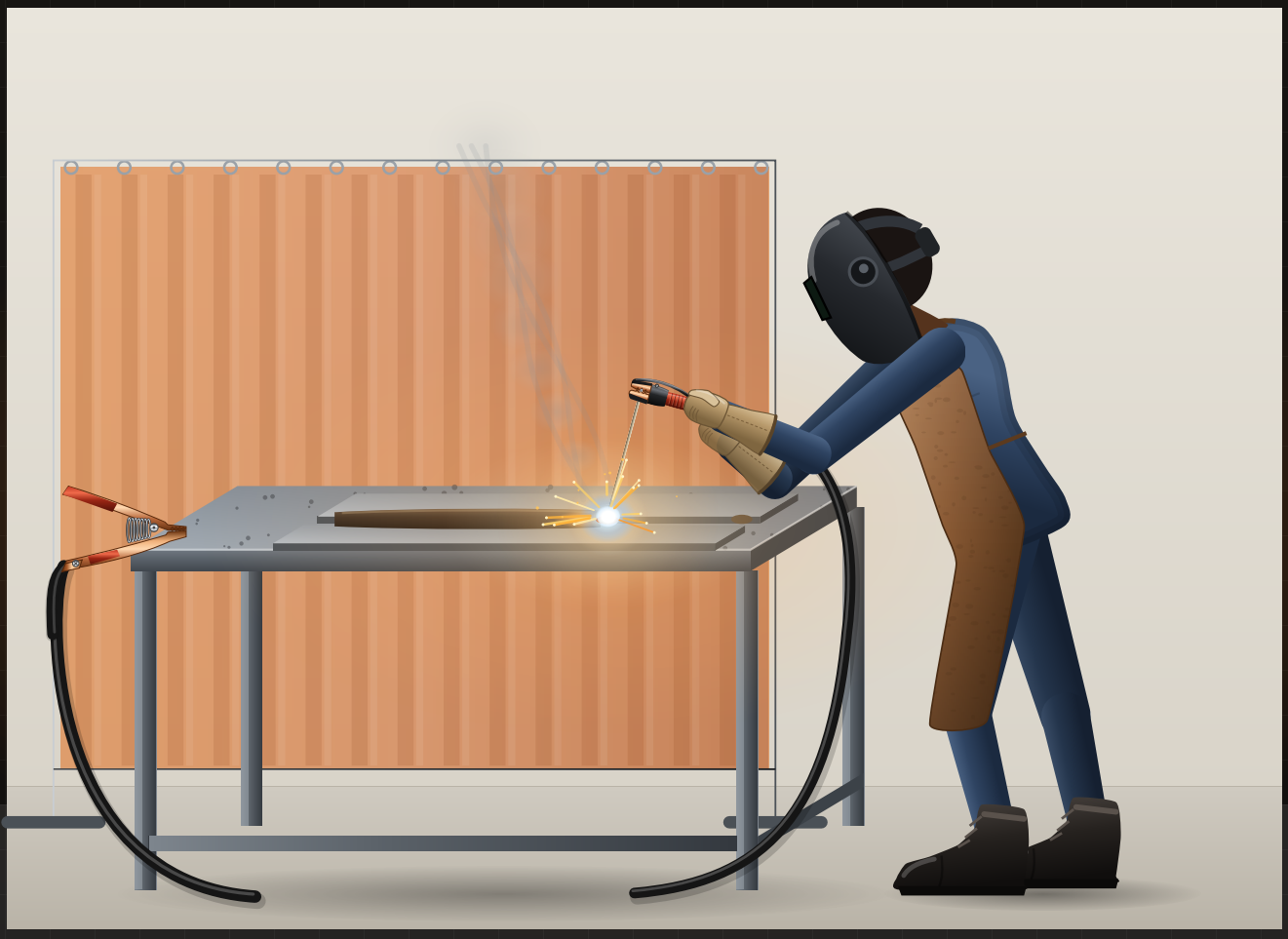
KNQF LEVEL 3 · TVET CDACC CYCLE 3

Welding Level 3

A Practical Study Guide for Kenyan Trainees

Fabrication · Arc welding · Gas welding, brazing and soldering



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

For trainees, RPL candidates, trainers and jua kali fundis

Alphonce Kimutai Kirui

Aligned to the TVET CDACC Competency-Based Modular Curriculum, Welding KNQF Level 3

Welding Level 3

A Practical Study Guide for Kenyan Trainees

Fabrication Processes · Arc Welding · Gas Welding, Brazing and Soldering
Kenya National Qualifications Framework (KNQF) Level 3

Alphonce Kimutai Kirui

Welding Level 3: A Practical Study Guide for Kenyan Trainees
First edition, October 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 Welding, KNQF Level 3 (Cycle 3, programme code 0715 254A, unit codes ENG/CU/WEF/CR/01–03/3/MA). Unit titles and codes are used for reference only. The book is not published, endorsed or approved by TVET CDACC, TVETA or the Ministry of Education. Always follow the current official curriculum and your trainer's guidance.

