive fluid build-up from the floor and other spaces. Power steering fluids, antifreeze, and lubricants can make the shop floor an unsafe environment for employees and customers but it can also be unattractive. Schedule for a deep cleaning and stick to the plan.

Arrangement of workplace

A clean, organized facility is more pleasant for workers and could make jobs go quicker too. When workers can find what they need, they don't waste time looking.

Designate a storage for tools and equipment

It is integral for technicians to have a designated space to put tools when they are finished using them. When a shop has a home for each instrument, technicians can quickly find the necessary tools, and the shop looks organized. Likewise, when new order for automotive repair parts or supplies comes in, these should have a designated place for them to be stored.

Use approved storage for hazardous materials

Often overlooked area in auto repair shop is hazardous materials. This area should stay

clean and safe when approved storage containers are used with securely closed lids and a proper fit.

-  **Keep gas cylinders away** from sources of heat, such as a furnace or room heater. Check and service furnaces and water heaters in the shop at least once every six months.
-  **Store toxic materials** properly, solvents, chemicals, and other materials can contaminate clothing and wind up on the hands when you remove personal protective equipment or put away the refinishing tools.



Activity 2: Guided Practice



Task 16:

1. Visit the school automobile workshop and follow the procedures to clean workplace, tools and equipment.
2. Ask your trainer for clarifications



Activity 3: Application



Task 17:

1. Visit a nearby automobile repair shop, clean and arrange the workplace.
2. Compile a report on the tasks undertaken by elaborating on the following elements:
 - a. The importance of the cleanliness of the workplace.
 - b. The cleaning methods used by the staff in the shop.
 - c. The procedures followed to clean the work area, tools and equipment.
 - d. The workplace arrangement
 - e. The weakness and strength observed of the shop in the cleaning of the workplace



Formative Assessment

1. List five items that are personal protective equipment (PPE).
2. What are the types of fire extinguishers and their usage?
3. What are the items included in a first aid kit?
4. List five common automotive chemicals or products that may be considered hazardous materials.
5. List five precautions to which every technician should adhere when working with automotive products and chemicals.
6. Describe how to use fire extinguisher.
7. Discuss the good housekeeping precautions that should be followed in every repair shop.
8. Describe the types of cleaning methods in repair shop.
9. Explain why cleanliness is important for workplaces.
10. Discuss skin and body protection in repair shop.
11. What are the safety precautions to be applied in case of the hazardous situations below?
 - a. Batteries contain highly corrosive and potentially explosive acids.....
 - b. Fuels and cleaning solvents are flammable.....
 - c. Exhaust fumes are poisonous.....
 - d. During some repairs, technicians can be exposed to harmful dust particles and vapors.....
 - e. High voltage on some types of vehicles present shock and burn hazards.....



Points to Remember

- Automobile mechanics and technicians often suffer injuries due to their work environment, tools, lack of appropriate protection, and machinery. Frequently these exposures can lead to poor health or even death if not appropriately addressed.
- Cuts are the leading causes of injury among automobile repair workers, with improper postures and repetitive work and tool design seen playing a role.
- Dressing safely for work is very important. Wear snug-fitting clothing, eye and ear protection, protective gloves, steel-toed shoes, and caps to cover long hair.
- Safety while using any tool or equipment is essential, and even more when using power tools. Before plugging in a power tool, make sure the power switch is off.
- Use care whenever it is necessary to move a vehicle in the shop. Carelessness and playing around can lead to a damaged vehicle and serious injury.
- Always connect an exhaust hose to the tailpipe of any running vehicle to help prevent the buildup of carbon dioxide (CO) inside a closed garage space.



Self-Reflection

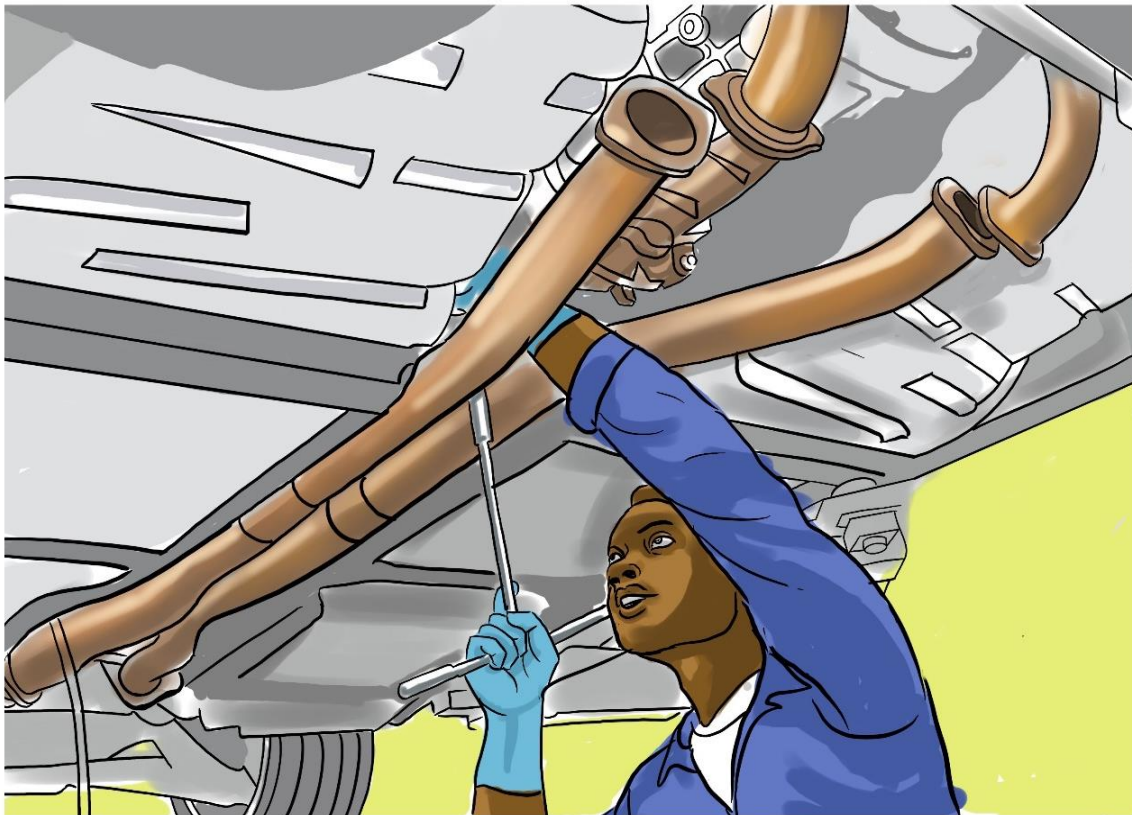
1. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.
 - a. There are no right or wrong ways to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?
 - c. Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Identify personal safety at workplace					
Describe the work area safety at workplace					
Describe the tools and equipment safety					
Classify personal protective equipment (PPE)					
Use of personal protective equipment (PPE)					
Identify types of cleaning method at workplace					
Describe the procedures for cleaning the workplace, tools and equipment					

Fill in the below table

Areas of strength	Areas for improvement	Actions to be taken to improve
1.	1.	1.
2.	2.	2.

UNIT 3: REPAIR ENGINE EXHAUST SYSTEM



Unit summary:

This unit provides you with the knowledge, skills and attitudes to repair engine exhaust system. It covers the selection of tools, materials and equipment, inspection of exhaust system components and correction of exhaust system damaged components.

Self-Assessment: Unit 3

1. Study the unit illustration above and answer the following questions.
 - a. What is happening on the illustration?
 - b. What topics do you think will be covered under this unit based on the illustration?
2. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.
 - a. There are no right or wrong ways to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?
 - c. Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.
 - d. At the end of this unit, you will assess yourself again.

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Select tools					
Select materials					
Select equipment					
Inspect exhaust system					
Correct exhaust system faults					
Test exhaust system					



Key Competencies:

Knowledge	Skills	Attitudes
1. Identify the tools, materials and equipment	1. Select the tools, materials and equipment	1. Pay attention to details while using the tools, materials and equipment
2. Identify exhaust system components faults	2. Use the tools, materials and equipment	2. Demonstrate team spirit while working with others
3. Identify exhaust system testing methods	3. Correct exhaust system faults	3. Be meticulous while repair exhaust system
4. Identify exhaust system repairing methods	4. Test exhaust system	4. Be careful while testing exhaust system
		5. Respect safety precautions at workplace while repairing the exhaust system
		6. Comply with safety rules related to the handling of tools and equipment



Discovery activity



Task 18:

1. Analyse the figure below and answer the following questions:

- What do you see on the picture below?
- Describe the steps you should follow to inspect exhaust system
- Explain the procedures of dismounting exhaust system.
- Describe the procedures of remounting exhaust system.
- Describe how to analyse exhaust system gases.



Topic 3.1: Selection of tools, materials and equipment.

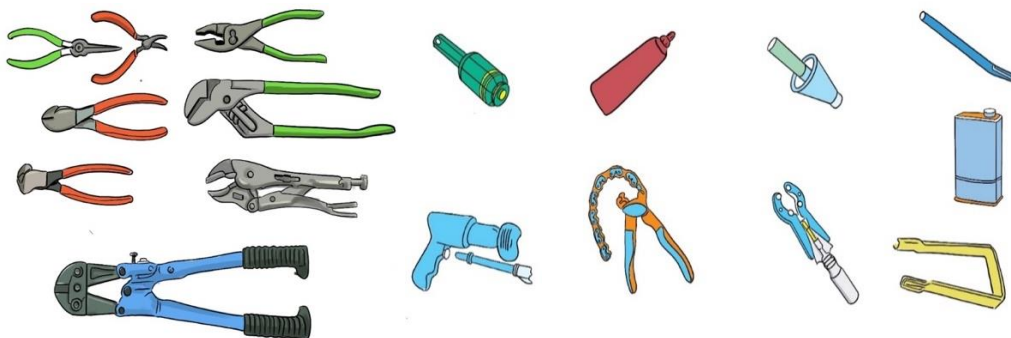


Activity 1: Problem Solving



Task 19:

1. Discuss on the pictures below and answer the questions that follow:



Questions:

- a. Name the tools you see on the pictures above and explain their use on exhaust system.
 - b. Name the materials you see on the pictures above and explain their use on exhaust system.
 - c. What is the function of a car lift?
 - d. What is the function of hydraulic jacks and jack stands?
 - e. Explain how to use an exhaust gas analyser.
2. Refer to the key facts for further information

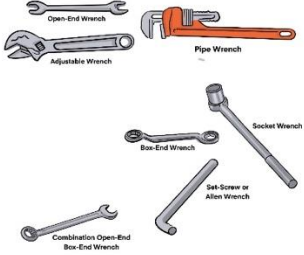
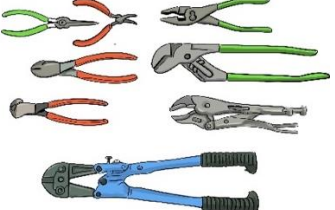
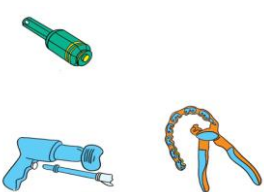
Key Facts 3.1a: Selection of tools, materials and equipment.

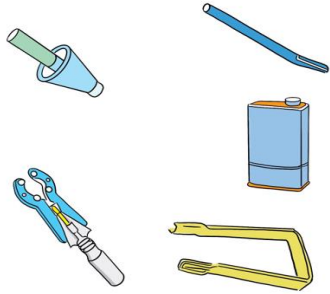
- **Selection of tools**

Exhaust system repair activities require a series of tools, materials and equipment to be performed. These are categorised as below.

✓ **Tools**

Type	Function
 Wrenches/ spanners	A wrench is a tool used for tightening or untightening or holding bolt heads or nuts

 Figure 22 Wrenches/ spanners	
 Screwdrivers  Figure 23 Screwdrivers	Screw drivers are used to tighten and untighten screws. Common screwdriver bits include slotted, Phillips, Pozidriv, Torx, square, star, security or tamper-proof bits, and hex or Allen bits.
 Pliers  Figure 24 Pliers	Pliers are gripping tools used for working with wires, clips, and pins.
 Hammers  Figure 25 Hammers	Hammers are identified by the material and weight of the head. There are two groups of hammer heads: steel and soft faced
 Special tool required for exhaust system work  Figure 26 air chisel, expander and chain pipe cutter	The exhaust pipe expander is designed to quickly and easily straighten clamp dents and clamp marks in mufflers and tail pipes, and stretch pipe openings or fix damaged pipe ends. Air chisel is a power tool that uses compressed air exclusively. The tool is used to carve, drill, or chip away at stone, metal, and other hard materials.

