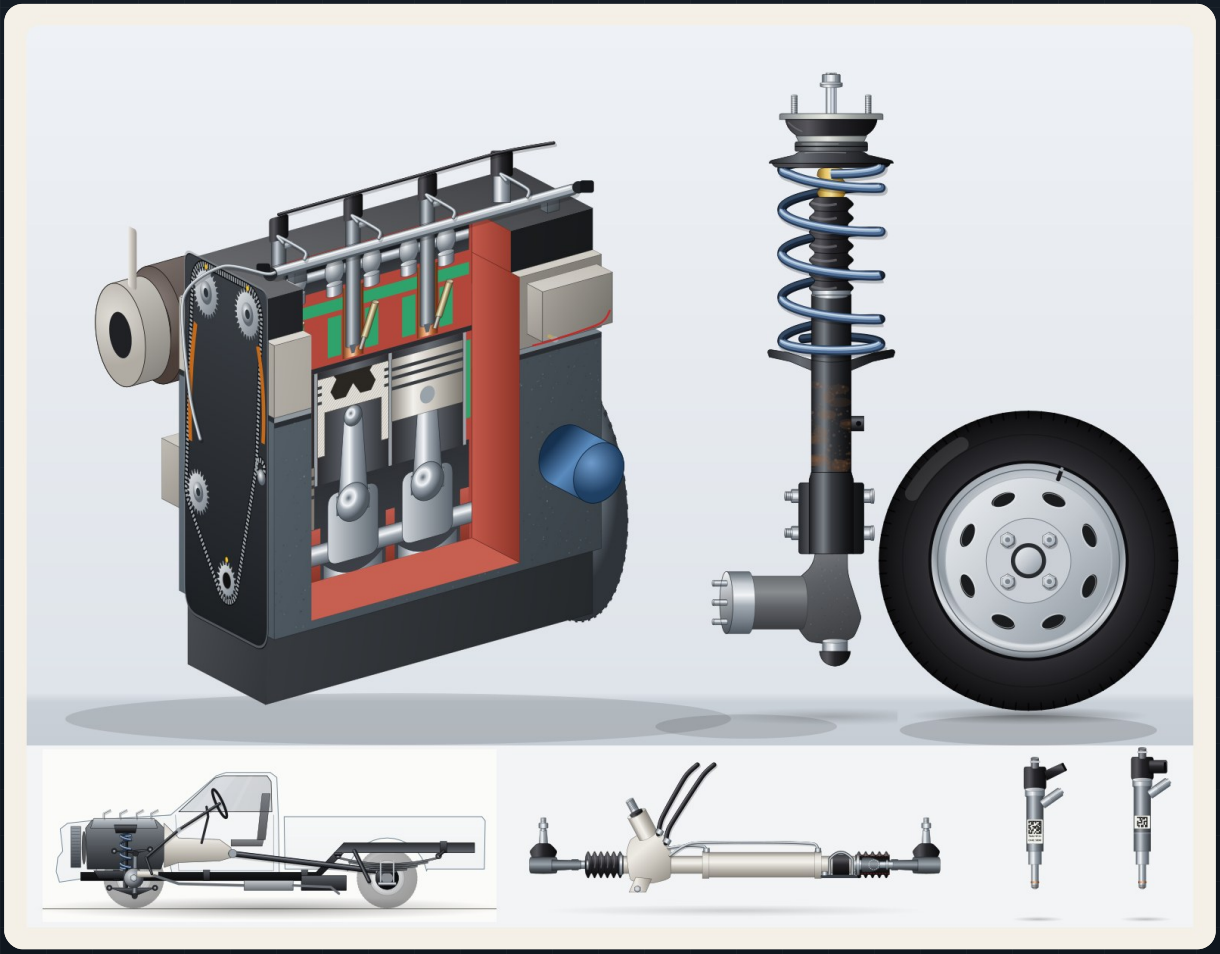
KNQF LEVEL 4 · TVET CDACC CYCLE 3

Motor Vehicle Mechanics Level 4

A Practical Study Guide for Kenyan Trainees

Diesel engines · Suspension & steering · Wheels & alignment



Realistic pictures **Step-by-step tasks** **Mock assessments**

For trainees, RPL candidates, trainers and diesel and chassis fundis

Alphonce Kimutai Kirui

Aligned to the TVET CDACC Competency-Based Modular Curriculum, Motor Vehicle Mechanics KNQF Level 4

Motor Vehicle Mechanics Level 4

A Practical Study Guide for Kenyan Trainees

Maintain Vehicle Diesel Engine · Maintain Vehicle Suspension and Steering System · Industrial Attachment
Kenya National Qualifications Framework (KNQF) Level 4

Alphonce Kimutai Kirui

Motor Vehicle Mechanics Level 4: A Practical Study Guide for Kenyan Trainees
First edition, November 2026

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Published by the author. Website: alphoncekirui.com

About the curriculum

This book is an independent study guide. It follows the topics and units of the TVET CDACC Competency-Based Modular Curriculum and Occupational Standard for Motor Vehicle Mechanics, KNQF Level 4 (Cycle 3, programme code 0716 354A), and the assessment documents for Motor Vehicle Mechanic Level 4. It covers the two Level 4 units (Module II): Maintain Vehicle Diesel Engine (ENG/OS/AUT/CR/01/4/MA) and Maintain Vehicle Suspension and Steering System (ENG/OS/AUT/CR/02/4/MA), which also covers wheels, tyres and wheel alignment, together with the 320 hours of industrial attachment (ENG/OS/AUT/CR/03/4/MA). The Level 3 units of the qualification (Module I: petrol engine and braking system) are covered in the companion book, *Motor Vehicle Mechanics Level 3: A Practical Study Guide for Kenyan Trainees*, by the same author. Unit titles and codes are used for reference only. The book is not published, endorsed or approved by TVET CDACC, TVETA, NTSA or the Ministry of Education. Always follow the current official curriculum and your trainer's guidance.

Safety and accuracy notice

Motor vehicle work can injure and kill. Diesel at injection pressure can pierce the skin, compressed road springs and split-rim wheels store deadly energy, vehicles can fall from jacks, turbochargers and exhausts burn, and diesel, used oil and coolant harm the skin and the environment. The methods in this book are for training under the supervision of a qualified trainer. Never work under a vehicle held only by a jack; never feel for a diesel leak with your hand; never open a high-pressure fuel line on a running engine; always inflate lorry and multi-piece wheels in an inflation cage. Any high-pressure injection injury is a surgical emergency: go to hospital at once (999 or 112). Figures given as "typical" or "example" (clearances, pressures, alignment angles, torques and prices) are general guidance only. Always use the manufacturer's manual for the vehicle in front of you, and follow the current Kenyan laws and rules, including the Traffic Act (Cap. 403) and the Traffic (Motor Vehicle Inspection) Rules, the Environmental Management and Co-ordination Act and its waste regulations, the Occupational Safety and Health Act 2007 and workplace rules. Prices are approximate (2026) and vary by town.

Names of people, businesses, email addresses, websites and phone numbers used in examples are made up for teaching. Vehicles are described by type; engine codes are given only as examples.

Illustrations and photographs

The illustrations in this book were drawn for it. They are realistic teaching illustrations and are not to scale unless dimensions are given. Charts marked "typical" or "illustrative" show typical shapes, not measured data. Photographs come from Wikimedia Commons under free licences (public domain, CC0, CC BY or CC BY-SA); some have been resized or cropped. Each photograph is credited under the picture, and the full list of credits is at the back of the book.

How this book was made

Automated tools, including AI writing and drawing assistants, were used under the author's direction to help draft the text, draw the illustrations and charts, and check calculations, cross-references and layout. The content was checked against the curriculum documents and against published sources such as makers' manuals, standards and Kenyan law, and the author is responsible for it. If you find a mistake, please report it through alphoncekirui.com so that it can be corrected in the next edition.

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Preface

Kenya runs on diesel. Matatus, lorries, buses, pick-ups, tractors, graders and standby generators carry our people, our food and our building materials over tarmac, murram and corrugated roads every day. Every one of them needs a mechanic who can find out why it smokes, why it will not start on a cold morning, why it pulls to one side or eats its front tyres, and who can put it right the first time. That is the Level 4 motor vehicle mechanic.

This guide covers the two new units of the Motor Vehicle Mechanics KNQF Level 4 course (Module II): Maintain Vehicle Diesel Engine and Maintain Vehicle Suspension and Steering System, which also includes wheels, tyres and wheel alignment, together with the 320 hours of industrial attachment and the assessments that lead to your certificates. The Level 3 units of the qualification (Module I: petrol engine and braking system) are not repeated here. They are covered in the companion book, *Motor Vehicle Mechanics Level 3: A Practical Study Guide for Kenyan Trainees*, which this book calls "the Level 3 guide". Where a Level 4 job uses a Level 3 skill, such as lifting a vehicle safely, using a micrometer or bleeding brakes, this book gives a short reminder and points you to the right chapter of the Level 3 guide.

The book is written for trainees in vocational training centres and technical colleges, for candidates seeking recognition of prior learning, for trainers, and for working fundis in jua kali, fleet, dealer and diesel pump workshops who want their skills recognised. Everything is explained in plain English, with realistic drawings, worked calculations using Kenyan prices and conditions, practical tasks with record sheets, and checklists matched to the way you will be assessed.

Above all, work safely. A pinhole leak in an injector pipe can inject diesel under your skin, a compressed coil spring can kill, and a lorry wheel with a split rim can explode. Learn the safety rules in Chapter 2 before you touch anything, and keep to them on every job.

Alphonce Kimutai Kirui
Bomet, November 2026

How to use this book

This book follows the Level 4 part of the Motor Vehicle Mechanics course from start to finish. It covers the two Level 4 core units and the industrial attachment, in the same order as your training. You can read it cover to cover, or study one unit at a time if you are taking a part qualification: the units are independent. Topics that both units share, such as safety, tools, test equipment and workshop science, are taught once in Part 1, and the later chapters refer back to them. Level 3 topics are summarised and referred to the Level 3 guide.

The course at a glance

Part	What it covers	Training time
1. Getting started and safety	The Level 4 mechanic and the course, assessment, safety and waste for diesel and chassis work, tools, test equipment and workshop science	Used throughout (about 26 hours of the two units)
2. Maintain vehicle diesel engine	Unit 1 (ENG/OS/AUT/CR/01/4/MA): how the diesel works, diagnosis, overhaul, timing and tune-up, cooling, lubrication and fuel injection	180 hours
3. Maintain vehicle suspension and steering system	Unit 2 (ENG/OS/AUT/CR/02/4/MA): diagnosis and electronic systems, suspension, steering, wheels and tyres, steering geometry and wheel alignment	160 hours
4. Attachment, work and assessment	The industrial attachment (ENG/OS/AUT/CR/03/4/MA), the mentoring tool and portfolio, running a job, and getting ready to be assessed	320 hours of industrial attachment

The new Level 4 work is 180 + 160 + 320 = 660 hours. The full Level 4 qualification also includes the two Level 3 units (Module I, 300 hours), covered in the Level 3 guide: 960 hours in all.

What is in each chapter

- **What you will learn:** the chapter's goals, with the unit, learning outcome and training hours it belongs to.
- **Key words:** the trade words you need, explained simply, with the garage name where Kenyan mechanics use one. More are in the Glossary at the back.
- **Explanations and drawings:** each topic explained step by step, with realistic labelled illustrations, sections, flow diagrams, charts and photographs.
- **Worked examples:** compression ratios, pressure conversions, injector settings, liner and piston protrusion, fuel use, spring rates, steering ratios, toe and camber angles, tyre sizes and job prices worked through with real numbers.
- **Practical tasks:** real jobs with the tools, materials, steps, safety points and a record sheet to fill in. Do them with your trainer.
- **Check your competence:** a checklist of what an assessor will expect you to show. Tick each item when you can do it without help.
- **Practice questions:** answers, with full working for calculations, are at the back of the book.

Look out for these boxes

SAFETY FIRST

Hazards and how to stay safe. Never skip these.

GREEN TIP

Ways to cut smoke and fuel use, make tyres and parts last longer, and handle used oil, coolant, filters, tyres and scrap correctly.

TRAINER'S TIP

Advice from experienced trainers, fleet mechanics and diesel pump specialists to help you work faster and better.

COMMON MISTAKES

Errors trainees often make, and how to avoid them.

IN A KENYAN GARAGE

How the topic looks in real Kenyan workshops: matatu and lorry fleets, county garages, dealer workshops, diesel pump shops, tyre centres and jua kali garages.

WORKED EXAMPLE

A calculation worked step by step with real numbers.

About the pictures and diagrams

This book uses realistic illustrations of real parts and vehicles, sections, flow diagrams, charts and photographs. Labels and thin leader lines point to the parts that matter. In fuel diagrams, low-pressure diesel is drawn olive-gold, high-pressure diesel deep orange and leak-off (return) fuel pale olive; engine oil is amber, coolant green, intake air light blue, boost air mid blue, exhaust grey and power-steering fluid red. Blue arrows show flow or movement. Red marks a danger or a mistake; green marks the correct way. Plan views of vehicles have the front to the left unless the caption says otherwise, and steering angles are drawn larger than life so that you can see them. Specifications shown are typical examples: always use the manufacturer's manual. Some photographs show real places where people are not following every safety rule; the captions point this out.

PART 1

Getting Started and Safety

What a Level 4 diesel and chassis mechanic does, how the two Level 4 units and the attachment are trained and assessed, and how this book links to the Level 3 guide. Then the safety, housekeeping and waste rules for high-pressure diesel, heavy engines, road springs, split-rim wheels and alignment rigs, and the Level 4 tools, test equipment and workshop science used in both units.

Chapter 1: Moving Up to Level 4: The Diesel and Chassis Mechanic in Kenya
Chapter 2: Workshop Safety, Housekeeping and Waste for Diesel and Chassis Work
Chapter 3: Level 4 Tools, Test Equipment and Workshop Science

CHAPTER 1

Moving Up to Level 4: The Diesel and Chassis Mechanic in Kenya

WHAT YOU WILL LEARN

- Describe what a Level 4 motor vehicle mechanic does beyond Level 3, and where the work is in Kenya.
- Explain how the Level 4 course is built: modules, units, hours, credits, the attachment and entry routes.
- Use the language of competency-based training and explain how you will be assessed and certified.
- Find where the marks are in each unit and plan your study time.
- Plan a career path and practise the professional habits every unit expects: codes, records, warranty, time and cost.

Course overview · Units ENG/OS/AUT/CR/01/4/MA, 02/4/MA, 03/4/MA

At Level 3 you learned to service petrol engines and brakes under supervision. Level 4 takes you under the bonnet of the vehicles that keep Kenya moving: diesel matatus, lorries, pick-ups and tractors. It also takes you underneath them, to the springs, shock absorbers, steering, wheels and tyres that take a beating on our roads. This chapter shows you the map of the course, how you will be assessed, and how to get the most from this book.

Key words

CBET
Competency-based education and training: you are trained and judged on what you can actually do to a set standard.

Unit of competency
A block of work that leads to a certificate, such as Maintain Vehicle Diesel Engine.

Element
One main task inside a unit, such as servicing the cooling system.

Performance criterion (PC)
A statement of what a competent worker does for an element; each PC carries marks.

Range
The list of tools, parts, vehicles and conditions the work must cover.

Evidence guide
The part of the standard that tells assessors what proof of competence to collect.

Formative assessment
Assessment during training, used to check progress and to build your mark.

Summative assessment
The final assessment of a unit.

Portfolio of evidence
Your file of job cards, measurement sheets, photos and reports that prove what you have done.

Industrial attachment
Supervised work placement in a real garage or fleet workshop.

RPL
Recognition of prior learning: assessment of skills you already have from work, which can lead to a certificate.