Safety and accuracy notice

Welding and fabrication carry serious hazards: arc radiation, burns, fire and explosion, toxic fumes, electric shock, compressed and flammable gases, flying particles, noise and heavy lifting. The methods in this book are for training under the supervision of a qualified trainer, always with the correct personal protective equipment. Figures given as "typical" (currents, pressures, shade numbers, temperatures, times and prices) are general guidance only. Always follow the manufacturer's instructions, your trainer, workplace rules and the Occupational Safety and Health Act 2007. Never weld or cut a drum, tank or container that has held fuel or chemicals unless a competent person has made it safe. 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.

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. Photographs come from Wikimedia Commons under free licences (public domain, CC0, CC BY or CC BY-SA). Each photograph is credited under the picture, and the full list of credits is at the back of the book.

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How to use this book

This book follows the Welding Level 3 course from start to finish. It covers the three core units and the industrial training, 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 course at a glance

Part	What it covers	Training time
1. Getting started	The job and the course, assessment, workshop safety and PPE, metals, drawings, measuring and marking out	Used throughout
2. Fabrication processes	Unit 1: Fabrication Processes I (ENG/CU/WEF/CR/01/3/MA)	150 hours
3. Arc welding	Unit 2: Arc Welding Processes I (ENG/CU/WEF/CR/02/3/MA)	100 hours
4. Gas welding, brazing and soldering	Unit 3: Gas Welding, Soldering and Brazing Processes (ENG/CU/WEF/CR/03/3/MA)	100 hours
5. Industrial attachment and assessment	Industrial attachment, starting a fabrication business and getting ready to be assessed	240 hours

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. More are in the Glossary at the back.
- **Explanations and drawings:** each topic explained step by step, with realistic labelled illustrations and photographs.
- **Worked examples:** cutting lists, steel mass, welding current, electrodes and gas used, paint and job costs worked through with real numbers.
- **Practical tasks:** real workshop jobs with the tools, materials, steps and safety points. 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 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 save electricity, gas and steel, reuse offcuts, and handle scrap and waste correctly.

TRAINER'S TIP

Advice from experienced trainers and welders to help you work faster and better.

COMMON MISTAKES

Errors trainees often make, and how to avoid them.

IN THE KENYAN WORKSHOP

How the topic looks in real Kenyan jua kali sheds, fabrication workshops and construction sites.

WORKED EXAMPLE

A calculation worked step by step with real numbers.

About the pictures

This book uses realistic illustrations of real tools, machines, joints and welds, technical cut-away drawings and photographs. Labels and thin leader lines point to the parts that matter. Blue arrows show movement or direction of travel. Red marks a danger, defect or mistake; green marks the correct way. Some photographs show real workshops where people are not wearing full PPE; the captions point this out. Always wear the PPE shown in Chapter 2.

PART 1

Getting Started

What a Level 3 welder does, how you will be trained and assessed, workshop safety and PPE, and the metals, drawings and measuring skills every unit needs.

Chapter 1: Becoming a Welder and Fabricator in Kenya
Chapter 2: Workshop Safety, PPE and First Aid
Chapter 3: Metals, Drawings, Measuring and Marking Out

CHAPTER 1

Becoming a Welder and Fabricator in Kenya

WHAT YOU WILL LEARN

- What a Level 3 welder and fabricator does, where they work and what they make.
- How you can grow from Level 3 to higher levels, trade tests and specialist jobs.
- How competency-based training (CBET) works: units, elements, performance criteria and certificates.
- How the course is organised: three units, the industrial attachment, hours and credits.
- How you will be assessed and how a mark becomes a competence rating.
- The professional behaviour that customers and employers expect from a good fundi.

Introduction to the Welder qualification · KNQF Level 3 · Programme ISCED code 0715 254A · All units

Walk through any Kenyan town and you will see the work of welders: gates, window grills, tank stands, roof trusses, kiosk frames, matatu bodies and wheelbarrows. Behind each item is a fundi who measured, cut, fitted, welded and painted it. This chapter explains what that job involves, how this course trains you for it and how you will be assessed. Read it first, and come back to it whenever you want to see where you are on the course.

Key words

Welding
Joining metal parts by melting their edges together, usually with an electric arc or a gas flame, so that they become one piece when cool.

Fabrication
Making a finished steel product (a gate, a tank stand) by cutting, bending, fitting and joining metal parts.

Fundi
Kiswahili for a skilled tradesperson. In this book it means a working welder or fabricator.

Jua kali
The informal sector of small workshops, often working in the open or under a simple roof.