 Figure 27 Muffler cutter, shaper, pipe cutter and hanger removal tool	Shaper is used to reshapes exhaust pipes bent or flared out by placing big end over pipe. Muffler cutter is designed for cutting thin-walled steel and copper tubing. suitable for cutting exhaust pipe with diameters from 20-75mm. Chain pipe cutter and pipe cutter are designed for cutting exhaust pipes Hanger removal tool is used to separate the rubber bracket from the exhaust hanger bracket.
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Key Facts 3.1 b: Selection of tools, materials and equipment

- Selection of materials used to repair exhaust system

✓ Penetrating oil

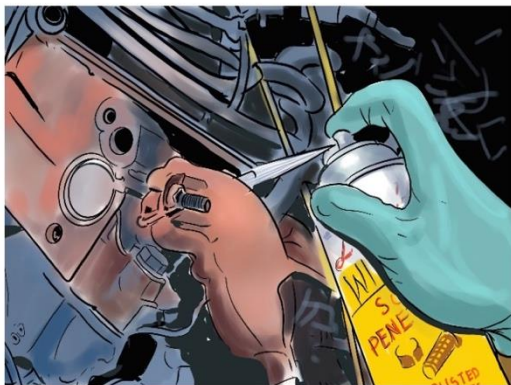


Figure 28 Penetrating oil

Before attempting to disassemble the exhaust system, spray all nuts and bolts with penetrating oil

✓ Exhaust gaskets

An **exhaust manifold gasket** seals the connection between the **manifold** and cylinder

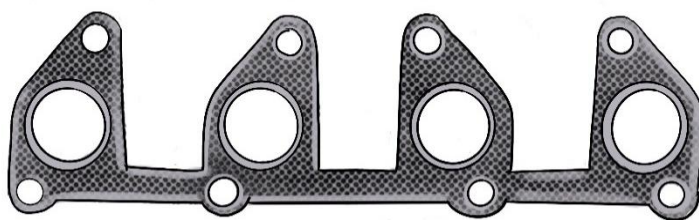


Figure 29 exhaust manifold gasket

head. This prevents **exhaust** leakage out of the connection and also ensures that all **exhaust** gas will flow through the catalytic converter for treatment.



Figure 30 Sealant

✓ Sealant

It is a heat resistant paste that is used to seal gaps, smooth seams or seal pipe connections within an exhaust system reassembly or repair. The paste is resistant to temperatures up to 850°F with negligible, if any shrinkage.

✓ Sand papers



Figure 31 Sand paper and glass paper

Sand paper and **glass paper** are names used for a type of coated abrasive that consists of Sheets of paper or cloth with abrasive material glued to one face. Are used for sanding exhaust pipe in abrasive cleaning.

✓ Grinding discs and Cutting discs

Cutting-off and grinding wheels are made from abrasive grains bonded together with resins and fillers and reinforced with fiberglass.



Figure 32 Grinding discs



Figure 33 Cutting discs

✓ Welding electrodes



An electrode is used to establish and maintain the electric arc during welding.

✓ **Catalytic converter cleaner**

Protects the catalytic converter from clogging with soot. Cleans intake valves and the combustion chamber. Improves the combustion of the fuel. Clean engines reduce fuel consumption and therefore CO2 emissions. Prevents corrosion in the fuel system.



✓ **Anti-seize**



Products are applied to bolts, fasteners, flanges and other clamped interfaces to prevent galling, seizing and corrosion, as well as lubricating to ease disassembly.

✓ **Epoxy adhesives**



Are commonly used to **bond** steel, to reinforce plates or carbon laminates and to strengthen beams and columns. ¹

✓ **Exhaust tape:** are used to seal exhaust pipe



✓ **Exhaust clamp**

If the hole or damage is not extensive enough, you can cover it using an exhaust clamp.



✓ **Aluminum patch**



You can use an Aluminum patch to cover holes of any size.

If you wrap the patch all around the pipe, secure it on both ends with hose clamps.

¹ <https://hpplunds.com.au/storage-in-a-snap-with-nine-new-boxes-3-4-3-2-2-2/>

Key Facts 3.1.c: Selection of tools, materials and equipment

- **Selection of equipment**

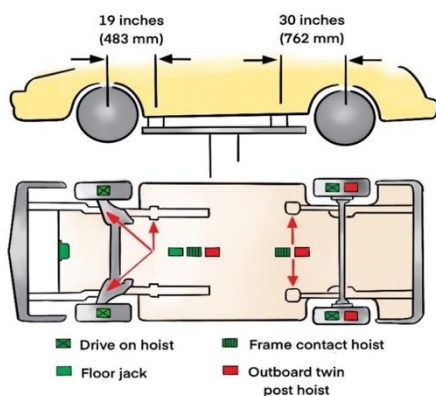
- ✓ **Air compressor**

Serious injury or property damage may result from careless operation of compressed air equipment. Follow these guidelines when working with compressed air:

- ✚ Wear safety glasses or a face shield when using pneumatic tools and other compressed air equipment.
- ✚ Wear ear protection when using compressed air equipment.
- ✚ Always maintain air hoses and fittings in good condition.
- ✚ Do not direct compressed air against the skin.
- ✚ Do not use an air gun to blow off clothing or hair.
- ✚ Do not clean the workbench or floor with compressed air.
- ✚ Never spin bearings with compressed air, because the bearing will rotate at an extremely high speed.
- ✚ All pneumatic tools must be operated according to the manufacturer's recommended operating procedure.
- ✚ Follow the equipment manufacturer's recommended maintenance schedule for all compressed air equipment.

- ✓ **Car lift**

A lift is used to raise a vehicle so a technician can work under the vehicle. The lift arms must be placed under the car at the manufacturer's recommended lift points. Twin posts are used on some lifts, whereas other lifts have a single post. Some lifts have an electric motor that drives a hydraulic pump to create fluid pressure and force the lift upward.

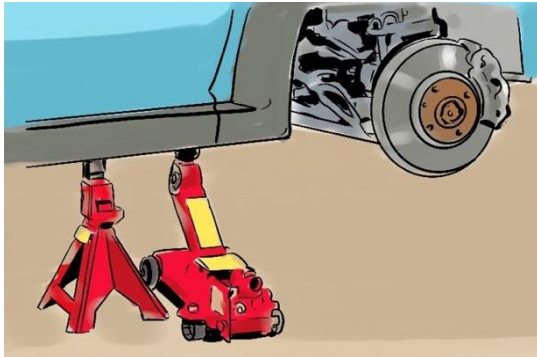


Other lifts use air pressure from the shop air supply to force the lift upward. If shop air pressure is used for this purpose, the air pressure is applied to fluid in the lift cylinder.

A control lever or switch is placed near the lift. The control lever supplies shop air pressure to the lift cylinder, and the switch turns on the lift pump motor.

Always make sure that the safety lock is engaged after the lift is raised. When the safety lock is released, a lever can be operated to slowly lower the vehicle.

✓ **Jack and jack stands**



A floor jack is a portable hydraulic lifting device that is used to lift part of a vehicle off the ground. Jack stands are used to support raised vehicles. Jack stands are also called safety stands.

Figure 34 floor Jack and jack stands

WARNING Never use a jack by itself to support a vehicle. Always use a jack stand with a jack, and make sure that the jack stands are properly positioned under the vehicle. Jack stands must always be positioned on a concrete floor, not on dirt or in gravel.

Accidents involving the use of floor jacks and jack stands may be avoided if these safety precautions are followed:

- ✚ Never work under a vehicle unless jack stands are placed securely under the vehicle chassis and the vehicle is resting on these stands.
- ✚ Prior to lifting a vehicle with a floor jack, be sure that the jack lift pad is positioned securely under a recommended lift point on the vehicle. Lifting the front end of a vehicle with the jack placed under a radiator support may cause severe damage to the radiator and support.
- ✚ Position the jack stands under a strong chassis member such as the frame or axle housing. The jack stands must contact the vehicle manufacturer's recommended lift points.
- ✚ Since the floor jack is on wheels, the vehicle and jack tend to move as the vehicle is lowered from a floor jack onto jack stands. Always be sure the jack stands remain under the chassis member during this operation, and be sure the jack stands do not tip. All the jack stand legs must remain in contact with the shop floor.

✓ Exhaust pipe stands



✓ An angle grinder



An angle grinder, also known as a side grinder or disc grinder, is a handheld power tool used for grinding (abrasive cutting) and polishing.

✓ Digital multimeter



A **digital multimeter** is a test tool used to measure two or more electrical values—principally voltage (volts), current (amps) and resistance (ohms).

✓ Digital pyrometer



Pyrometer is a device for measuring relatively high temperatures.

✓ Scan tool



The tool communicates with the vehicle's onboard computer and retrieves the DTC codes. The codes are then interpreted by the mechanic or technician to determine the specific problem with the vehicle.

✓ Exhaust gas analyzer

Before getting into how to use a gas analyzer, you must first know the various functions of a gas analyzer in everyday life. Generally, industries involving gas will use this tool for

testing. Some of the functions of a gas analyzer include:

- ✚ Helps adjust the air and fuel mixture appropriately.
- ✚ Knowing the effectiveness of the fuel combustion process in the engine. You do this by analyzing the content of hydrocarbons (HC) and carbon monoxide (CO) contained in the flue gas.
- ✚ Get certainty the performance of the vehicle engine used, whether in prime condition or not.
- ✚ Emission tests to save vehicle fuel, maintain optimal engine power, and create a healthy environment with clean air.
- ✚ Knowing the damage to the engine of the vehicle.
- ✚ Measuring the level of vehicle exhaust emissions.

✓ **Tips to use a gas analyzer**

After you know the functions and working principles, now go to the section on how to use a gas analyzer. The procedure is as follows:

- ✚ Insert the probe hose into the INLET section.
- ✚ Plug in the power cord and connect it to a power source. After that, press the ON button on the power to start turning on.
- ✚ Wait for the tool to sound and the AFR section to display the TEST on the display. When 6 displays show changing numbers, wait until the numbers on the AFR display show the number 0.
- ✚ While waiting, you can start the vehicle and gas until the speed becomes 2000 rpm for 1-2 minutes.
- ✚ When the AFR has shown the number 0, then how to use the gas analyzer can be started. Connect the probe hose to the probe, then insert the probe into the exhaust of the vehicle to be tested.
- ✚ Press MEAS / ENT and wait for the number on the display to stabilize.
- ✚ When the number is stable, press the Hold Print button twice.



- ✚ Enter the vehicle police number as the identity of the vehicle to be tested on the flashing O2 display.
- ✚ Print the measurement results by pressing the Hold Print button once.
- ✚ Calibrate the device by pressing the ESC / Stand by button.

✓ **Welding equipment**



✚ **Arc Welding:** Electric welding is called arc welding. It is inexpensive and fast but usually requires a 220-volt electrical hookup (which some shops do not have). A ground (negative) clamp is connected to the piece to be welded. A welding rod attached to the positive clamp is “struck” against the

workpiece in a motion similar to striking a match. The resulting electric arc melts the metal when electrons flow across the arc between the positive and negative electrodes.

✚ **Oxyacetylene Welding:** Gas welding is called oxyacetylene welding, or torch welding. Gas welding has an advantage over arc welding in that it is more versatile. Gas welding equipment can be used to cut and heat metals.

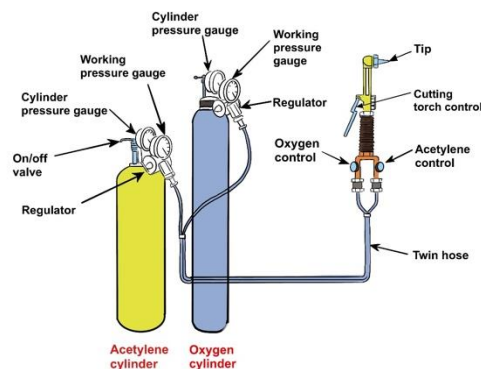


Figure 35 oxyacetylene gas welding and cutting equipment

✚ **Bench vices:**

Every shop should have a bench vices for various mechanical activities. Some vices have pivoting bases that allow them to be turned on the bench. The jaws of automotive vices usually have teeth.

A set of brass jaw caps is a good investment to prevent the vice from leaving marks on the workpiece.