1.1 What a Level 4 Mechanic Does

A Level 4 mechanic is trusted with bigger, more expensive jobs and works with less supervision. In a typical week you might:

- diagnose a hard-starting, smoking diesel and test its compression, glow plugs and injectors;
- overhaul a diesel engine, measure its parts and rebuild it to the manual's limits;
- service the cooling, lubrication and fuel systems of pick-ups, lorries and tractors;
- replace shock absorbers, springs, bushes, ball joints and steering parts, and read steering and suspension fault codes with a scan tool;
- repair, fit and balance tyres, and align wheels with a computerised or optical machine;
- fill in job cards, measurement sheets and service reports, and guide Level 3 trainees working beside you.

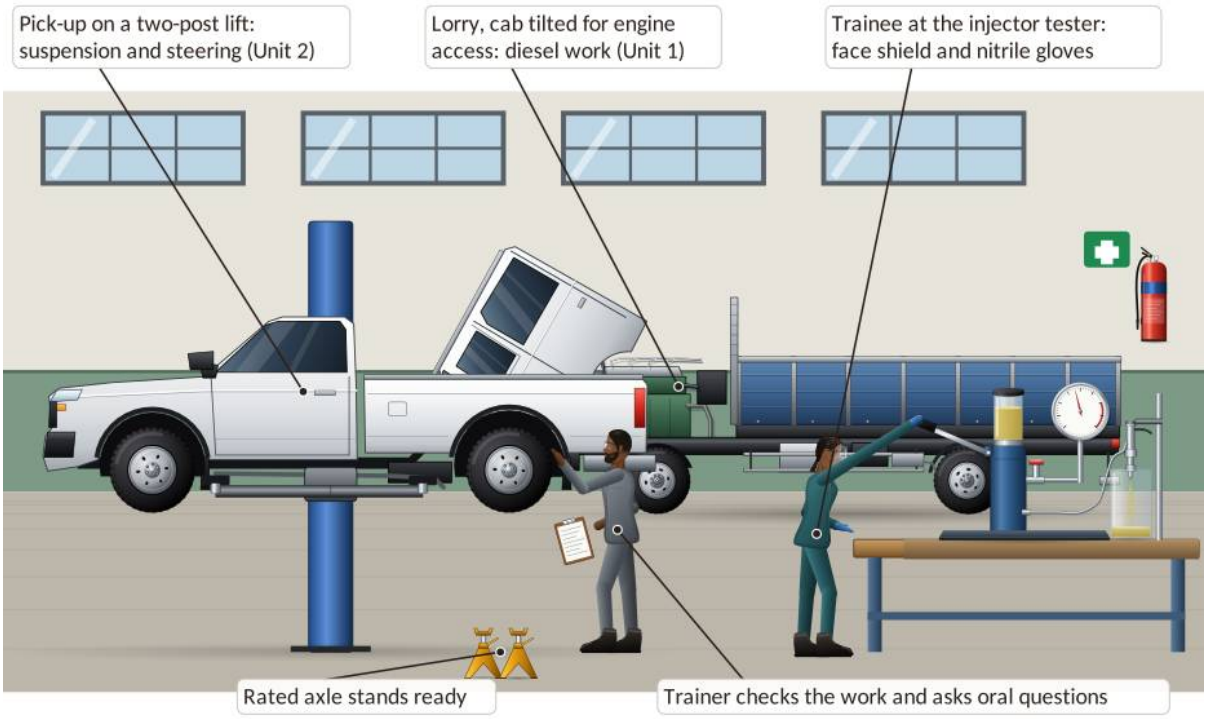
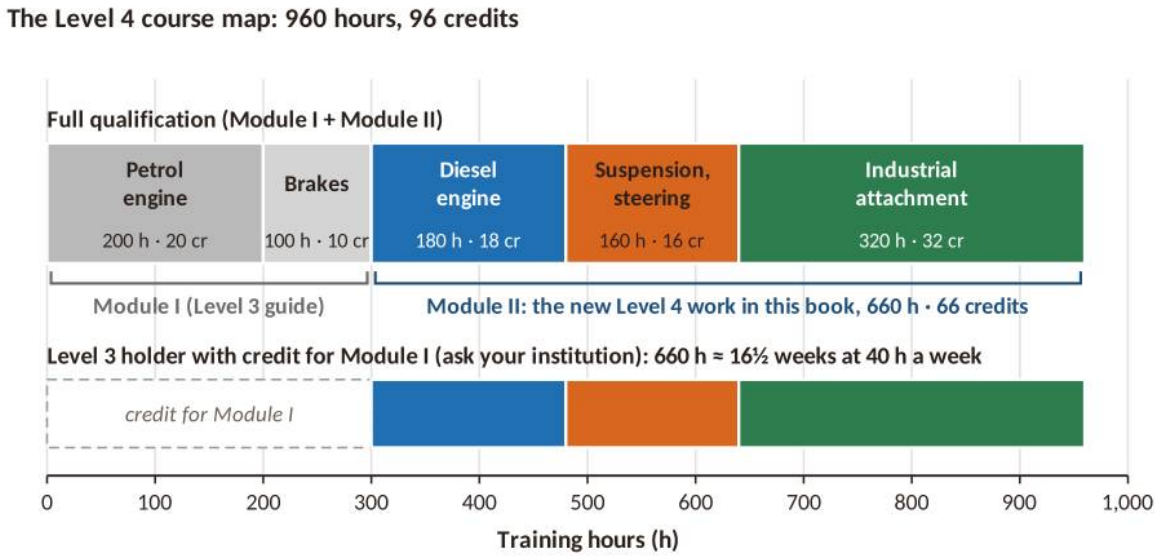


Figure 1.1 A Level 4 workshop: chassis work on the lift, diesel work under a tilted cab, injector testing in full PPE, and a trainer assessing as the work is done.

1.2 The Course Map

1.2.1 Where this book fits

The TVET CDACC curriculum for Motor Vehicle Mechanic Level 4 (programme code 0716 354A) has two modules. **Module I** holds the two Level 3 units, petrol engine and braking system, which are taught in the companion book *Motor Vehicle Mechanics Level 3: A Practical Study Guide for Kenyan Trainees* (the Level 3 guide). **Module II** holds the new Level 4 work, and that is what this book covers (Figure 1.2).



Data: TVET CDACC curriculum, Motor Vehicle Mechanic Level 4, summary of units. cr = credits; 1 credit = 10 hours.

Figure 1.2 The course map. Module I is the Level 3 work; this book covers Module II. Credits are hours divided by ten.

Table 1.1 The Level 4 units in this book

Unit and code	Learning outcomes (hours)	Chapters
Maintain Vehicle Diesel Engine ENG/OS/AUT/CR/01/4/MA 180 h, 18 credits	1 Engine overhaul (80) 2 Cooling system (30) 3 Lubrication system (30) 4 Fuel system (40)	2–9
Maintain Vehicle Suspension and Steering System ENG/OS/AUT/CR/02/4/MA 160 h, 16 credits	1 Diagnosis (20) 2 Suspension (50) 3 Steering (40) 4 Wheels and tyres (30) 5 Wheel alignment (20)	2, 3, 10–14
Industrial Attachment ENG/OS/AUT/CR/03/4/MA 320 h, 32 credits	At least 320 h in the automotive sector	15

Note two things about the table. First, the curriculum prints these codes with OS (occupational standard); you may also see CU on other CDACC documents. They refer to the same units. Second, despite its name, the suspension and steering unit also covers **wheels, tyres and wheel alignment**, which carry real marks; do not leave them for the last week.

The full qualification totals **960 hours and 96 credits**, but that includes Module I (petrol engine 200 h and brakes 100 h). The new Level 4 work is 180 + 160 + 320 = **660 hours, 66 credits**. If you already hold Level 3 in Motor Vehicle Mechanics, the CDACC guidelines on credit accumulation and transfer apply; ask your institution whether you can be credited for Module I. If you are starting at Level 4 without Level 3, study the Level 3 guide alongside this one.

WORKED EXAMPLE 1.1: HOW LONG IS THE COURSE?

At 40 training hours a week:

New Level 4 work: 660 h ÷ 40 h per week = **16.5 weeks** (about four months).

Full qualification: 960 h ÷ 40 h per week = **24 weeks** (about six months).

The attachment alone: 320 h ÷ 40 = 8 weeks. Sense-check: the mentoring tool asks for at least three months on attachment, which is longer than 8 weeks, so your institution will give you the exact dates.

1.2.2 Entry, trainers and certificates

You can enter with KCSE, with KNQF Level 3 in Motor Vehicle Mechanics or a related course, or with another qualification that TVETA accepts as equivalent. Your trainers must hold at least a KNQF Level 5 certificate in Automotive Engineering Technician or its equivalent, be licensed by TVETA, and be registered by the Engineers Board of Kenya (EBK) or the Kenya Engineering Technology Registration Board (KETRB).

TVET CDACC issues a **Certificate of Competency** for each core unit you pass, and may issue a **Statement of Attainment** for a certifiable element. When you are competent in every unit, you receive the full award, printed in the curriculum as the "Kenya National TVET Certificate in Automotive Mechanics Level 4"; the qualification itself is named Motor Vehicle Mechanic Level 4. Experienced fundis can also reach part or all of the qualification through RPL.

1.3 The Vehicle as Systems

Figure 1.3 shows a diesel pick-up with the systems in this book picked out. Part 1 (Chapters 1–3) covers what both units share: safety, tools and workshop science. Part 2 (Chapters 4–9) is the diesel engine unit. Part 3 (Chapters 10–14) is the suspension and steering unit. Part 4 (Chapter 15) covers the attachment, running a job and assessment.

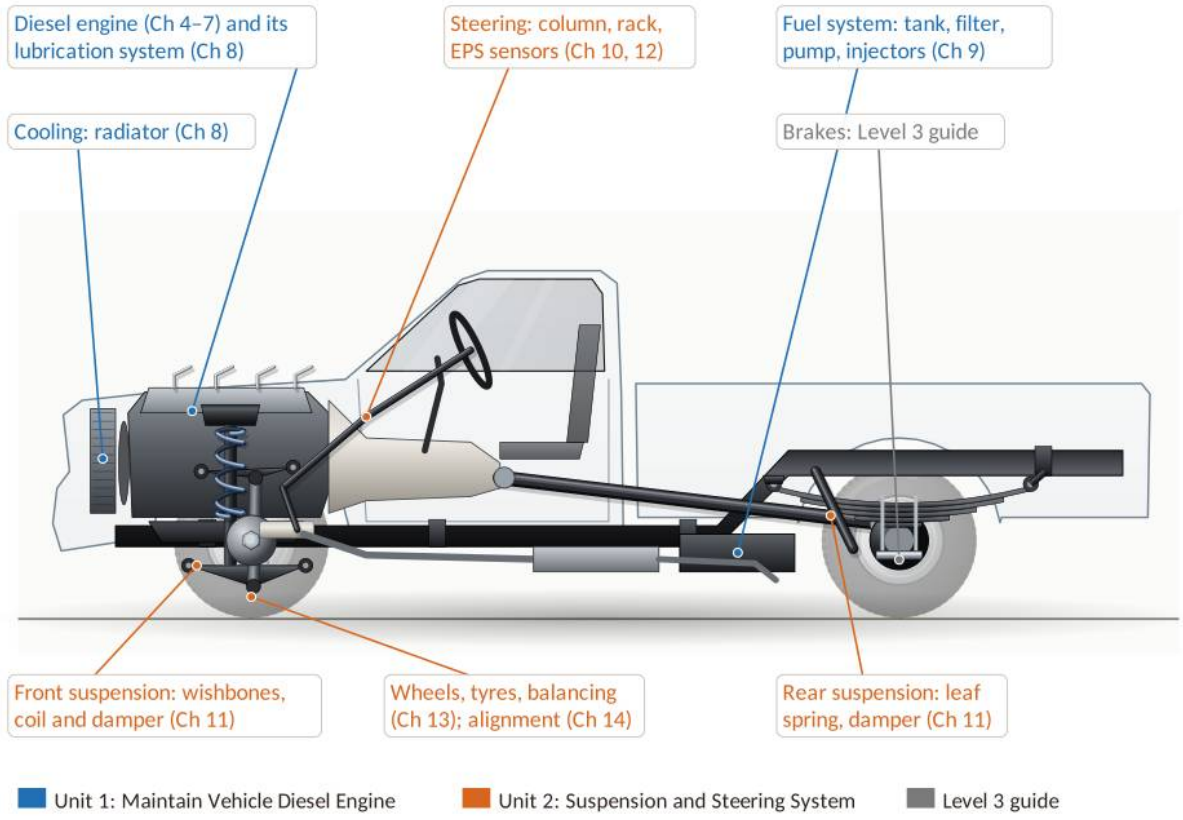


Figure 1.3 The systems of a diesel pick-up covered by the two Level 4 units, with the chapters that teach them (body shown as a see-through outline).

1.4 How You Are Assessed

1.4.1 The rules

- Every performance criterion is assessed **formatively**, using the PC weighting. You will have at least as many formative assessments as there are elements: at least 4 for the diesel unit and 5 for suspension and steering.
- Theory is not a separate paper. It is **built into the practical and asked orally**, and the weighting is theory 10 : practical 90.
- Your unit score is **60% formative and 40% summative** (Figure 1.4).
- You are assessed working on your own, in a real or simulated workplace, with real equipment, work instructions and a time limit. Assessors are TVETA-licensed trainers registered by CDACC as assessors, or industry experts registered by CDACC.
- Methods include practical tasks, projects, your portfolio of evidence, third-party reports from employers, written tests and oral questions.
- Ratings: 80–100 Attained Mastery; 65–79 Proficient; 50–64 Competent; 49 and below Not Yet Competent. The codes Y (malpractice), X (absent) and CRNM (course requirement not met) are also used.