CBET
Competency-Based Education and Training: you are judged on what you can do to a set standard, not on how long you sat in class.

Unit of competency
A block of work skills that can be assessed and certified on its own, for example Arc Welding Processes I.

Element
One main task inside a unit, for example "carry out arc cutting".

Performance criteria
The checks an assessor uses to decide whether you did a task to the standard.

Credit
A measure of learning time. In this course one credit equals 10 hours.

Formative and summative assessment
Formative: continuous assessment during training. Summative: the final assessment at the end of a unit.

Portfolio of evidence
Your file of proof of competence: photos of your work, drawings, cutting lists, assessment records and logbook pages.

RPL
Recognition of Prior Learning: getting assessed and certified for skills you already learned at work.

1.1 What a Level 3 welder and fabricator does

A Level 3 welder turns steel stock into useful products. The stock comes in standard forms: flat bar, angle line, square tube, round bar, pipe, plate and sheet. Most lengths are 6 m long and most sheets are 8 ft × 4 ft. The fundi cuts these to size, shapes them and joins them.

On a normal working day you may do any of these tasks:

- Read a simple drawing or sketch and agree the sizes with the customer.
- Prepare a cutting list, then measure and mark out the steel.
- Cut with a hacksaw, an angle grinder, an electric arc or an oxy-acetylene flame.
- Drill, file, tap threads and bend or fold metal at the bench.
- Make sheet metal items such as trays, boxes, gutters and small tanks.
- Fit parts together square and true, then tack and weld them with manual metal arc welding (MMAW).
- Gas weld, braze and solder thin metal, copper and brass.
- Grind, clean and paint the finished job.
- Keep tools, welding machines and gas equipment in good working order.
- Work safely, keep the workshop tidy and talk politely with customers and workmates.

At Level 3 you work on mild steel up to 6 mm thick, mostly in the flat and horizontal positions. You work under supervision, but you are expected to finish a simple job on your own once the drawing and materials are agreed.

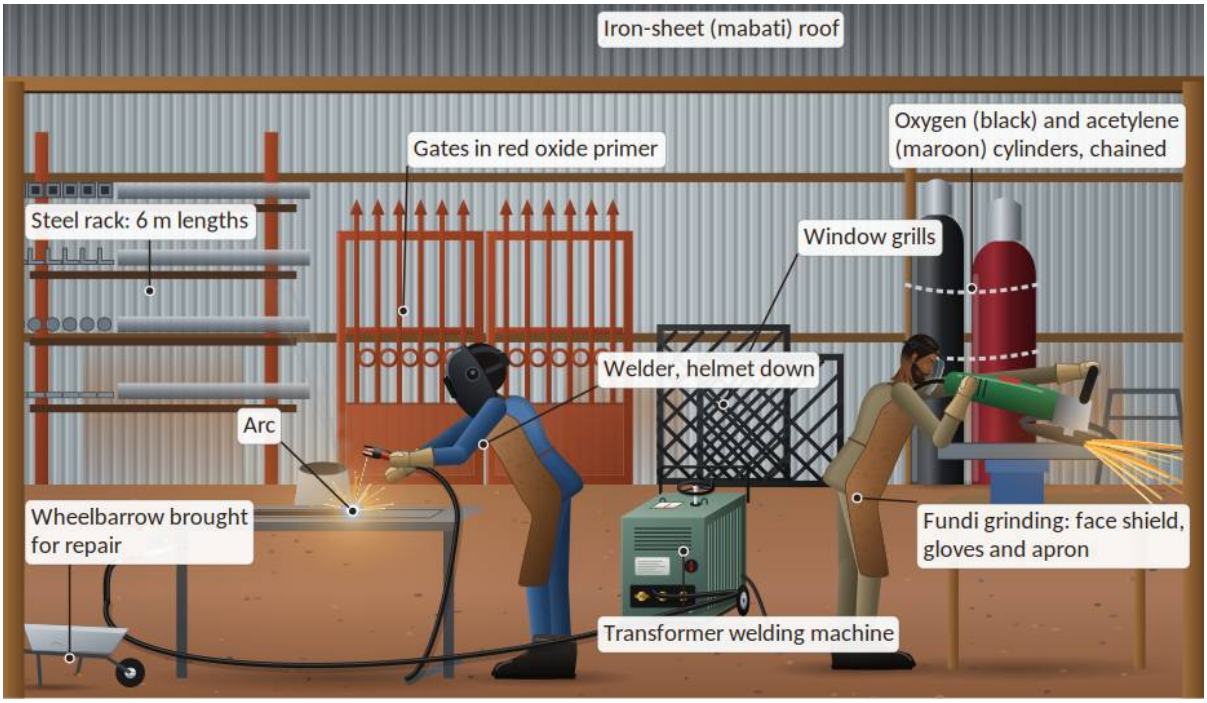


Figure 1.1 A typical jua kali fabrication shed. Everyone near the arc or the grinder wears the right protective equipment, steel stock is racked off the floor, and gas cylinders are chained upright.