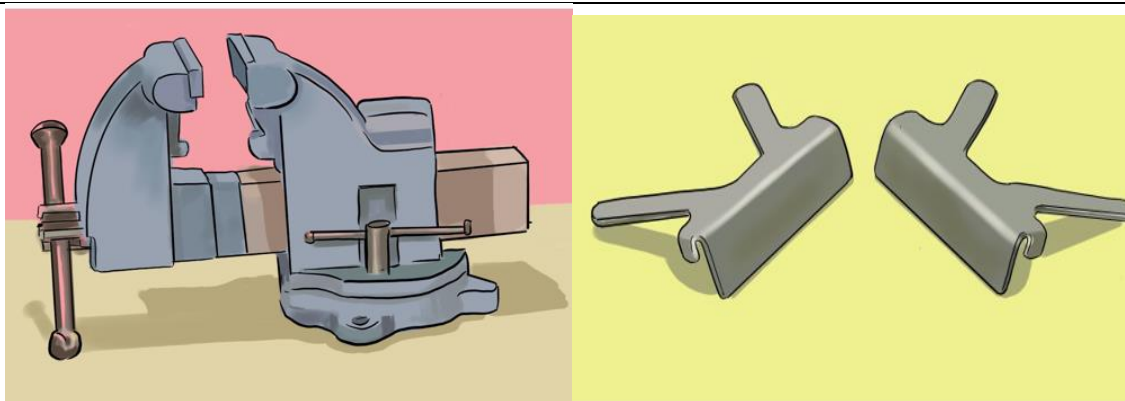


Figure 36 A bench vice with pivoting base and soft jaw caps.

Bench drilling machine



The drilling machine is a large, bench stationary machine used to drill parts that are clamped to the press table using various clamping methods.

Air tools:

- Impact Wrenches
- Air Ratchet
- Air Chisel
- Air Drill
- Air-Powered Grinder

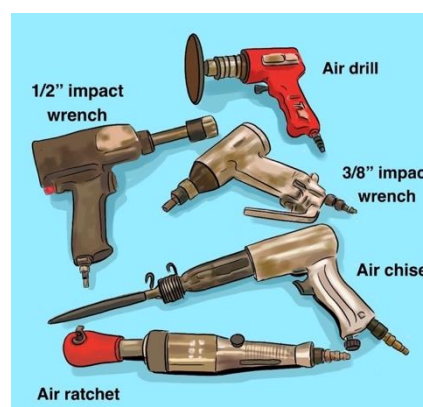


Figure 37 Miscellaneous air tools.

Battery-operated drill motors:



Figure 38 Battery-operated drill motor

Battery-operated tools, especially drill motors, are popular in shops.



Activity 2: Guided Practice



Task 20:

1. Visit your school automobile workshop and perform the following task, under the guidance of the trainer
 - a. Select the tools and equipment used for exhaust system repair.
 - b. Differentiate tools from equipment selected.
 - c. Select the materials used for exhaust system repair
 - d. Apply maintenance techniques to the selected tools and equipment.
2. For any challenge, please ask help from your trainer.
3. Refer to the Key facts 3.1d for clarification

Key Facts 3.1d:

- **Maintenance of tools and equipment**

Tools and equipment suffer a lot of wear and tear; it is important therefore to maintain them regularly to increase the service life as well as the performance of the equipment. Preventive maintenance helps to reduce unwanted expenses related to broken or faulty equipment as minor faulty generally leads to bigger issues if left unattended.

- ✓ **Tools and equipment maintenance techniques**

- 🔧 **Cleaning:** Cleaning the tools regularly is essential to their proper functioning. After a day of work, your tools will be covered with some amount of dirt.

- 🔧 **Lubrication:** Lubricating tools & equipment helps them to perform better and reduces wear and tear of components.

- 🔧 **Regular inspection:** Regularly inspect your tools and equipment for signs of damage and faulty functioning. Inspections should take place at the end of each construction job. Ensure that you repair them immediately if there is any damage. This will avoid any last-minute hassle.

- 🔧 **Careful storing:** Storing tools and equipment properly is of prime

importance. Although they are designed for rough use, it is important to store them properly.

Before storing tools and equipment, use a clean rag to wipe them dry so that the metal surfaces do not get corroded. Inspect all parts of the tools for fragments, breaks and cracks. Ensure that there are no signs of corrosion in the metal parts.



Activity 3: Application



Task 21:

1. Visit a nearby automobile repair shop, or school storing room, select from their store tools and equipment used to repair exhaust system.
2. Make a report on the types of tools and equipment found at the shop as well as the maintenance techniques used to keep them safe.
 - a. Identify tools and equipment found at the automobile repair shop.
 - b. Differentiate tools from equipment
 - c. Describe how the tools and equipment are maintained at the site.

Topic 3.2: Inspection of exhaust system components faults



Activity 1: Problem Solving



Task 22:

1. Analyse the picture below and answer the following questions:



- a. What do you see on the picture?
- b. Describe exhaust system visual inspection
- c. Explain how to inspect a

restricted exhaust system

- d. Describe how to inspect a leaking exhaust system
- e. Describe how to test a catalytic converter using a digital pyrometer

Refer to the key facts 3.2 for further information

Key Facts 3.2: Inspection of exhaust system components faults

- **Inspection of exhaust system components**

When a vehicle has an exhaust system concern, be sure to do a thorough examination of the entire exhaust system before beginning the repair. Looking for signs of premature failure throughout the exhaust system ensures that all necessary repairs are completed rather than just the problem that initially brought the customer into your shop. From looking for leaks to inspecting the catalytic converter, learn the steps involved with examining the exhaust system.

This can be done both physical and chemical. Any physical damage to an exhaust system part that causes a partially restricted or blocked exhaust system usually results in loss of power or backfire up through the throttle plate(s). In addition to improper engine operation, a blocked or restricted exhaust system causes increased noise and air pollution.

- ✓ **Exhaust System Inspection steps**

Step 1: Look for exhaust leaks

Leaks can be visible or audible. Look under the vehicle for leaks that you can see. Pay attention to the following areas:

- ✚ **Welds** – Look for breaks, cracks or corrosion.
- ✚ **Pipe connections** – Check for improper alignment or burned gaskets.
- ✚ **Clamp connections** – Ensure there are no leaks.
- ✚ **Flex pipe** – A common area for failure, make sure there are no leaks.

To check for audible leaks, take the vehicle for a test drive and listen for any unusual sounds coming from the exhaust system. While you are still testing the car, have the opportunity to check for the smell of exhaust gases in the cabin of the vehicle.

Step 2 – Check for damaged parts

Check the hangers and isolators for wear, and look for any loose, damaged or missing

parts.

Step 3 – check for blockages

Check for blockages in the exhaust system by performing an engine vacuum or backpressure test.

Step 4 – Inspect the catalytic converter

Examine the catalytic converter. Before replacing the catalytic converter, be sure to:

- ✚ Retrieve and repair all PCM trouble codes.
- ✚ Check for any technical service bulletins (TSB) or any updates on the PCM.

Step 5 – Check fuel control

Make sure the vehicle is in proper fuel control and is at operating temperature and that it is in closed loop. Next, check oxygen sensors. Under normal operating conditions, the front oxygen sensor should be around 450MV and the rear sensor should be between 650MV and 850MV.

✓ Inspection for noise

Any exhaust system inspection should include listening for hissing or rumbling that would result from a leak in the system. An on-lift inspection should pinpoint any of the following types of damage:

- ✚ Holes, road damage, separated connections, and bulging muffler seams
- ✚ Kinks and dents
- ✚ Discoloration, rust, soft corroded metal, and so forth
- ✚ Torn, broken, or missing hangers and clamps
- ✚ Loose tailpipes or other components
- ✚ Bluish or brownish catalytic converter shell, which indicates overheating

✓ Catalytic Converter Testing

 **Using scan tool:** The shell of a catalytic converter can become damaged like any other part of the exhaust system and require replacement as shown below. The converter can also be damaged internally and fail to perform as designed. A converter can fail to reduce emissions adequately. On an OBD II vehicle, the malfunction indicator light (MIL) will illuminate and a diagnostic trouble code (DTC) will be stored if the catalytic converter is not functioning properly.

If the MIL is flashing during engine operation, it is a warning that if the vehicle continues to operate in that condition, catalytic converter damage may occur. A flashing

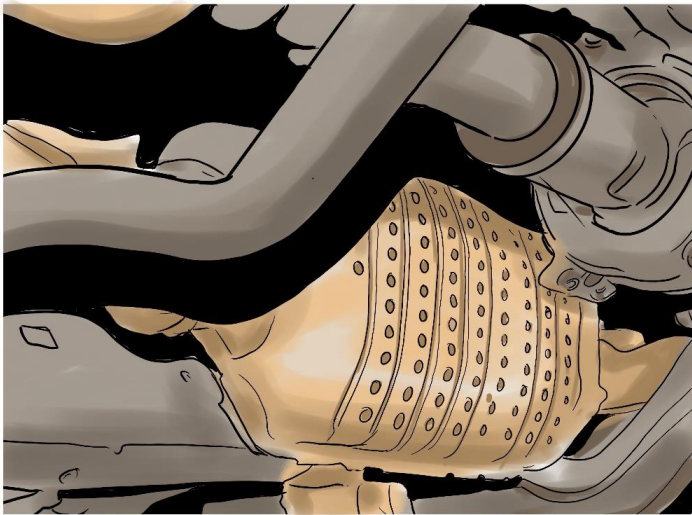


Figure 38 Catalytic Converter Testing

MIL, usually caused by a severe misfire, will set a DTC or continuing of misfires. The DTC will usually be P0420, low catalyst efficiency. The on-board diagnostic (OBD) system checks the efficiency of the catalytic converter by comparing the signals from the pre- and post-catalytic converter oxygen sensors. When the OBD system has

determined that the catalyst is no longer at least 60 percent efficient, it must be replaced.

Using a digital pyrometer



On an older vehicle, you can test if the catalytic converter is functioning by using a digital pyrometer. Be sure the vehicle is thoroughly warmed up before testing.

Measure the temperature of the pipe going into the converter and the temperature of the pipe coming out. The outlet pipe should be at least 1008 8 F (37.7 C) hotter than the inlet pipe if the converter is working. If the outlet temperature is the same or lower, nothing is happening inside the converter.

✓ Inspection of a restricted exhaust system

A common source of drivability problems related to the catalytic converter is a restricted exhaust. The catalytic converter can often become partially or fully blocked, particularly after it has been overheated by extended periods of misfire or rich running. When this happens, the engine will lose power. It will accelerate slowly and have a hard time reaching higher speeds. In severe cases, the engine may stall or fail to start. If you suspect a restricted exhaust, give a light tap to the converter and to the muffler. Rattling in either component indicates internal damage that may be causing a restriction. There are several ways to test for a restricted exhaust:

✚ Vacuum test

Place a vacuum gauge on an intake manifold vacuum port, and watch the gauge while you rev the engine to 2,500 rpm. Hold the rpm up for a couple of minutes, and monitor the



Figure 39 a vacuum gauge to test the exhaust system

gauge. If the vacuum falls, the exhaust is restricted. The vacuum falls because the high volume of air trying to pass through the exhaust starts to back up in the system and leaves residual pressure in the cylinder on the intake stroke. This reduces engine vacuum and power.

✚ Backpressure gauge to test the exhaust system.



Figure 40 Backpressure gauge to test the exhaust system

Install the gauge into the exhaust ahead of the converter. The gauge will typically read from 0 psi to 10 psi in half-psi increments. Often the gauge has an adapter that screws into the front oxygen sensor port.

Other setups may require that you drill or punch a small hole in the front exhaust pipe

and screw the gauge in. Always seal that hole before returning the vehicle to the customer. With the gauge installed, check the pressure at idle, 2,500 rpm, and under a hard, quick snap of the throttle. The pressure at idle should be near 0 psi, and it should stay below 1.5 psi at 2,500 rpm. During a snap of the throttle, the pressure should not exceed 4 psi. If the pressure is too high, remove the converter, and inspect it for damage. It is more common for a converter to fail than a muffler, but you may also have to remove and check the muffler or mufflers. Always consult the service manual for specific testing procedures on each vehicle.

Table 1. Exhaust System Symptom Chart	
Condition	Possible Causes
Rattle, squeaks, or buzzing	▪ Loose or damaged heat shield ▪ Loose or damaged exhaust isolators or isolator hanger brackets ▪ Loose or damaged catalytic converter or muffler ▪ Exhaust contacting the chassis
Droning or clunking	▪ Loose or damaged exhaust isolators ▪ Exhaust contacting the chassis
Whistling, humming, or ticking noise that tends to change as the engine warms	▪ Broken, loose, or missing exhaust manifold fasteners or gaskets ▪ Loose heated oxygen or catalyst monitor sensor ▪ Exhaust system leak
High-frequency hissing or rushing noise	▪ Exhaust system leak
Pinging noise that occurs when the exhaust system is hot and the engine is turned off	▪ Cool-down pinging is normal. It is caused by the exhaust system expanding and contracting during heating and cooling.
Vibration at idle and at low speeds; may be accompanied by clunking or buzzing	▪ Loose or damage exhaust isolators or isolator hanger brackets ▪ Exhaust damper broken or out of position ▪ Exhaust contacting the chassis
Vehicle has low or no power	▪ Exhaust pipe pinched or crushed ▪ Damaged catalytic converter ▪ Loose obstruction in the exhaust system ▪ Restricted exhaust (possibly ice in the

	muffler or tailpipe)
Burning smell	- Foreign material in the exhaust system - Missing heat shields
Sulfur or rotten egg smell from exhaust	- Rich fuel conditions - Misfire conditions - Excessive sulfur content in fuel
Visible rust on the surface of the exhaust pipes	If there are no perforations, the condition is normal.