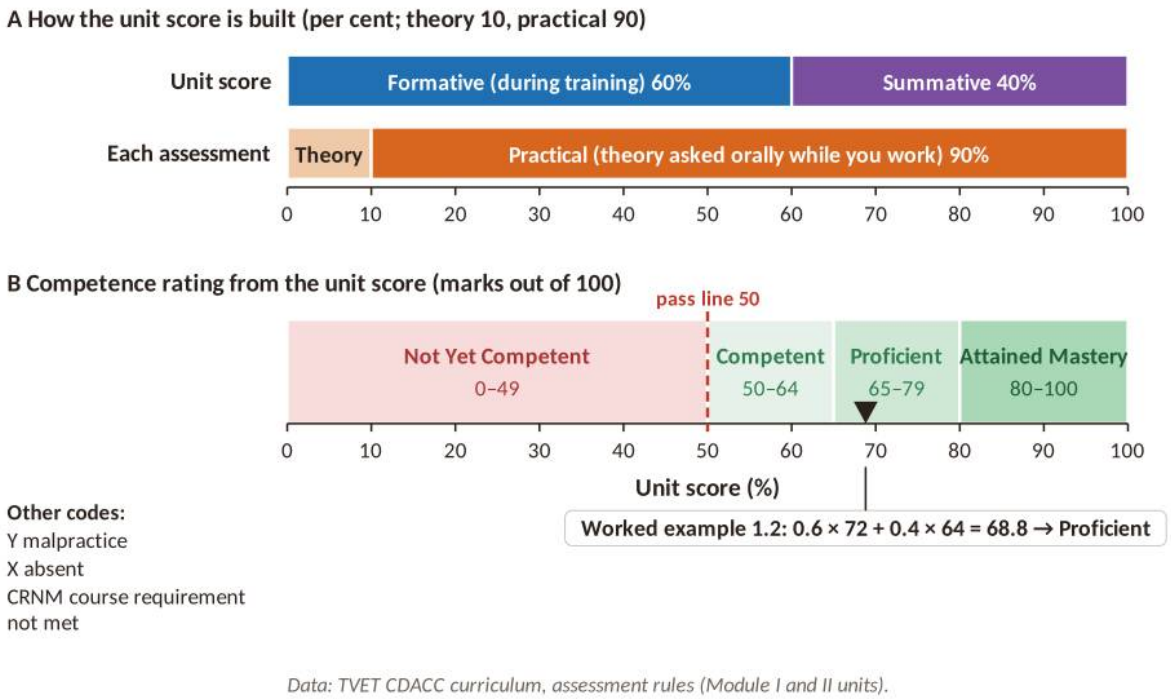
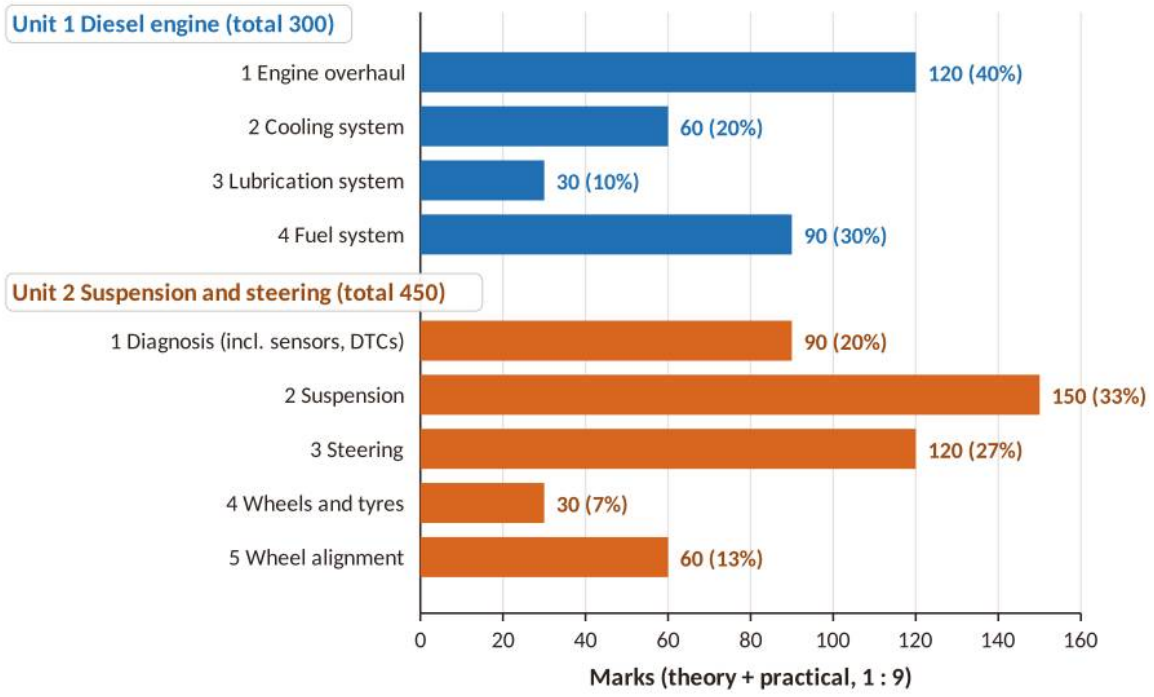


Figure 1.4 How a unit is scored and rated. The marker shows the result of Worked example 1.2.

> **WORKED EXAMPLE 1.2: YOUR UNIT SCORE**
>
> Wanjiru's formative marks for the diesel unit average 72, and she scores 64 in the summative assessment.
>
> Unit score = 0.6 × formative + 0.4 × summative = 0.6 × 72 + 0.4 × 64 = 43.2 + 25.6 = **68.8**.
>
> 68.8 lies in 65–79, so her rating is **Proficient**. Sense-check: the answer lies between her two marks and nearer 72, because the formative part carries more weight.

1.4.2 Where the marks are

The PC weighting gives the diesel unit 300 marks and the suspension and steering unit 450 marks (Figure 1.5). Look at the bars before you plan your study. In the diesel unit, engine overhaul alone carries 40% of the marks and the fuel system 30%. In the second unit, suspension and steering carry most marks, but the electronic diagnosis element, with sensors and fault codes, is worth 90 marks: three times as much as wheels and tyres. Practise scan-tool work as hard as spanner work.



Data: TVET CDACC performance-criteria weighting, printed element subtotals. % = share of the unit total.

Figure 1.5 Marks per element in the two Level 4 units (printed subtotals of the CDACC performance-criteria weighting).

1.4.3 The attachment and the mentoring tool

During attachment your workplace mentor uses the CDACC mentoring tool, which covers all four Level 4 units and your worker behaviour. You are assessed three times, in the first, second and third months; only the third counts. Your attachment mark for each unit is the number of items you have met divided by the total items, times 100%, and the final mark is the average across units. Some items are **critical**: you must meet them whatever your total. The Industrial Liaison Officer (ILO) at your institution uploads the mark to the CDACC portal. Chapter 15 explains every item.

1.5 The Diesel and Chassis Scene in Kenya

Kenya's working fleet runs on diesel: 14-seater matatu vans and 25- to 33-seater minibuses, light lorries of 4 to 7 tonnes, three-axle tippers and long-haul trucks, 3-litre pick-ups and 4x4s, farm tractors, county graders and water bowsers, and the standby generators of hospitals and banks. All of them are driven on murram, corrugations, potholes and speed bumps, often loaded beyond what the springs were built for. Broken leaf springs, knocked-out shock absorbers, worn kingpins and bald tyres are everyday work.

The work is found in many places: county and parastatal fleet garages, sacco and transport-company workshops, dealer workshops with diagnostic laptops, the diesel pump shops of Nairobi's Industrial Area, Kirinyaga Road and every big town, tyre and alignment centres, roadside vulcanisers, agricultural machinery dealers and jua kali garages. NTSA inspection checks steering, kingpins and bushes, suspension, tyres and smoke, so owners need mechanics who can put these right (Figure 1.6).



Figure 1.6 A matatu minibus on a light-lorry chassis in Nairobi. Vehicles like this usually have a turbo-diesel engine and beam axles on leaf springs, and they work long hours with full loads.

Photo: AEira-WMF, CC BY 4.0, via Wikimedia Commons

WORKED EXAMPLE 1.3: HOW FAST IS THE FLEET GROWING?

The KNBS Economic Survey 2026 reports 395,235 new registrations in 2025, of which 142,994 were vehicles (the rest were mainly motorcycles and three-wheelers).

Vehicle share = 142,994 ÷ 395,235 × 100 = **36.2%**, about 36%.

That is roughly 143,000 more vehicles in a single year, each needing tyres, alignment, suspension work and, for many, diesel servicing. Sense-check: 36% is a little over a third, and 143,000 is a little over a third of 395,000.

Pay varies widely by employer and town. As an estimate, a Level 4 diesel or fleet mechanic earns about KSh 30,000–60,000 a month, and casual work pays about KSh 1,000–2,000 a day. The statutory minimum for an Artisan Grade III in Nairobi is KSh 27,352 a month.

1.6 Your Career Path

Level 4 is a step, not the top of the ladder (Figure 1.7). From here you can go on to Level 5 (Automotive Engineering Technician) and a Level 6 diploma, or specialise in diesel fuel injection, heavy vehicles, tyres and alignment, auto-electrics or farm machinery. NITA trade tests run alongside and are well known to employers. Keep every certificate, letter and portfolio page: they are your evidence for the next step and for RPL.

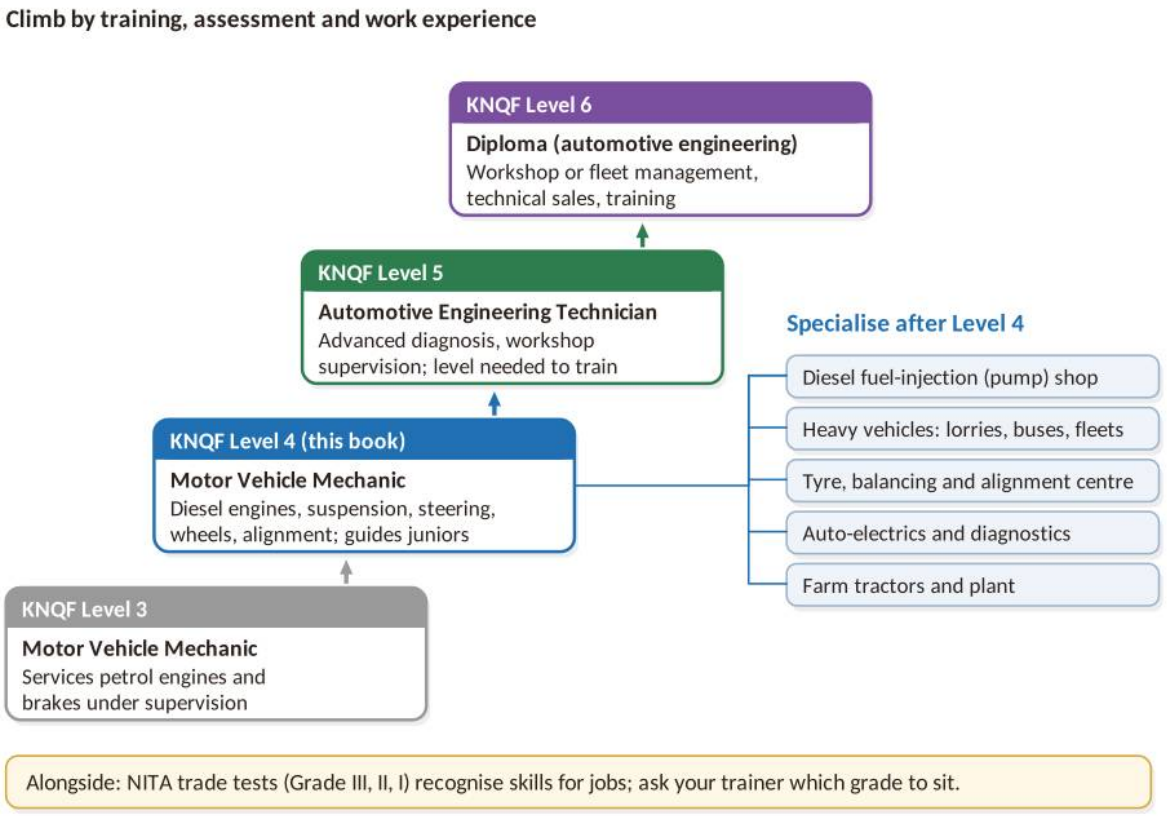


Figure 1.7 A career ladder for motor vehicle mechanics, with specialisms open after Level 4.

1.7 Professional Habits Every Unit Expects

Both Level 4 units list the same knowledge about how a professional works. You will be asked about it orally, so learn it now.

- **Warranty and insurance.** Work that is not done to the maker's specification, with the wrong parts or fluids, can cancel a vehicle's warranty. Report any damage you find or cause, and keep records. For insurance jobs after an accident, the assessor must approve the work first; record the steering and suspension damage carefully.
- **Identification codes.** The vehicle identification number (VIN) or chassis number, the engine number and part numbers tell you exactly what you are working on and which parts fit (Figure 1.8). Copy them carefully onto every job card.
- **Documents.** Job cards, measurement sheets, parts lists, diagnostic and service reports, and invoices. Each Level 4 practical task in this book ends with a record sheet for your portfolio.
- **Time and informing others.** Agree a finish time, keep your supervisor and the customer informed, and say early if a job will overrun.
- **Time, cost and profit.** Every hour of labour and every part has a cost. A job done right the first time makes a profit; a comeback loses it.
- **Digital tools.** Scan tools, online parts catalogues and manuals, and your phone camera for portfolio photos (always ask the owner's permission).

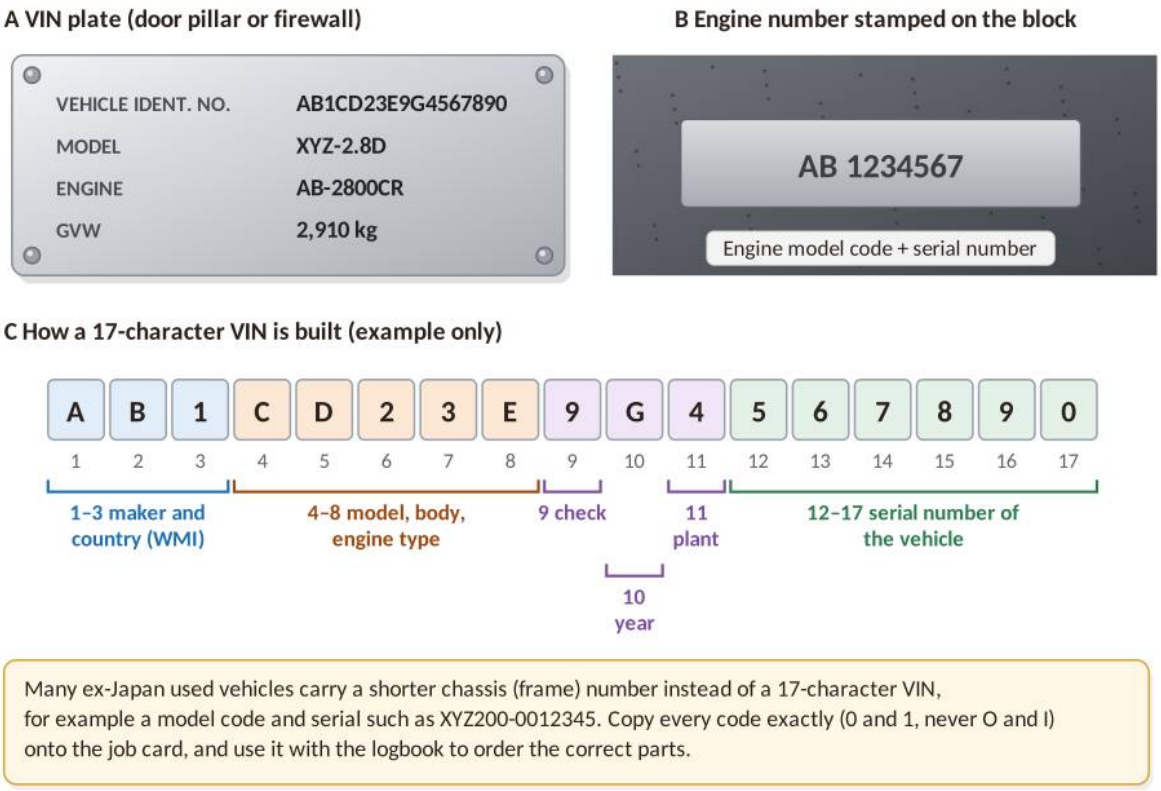


Figure 1.8 Identification codes. All characters shown are made-up examples; real positions and formats vary, so check the manual and the logbook.

SAFETY FIRST

Level 4 brings new dangers. Diesel at injection pressure can pass through skin; never feel for a leak with your hand. Diesel heads, flywheels and lorry wheels are heavy: use the crane or a second person. Compressed road springs store enough energy to kill; use the correct spring compressor. Lorry tyres on split rims can explode; inflate them only in a cage. Chapter 2 teaches each of these in full. Until you have completed it, do not use the injector tester, spring compressor or tyre cage without your trainer.

GREEN TIP

Level 4 skills are green skills. A diesel with good injectors and a clean air filter burns less fuel and makes less smoke; correctly aligned wheels and correct tyre pressures save fuel and make tyres last longer. Used oil, coolant, drained fuel filters, old tyres and scrap springs all go to licensed handlers, never into drains, soil or a fire (Chapter 2).