Most parts of the exhaust system, particularly the front pipe, muffler, and tailpipe, are subject to rust, corrosion, and cracking. Broken or loose clamps and hangers can allow parts to separate or hit the road as the car moves. Some newer diesel engines use a different type of exhaust system that is essential to its emissions system. This is known as an after-treatment system. This type of exhaust uses a diesel particulate filter that captures soot to incinerate it during regeneration cycles.

The engine computer uses a strategy to spray a fine mist of diesel exhaust fluid (DEF) in the exhaust during certain periods. This helps clean up the exhaust emissions and burn the soot in the filter. This reduces the black smoke typically found in the exhaust of a diesel engine.

Warning

- If the engine has been running, exhaust system components may be extremely hot! Wear protective gloves when working on these components, and keep flammable objects away from hot areas.
- Exhaust gas contains poisonous carbon monoxide (CO) gas. This gas can cause illness and death by asphyxiation. Exhaust system leaks are dangerous for customers and technicians.



Activity 2: Guided Practice



Task 23:

Visit the school workshop and inspect the exhaust system of a vehicle that has high-frequency hissing or rushing noise. You as a mechanic inspect the components faults and pinpoint the root cause of the problem.



Activity 3: Application



Task 24:

1. Visit garage in the school neighborhood where Mr.MUGENZI brought his Mercedes Benz C 200 in garage for repair the exhaust system which has low or no power. You as a mechanic, , are requested to inspect a restricted exhaust system for faults.
2. Compile the report showing what to be done.

Topic 3.3: Correction of exhaust system damaged components



Activity 1: Problem Solving



Task 25:

1. Analyse the picture below and answer the questions that follow:



Questions:

- a. What do you see on the picture aside?
- b. Explain how to dismount exhaust system.
- c. Explain how to remount exhaust system.

- d. Explain how to clean exhaust system catalytic converter.
- e. Explain how to replace exhaust system muffler.
- f. Explain how to test exhaust system for leakage, noise and vibration.

Key Facts 3.3.a: Correction of exhaust system damaged components

- **Correction of exhaust system damaged components**

Correction of damaged components can be done in two different ways: Trouble shoot the faults or replace the damaged component by a new one.

- ✓ **Dismounting procedures of exhaust system**

Step 1: Prepare the workplace

Park on a flat surface: Ensure the vehicle is located on a flat surface and turned off

Before beginning work on an exhaust system, make sure it is cool to the touch. Disconnect the battery's negative cable before starting to work to avoid short-circuiting the electrical system. Soak all rusted bolts, nuts, and other removable parts with good penetrating oil.

Step 2: Let the exhaust system cool if you've used your vehicle recently.

Exhaust fumes can get extremely hot while you're driving, which can cause the pipes to heat up and cause burns. If you've driven your vehicle before you want to install the new system, put it in park, turn off the ignition, and allow the engine and pipes to cool down. Leave the vehicle alone for about 1 hour until you can comfortably handle the exhaust pipes.

- ✚ Do not touch the exhaust pipes immediately after running your vehicle since they will be extremely hot.

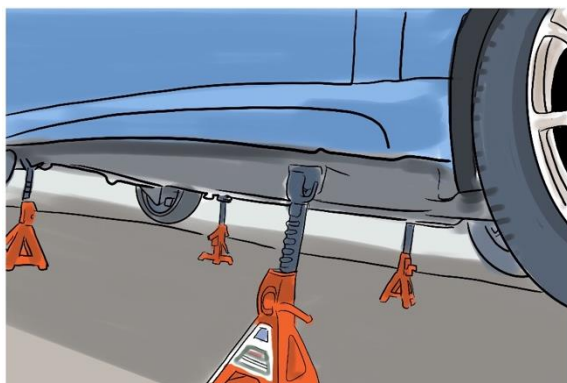
- ✚ You can try spraying the exhaust system with lukewarm water to help cool it down faster.

Step 3: Raise your vehicle so you can work underneath it using a jack or car lift.

Park your vehicle on a flat, level surface so it's less likely to roll or move while you're working. Place the jack so the arm that raises up underneath the frame at the front or back of the vehicle. Pull the handle of the jack down to lift the vehicle off of the ground high enough so you can get underneath it.

- ✚ Avoid using a scissor jack when you raise your vehicle since they aren't as

reliable and they could easily slip.



✚ You can also drive your vehicle onto ramps to lift it off of the ground. If you use ramps, be sure to put heavy blocks behind your tires so they're less likely to roll.

✚ Position all four jack points under the vehicle.

Figure 41 Raise your vehicle using a jack and jack stands.

Step 4: Place jack stands near each tire to keep the vehicle from moving around.

Jack stands have sturdy bases and are less likely to slip than when you're using a jack. Position the jack stands underneath the vehicle's frame or lift points in front of or behind the tires. Slowly lower your jack so the body of your vehicle sits on the jack stands.

- ✚ You can buy jack stands from an automotive supply shop.
- ✚ Don't get underneath your vehicle until you have jack stands firmly in place, or else the vehicle could fall on top of you.

Step 5: Disconnect the oxygen sensors from underneath your vehicle.

The oxygen sensors are small metal pieces attached to wires that connect into the sides of the exhaust pipe. Place a wrench around the bolt connecting the sensor to the pipe and rotate it counterclockwise until it's loose. Pull the oxygen sensor straight out from the pipe before unplugging it from the wires connecting to your vehicle.

- ✚ Your vehicle will usually have 1–2 Oxygen sensors connected to the exhaust, but it may vary between make and model.
- ✚ Vehicles only have oxygen sensors if they have a catalytic converter. If your vehicle is from 1974 or prior, then the exhaust may not have oxygen sensors.
- ✚ Lie on a rolling creeper trolley to move around under your vehicle more easily. You can buy a creeper trolley from an automotive supply store.
- ✚ Wear clothes that you don't mind getting dirty as well as disposable gloves so you don't get too greasy.
- ✚ Make sure you don't touch the oxygen sensor when the car is hot or the engine and the exhaust are hot, since it is attached to the exhaust pipe or to the muffler pipe.

- ✚ Most manufacturers of oxygen sensors now provide anti-seizing or corrosion lubricant that should be applied to the new oxygen sensor when being installed. This is to prevent seizing from occurring.

Step 6: Spray the nuts along the exhaust pipe with penetrating fluid.



Penetrating fluid works between the bolt and nut threads to add lubrication and make it easier to unscrew the system. Point the spout of the penetrating fluid directly at the nuts connecting the exhaust pipe to the downpipe attached to your engine. Make sure to coat all of the threads evenly to make the job easier.

Figure 42 Spray the nuts along the exhaust pipe with penetrating fluid.

- ✚ You can buy penetrating fluid from your local hardware or automotive care store.
- ✚ If you don't have any penetrating fluid, it may be difficult to remove your exhaust system on your own.
- ✚ If your exhaust system is made up of multiple pieces, then look for bolts where the pieces connect to one another. Spray those with your penetrating fluid as well so you can remove each of the pieces separately.

Step 7: Unscrew the nuts with a ratchet.

Start where your exhaust pipe connects to the engine at the front of your vehicle. Choose a ratchet bit that matches the size of the nuts holding the exhaust system to your vehicle. Place the end of the ratchet over the nut you're loosening and turn it counterclockwise. Apply firm pressure as you rotate the nut since it may be stuck or locked in tightly. Continue unscrewing the rest of the nuts if the pieces of your exhaust system are held together by other bolts or clamps.

- ✚ Use a ratchet with a long handle so you can get more leverage while you're disconnecting the old exhaust system.

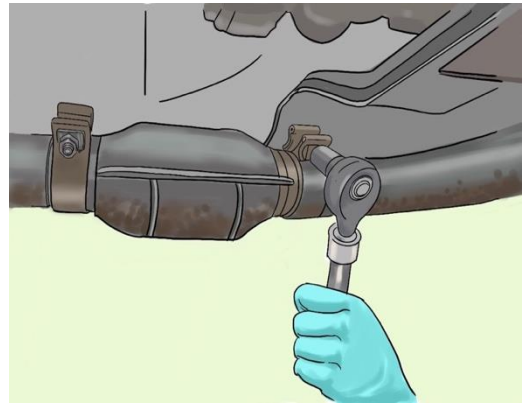


Figure 43 Unscrew the nuts with a ratchet

Step 8: Unhook the pipes from the rubber exhaust hangers.

Look near the top of the pipe along its entire length to find the metal pins that extend up and into rubber rings on your vehicle's body. Support the exhaust pipe with your non-dominant hand as you slide the metal pin out from the rubber. Slowly and carefully take the other pins off so the exhaust system comes loose from the body of your vehicle.

- ✚ If you have trouble pulling the metal pins off of the rings, try lubricating them with soapy water to help them slide out more easily.
- ✚ Don't let the exhaust pipe drop since it could be heavy and it may hurt you or damage other components under your vehicle.

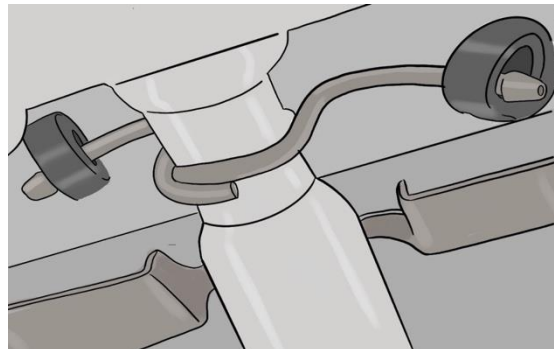


Figure 44 Unhook the pipes from the rubber exhaust hangers.

Step 9: Pull the exhaust system down from your vehicle.

Slowly take the exhaust system from the catalytic converter to the tailpipe and lower it to the ground. Carefully remove the system out from underneath the vehicle so it's out of the way while you're working. You can either throw the old exhaust system away or you can try to sell the parts if they're in usable condition.

- ✚ Do not drive your vehicle while you have the exhaust system removed since it may be illegal in your area and you will release harmful fumes.

Tip: If the exhaust pipe bends over your rear axle, it may be difficult to pull out in 1 piece.

Instead, you can cut through the pipe at the top of the bend with a hacksaw or reciprocating saw with a metal-cutting blade. Remove the pieces of the exhaust system separately.

Key Facts 3.3.b Correction of exhaust system damaged components

- **Replacement of exhaust system damaged components**

- ✓ Replacing exhaust system components before beginning work on an exhaust system, make sure it is cool to the touch.
- ✓ Some technicians disconnect the battery's negative cable before starting to work to avoid short-circuiting the electrical system.
- ✓ Soak all rusted bolts, nuts, and other removable parts with a good penetrating oil, and give plenty of time for the oil to sit on the bolts.
- ✓ Finally, check the system for critical clearance points, so they can be maintained when new components are installed.

Most exhaust work involves the replacement of parts. When replacing exhaust parts, make sure the new parts are exact replacements for the original parts. Doing this will ensure proper fit and alignment, as well as ensure acceptable noise levels. Exhaust system component replacement might require the use of special tools. Many technicians will use oxyacetylene torches to heat or cut exhaust connections and components. With practice, it is possible to cut a leaky pipe off of a good one without damaging the good pipe. This process is often faster than trying to use an air chisel or muffler cutter to remove a bad pipe. You can also use torches to apply heat. Heating the outer pipe of a connection will usually cause the metal to expand enough to allow you to pull the pipes apart. Similarly, heating rusty nuts in the exhaust system will greatly help removal.

✓ Exhaust manifold replacement

As mentioned, the manifold itself rarely causes any problems. On occasion, an exhaust manifold will warp because of excess heat. A straightedge and feeler gauge can be used to check the machined surface of the manifold. Another problem, also the result of high temperatures generated by the engine, is a cracked manifold. This usually occurs after the car passes through a large puddle and cold-water splashes on the manifold's hot surface. If the manifold is warped beyond manufacturer's specifications or is cracked, it must be replaced. Also, check the exhaust pipe for signs of collapse. If there is damage, repair it. These repairs should be done as directed in the vehicle's service manual.

Step 1: Let engine cool off

Before you do anything to the exhaust manifold, let your engine cool down

Step 2: Jack up the car in order to get under your vehicle in order to access the exhaust outflow pipe.

Step 3: Locate the exhaust manifold

Step 4: Disconnect the exhaust manifold

Now the exhaust manifold is exposed, you should have sufficient room to detach this part from the engine block. It will be held in place by a number of bolts that sit on either side of each outlet, which ensure that the manifold is held flush against the engine block. When all of these are removed gently pull the manifold out of its position.