IN A KENYAN GARAGE

Otieno had fixed matatus at a stage garage in Kisumu for six years, but every time a common-rail van came in he sent it to a dealer. He enrolled for Level 4 through RPL guidance at his local VTC, was credited for his Level 3, and spent his attachment at a sacco fleet workshop. Within a year he was doing back-leak tests and wheel alignments himself, and the dealer jobs came back to his bay.

TRAINER'S TIP

Start your portfolio on day one. Buy a strong file, label a section for each chapter, and after every practical put in the record sheet, signed by your trainer, with a dated photo. At assessment time you will have the evidence ready instead of trying to remember what you did.

COMMON MISTAKES

- Thinking theory does not count because there is no written paper: it is asked orally during every practical.
- Leaving wheels, tyres and alignment until last because the unit is called "suspension and steering".
- Ignoring the scan tool: electronic diagnosis is worth more marks than wheels and tyres together.
- Copying a VIN or engine number carelessly (O for 0, I for 1), so the wrong parts are ordered.
- Treating the attachment as a holiday job: the mentoring tool has critical items you must meet.

1.8 How to Use This Book

Each chapter opens with what you will learn and the unit, learning outcome and hours it covers. Key words are explained first. The boxes have fixed jobs: **Safety first** for hazards, **Green tip** for the environment and saving resources, **Trainer's tip** for workshop wisdom, **Common mistakes** for what trainees get wrong, **In a Kenyan garage** for real local practice, and **Worked examples** with every calculation set out step by step, with units. Practical tasks list tools, materials, steps and safety, and end with a **Record your results** sheet for your portfolio. Specifications in this book are typical examples: always check the manufacturer's manual for the vehicle in front of you. Answers to the practice questions are at the back.

Practical task 1.1: Know your Level 4 workshop

Tools and equipment

- The workshop's Level 4 equipment: injector tester, diesel compression gauge, spring compressor, tyre changer, wheel balancer, alignment machine or gauges, tyre inflation cage, scan tool
- Torch

Materials

- Equipment checklist (below), clipboard, pen
- Workshop layout sketch
- PPE: overall, safety boots, safety glasses

Steps

1. Wear your PPE and report to your trainer. Note the fire exits, extinguishers, first-aid box and eyewash.
2. Sketch the workshop: diesel bay, alignment and tyre area, store, waste station.
3. Find each piece of Level 4 equipment and mark it on the sketch.
4. For each item, record its condition (complete, damaged or missing parts), any calibration or inspection label and date, and the safety guard or device it uses.
5. Ask your trainer for the one main safety rule for each item and write it down.

6. Do not operate any equipment in this task. Report anything damaged to your trainer at once.
7. File the sketch and checklist as the first pages of your portfolio.

Safety

- Look, do not operate: the equipment is introduced in Chapters 2 and 3.
- Keep clear of vehicles on lifts and of any work in progress.

Record your results: Level 4 equipment checklist

Equipment	Location	Condition	Calibration or inspection date	Main safety rule
Injector (pop) tester				
Diesel compression gauge				
Coil spring compressor				
Tyre changer and inflation cage				
Wheel balancer				
Alignment machine or gauges				
Scan tool				
Trainer's signature and date				

Chapter summary

- A Level 4 mechanic overhauls and services diesel engines and maintains suspension, steering, wheels and tyres, with less supervision.
- This book covers Module II: diesel engine (180 h), suspension and steering (160 h) and the attachment (320 h): 660 h, 66 credits. Module I is in the Level 3 guide.
- The suspension and steering unit also includes wheels, tyres and wheel alignment.
- Assessment is mostly practical, with theory asked orally (10 : 90); the unit score is 60% formative and 40% summative; 50 is the pass mark.
- The diesel unit carries 300 marks and the suspension and steering unit 450; engine overhaul, the fuel system, suspension and steering are the heavy elements.
- Kenya's working fleet is mostly diesel and its roads are hard on chassis parts, so these skills are in demand.
- Professional habits matter: identification codes, documents, warranty, time and cost.

Check your competence

- [ ] I can list the tasks a Level 4 mechanic does beyond Level 3.
- [ ] I can name the Level 4 units with their codes, hours and credits.
- [ ] I can explain unit, element, PC, range and evidence guide.
- [ ] I can calculate a unit score and state its rating.
- [ ] I can say which elements carry the most marks.
- [ ] I can find and copy a VIN, chassis number and engine number correctly.
- [ ] I have started my portfolio of evidence.

Practice questions

1. Name the two Level 4 units and the attachment, with their codes, hours and credits.
2. Explain why the full qualification shows 960 hours but this book covers only 660 hours.
3. (Oral) Explain to a new trainee what a performance criterion is and how theory is assessed at Level 4.
4. A trainee's formative marks average 58 and the summative mark is 45. Calculate the unit score and give the rating. Would the rating change if the two marks were simply averaged?
5. A part-time trainee studies 25 hours a week. How many weeks will the 340 hours of the two Level 4 units take?
6. Using Figure 1.5, what percentage of the diesel unit's marks are for the fuel system, and which element of the second unit carries the most marks?
7. State three things the mentoring tool records and explain how the attachment mark for one unit is calculated.
8. Give two reasons why diesel and chassis skills are in demand in Kenya.
9. Fault finding: a customer's new pick-up is under warranty. A trainee fits a cheaper oil filter and an oil grade not listed in the manual, and a month later the engine is damaged. Explain what may happen to the warranty and what the garage should have done.
10. Practical: on a workshop vehicle, find the VIN or chassis number and the engine number, copy them onto a job card, and show your trainer where each is located.

PART 2

Maintain Vehicle Diesel Engine

Unit 1: Maintain Vehicle Diesel Engine (ENG/OS/AUT/CR/01/4/MA, 180 hours). How the diesel engine works; diagnosing smoke, starting, power and noise faults; dismantling, cleaning, inspecting and measuring; rebuilding with liner and piston protrusion, timing, tune-up and refitting; the cooling and lubrication systems; and fuel injection from the in-line pump to common rail, with bleeding, injector testing and service records.

Chapter 4: How the Diesel Engine Works
Chapter 5: Diagnosing Diesel Engine Faults
Chapter 6: Dismantling, Cleaning and Inspecting the Diesel Engine
Chapter 7: Rebuilding, Timing, Tune-up and Refitting the Diesel Engine
Chapter 8: Diesel Engine Cooling and Lubrication Systems
Chapter 9: Diesel Fuel Systems: Injection, Common Rail, Service and Testing

CHAPTER 9

Diesel Fuel Systems: Injection, Common Rail, Service and Testing

WHAT YOU WILL LEARN

- Explain what makes good diesel fuel and how water, dirt, wax and high sulphur damage a fuel system.
- Trace the fuel from the tank to the injectors on in-line, rotary and common-rail systems.
- Explain how pumps and injectors meter, time and atomise the fuel, and what the ECU controls on common rail.
- Diagnose fuel system faults, including open and short circuits in injector and sensor wiring.
- Service filters and water separators, test mechanical injectors, check common-rail injectors, and record your results.

Unit: Maintain Vehicle Diesel Engine · ENG/OS/AUT/CR/01/4/MA · Learning outcome 4 · About 36 hours

Many diesel complaints start in the fuel system: a matatu that dies after a bad tank of fuel, a lorry that smokes on the Mau Summit climb, a pick-up that knocks after a hurried injector job. Fuel work also carries the highest safety weighting in the diesel unit, because it combines fire with pressures that cut skin. Injection-injury rules are in Chapter 2, test equipment in Chapter 3, and pump timing and bleeding in Chapter 7 (Section 7.5.2, Figure 7.9).

Key words

Lift pump (feed pump)
The low-pressure pump that draws fuel from the tank and pushes it through the filters.

Sedimenter (water separator)
A bowl where water and heavy dirt settle out of the fuel; drained through a tap.

Injection pump
The pump that raises fuel to injection pressure and, on mechanical systems, meters and times it.

Common rail
A thick steel tube that stores fuel at very high pressure for all the injectors; the ECU opens each injector electrically.

Opening pressure
The pressure at which a mechanical injector's needle lifts and fuel sprays; set with shims.

Atomisation
Breaking fuel into a fine mist so that it mixes with hot air and burns fully.

Leak-off (return)
Fuel that leaves the injectors or pump through small pipes and returns to the tank.

Open circuit
A break in a circuit, so no current flows; the meter reads OL.

Short circuit
An unwanted path, such as a bare wire touching the engine, that bypasses the load.

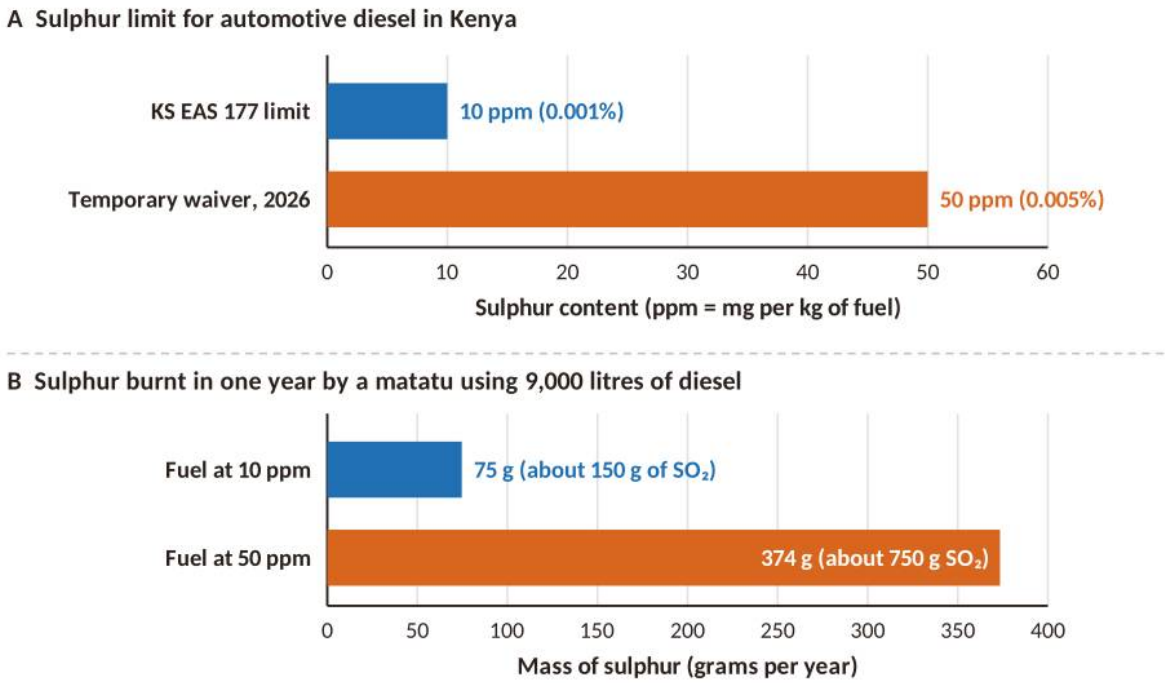
9.1 Diesel Fuel and Its Quality

Diesel is the fuel, the oil that lubricates pump plungers and injector needles, and on many pumps the coolant too. Table 9.1 lists the properties that matter. **Cetane number** measures how readily diesel ignites in hot air.

Table 9.1 Diesel fuel properties and the problems they cause

Property	Why it matters	What goes wrong
Cetane number (ignition quality)	Short ignition delay, smooth start	Low cetane: hard cold starts, knock, white smoke
Viscosity and lubricity	Fuel must flow and lubricate pump and injector parts	Thin, dry fuel (for example with kerosene added) wears plungers and needles
Water	Diesel and water do not mix; water sits at the bottom of tanks	Rust and scoring of precision parts, white smoke, misfire; water lamp on
Microbial growth ("diesel bug")	Bacteria and fungi live where water meets fuel	Black or brown slime that blocks filters quickly
Wax (cloud point)	Wax crystals form in very cold fuel	Blocked filter on a cold highland morning; rare in most of Kenya
Sulphur	Burns to sulphur oxides and acids	Acid wear in the engine; poisons the DOC, DPF and SCR catalyst
Cleanliness	Common-rail clearances are a few thousandths of a millimetre	Scored pumps, leaking injectors, P0087

Diesel sold in Kenya is specified by **KS EAS 177** (automotive gasoil), which sets a sulphur limit of **10 ppm** (10 mg of sulphur per kg of fuel). A temporary waiver in 2026 allowed up to **50 ppm** because of supply problems. Check with your trainer which limit is in force when you read this. Figure 9.1 shows what the difference means for one vehicle.



B assumes a typical density of 0.83 kg/L and 30 L a day for 300 days (Worked example 9.1).
Data: KS EAS 177:2025 and the 2026 temporary waiver. Check the limit now in force with KEBS or EPRA.

Figure 9.1 Sulphur in diesel. A: the KS EAS 177 limit and the temporary 2026 waiver. B: what each means in sulphur burnt by one matatu in a year.

WORKED EXAMPLE 9.1: SULPHUR IN A MATATU'S FUEL

A matatu uses 30 L of diesel a day for 300 days a year. Take a typical diesel density of 0.83 kg/L (diesel is about 0.82–0.87 kg/L).

Fuel per year: 30 × 300 = **9,000 L**. Mass: 9,000 × 0.83 = **7,470 kg**.

At 10 ppm: 7,470 kg × 10 mg/kg = 74,700 mg = **about 75 g** of sulphur. At 50 ppm: 7,470 × 50 = 373,500 mg = **about 374 g**.

Each gram of sulphur burns to about 2 g of sulphur dioxide: about 150 g against 750 g a year. Sense-check: 50 ppm is five times 10 ppm, and 374 ÷ 75 ≈ 5.

IN A KENYAN GARAGE

A sacco brings in three matatus in one week, water lamps lit and engines dying. All filled at the same small station after heavy rain. The mechanic drains a cupful of water from each separator, finds slime in one tank, and advises a change of station and daily draining for a week. Mixing kerosene into diesel is illegal and wears pumps and injectors.

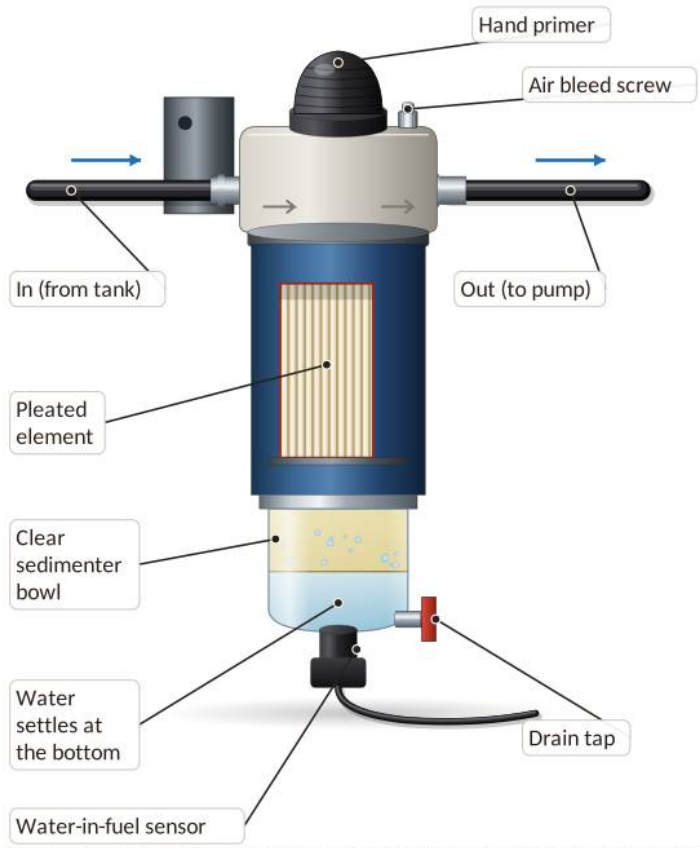
9.2 The Low-Pressure Side

Every diesel system has a low-pressure side that supplies clean, air-free fuel to the injection pump:

- **Tank and pick-up.** The pick-up stands above the tank floor, clear of water and sediment. Running the tank dry draws in dirt and air.

- **Lift (feed) pump and hand primer.** A plunger pump on an in-line pump, a vane pump inside a rotary pump, or a gear or electric pump on common rail. The primer fills filters and pushes out air.
- **Sedimenter and water separator.** Water is heavier than diesel and settles in a clear bowl. A water-in-fuel sensor lights a lamp on the dash when the level is high.
- **Filters.** Lorries often have primary (coarse) and secondary (fine) filters; common-rail filters are much finer. Some have an electric fuel heater.
- **Return and leak-off lines** carry surplus fuel, heat and air back to the tank.

Fuel filter and water separator (sedimenter) on a pick-up



Service routine (typical)

1. Engine off; card and drip tray under the filter; gloves on
2. Drain water: open the tap and the bleed screw until clean diesel runs; close both
3. Unscrew the canister; keep the bowl and sensor if re-used
4. New seals, oiled with diesel; fill a spin-on filter with clean diesel; hand-tighten
5. Open the bleed screw; pump the primer until no bubbles; close
6. Start; check for leaks with card; water lamp out
7. Drained fuel and old element to the waste-fuel drum

Interval: when the water lamp lights or at every service; filter typically 20,000–40,000 km, sooner on poor fuel (check the manual).

Figure 9.2 Fuel filter and water separator with its parts, and the routine for servicing it.

Drain the separator when the lamp lights and at every service. Replace the filter at the manual's interval, typically 20,000–40,000 km, sooner after bad fuel. A filter costs about KSh 2,000 (approximate, 2026): far less than one injector.

> **SAFETY FIRST: FUEL WORK**
>
> Diesel fires are Class B: keep a foam, CO_2 or dry-powder extinguisher and a spill kit at the bay, never water. No smoking or flames. Nitrile gloves and safety glasses (diesel causes dermatitis). Catch fuel in a labelled container and wipe spills at once. Never prime with petrol.

9.3 Three Kinds of Injection System

Chapter 4 explained direct injection (DI: fuel sprayed into a bowl in the piston) and indirect injection (IDI: fuel sprayed into a swirl chamber in the head). Either way, the injection system has four jobs: **raise** the fuel to injection pressure, **meter** the right quantity for the load, **time** the start of injection to the crank angle, and **atomise** the fuel into a fine spray. Figure 9.3 shows the three main layouts you will meet.

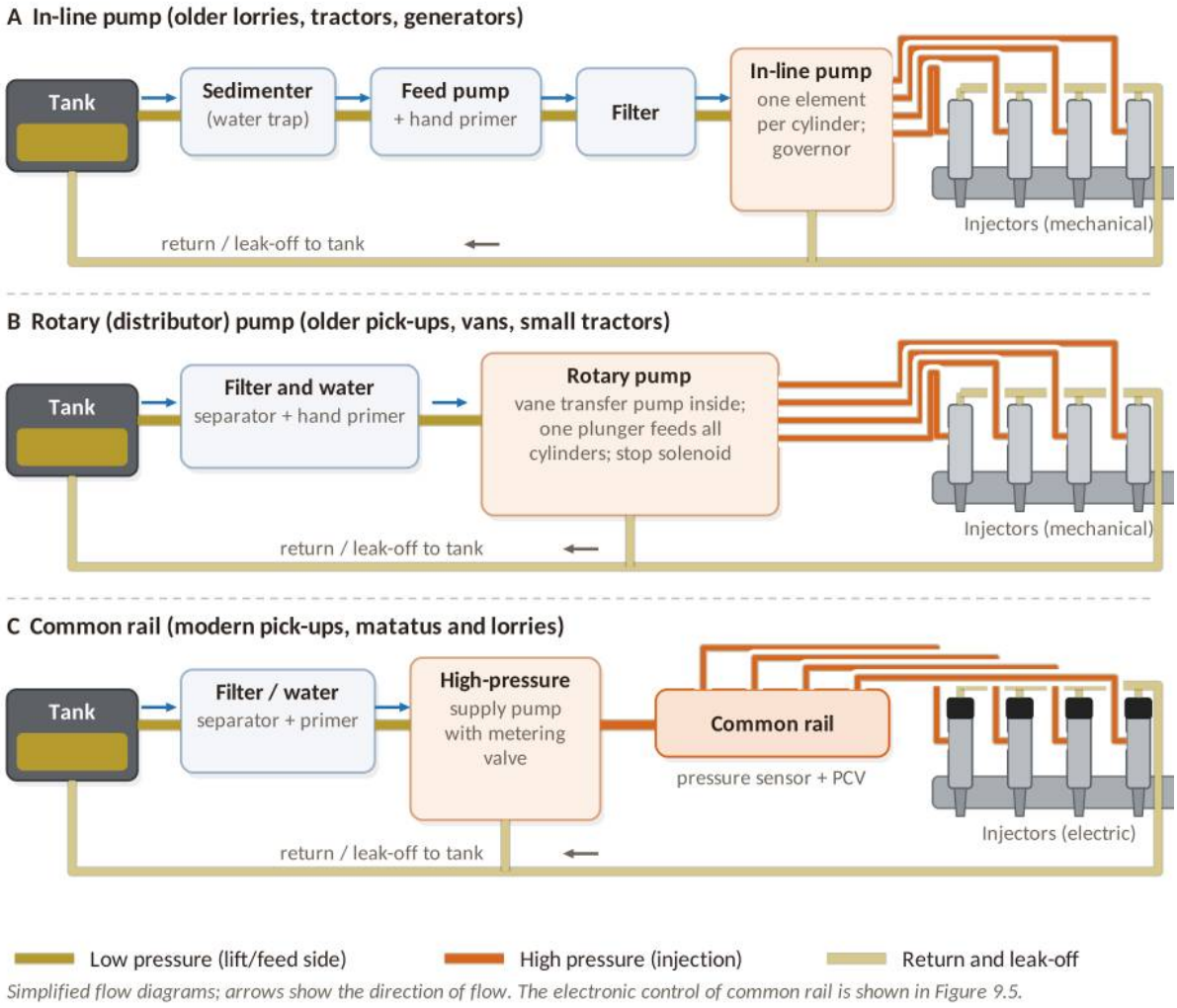


Figure 9.3 The three main diesel fuel system layouts. Olive-gold: low pressure; deep orange: high pressure; pale olive: return and leak-off.

Table 9.2 Injection systems compared (typical)

System	How fuel is metered and timed	Where you meet it
In-line pump	One plunger per cylinder; helix and rack (quantity); camshaft (timing); mechanical governor	Older lorries, buses, tractors, generators, graders
Rotary (distributor) pump	One plunger feeds all cylinders through a distributor head; internal governor and advance	Older pick-ups, vans and small tractors; 1HZ-type 4x4s and buses
Unit injector / unit pump	A pump element for each cylinder, worked by the engine camshaft	Some heavy lorries and buses
Common rail	Pump keeps the rail at a pressure set by the ECU; the ECU opens each injector electrically	Modern pick-ups, matatus and Isuzu-type lorries (4J-series, 4HK1)

9.4 Mechanical Pumps

9.4.1 The in-line pump

An in-line ("jerk") pump has a camshaft driven at half engine speed and one pumping element for each cylinder. Each element is a plunger moving in a barrel with a port in the wall (Figure 9.4). As the cam lifts the plunger, its top closes the port and fuel is pushed through the delivery valve to the injector. Delivery stops when the sloping **helix** on the plunger uncovers the port. The **control rack** turns every plunger through a toothed control sleeve, so the helix meets the port earlier (less fuel) or later (more fuel). At the stop position, the vertical slot faces the port and nothing is delivered.

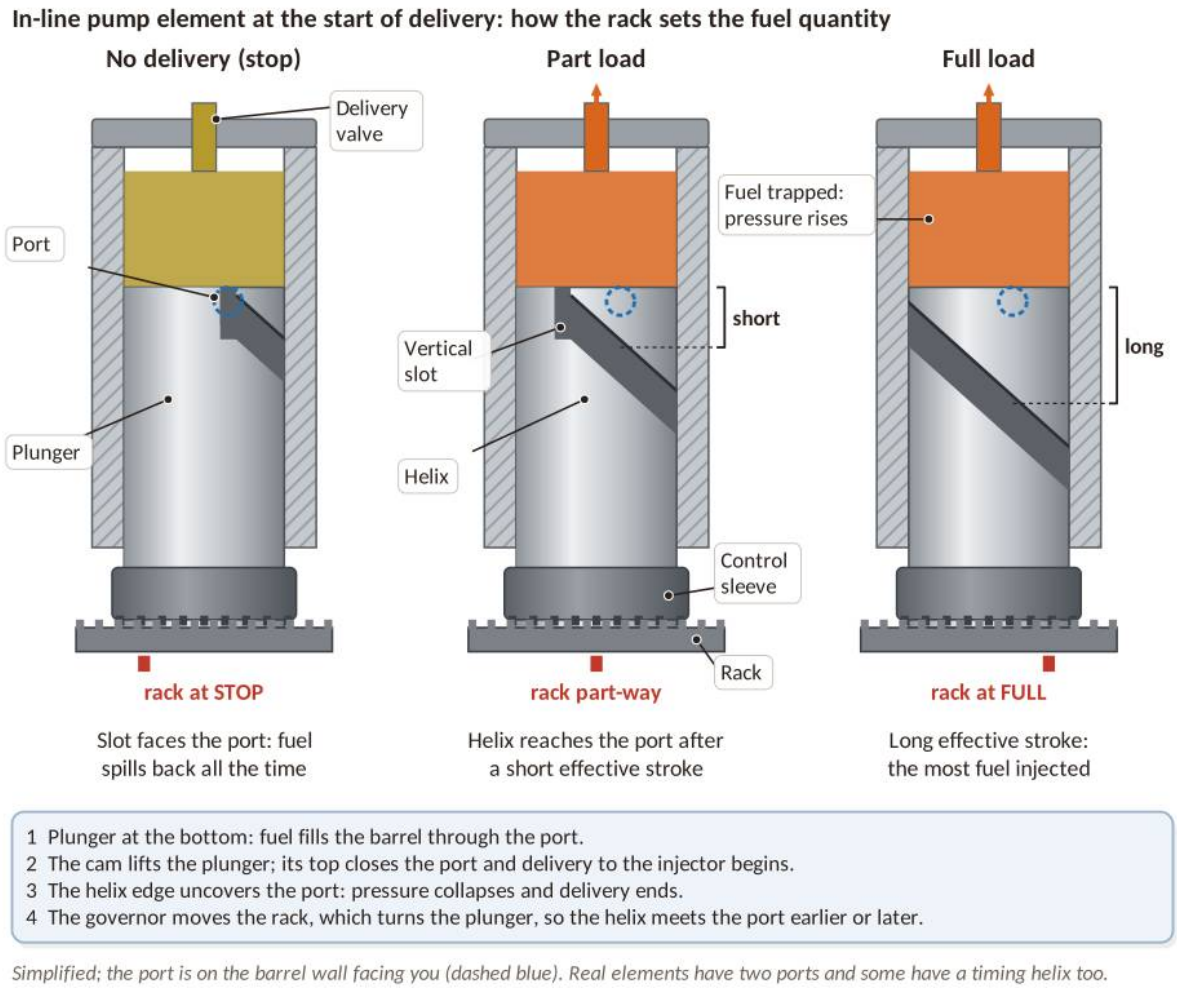


Figure 9.4 In-line pump element at the start of delivery, at the stop, part-load and full-load rack positions (simplified).

The **governor** moves the rack; the throttle only tells it what speed the driver wants. Flyweights swing out as speed rises and pull the rack towards less fuel, holding the idle steady and preventing over-speed downhill. The **delivery valve** closes sharply after each injection so that the injector stops without dribbling.

9.4.2 The rotary pump

A rotary (distributor) pump does the same work with one plunger. In the common axial-plunger type, a cam plate makes the plunger move in and out as it turns, and a slot in the plunger lines up with each outlet in turn. A spill ring controlled by the governor sets the quantity; a piston worked by transfer-pump pressure turns the cam ring to **advance** injection as speed rises. An electric **fuel shut-off (stop) solenoid** on the pump head cuts the fuel when the key is switched off. If that solenoid fails, the engine cranks but never starts. Rotary pumps are lubricated by the fuel itself, so water kills them quickly.

Electronic rotary pumps, unit injectors and unit pumps (heavy lorries) are specialist work. Timing a mechanical pump to the engine is in Chapter 7 (Figure 7.7).

9.5 Common Rail

In common rail, making pressure and injecting are separate jobs (Figure 9.5). An engine-driven **high-pressure supply pump** feeds a thick steel **rail**; short pipes feed **electric injectors**; the **ECU** decides the pressure and when and how long each injector opens.

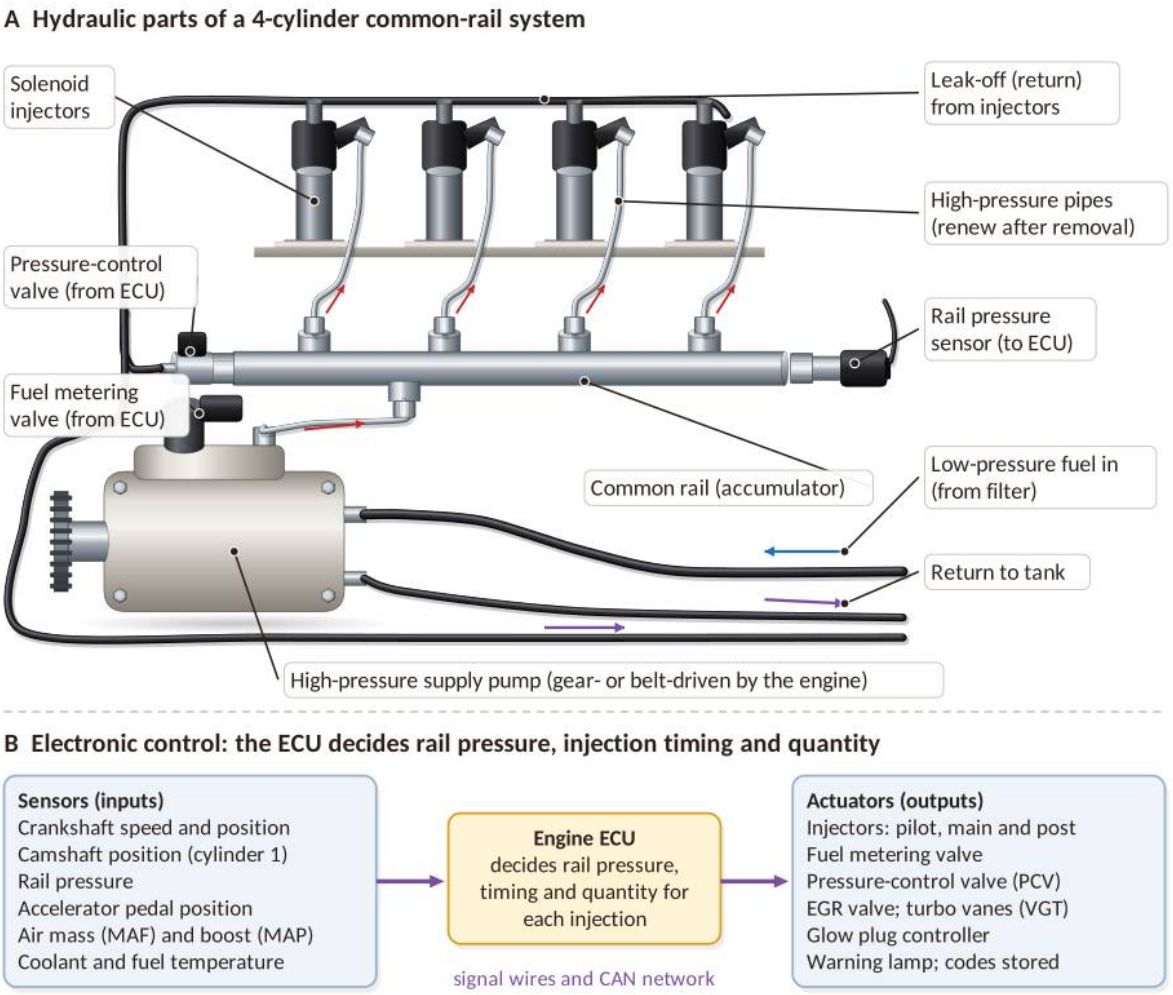


Figure 9.5 A common-rail system. A: hydraulic parts. B: the ECU, its sensors and the actuators it controls.