Step 5: Remove exhaust pipe

Get under the car and now disconnect the exhaust pipe from the manifold. This is held in position by two bolts and a hanger. When these are removed you should be able to slide the exhaust pipe out of the engine, leaving the manifold free to be completely removed from the car.

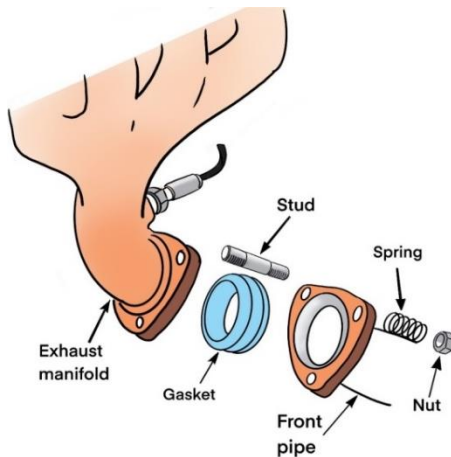
Step 6: Remove the old gasket

Remove the old gasket. This is a piece of rubber that's used to keep the gap sealed between the engine block and the manifold. There may be pieces of the old gasket stuck in place on the engine block, which will have to be carefully removed with a flat knife, attacking the pieces from underneath to lift them off the block.

Step 7: Replace the Gasket and Exhaust Pipe

Next fit the new gasket into position around the bolt holes on the engine block. This should simply slip into place. Now reattach the exhaust outflow pipe to the manifold in preparation to ready the new part for connection with engine block.

Step 8: Connect the Exhaust Manifold



You should now be able to place the manifold on top of the gasket. Wiggle this part into place and loosely place the bolts in their holes to keep the manifold in the correct holes to ensure the part is held in position. When you are satisfied this is the case tighten all the bolts until the manifold is held flush against the engine. Finally take the car off the jack stands.

Figure 45 Connect the Exhaust Manifold

When you have completed the reattachment work the easiest way of checking that everything has been fitted correctly is to simply run the engine. If there are any problems with the installation of the exhaust manifold you will see gasses escaping from the engine and there may also be a noise associated with this leak. Locate the leak and tighten the fixings around this accordingly to solve any problems.

✓ Replace the exhaust muffler

Step 1: Let engine Cool Off

Before you do anything to the exhaust manifold, let your engine cool down

Step 2: Prepare your vehicle

Before you commence with the replacement work, you'll need to jack up the car on a hard, dry and level surface or use a car lift to lift it. Jack up the rear of the vehicle and put a jack stand on each side of the car to support its weight. This will allow you access to the exhaust muffler.

Step 3: Locate the exhaust muffler

Using a backboard, slide under the car and look for the exhaust back box. This will usually be found in between your vehicle's catalytic converter and the rear axle. Once you are aware of the position of the silencer, spray some lubricant on the fixing nuts. As these are

under the car the chances are they will be partially rusted or affected by dirt, making them difficult to detach.

Step 4: Remove the exhaust muffler

Use a spanner or a deep socket to now start working on the fixing bolts that hold the exhaust muffler to the car. These may take a considerable amount of effort and energy, and if you're having trouble try using more lubricant and then waiting for it to take effect. When you have detached the bolts, use the saw to cut away the exhaust pipes immediately in front and behind the silencer. Finally remove the hanger that holds the silencer in place.

Step 5: Attach the exhaust pipes

Carefully smooth the ends of the exhaust pipe and split them slightly to allow them to slip into place on the muffler. Next slide clamps up both ends of the pipe, and apply a liberal touch of sealant. You should now be able to slip the silencer onto the ends of the exhaust pipe and move the clamps into place.

Step 6: Bolt the exhaust muffler to the car

Now that both exhaust pipes are attached to the muffler, use the hanger to reattach the part to the car. Take the original bolts and use the spanner or socket set to tighten them in place and finally make sure that the clamps are fully tightened around the in and out vents on the silencer. Once you are satisfied with their placing, take the car off the jack stands. As with all mechanical work, once you have replaced the back box, you'll want to go out on a short test drive. If the exhaust is still making an undue amount of noise, then go back and check the seals and the fixings on the muffler to make sure these are held properly in place.

✓ Replace leaking gasket and Seal

The most likely spot to find leaking gaskets and seals is between the exhaust manifold and the exhaust pipe. To replace an exhaust manifold gasket, follow the torque sequence in reverse to loosen each bolt. Repeat the process to remove the bolts. Doing this minimizes the chance that components will warp.

✓ Replace exhaust flange gasket procedures

Step 1 - Locate the Bolts. Jack up your car, secure with jack-stands, and roll under it.

Step 2 - Loosen the Bolts. Once you have located the bolts, you will need to loosen all of them.

Step 3 - Loosen the Exhaust Flange Gasket.

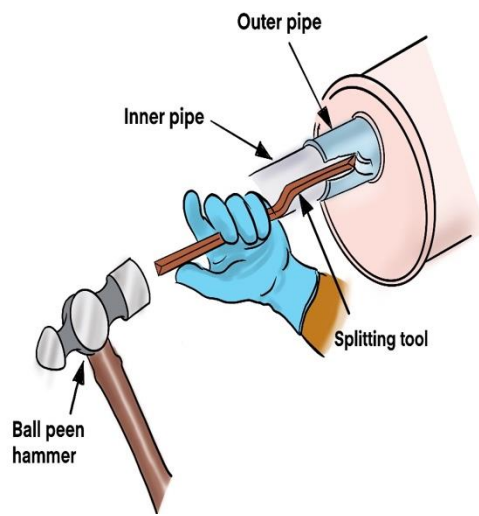
Step 4 - Remove the Exhaust Flange Gasket.

Place the gasket between the flanges. On most flange connections, there's a small piece of pipe protruding on the inside of the flange to place the gasket on, depending on the type of application. Some front pipe gaskets are called "donut" gaskets and fit into a ball-flared exhaust pipe.

✓ **To replace a damaged front pipe**

-  Begin by supporting the converter to keep it from falling.
-  Carefully remove the oxygen sensor if there is one.
-  Remove any hangers or clamps holding the exhaust pipe to the frame.
-  Unbolt the flange holding the exhaust pipe to the exhaust manifold.
-  When removing the exhaust pipe, check to see if there is a gasket.
-  If so, discard it and replace it with a new one. Once the joint has been taken apart, the gasket loses its effectiveness.
-  Disconnect the pipe from the converter, and pull the front exhaust pipe loose and remove it. Although most exhaust systems use flanges or a slip joint and clamps to fasten the pipe to the muffler, a few use a welded connection.
-  If the vehicle's system is welded, cut the pipe at the joint with a hacksaw, angle grinder, oxyacetylene gas welding equipment or pipe cutter.
-  The new pipe doesn't need to be welded to the muffler. An adapter, available with the pipe, can be used instead. When measuring the length for the new pipe, allow at least 2 inches (50.8 mm) for the adapter to enter the muffler.

- ✚ When trying to replace a part in the exhaust system, you may run into parts that are rusted together. This is especially a problem when a pipe slips into another pipe or the muffler.



- ✚ If you are trying to reuse one of the parts, you should carefully use a cold chisel or splitting tool on the outer pipe of the rusted union.

- ✚ You must be careful when doing this, because you can easily damage the inner pipe. It must be perfectly round to form a seal with a new pipe.

- ✚ Slide the new pipe over the old.

- ✚ Position the rest of the exhaust system so that all clearances are evident and the parts aligned, then put a U-clamp over the new outer pipe to secure the connection.



Activity 2: Guided Practice



Task: 26

Follow the procedures below in key fact 3.3.c and perform the senario below with your trainer.

Mr. NDABAGA brought his vehicle MITSUBISHI 2023 Mirage in school garage for repair the vehicle which loosing power. After inspection garage foreman found that the catalytic converter is partialy blocked. He assigns you as a mechanic for exhaust system repair to clean that catalytic converter.

Key Facts 3.3.c Correction of exhaust system damaged components

- Repairing of clogged exhaust system
 - ✓ Symptoms of clogged exhaust system
 - ✚ **Reduced Engine Performance:** One of the primary symptoms of a clogged

exhaust is a noticeable reduction in engine performance. The engine may struggle to generate power, resulting in sluggish acceleration and overall poor vehicle performance.

✚ **Decreased Fuel Efficiency:** A clogged exhaust can cause the engine to work harder, leading to increased fuel consumption. Drivers may notice a significant drop in fuel efficiency, and the vehicle may require more fuel to cover the same distance.

✚ **Engine Misfires or Difficulty starting your engine:** The increased back pressure caused by a clogged exhaust can contribute to engine misfires or difficulty starting your engine. This occurs when the air-fuel mixture in the engine's cylinders does not ignite properly, leading to a rough running engine.

✚ **Unusual Engine Sounds:** A clogged exhaust may produce unusual sounds from the engine, such as hissing, popping, or rattling noises. These noises can indicate that exhaust gases are not flowing smoothly through the system.

✚ **Vibrations and shaking:** As the exhaust system becomes more restricted, it can cause the vehicle to vibrate or shake, especially during acceleration. This vibration may be felt throughout the car and could indicate a clog in the exhaust.

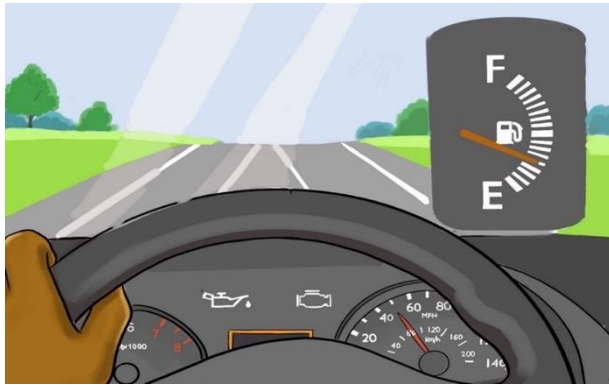
✚ **Overheating:** A clogged exhaust system can cause the engine to overheat. The increased back pressure prevents the proper cooling of the engine, leading to higher temperatures and potential damage to engine components.

✚ **Strange Smells:** A clogged exhaust can result in a buildup of exhaust gases inside the engine compartment. This can lead to unusual odors, such as a burning smell, which may be an indication of overheating.

✚ **Dashboard Warning Lights:** In some cases, a clogged exhaust can trigger the vehicle's onboard diagnostics system to illuminate the check engine light. This light may indicate a problem with the exhaust system, and a diagnostic scan can provide more specific information.

✓ **Unclogging catalytic converter without removing**

Step 1: Drive until your gas tank is ¼-full: Cleaners work more effectively when you have



less fuel in your tank, so drive for a little while if you recently filled up. Once your tank has about 4 gallons (15 L) or drops to ¼-full on the gas gauge, then you're ready to unclog your catalytic converter. Alternatively, drain your gas tank with siphon until it's only ¼-full.

Step 2: Pour catalytic converter cleaner into your gas tank: Get a bottle of catalytic converter cleaner made for the type of fuel your vehicle uses. Check the instructions on the cleaner to find out how much to add to your tank. Unscrew the gas cap on your vehicle, and stick the bottle inside to pour in the cleaner. Once you add the proper amount, take the bottle out and screw your gas cap back on.

✚ Put a funnel in the gas tank nozzle and pour the cleaner through it to prevent spills.



✚ While they're generally safe, many vehicle manufacturers don't recommend using catalytic converter cleaners since they could potentially damage the internal components.

Step 3: Drive the vehicle for about 15 minutes: Start the vehicle and drive it around on either city streets or highways. Spend at least 15 minutes driving so the catalytic converter warms up enough for the cleaner to pass through it.

✚ As you drive, the cleaner will move through your engine and into your catalytic converter to break apart clogs.

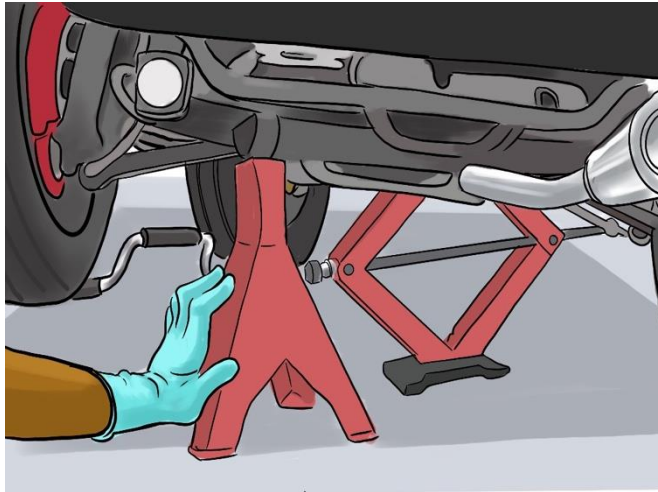
Step 4: Fill up your gas tank as you normally would: Once your tank is near empty, visit the gas station and fill up with the fuel grade recommended in your vehicle's manual. Now that the cleaner worked through your catalytic converter, your vehicle should run properly again.