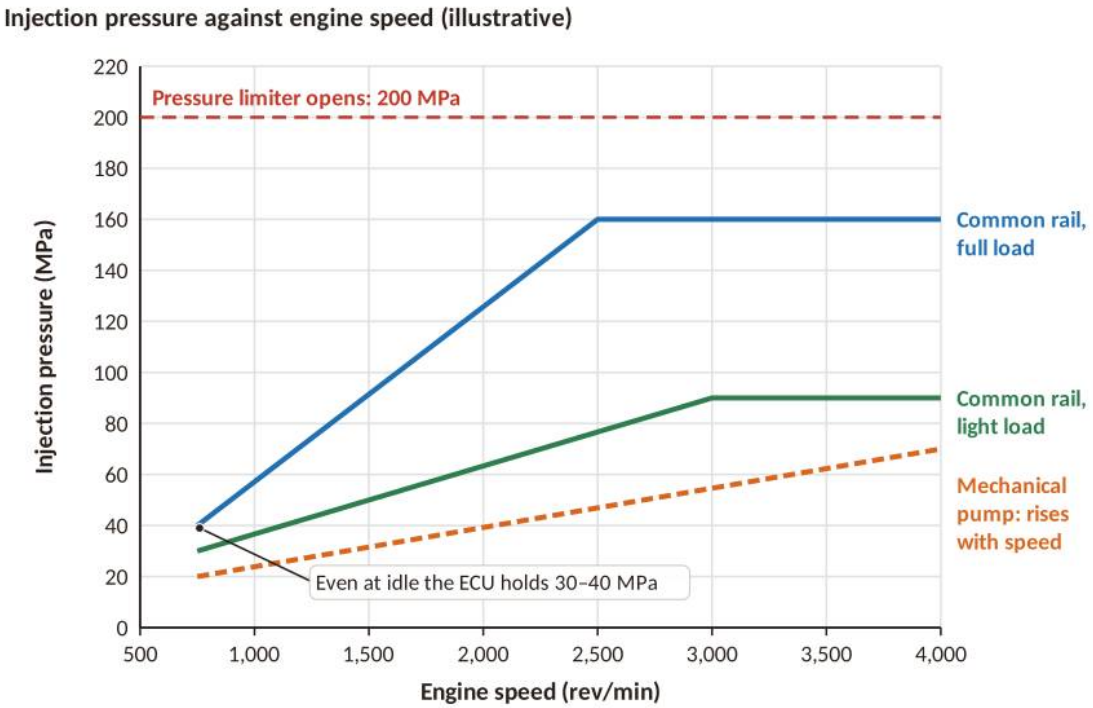
- **Fuel metering valve** (suction control valve): controls how much fuel enters the pump, and so the rail pressure.
- **Rail pressure sensor:** a three-wire sensor (5 V reference, signal, earth) that tells the ECU the actual pressure.
- **Pressure-control valve (PCV):** on some rails, spills fuel to the tank. Many rails also have a pressure limiter (about 200 MPa on a 1KD-FTV-type).
- **Injectors:** solenoid or piezo (Section 9.6), each with a code to enter into the ECU when fitted (Chapter 7).

Pressure no longer depends on speed, so the ECU keeps high pressure at idle and splits injection into a small **pilot** (softens knock), the **main**, and **post** injections (heat the exhaust for the DPF); the newest systems inject up to about ten times per cycle. Typical rail pressures are about 1,350–1,800 bar on older and light systems and 2,000–2,700 bar (200–270 MPa) on modern ones; a 1KD-FTV-type pick-up engine works at about 30–160 MPa (Figure 9.7).



Figure 9.6 The common rail on a six-cylinder lorry engine. Each union on the rail feeds one injector through its own high-pressure pipe; note how close the pipes run to the wiring loom.

Photo: Panoha, CC BY-SA 3.0, via Wikimedia Commons



Common rail values follow a 1KD-FTV-type engine (rail about 30–160 MPa, limiter 200 MPa); the mechanical line shows only the trend. 1 MPa = 10 bar. Typical values for illustration — always use the manufacturer's data.

Figure 9.7 Injection pressure against engine speed. Common rail holds high pressure even at idle and raises it with load; a mechanical system's pressure rises with speed (illustrative).

> **SAFETY FIRST: COMMON-RAIL PRESSURE**
>
> Rail pressure stays high after the engine stops: wait until it has fallen (scan tool reading or the manual's time) before loosening any high-pressure union. Never crack a pipe on a running engine to "bleed" it, and never feel for a leak by hand: use card and a face shield. A fuel injection into the skin is a surgical emergency: hospital at once (999 or 112); say it was high-pressure diesel (Chapter 2).

9.6 Injectors and Nozzles

9.6.1 Mechanical injectors

A mechanical injector (Figure 9.8) is a spring-loaded valve. When fuel pressure on the needle's shoulder in the **pressure chamber** beats the spring, the needle lifts and fuel sprays; when delivery stops, the spring snaps it shut. **Shims** above the spring set the opening pressure. Fuel leaking past the needle lubricates it and leaves through the leak-off.

Two nozzle types are common. **Pintle nozzles** (IDI engines) have a pin that projects through a single hole and gives one hollow cone; they open at lower pressures, typically 10–15 MPa. An early Toyota manual sets a 1HZ-type nozzle to 13.2–15.2 MPa (135–155 kgf/cm²); later manuals give higher figures, so check yours. **Multi-hole nozzles** (DI engines) have 4–8 tiny holes that aim jets into the piston bowl; they typically open at 17–30 MPa.

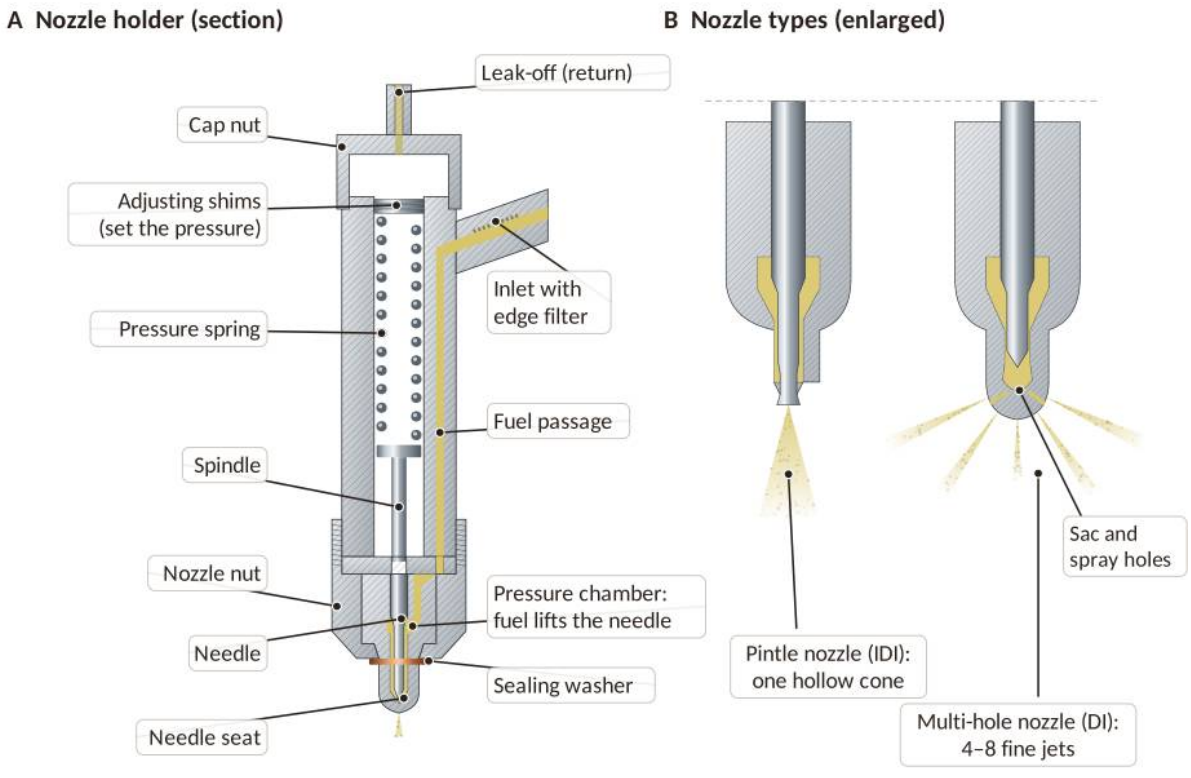


Figure 9.8 Mechanical injector. A: the nozzle holder in section. B: pintle and multi-hole nozzle tips.

WORKED EXAMPLE 9.2: INJECTOR PRESSURES IN OTHER UNITS

Pressure gauges and manuals use different units. Use 1 MPa = 10 bar = 1,000 kPa; 1 bar ≈ 14.5 psi; 1 kgf/cm² = 0.0981 MPa.

A nozzle opens at 14.2 MPa: 14.2 × 10 = **142 bar**; 142 × 14.5 = **about 2,060 psi**; 14.2 ÷ 0.0981 = **about 145 kgf/cm²**.

A pop-tester gauge reads 200 bar: 200 ÷ 10 = **20 MPa**; 200 × 14.5 = **about 2,900 psi**; 20 ÷ 0.0981 = **about 204 kgf/cm²**.

Sense-check: 1 kgf/cm² ≈ 0.98 bar, so 142 bar and 145 kgf/cm² should be close, and they are.

9.6.2 Common-rail injectors

A common-rail injector is always full of fuel at rail pressure, so a spring alone cannot hold it shut. It uses a hydraulic trick (Figure 9.9). Rail pressure acts on the top of a **control plunger** in a small **control chamber**, as well as on the needle's shoulder. With the spring helping, the downward force wins and the needle stays shut. When the ECU energises the **solenoid**, it lifts an armature and a tiny ball valve opens the **outlet throttle**. Fuel escapes from the control chamber to the leak-off faster than the **inlet throttle** can refill it. The pressure on top of the plunger falls, and the pressure under the needle shoulder lifts the needle. Switch the current off and the needle closes in a fraction of a millisecond.

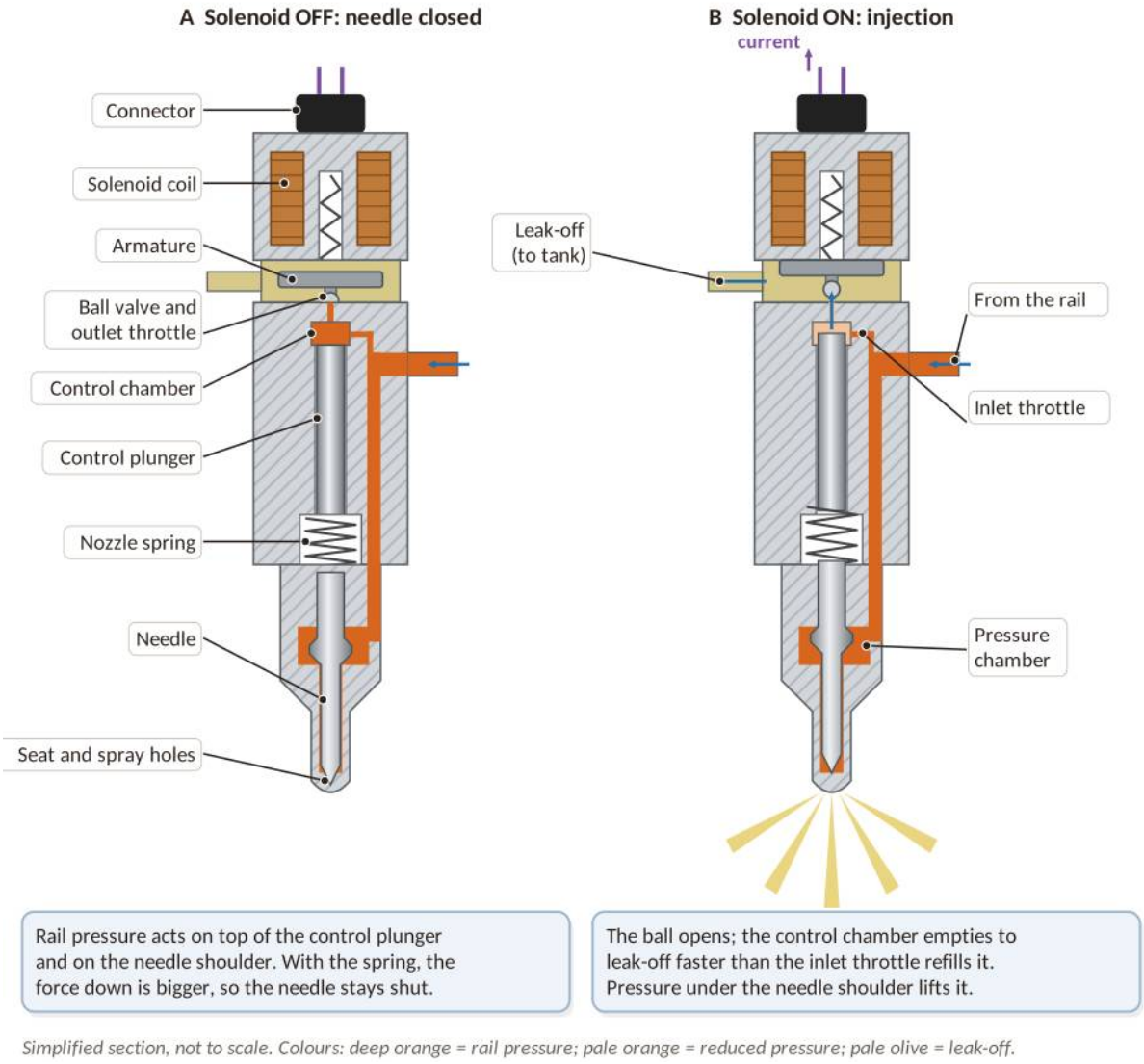


Figure 9.9 How a solenoid common-rail injector works. A: solenoid off, needle closed. B: solenoid on, the control chamber empties and the needle lifts (simplified section).

Piezo injectors use a crystal stack that grows slightly under voltage; they switch faster. Both types return fuel to the leak-off each time they open, and more when worn, which is why the back-leak test works (Section 9.8.4). Worn injectors also show in the correction values (Chapter 5, Figure 5.10).

9.7 Diagnosing Fuel System Faults

Use the Chapter 5 method. Table 9.3 links symptoms to fuel system checks.

Table 9.3 Fuel system symptoms, likely causes and first checks

Symptom	Likely fuel causes	First checks
Cranks, no start	Empty tank, air in fuel, blocked filter, stop solenoid, rail pressure too low	Fuel in clear pipe; solenoid click; rail pressure while cranking
Hard start, white smoke	Water in fuel, worn injectors, late timing, low cetane fuel	Drain separator; pop test; timing marks
Black smoke, low power	Dribbling or worn injectors, over-fuelling, wrong timing (also air filter, turbo)	Pop test or back-leak test; corrections; boost
Loss of power under load	Blocked filter, weak lift pump, restricted pick-up, metering valve fault	Vacuum and pressure test; rail pressure actual vs desired
Knock in one cylinder	Injector stuck open, dribbling or high opening pressure	Cylinder cut-out test; pop test
Rough idle, hunting	Air leak on suction side, unequal injectors, governor fault	Bubbles in clear pipe; balance rates
High fuel use	Leaking injectors, external leaks, wrong timing, overload	Leak check with card; injector tests; logbook
Stops after a filter change	Air not bled	Bleed in flow order (Figure 7.9)

9.7.1 Testing the low-pressure side

Many "injector" faults are really cheaper supply faults. Check first:

- **Air:** fit a short clear pipe in the line to the pump. A stream of bubbles means an air leak on the suction side: a loose union, cracked pipe, damaged filter seal or a loose primer.
- **Restriction:** a vacuum gauge on the lift pump inlet. A high vacuum under load means a blocked pick-up, kinked pipe or clogged filter.
- **Supply pressure:** a low-pressure fuel gauge after the filter. Compare with the manual; a low reading means a weak lift pump or blocked filter.
- **Water and dirt:** drain the separator into a clear jar; slime in the old filter means diesel bug.

9.7.2 Short and open circuits

On electronic systems, many faults are wiring faults. The injectors, metering valve and PCV are actuators with two wires; the rail pressure sensor has three (Chapter 3, Section 3.10). An **open circuit** (break) stops all current: the part is dead and the ECU stores a "circuit open" code. A **short circuit** lets current bypass the part: a chafed wire touching the engine, or turns of a coil bridged inside. Figure 9.10 shows where to test with the key off and the connectors unplugged.

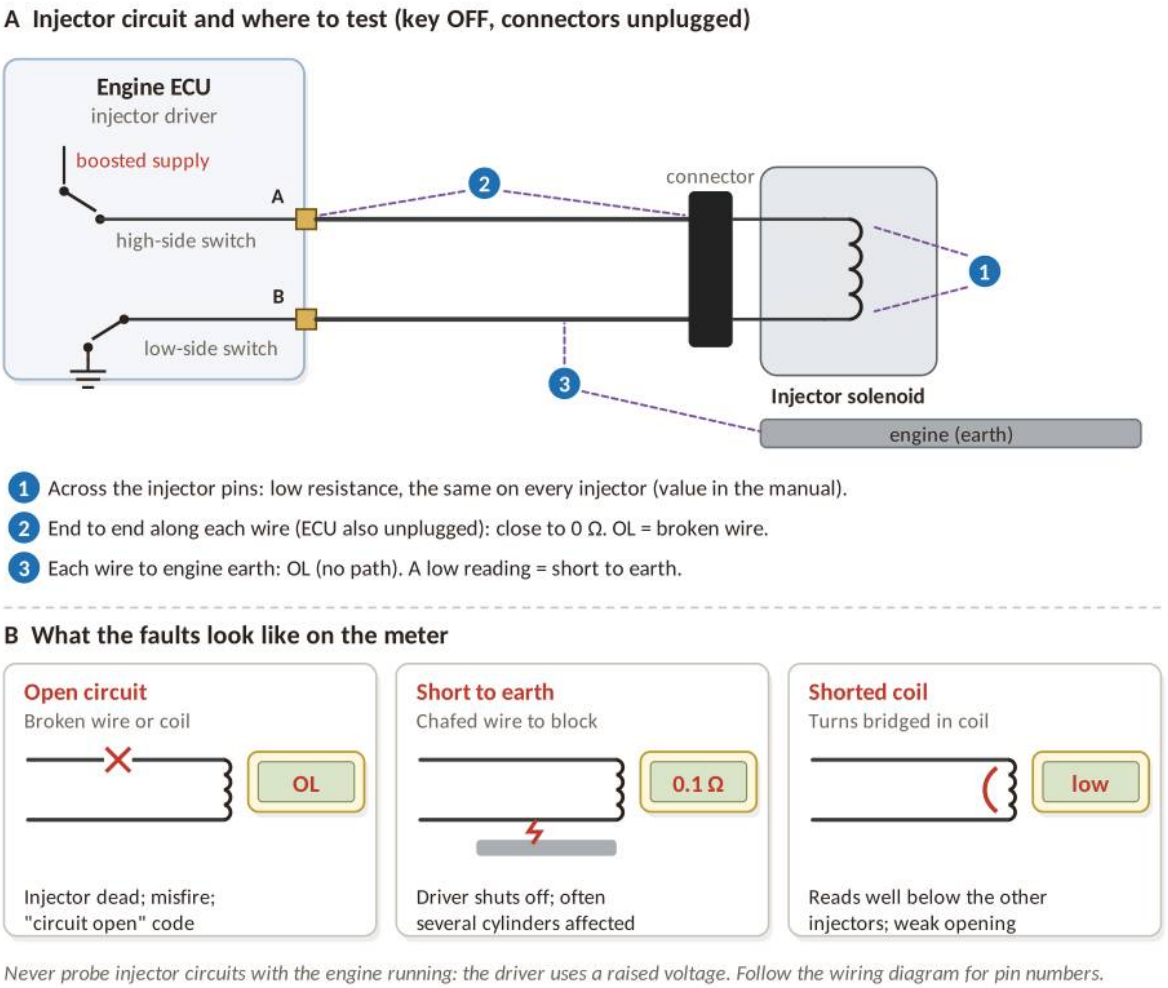


Figure 9.10 Testing a common-rail injector circuit with the key off. A: the three test points. B: what an open circuit, a short to earth and a shorted coil look like on the meter.

Compare each coil's resistance with the others and the manual: OL means an open coil or broken wire; a reading well below the others means shorted turns. Then check each wire end to end (close to 0 Ω) and to engine earth (OL). Looms often rub through where they cross the cam cover or a bracket. On the rail pressure sensor, check the 5 V reference and earth with the key on, and watch the live reading.

> **SAFETY FIRST: INJECTOR CIRCUITS**
>
> Injector drivers use a raised voltage to open the injectors quickly, and piezo injectors use more. Never back-probe injector connectors with the engine running unless the manual tells you to. Disconnect the battery negative before unplugging the ECU; most lorries are 24 V with two batteries in series.

9.8 Inspecting and Testing Injectors

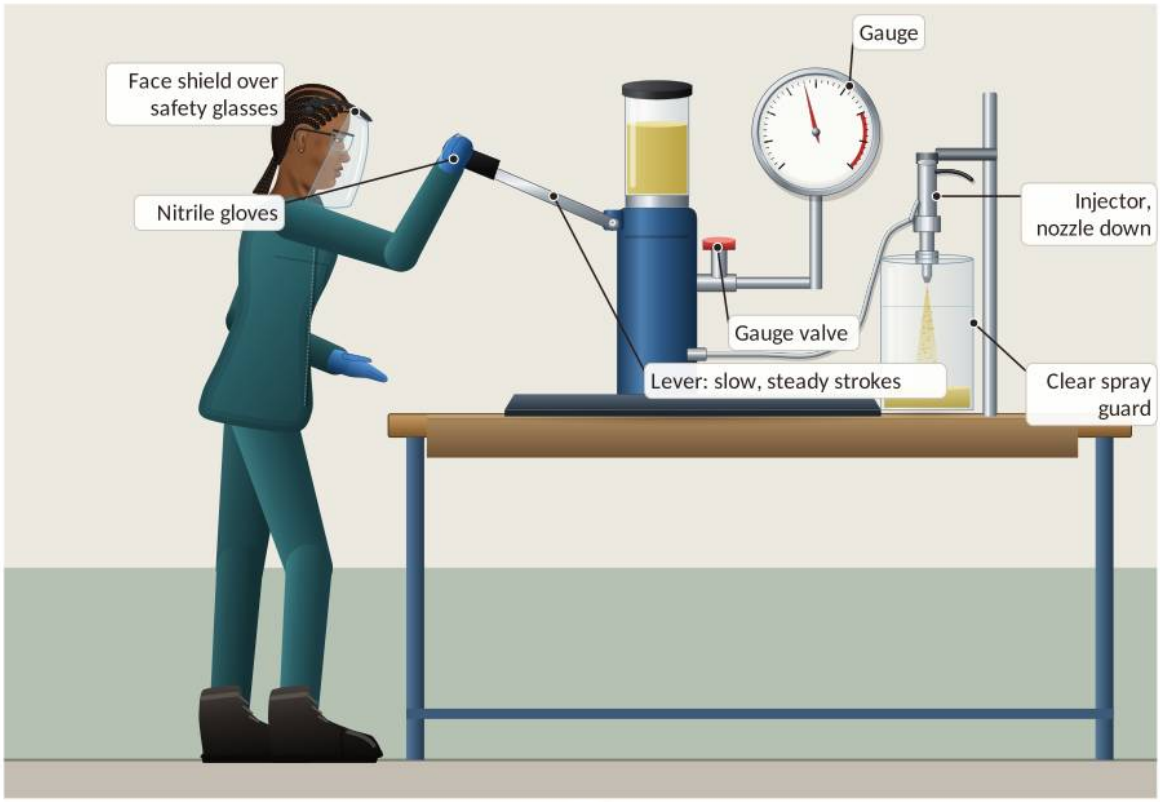
9.8.1 Visual inspection

Look for wet unions, fuel stains, chafed pipes, missing clamps, cracked leak-off hoses and black, tarry soot round an injector (a leaking copper washer). Check running joints with a piece of card, never your hand.

9.8.2 The pop test (mechanical injectors)

The hand pop tester (Figure 9.11) checks **opening pressure**, **seat tightness**, **chatter** and **spray**. The Toyota method for a 1HZ-type nozzle is typical: hold the pressure 1–2 MPa below the opening pressure for 10 seconds and the tip must stay dry; then pump at 15–60 strokes a minute for a used nozzle (30–60 for a new one) and listen for a sharp chatter with a fine spray and no after-drip.

Pop-testing a mechanical injector: face shield, gloves and the spray into the guard



1 Opening pressure (gauge valve open)
Pump slowly; read the gauge when the needle "pops" open. Example spec for a 1HZ-type nozzle: 13.2–15.2 MPa.

2 Leak (seat) test
Hold 1–2 MPa below the opening pressure for 10 s: the tip must stay dry.

3 Chatter and spray (gauge valve closed)
Pump briskly (15–60 strokes a minute for a used nozzle): a sharp chatter, a fine even spray, no after-drip.

4 Record and decide
Write each result; reset the pressure with one shim, clean or replace the nozzle.

Values from a Toyota 1HZ/1PZ-type manual; other engines differ — check the manual. Never put a hand near the nozzle.

Figure 9.11 Pop-testing a mechanical injector, with the four tests in order.

Judge the spray against Figure 9.12: dribbles, streaks, a missing jet or a solid stream mean clean or replace.



Figure 9.12 Spray patterns: two good and four faulty, with their likely causes.

In Figure 9.13, nozzle 3 opens too low, nozzle 6 too high, and nozzle 5 drips.

WORKED EXAMPLE 9.3: RESETTING A NOZZLE WITH ONE SHIM

Nozzle 3 opens at 12.5 MPa. Specification (early manual): 135–155 kgf/cm² (13.2–15.2 MPa). The manual says a 0.025 mm thicker shim raises the pressure by about 3.5–4.5 kgf/cm².

Present pressure: 12.5 ÷ 0.0981 = **about 127.5 kgf/cm²**, which is below 135.

Try 0.050 mm thicker (2 steps): rise 7.0–9.0, new pressure 134.5–136.5 kgf/cm². The low end may still fail. Try **0.075 mm thicker (3 steps)**: rise 3 × 3.5 = 10.5 to 3 × 4.5 = 13.5, new pressure **138.0–141.0 kgf/cm²** (13.5–13.8 MPa). That is inside the specification.

Fit **one** shim 0.075 mm thicker (for example 1.575 mm for 1.500 mm, if the kit has it); never stack shims. Re-test. Sense-check: nozzle 6 (158 kgf/cm²) needs the opposite: 0.050 mm thinner gives about 149–151 kgf/cm².

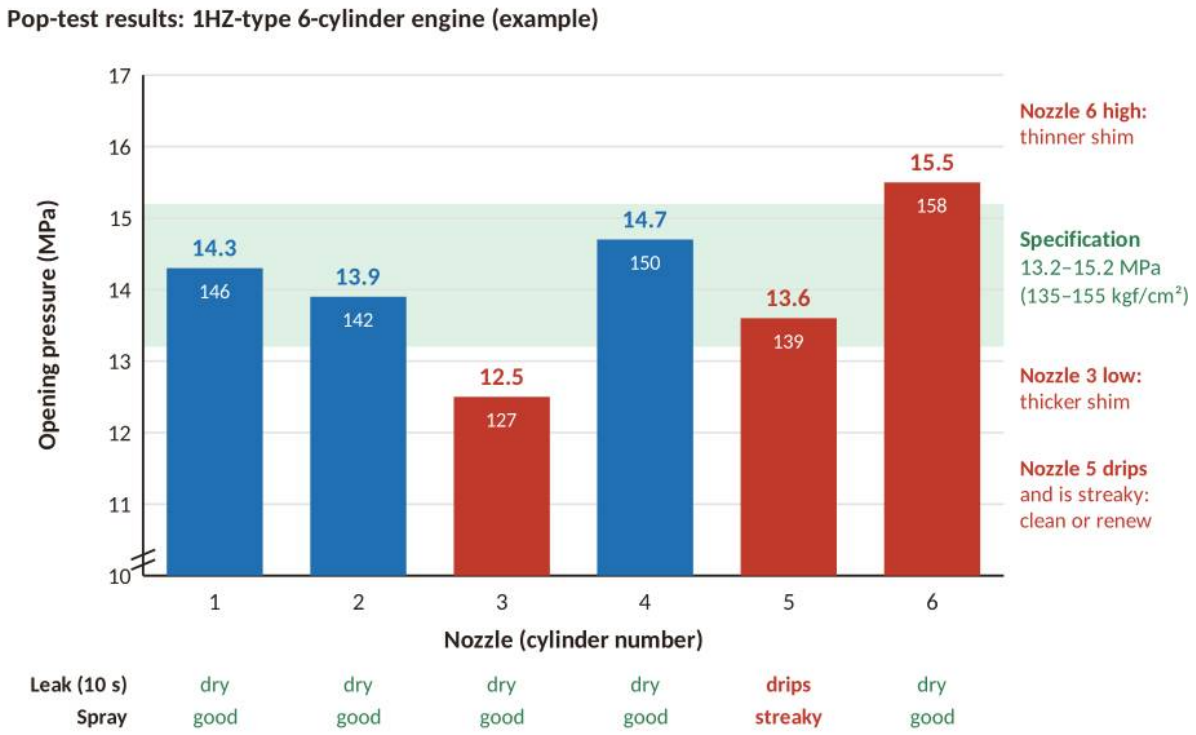


Figure 9.13 Pop-test results for a six-cylinder 1HZ-type engine. Nozzles 3 and 6 are outside the specification band; nozzle 5 is in band but drips and sprays unevenly.

9.8.3 Common-rail injectors

Common-rail injectors are **not** pop-tested. Check them with the scan tool (corrections, contribution test, rail pressure), electrical tests (Section 9.7.2) and the **back-leak test**. Bench testing and recoding are specialist work; never dismantle one on an open bench.

9.8.4 The back-leak test

Fit a measuring tube to each injector's leak-off port, blank the return, run (or crank) for the manual's time and compare. A worn injector returns far more fuel, and the rail may not keep up (P0087).