✚ Use a cleaner every 5,000 miles (8,000 km) to maintain the converter.

- ✚ If your vehicle still has issues or the check engine light is on after using cleaner, try removing the converter to get rid of the clog.

✓ **Taking the Converter off for Cleaning**

Step 1: Jack up your vehicle on jack stands: Wait for about 30 minutes after you drive for

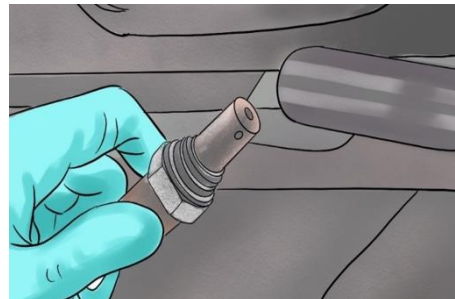


your vehicle to cool down. Then, find the flat jack point along the car's frame in front of or behind the tires.

Place a jack against the frame and raise your vehicle. Position jack stands under the frame and lower your vehicle back down.

Then, repeat the process on the other side of your vehicle.

Step 2: Remove the Oxygen sensor from your exhaust line: Get under your vehicle and look along the main exhaust line for an Oxygen sensor, which looks like a black cylindrical spark plug connected to wires. Spray penetrating oil on the bolt holding the oxygen sensor in place and use a socket wrench to remove it from your exhaust line.

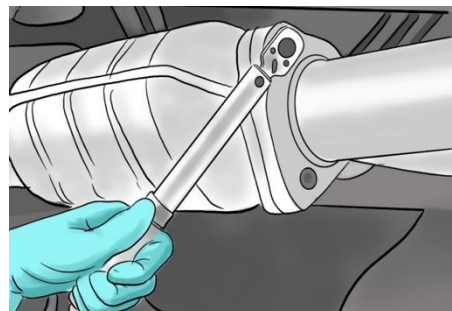


- ✚ If the Oxygen sensor looks dirty when you disconnect it, clean it off by soaking it in gasoline.

Step 3: Loosen the bolts to remove your catalytic converter: Your catalytic converter looks like a rectangular box near the middle of your exhaust system. Spray the bolts on either end of the catalytic converter with penetrating oil and then use a socket wrench to turn the bolts counterclockwise until they're loose. Carefully set your catalytic converter down once you remove it so it doesn't get damaged.

- ✚ If your catalytic converter is welded to your exhaust pipe, then cut it off of your exhaust line.

- ✚ Tap on your catalytic converter with a rubber



mallet and listen for a rustling sound. If you hear anything moving around inside, then it's a sign your catalytic converter is damaged and should be replaced instead.

- ✚ Once you remove your catalytic converter, avoid driving your vehicle since it will let toxic chemicals into the air and may be illegal in your area.

Step 4: Spray inside the converter with a pressure washer on low: Rent a pressure washer from your local hardware store and set it to the lowest possible setting. Point the pressure washer into the catalytic converter and flush out all the debris and buildup that's inside. Spray the washer into both ends of the catalytic converter until you don't see any more residue come out.

- ✚ Avoid using high pressure since you could break the components inside the catalytic converter.
- ✚ If you don't have access to a pressure washer, use a garden hose with a nozzle attachment. It may not break up as much of the clog as a power washer, but it will still help loosen it up.

Step 5: Soak your catalytic converter overnight in soapy water:

Find a bucket or container large enough so your catalytic converter can stand vertically. As you fill the container with hot water, add about $\frac{1}{2}$ cup (120 ml) of dish soap and let it suds up. Set the catalytic converter in the soapy water and leave it overnight so the soap has time to remove all the oil and grease buildup inside.

- ✚ Add a splash of ammonia to the soapy water for a little extra cleaning power.



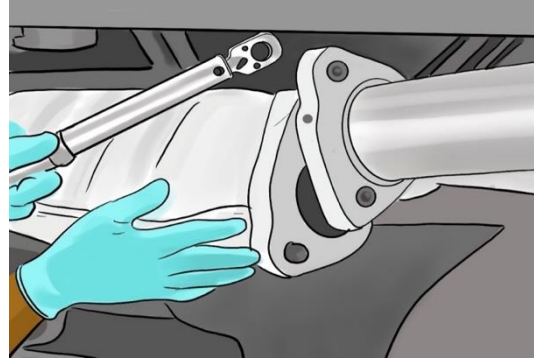
Step 6: Rinse your catalytic converter and let it dry completely:

Use a pressure washer or hose to spray clean water through your catalytic converter. Keep running water through the converter until it comes out clean on the other side to ensure you've broken up all the clogs and buildup inside. Then, set your catalytic converter vertically on a towel and let it air-dry for a few hours.



✚ Attaching your catalytic converter while it's still wet could cause it to get damaged.

Step 7: Reattach your catalytic converter and oxygen sensor to your vehicle: Line your catalytic converter back up with your exhaust line and reattach the bolts by screwing the clockwise. Push the Oxygen sensor back into the port next to your converter and tighten the nut with a socket wrench. After reinstalling them, start your vehicle to check if it runs smoother or has any lit warning lights.



- ✚ If your catalytic converter was welded in, weld it back into place after you clean it.
- ✚ If your vehicle isn't running properly, then have a professional check your catalytic converter.

Key Facts 3.3.d Correction of exhaust system damaged components

- **Repairing exhaust system leakage and noise**

- ✓ **Exhaust system noise**

Here are two methods used to fix exhaust system noise which are temporarily and permanently by welding exhaust leak.

- ✓ **Repairing exhaust pipe without welding**

you can purchase all the materials listed below from your local store without breaking the bank.

- ✚ Sandpaper
- ✚ Metal wire brush
- ✚ Soapy water
- ✚ Putty
- ✚ Muffler bandage
- ✚ Exhaust band clamp

- 1. Preparation**

Before fixing exhaust pipe without welding, you need to clean the area first to create a

good bonding surface. Use sandpaper or metal wire brush to remove any dirt, grease, or rust. Afterward, use a towel to wipe the surface with isopropyl alcohol to wipe the areas you just scraped. You can use four different methods to seal a leak. The one you pick will depend on the nature and size of the damage. Let's dive right in.

2. Apply an epoxy bond

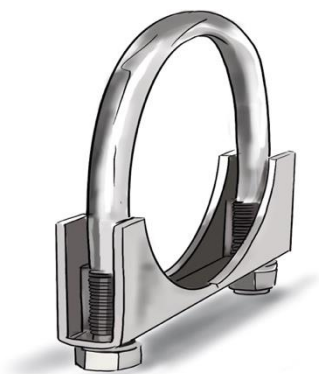


If the hole is small enough, you can use epoxy to seal the leak. Once you clean the surface, stir the epoxy to mix it evenly before applying it on and around the hole. You can use a wooden dowel to spread the sealant around the affected area. Different products will have varying curing rates. So, make sure to read the instructions to know how long you must allow it to dry before starting the engine

3. Wrap it with exhaust tape

An exhaust tape is an ideal solution if you are dealing with a larger hole. Wrap the tape around the hole, making sure to extend a few inches on either side. Cover the hole with at least two layers of tape for effective sealing. Since different exhaust tapes require different methods of application, make sure to read the instructions beforehand. Some require you to heat the engine first, while others need to be wet before application.

4. Use an exhaust clamp



If the hole or damage is not extensive enough, you can cover it using an exhaust clamp. The process is straightforward. You only need to wrap the clamp around the whole, fix the bolts, and tighten them down to cover the hole. Since the clamp is made from stainless steel, you should expect it to outlive the exhaust pipe.

5. Cover the Hole with an Aluminum patch

You can use an Aluminum patch to cover holes of any size. Once you examine the extent of the damage, use a pair of heavy-duty scissors to cut a slightly larger Aluminum patch. You may only need to cut a small piece of Aluminum for small holes. With larger areas,

wrap the aluminum around the pipe for effective sealing.

Cover the area around the leak with epoxy. Apply enough to seal the patch but not so



much that it drips into the exhaust pipe. Place the patch directly over the leak or wrap it around the exhaust pipe, depending on the damage. Afterward, use a wooden dowel to apply epoxy along the edges of the patch. If you wrap the patch all around the pipe, secure it on both ends with hose clamps.

Figure 46 Aluminum patch to cover holes of any size

✓ **Welding an exhaust leak**

Welding is a permanent and durable way to fix an exhaust leak. It involves melting metal and fusing it together to create a strong bond that seals the hole or crack.



Welding can be done with a gas torch, an arc welder, or a MIG welder, depending on the thickness and material of the exhaust pipe. Welding an exhaust leak requires some skill, experience, and safety precautions, as well as proper preparation and cleaning of the metal surface.

Steps to weld exhaust pipe

1. Prepare the area

Before you begin welding, you will need to prepare the area. You have to make sure that the area is clean and free of debris. You don't want anything to get in the way of your welding, so it's important to make sure the area is clean.

2. Decide which welder you are going to use

MIG (Metal Inert Gas) welding is the most common type of welding, and it's also the easiest to learn. If you're a beginner, MIG welding is a great place to start.

TIG (Tungsten Inert Gas) welding is more difficult than MIG welding, but it produces cleaner welds. If you're experienced with welding, TIG welding is a great choice for

welding exhaust pipes.

Flux-core welding is similar to MIG welding, but it uses a flux-cored wire instead of a solid wire. Flux core welding is a good choice for welding exhaust pipes because it's less likely to produce weld defects.

Stick welding is the most versatile, but one of its main disadvantages is that it's the most difficult type of welding to learn. Another downside is that it can produce slag, which can be a serious defect in welds.

This type of welding is not the best choice for beginners, so we only recommend it to professional welders.

3. Choose the right wire

The type of wire you use will depend on many factors, including the type of welder you're using, and from what metal (i.e. alloys or soft metal) your exhaust pipe is made.

If you're using a MIG welder, you'll need to use a solid wire. The most common type of solid wire is ER70S-6. This wire is copper-coated, containing high levels of silicon and manganese, resulting in high-quality welds.

If you're using a TIG welder, we recommend an ER70S-2 wire. For flux core welders, we advise a general-use flux-cored welding wire like E71T-11.

If you're using a stick welder, you'll need to use a rod of metal. One of the most common types of electrodes is 6011, which are general-purpose rods that produce great welds.

4. Set up your welder

The process for setting up your welder will vary depending on the type of welder you're using. It's always best to follow the manual that comes with the welder of your choice.

5. Clean the metal

Before you start welding, you'll need to clean the metal. The best way to clean the metal is to use a wire brush. The wire brush will remove any dirt, grease, or paint from the metal.

6. Put on your safety gear

Now that the area is prepared and the metal is clean, it's time to put on your safety gear. You'll need to wear a welding helmet or a mask, and a pair of gloves.

7. Tack welds the pipe

Tack welding is a type of welding that's used to hold two pieces of metal together before you make the final weld. To tack weld the pipe, you'll need to weld two small beads on either side of the pipe, connecting it.

8. Begin welding

As you weld, you'll need to keep the electrode at a consistent distance from the metal. If you're using a MIG welder, you'll need to keep the electrode from the pipe between $\frac{3}{8}$ and $\frac{1}{2}$ " away.

If you're using a TIG welder, you'll need to keep the working distance of 1 to 3mm. For those using a flux core welder, you'll need to maintain a distance from $\frac{3}{8}$ to $\frac{1}{2}$ ". Finally, with a stick welder, the distance between the rod tip and exhaust pipe should be about $\frac{1}{8}$ ".

9. Finish welding and let it cool

Once you've finished welding, you'll need to turn off your welding system. Depending on the type of welder, you'll need to release the trigger, turn off the gas, and turn off the power when your welder is off, you'll need to let the exhaust pipe cool before moving on.

10. Inspect your work and test it out.

Once the metal has cooled, you'll need to inspect your work. You should look for any cracks, holes, or defects in the weld. If it looks alright, you can finally test it out.

The best way to test the exhaust pipe is to start the car and let it idle. If you find any defects, you'll need to repair the exhaust pipe and weld it again. If there are no visible defects, you can ride the car for the ultimate test.

Remounting procedures of exhaust system

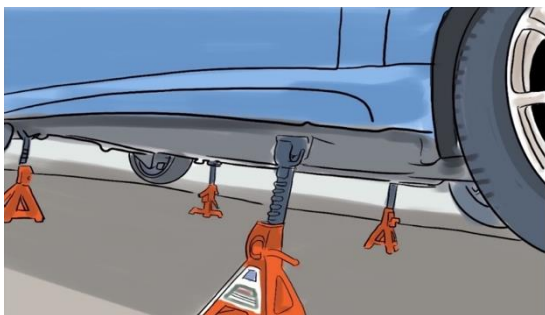
Step 1: Prepare the workplace

Park on a flat surface: Ensure the vehicle is located on a flat surface and turned off

Before beginning work on an exhaust system, make sure it is cool to the touch.

Disconnect the battery's negative cable before starting to work to avoid short-circuiting the electrical system. Soak all rusted bolts, nuts, and other removable parts with good penetrating oil.

Step 2: Position the vehicle

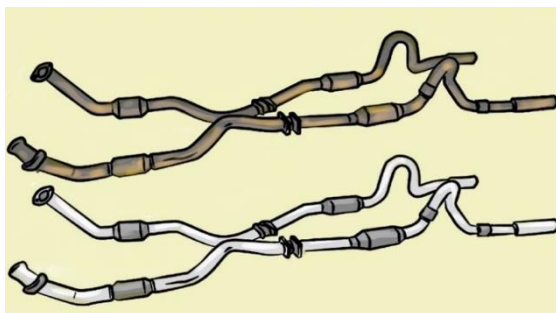


Raise the car safely off the ground with the floor jack. Position jack stands at all four points under the vehicle.

Step 3: Get a new exhaust system that matches the make and model of your vehicle.

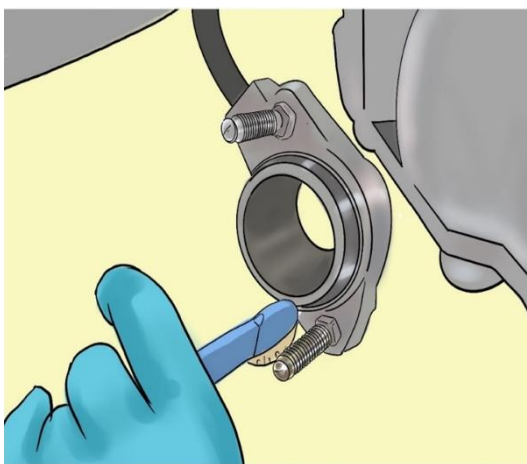
Look up your vehicle's year, make, and model online or at an auto parts store to find out what systems are compatible in your vehicle. The system will contain the main exhaust pipe, catalytic converters, a muffler, and tailpipe. Choose a system that's within your budget and is made from stainless steel so it's less likely to rust or corrode after heavy use. Order the exhaust system you want so you can install it on your vehicle.

- ✚ Compare the layout of your old exhaust system to the new one to make sure it can fit. For example, if you have a dual-exhaust engine, then you need a system that has 2 exhaust ports.



- ✚ If your old exhaust system went over your rear axle, then get an exhaust system that comes in multiple pieces so you can easily install it. If you aren't able to, then you need to see a mechanic to install the system for you.

Figure 47 New and old exhaust systems



Step 4: Clean the rust off of the bolt threads with a wire cleaning brush.

Use the bolts you removed from the old exhaust system if they are still in good condition. Rub a wire brush horizontally across the threads of each bolt to remove any rust or corrosion that's stuck on the surface. Try to get the most rust off of the

threads as possible so you can easily screw and unscrew the nuts on them.

- ✚ You can buy a wire cleaning brush from a hardware or automotive care store.
- ✚ If you can't get the rust off of the bolts, then you may need to replace them so they don't get stuck later on.

Step 5: Apply anti-seize fluid on all of the bolt threads.

Anti-seize fluid helps prevent bolts from locking in place so they're easier to remove when you need to make repairs or buy replacements. Put the anti-seize fluid on your finger and



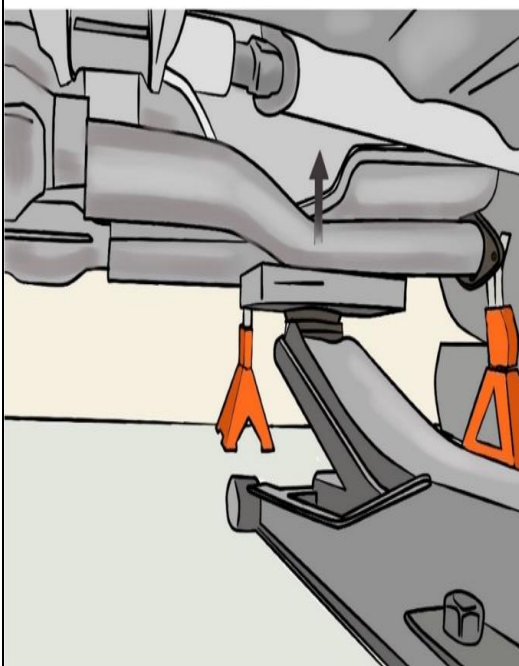
rub it around the threads of the bolt. Make sure that each bolt has an even coat of the fluid so it doesn't get stuck later on.

- ✚ You can buy anti-seize fluid from an auto care or hardware store.

- ✚ You can also apply the anti-seize fluid on the threads for the oxygen

sensors, but don't let the fluid touch the interior metal sensors, or else they won't work properly.

Step 6: Lift the new exhaust system into place using your jack.



Ask a helper to guide the exhaust system underneath your vehicle without it touching the ground so it doesn't get scratched. Place the front end of the exhaust pipe on top of the jack's arm and carefully raise it up so it doesn't fall. Keep lifting the exhaust system until the end of the pipe lines up with the port on the downpipe, which comes down from the engine and connects to the entire system.

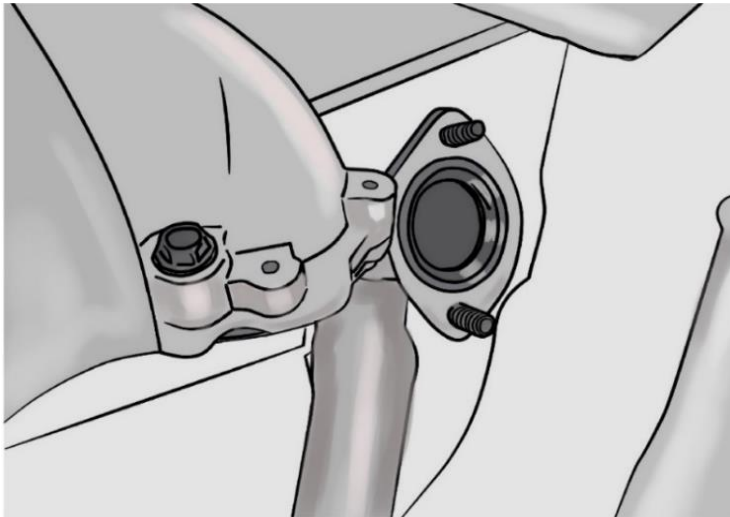
- ✚ You don't need to use a jack, but the exhaust system may be too heavy to support and

secure on your own.

Tip: If your exhaust system comes in multiple pieces, start with the section of pipe that attaches to the downpipe. Continue installing the pieces of your exhaust system as you work back toward the rear of your vehicle.

Step 7: Place a gasket over the downpipe with one of the bolts.

A gasket is a thin piece that fits between pipes to prevent any leaks from escaping the connection. Hold the port at the end of the downpipe steady and lay the gasket on top of it.

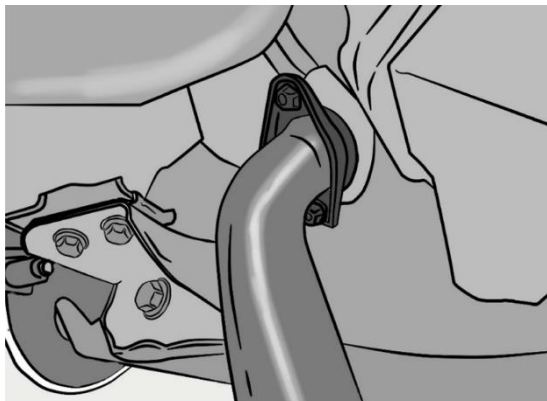


Slide one of the bolts through the downpipe and gasket so the threaded end points toward the rear of your vehicle.

✚ Your new exhaust system should come with a gasket, but you can also buy them from an auto supply shop.

Step 8: Attach the front of the exhaust system loosely to the downpipe with the bolts.

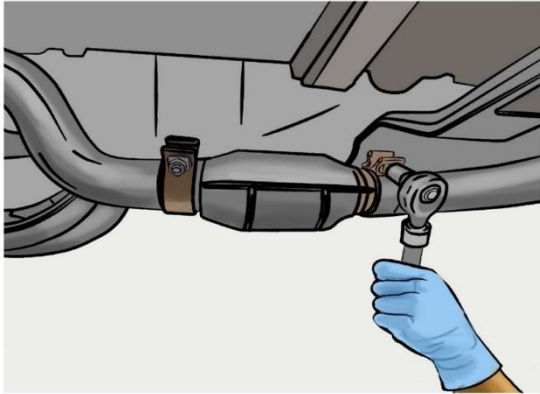
Position the end of the new exhaust pipe with the port on the downpipe so the bolt holes line up. Slide a nut onto the bolt that you've already installed and turn it clockwise by hand until it holds the new system against the downpipe. Slide the rest of the bolts



through the other holes on the pipe connection and tighten them with nuts until they're halfway down the threading.

✚ Don't fully tighten the nuts and bolts yet, or else you won't be able to move the exhaust system around if you need to reposition it slightly.

Step 9: Connect sections of your system with exhaust clamps, if needed.



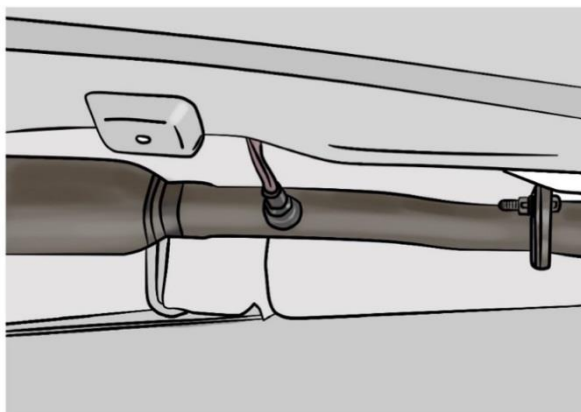
Exhaust systems that come in multiple pieces will fit together easily, but they may be prone to leaking if they aren't tightened. Get exhaust clamps, which are metal loops that you can tighten around pipes to hold them together, from your local hardware or automotive store. Slide the clamp onto the

section of pipe you're attaching before you connect it to the exhaust pipe. Tighten the clamp with a ratchet so it holds the pieces tightly.

- ✚ Working from the engine toward the back of your vehicle, connect the first exhaust pipe followed by the catalytic converters, the resonator, the muffler, and end with the tailpipe. You may also have extension pipes that connect between some of the pieces.
- ✚ In some cases, you may need to weld the pieces together rather than use clamps, so see what the manufacturer recommends.
- ✚ Systems that come in a single piece won't use exhaust clamps.

Step 10: Plug the Oxygen sensors back into the ports on your vehicle.

Locate the small holes in the sides of the exhaust pipe near the front axle of your vehicle. Slide the old oxygen sensors back into the holes and tighten them by hand by turning the

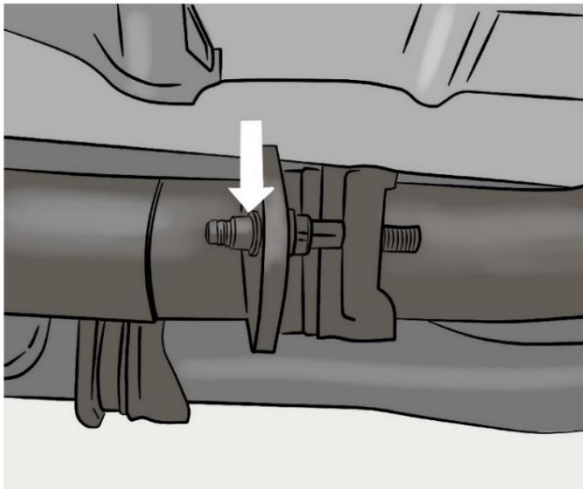


bolts clockwise. Use your ratchet or wrench to fully secure the sensors so they're tight. Plug the ends of the sensors back into the wires so they'll work when you start your vehicle.

- ✚ You can also screw in the oxygen sensors before you install the exhaust system if it's easier to access.

Step 11: Slide the metal pins on the system into the rubber exhaust hangers.

The metal pins will line up with the rubber hangers you already have under your vehicle.



Find the hole on the hanger that's slightly smaller than the width of the metal pin and push the pin through it. Apply firm pressure until you see the end of the pin poke through the other side of the hanger. Continue putting the pins through the other hangers to secure the pipe against your vehicle.