WORKED EXAMPLE 9.4: COMPARING BACK-LEAK RESULTS

A 4HK1-type lorry engine is idled for 2 minutes with tubes fitted. Results: injector 1 = 18 mL, 2 = 20 mL, 3 = 52 mL, 4 = 19 mL. The manual's limit for this test is 40 mL (example value).

Average of the three similar injectors: (18 + 20 + 19) ÷ 3 = 57 ÷ 3 = **19 mL**. Injector 3 ratio: 52 ÷ 19 = **about 2.7 times** the others.

Injector 3 is above the 40 mL limit and far above its neighbours: **send it for testing or reconditioning**. Total return: 18 + 20 + 52 + 19 = 109 mL in 2 minutes, about 55 mL a minute.

Sense-check: injector 3's correction value should also be well away from zero.

9.9 Servicing and Replacing Fuel System Parts

9.9.1 Filters and water separator

Replace the element as in Figure 9.2 and Practical task 9.1: drain the water first, fit new seals oiled with clean diesel, fill a spin-on filter before fitting, and bleed. On mechanical systems bleed in the flow order (Figure 7.9). On common rail, prime only the low-pressure side with the hand primer or by switching the key on and off several times, as the manual says.

9.9.2 Removing and fitting injectors

- Clean round the injectors first; cap every opening at once. Label parts by cylinder and note common-rail injector codes.
- Use a flare-nut spanner and a second spanner on the union. Use the correct puller on a seized injector, never a lever on the solenoid.
- Remove the old **copper sealing washer** from the bottom of the bore, and clean the seat with the correct cutter or brush.
- Fit a **new** washer and O-rings, tighten the clamp bolt to the specified torque, and fit the pipes without strain. Many makers say common-rail high-pressure pipes must be renewed once removed; follow the manual.
- Refit leak-off pipes with new clips or seals. Enter the injector codes (Chapter 7) and clear any fault codes.

9.9.3 Nozzles, pumps and specialists

A failed mechanical nozzle can be cleaned (brass brush and the correct hole probe, in clean fluid) and re-tested. A new nozzle costs about KSh 2,500, and a pop test and clean of four about KSh 2,500 (approximate, 2026). You remove and refit pumps (timing in Chapter 7), but only a diesel pump shop with a calibration bench opens and calibrates them (about KSh 15,000). Never break the seals on a pump's adjusting screws: it is tampering and ruins the smoke level.

WORKED EXAMPLE 9.5: RECONDITIONED OR NEW COMMON-RAIL INJECTORS?

A 3.0 L pick-up at 130,000 km needs injectors. Prices (approximate, 2026): reconditioned KSh 25,000, new KSh 55,000 each.

Reconditioned set: 4 × 25,000 = **KSh 100,000**. New set: 4 × 55,000 = **KSh 220,000**. Difference: **KSh 120,000**.

If tests show only one is bad: **KSh 25,000**. Sense-check: testing first saves at least KSh 75,000 against changing all four. Insist on the new code and a warranty.

GREEN TIP

Used fuel filters are full of diesel and water. Drain them into the waste-fuel drum, then bag them for a NEMA-licensed handler with oily rags. Collect pop-tester fluid and back-leak fuel too, never on the floor. Return old injectors and pumps as exchange cores for reconditioning. Good injectors and clean filters also cut fuel use and black smoke.

9.10 Emission Parts Linked to the Fuel System

The occupational standard lists catalytic converters, EGR valves and sensors with the fuel system, because injection decides how hard they work. Chapter 4 (Section 4.9) describes the EGR, DOC and DPF. The ECU uses **post-injection** to heat the exhaust for DPF regeneration; repeated failed regenerations dilute the oil with fuel. Many Euro IV and V lorries and buses also have **selective catalytic reduction** (SCR) with **AdBlue** (diesel exhaust fluid, DEF) (Figure 9.14).

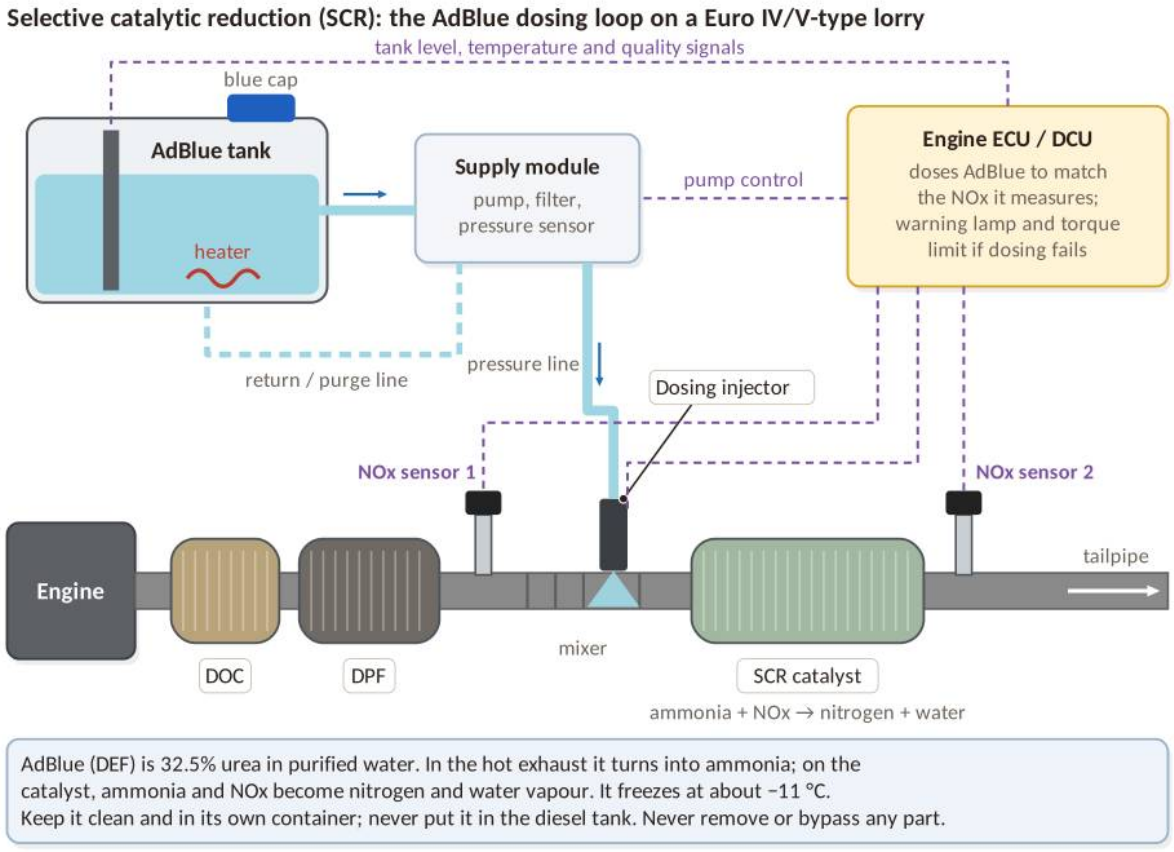


Figure 9.14 Selective catalytic reduction: the AdBlue dosing loop on a lorry.

The control unit reads the NOx sensors and doses just enough AdBlue (32.5% urea in purified water; freezes at about −11 °C). Faults show as a lamp, a code and often a torque limit: an empty or dirty tank, crystals in the dosing injector, a failed pump or heater, or a NOx sensor. Never top up with water, never put AdBlue in the diesel tank, and never remove, bypass or "delete" any SCR, EGR or DPF part: it is tampering and it pollutes.

COMMON MISTAKES

- Changing injectors before checking filters, water, air and supply pressure.
- Cracking a high-pressure union on a running common-rail engine to "bleed" it. Prime the low-pressure side only.
- Re-using the old copper washer, or leaving the old one stuck in the bore so that two are fitted.
- Fitting a common-rail injector without entering its code into the ECU.
- Leaving fuel openings uncapped: one grain of murram dust can ruin a common-rail injector.

9.11 Re-installation Checks and the Service Report

After any fuel system work, check before you hand the vehicle back:

1. **Lines and clamps:** every pipe fitted without strain, clamps refitted, leak-off pipes clipped.
2. **Bleeding:** no air (clear pipe or steady idle); the engine starts within normal cranking time.
3. **Pressure:** low-pressure supply on a gauge where the manual gives a value; on common rail, actual rail pressure following desired on the scan tool at idle and on a snap acceleration.
4. **Injector function:** smooth idle; balance or cut-out test; corrections near zero.
5. **Leaks and smoke:** card test at every joint, face shield on; no abnormal smoke on a road test.

Record the work on a **fuel system service report**: customer and vehicle details (registration, engine number, km or hours), complaint, findings, tests and readings, parts fitted, and the condition handed back.

Practical task 9.1: Replace the fuel filter and water separator element, bleed and check for leaks

Tools and equipment

- Filter wrench, assorted spanners and screwdrivers
- Clear jar and drip tray; low-pressure fuel gauge (if specified)
- Scan tool (common-rail engine); manufacturer's manual
- Fire extinguisher (foam, CO_2 or dry powder) and spill kit at the bay

Materials

- New filter element or spin-on filter with seals
- Clean diesel in a clean container
- Nitrile gloves, safety glasses, rags, card for leak checks
- Labelled waste-fuel container; service report sheet

Steps

1. Place the tray. Open the drain tap and bleed screw and drain the water into a clear jar. Note how much water and whether there is slime.
2. Unplug the water sensor. Remove the filter; keep the bowl and sensor if they are reused.
3. Fit new seals oiled with clean diesel; fill a spin-on filter with clean diesel and fit it by hand.
4. Open the bleed screw and pump the primer until bubble-free fuel flows; close the screw. On a mechanical pump continue bleeding in flow order if needed (Figure 7.9).
5. Start the engine. It may run rough for a few seconds. On common rail, check that rail pressure rises normally on the scan tool.
6. Check every joint for leaks with card, and check that the water lamp is out.
7. Dispose of waste correctly and complete the record.

Safety

- No smoking or flames; extinguisher within reach.
- Never open a common-rail high-pressure pipe to bleed.
- Wipe spills at once; gloves and glasses on.

Record your results: fuel filter service

Item	Result
Vehicle, registration, engine number, km or hours	
Water drained (approx. mL) and condition (clear, cloudy, slime)	
Filter part number fitted; interval due	
Bleeding: method used; start time	
Rail or supply pressure at idle (if checked)	
Leak check (pass / fail); water lamp out (yes / no)	
Waste disposed (container used); trainer's signature	

Practical task 9.2: Test injectors and complete a fuel system service report

Tools and equipment

- Hand injector (pop) tester with spray guard, or an injector testing machine
- Injector puller, flare-nut spanners, torque wrench
- Back-leak test kit and scan tool (common-rail option)
- Face shield, safety glasses, nitrile gloves

Materials

- Clean test fluid or filtered diesel
- New copper washers, O-rings, leak-off clips; shim kit
- Caps and plugs for open ports; card for leak checks
- Waste-fuel container; service report sheet

Steps

1. Mechanical engine: clean round the injectors, remove them in order, cap all openings and remove the old washers.
2. Fit each injector to the tester with the spray into the guard. With the gauge valve open, find the opening pressure.
3. Hold 1–2 MPa below opening pressure for 10 s; check that the tip stays dry.
4. Close the gauge valve; check chatter and spray at brisk strokes.
5. Record; reset with one shim, or clean or replace the nozzle; re-test. Refit with new washers to torque, bleed and leak-check.
6. Common-rail option: read corrections and run a cylinder cut-out test; then do a back-leak test as the manual says and compare the tubes.
7. Complete the fuel system service report and explain your decision to the trainer.

Safety

- Face shield on at the tester; hands never near the spray.
- Wait for rail pressure to fall before opening common-rail pipes.

- Collect all test fluid in the waste container.

Record your results: injector test

Injector	1	2	3	4	5	6
Opening pressure (MPa)						
Leak 10 s (dry / drips)						
Chatter and spray						
Or: back-leak (mL) / correction						
Action (shim, clean, replace, OK)						
Specification and source; parts used; leak check after refitting; condition handed back; trainer's signature:						

Chapter summary

- Diesel is fuel, lubricant and coolant for the pump: water, dirt, wax, kerosene and high sulphur all cause damage. KS EAS 177 sets 10 ppm sulphur; a 2026 waiver allowed 50 ppm.
- The low-pressure side (tank, lift pump, primer, separator, filters, return) must deliver clean, air-free fuel; test it before blaming injectors.
- In-line pumps meter fuel with a helix and rack; rotary pumps use one plunger and a distributor; both need timing to the engine.
- Common rail stores fuel at up to about 1,350–2,700 bar; the ECU sets pressure with a metering valve or PCV and opens each injector electrically, with pilot, main and post injections.
- Mechanical injectors are pop-tested for opening pressure, seat tightness, chatter and spray; opening pressure is reset with one shim.
- Common-rail injectors are checked with the scan tool, electrical tests and a back-leak test, and bench-tested by a specialist.
- SCR uses AdBlue (32.5% urea) to remove NOx; never delete emission parts. Record all work on a fuel system service report.

Check your competence

- [ ] I can explain how fuel quality affects a diesel and check fuel for water and dirt.
- [ ] I can trace the fuel circuit on in-line, rotary and common-rail systems.
- [ ] I can test the low-pressure side for air, restriction and supply pressure.
- [ ] I can find open and short circuits in injector and sensor wiring safely.
- [ ] I can pop-test a mechanical injector and reset its opening pressure.
- [ ] I can carry out and interpret a back-leak test on a common-rail engine.
- [ ] I can replace a fuel filter and water separator, bleed the system and check for leaks.
- [ ] I can complete a fuel system service report.

Practice questions

1. Give three jobs that diesel fuel does in a fuel system, and explain why kerosene in diesel damages a rotary pump.
2. (Oral) List the parts of the low-pressure side in order from the tank to the injection pump, and say what each does.
3. Explain, with a sketch, how turning the plunger of an in-line pump changes the amount of fuel delivered.
4. A scan tool reads rail pressure of 250 bar at idle. Convert this to MPa, psi and kgf/cm². Why does a common-rail engine need high pressure even at idle?
5. A nozzle with a specification of 135–155 kgf/cm² opens at 128 kgf/cm². Each 0.025 mm of shim changes the pressure by 3.5–4.5 kgf/cm². What single shim change would you make, and what range of opening pressure do you expect?
6. A lorry uses 165 L of diesel on a 600 km trip. Calculate its consumption in L/100 km and the fuel cost of the trip at KSh 227.76 per litre.
7. Explain how a solenoid common-rail injector opens and closes. Why can it not be pop-tested?
8. Describe how you would test an injector circuit for an open circuit and for a short to earth. What readings do you expect for a good circuit?
9. Fault finding: a 3.0 L common-rail pick-up loses power on hills, sets P0087, and the water lamp flickers. The owner says it was filled at a new station last week. List your checks in order and the likely cause.
10. Practical: replace the fuel filter on a workshop vehicle, bleed the system, and pop-test one injector, then present your completed service report to your trainer.

Enjoyed this sample?

This free sample has the front matter, Chapter 1 and the full Chapter 9 on diesel fuel systems: in-line, rotary and common-rail injection, bleeding, injector testing and service records. The complete guide has **15 chapters** and **333 pages**. It covers both Level 4 units (Maintain Vehicle Diesel Engine and Maintain Vehicle Suspension and Steering System) plus the 320-hour industrial attachment: diesel diagnosis, overhaul, timing and tune-up, cooling and lubrication; suspension, steering, wheels and tyres, steering geometry and wheel alignment.

It also includes 150+ realistic illustrations, diagrams, charts and photos, 72 worked examples, 27 practical tasks with record sheets, 150 practice questions with full answers, two mock assessments, a 184-term glossary, a quick reference of typical values and photocopiable logbook and test sheets.

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