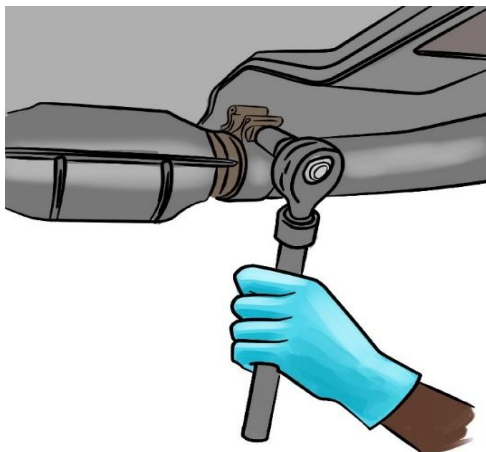
✚ If you have trouble sliding the pins into the hangers, lubricate them with soapy water so they're easier to move.

Step 12: Tighten the bolts at the front of the exhaust until they form a tight seal.

Go back to the front of your exhaust system and use your ratchet to rotate the nuts clockwise. Continue tightening the nuts until the pipes are firmly connected to one another and don't move around easily.

Be careful not to overtighten them since you could damage the exhaust system or cause leaks.

✚ If your exhaust system came in pieces, then make sure all of the bolts are tight along the length of the pipe.

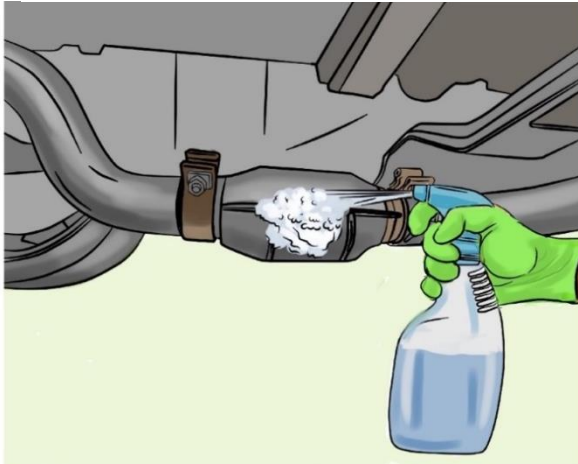


Step 13: Spray the connections with soapy water to see if there are any leaks.

Turn your vehicle's engine so fumes run through the new exhaust system. Fill a bottle with soapy water and spray any areas where you had to connect pipes to one another. If you notice bubbles forming around the connection, tighten the bolts more to see if it fixes

your problem.

- ✚ Try repositioning the gasket inside the pipe if you still notice a leak.



- ✚ If your vehicle doesn't have any exhaust leaks, you can remove the jack stands and lower your vehicle with a jack.

- **Testing exhaust system for leakage, noise and vibration**

Method 1: Plug the tail

Use a pair of gloves to plug the tail of your exhaust and start the engine. After making sure the emergency brakes are on, press the gas pedal. Pressure will start to build inside the exhaust system. And with the only way of escape blocked, the fumes will escape through the leaks. You can spray soapy water along the exhaust pipe to identify small leaks faster through air bubbles.

If you do not want to keep your engine running, you can create positive pressure inside the exhaust system by pushing air inside. A leaf blower, air compressor, or shop vac will do the trick. If your vehicle has two exits, make sure to seal one of them first. Also, ensure the engine is cold before pumping cool air into the exhaust. Rapid cooling could warp or crack parts of your vehicle.

Method 2: Exhaust Analyzer

Early emission analyzers measured the amount of HCs and COs in the exhaust. HCs in the exhaust are raw, unburned fuel. HC emissions indicate that complete combustion is not occurring in the engine. Emissions analyzers measure HC in parts per million (ppm) or grams per mile (g/mi). CO is an odorless, toxic gas that is the product of combustion and is typically caused by a lack of air or excessive fuel. CO is typically measured as a percent of

the total exhaust.

An exhaust analyzer has a long sample hose with a probe in the end of the hose. Before measuring the exhaust gases, disable the air injection system, if the engine is equipped with one. Start the engine. Once the engine is warmed up, insert the probe in the tailpipe. When the analyzer is turned on, an internal pump moves an exhaust sample from the tailpipe through the sample hose and the analyzer. A water trap and filter in the hose removes moisture and carbon particles. The pump forces the exhaust sample through a sample cell in the analyzer. The exhaust sample is then vented to the atmosphere. In the sample cell, the analyzer determines the quantities of HC and CO, if the analyzer is a two-gas analyzer, or HC, CO, carbon dioxide (CO₂), and oxygen (O₂), if it is a four-gas analyzer. Most newer analyzers also measure NO_x and are called five-gas analyzers (Figure 101).



Figure 48 The analyzer's probe is inserted into the vehicle's tailpipe.

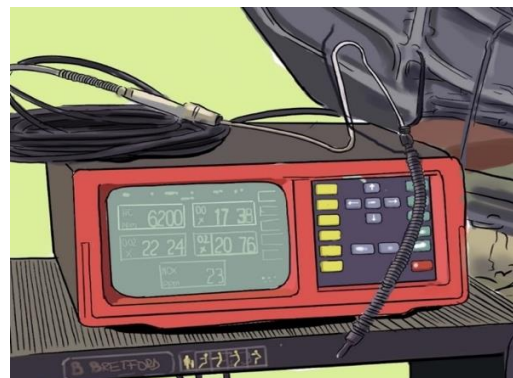


Figure 49 five-gas exhaust analyzer.

	IDLE	2500 RPM	PROBABLE CAUSE
HC ppm CO% CO ₂ % O ₂ % NO _x ppm	0-150 1-15 10-12 0.5-2.0 100-300	0-75 0-0.8 11-13 0.5-1.25 200-1,000	Normal reading
HC ppm CO% CO ₂ % O ₂ % NO _x ppm	0-150 3.0+ 8-10 0-0.5 0-200	0-75 3.0+ 9-11 0-0.5 100-500	Rich mixture
HC ppm CO% CO ₂ % O ₂ % NO _x ppm	0-150 0-1.0 8-10 1.5-3.0 300-1,000	0-75 0-0.25 11 1.0-2.0 1,000+	Lean mixture
HC ppm CO% CO ₂ % O ₂ % NO _x ppm	50-850 0-0.3 5-9 4-9 300-1,000	50-750 0-0.3 6-10 2-7 1,000+	Lean misfire
HC ppm CO% CO ₂ % O ₂ % NO _x ppm	50-850 0.1-1.5 6-8 4-12 0-200	50-750 0-0.8 8-10 4-12 100-500	Misfire

By measuring NO_x, CO₂, and O₂, in addition to HC and CO, a technician gets a better look at the efficiency of the engine this table. Ideally, the combustion process will combine fuel (HC) and O₂ to form water and CO₂. Although most of the air brought into the engine is nitrogen, this gas should not become part of the combustion process and should pass out of the exhaust as nitrogen. Maximum limits for the measured gases are set by regulations according to the model year of the vehicle. These limits also vary by state or locale. It is always desirable to have low amounts of four

of the five measured gases at all engine speeds. The only gas that is desired in high percentages is CO₂. Normally, the desired amount of CO₂ is 13.4% or more. The other gases should be kept to the lowest levels possible. Typically, CO should be 0.5% or less, O₂ should be about 0.1–1%, HC should be about 100 ppm or less, and NO_x should be 200 ppm or less. Many of the emission control devices that have been added to vehicles over the past 30 years have decreased the amount of HC and CO in the exhaust. This is especially true of catalytic converters. These devices alter the contents of the exhaust. Therefore, checking the HC and CO contents in the exhaust may not be a true indication of the operation of an engine. However, a look at the other measured gases, those not altered by the system, can give a good picture of the engine and its systems.²



Activity 3: Application



Task: 27

1. Read the scenario below and do as instructed.

Visit different automobile repair shops in the neighbourhood where the exhaust system repair activities are carried out and replace the defective muffler with a rusted pipe with a new one.

2. Make a report of what you performed



Formative Assessment

1. List five tools that are used to repair exhaust system.
2. List five materials that are used to repair exhaust system.
3. List five equipment that are used to repair exhaust system.

² Chris Hadfield, Randy Nussler - Today's Technician_ Automotive Engine Repair & Rebuilding, Classroom Manual and Shop Manual, Spiral bound Version (2017, Cengage Learning) - libgen.li

4. Explain the procedures of dismounting exhaust system.
5. Explain the procedures of remounting exhaust system.
6. Explain how to inspect a restricted exhaust system.
7. Describe how to inspect a leaking exhaust system.
8. Explain the how to clean exhaust system catalytic converter.
9. Describe how to weld an exhaust leak



Points to Remember

- The catalytic converter is a metal box near the front of the exhaust pipe that filters out harmful gases, such as nitrogen oxide and carbon monoxide. Your exhaust system may have more than 1 catalytic converter.
- The oxygen sensors are electronic ports that plug into the exhaust system before and after the catalytic converters to check if your engine is burning oxygen efficiently. The wires for the oxygen sensors will go directly into your vehicle's body.
- The resonator is a slightly wider section of your exhaust pipe that helps reduce the amount of noise when you run your engine at certain RPM. Not every exhaust system will have a resonator.
- The muffler is the large metal box near the rear of your vehicle that helps reduce the exhaust noise.
- The tailpipe is the small section of tubing that connects to the back of the muffler and allows the fumes to escape into the air.
 - ✓ A crack in the exhaust pipe or muffler – This can happen if the car hits something underneath or just from rust or regular wear and tear. You may need to crawl under the car to see this.
 - ✓ A leak in the exhaust system – To detect if this is the case, lay next to your car while it is running in park and check for any fluid dripping along your exhaust system.
 - ✓ A rusty muffler or exhaust pipe – Exterior rust will not cause the system to make a noise at first. But rust will work its way through the muffler or pipe over time causing cracks and holes.

- If the engine has been running, exhaust system components may be extremely hot! Wear protective gloves when working on these components, and keep flammable objects away from hot areas.
- Exhaust gas contains poisonous carbon monoxide (CO) gas. This gas can cause illness and death by asphyxiation. Exhaust system leaks are dangerous for customers and technicians.
- Any exhaust system inspection should include listening for hissing or rumbling that would result from a leak in the system. An on-lift inspection should pinpoint any of the following types of damage:
 - ✓ Holes, road damage, separated connections, and bulging muffler seams
 - ✓ Kinks and dents
 - ✓ Discoloration, rust, soft corroded metal, and so forth
 - ✓ Torn, broken, or missing hangers and clamps
 - ✓ Loose tailpipes or other components
 - ✓ Bluish or brownish catalytic converter shell, which indicates overheating



Self-Reflection

1. Fill in and complete the self-assessment table below to assess your level of knowledge, skills and attitudes under this unit.
 - a. There are no right or wrong ways to answer this assessment. It is for your own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - b. Think about yourself: do you think you have the knowledge, skills or attitudes to do the task? How well?
 - c. Read the statements across the top. Put a check in a column that best represents your level of knowledge, skills and attitudes.

My experience	I don't have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Knowledge, skills and attitudes					
Select tools					
Select materials					
Select equipment					
Inspect exhaust system					
Correct exhaust system faults					
Test exhaust system					

Areas of strength	Areas for improvement	Actions to be taken to improve
1.	1.	1.
2.	2.	2.



Summative assessment (Integrated situation)

Integrated situation	
Mr.KALISA brought his vehicle FORD 2023 Escape in garage for repair that vehicle which loosing power, laurd noise and vibration . After inspection garage foreman found that the catalytic converter and muffler are leaking and the pipe is rusted. He assign you as a mechanic for exhaust system repair to replace that exhaust system with new one in 2 hours.	
Tools	Spanners, Screw drivers, Tire lever, chipping hummer, Tongue, Chisels, Scriber, Ruler, Hummer, Scan tool, Exhaust Pipe and Tail Pipe Expander, Exhaust Pipe and Tubing Cutter, Exhaust Pipe Cutter, Hanger Removal Pliers, Oxygen Sensor Socket, Sensor Wrench, Socket Set

Equipment	Personal protective equipment (PPE), Multimeter, Exhaust gas analyzer, Welding machine, Gas welding equipment, Cutting machine, Grinding machine, Drilling machine, Air tools, Battery-operated drill motors, Drill press, Bench vises, Exhaust pipe stands, An angle grinder, Digital multimeter, Digital pyrometer, Jack and jack stands.
Materials/ Consumables	Exhaust gaskets, Bolts and nuts, Rags, Welding electrodes, Wire brushes, grinding disc, cutting disc, Penetrating oil, Exhaust gaskets, Sealant, Sandpapers, grinding discs, cutting discs, Welding electrodes, Catalytic converter cleaner, Anti- seize, Epoxy adhesives, Exhaust tape, Exhaust clamp, Aluminum patch.

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