1.2 Where welders work

Welding skills are needed almost everywhere steel is used. Table 1.1 shows the main places you can work after this course.

Table 1.1 Where Level 3 welders work in Kenya

Workplace	Typical work
Jua kali shed or small fabrication workshop	Gates, window grills, burglar-proof doors, chicken cages, jikos, wheelbarrow and cart repairs
Larger fabrication company	Roof trusses, steel structures, tanks, school and hospital furniture, machine frames
Construction site	Reinforcement and anchor bolts, steel stairs and railings, fixing grills and doors, site repairs
Garage or vehicle body builder	Matatu and lorry body repairs, carriers, trailer frames, exhaust repairs
Factory (food, sugar, tea, cement, steel)	Maintenance welding, guards, chutes, pipe repairs, breakdown repairs
County and national government works	Repairs to water supply, bridges, markets, school and health centre furniture
Self-employment	Your own workshop, or mobile work with a small inverter machine and a generator

> **IN THE KENYAN WORKSHOP**
>
> Many fundis start as helpers in a jua kali shed, carrying steel and grinding welds. A Level 3 certificate tells an employer, a county office or a customer that you have been trained and assessed to a national standard. It also lets you tender for small jobs that ask for certified artisans, and it is the first step to higher qualifications.

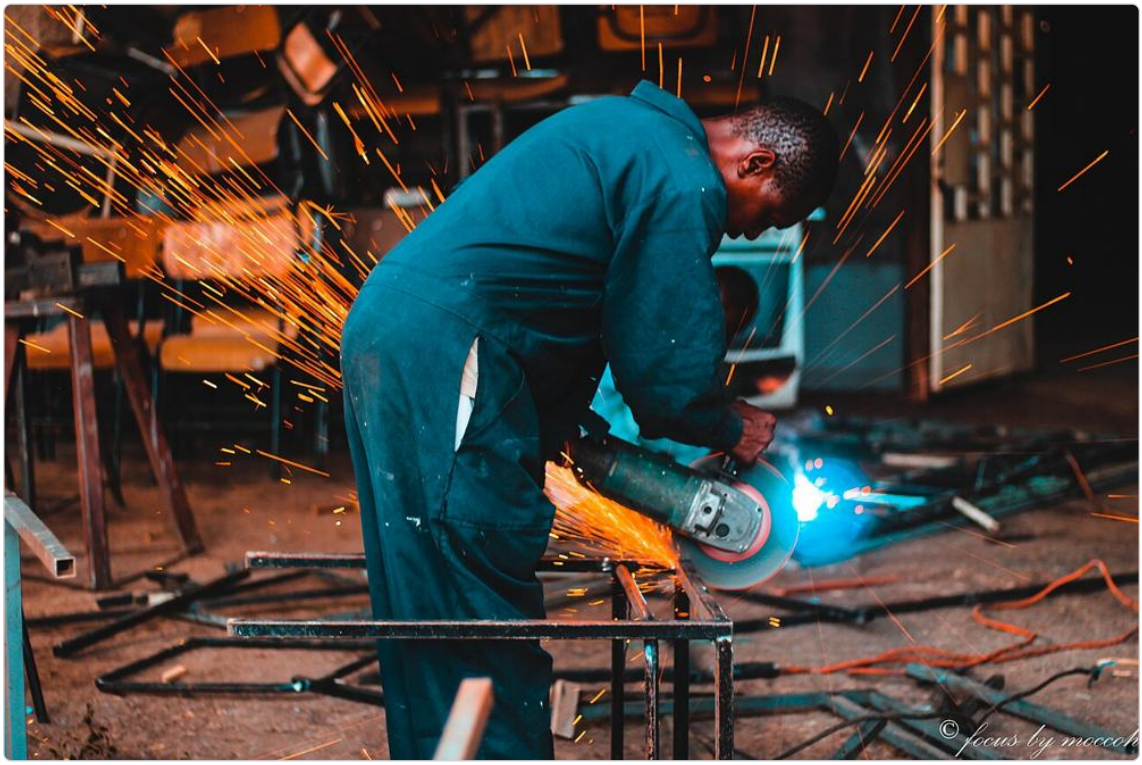


Figure 1.2 Grinding a welded frame in a fabrication workshop. Look carefully: the worker has no face shield, no gloves and no hearing protection, and an arc is burning just behind him with no screen. You will learn the correct PPE in Chapter 2.

Photo: Kehvkevv, CC BY-SA 4.0, via Wikimedia Commons

1.3 Typical products and what they earn

Most work in a small workshop is made to order. The customer describes what they want, the fundi takes measurements and gives a price, and the job is made, delivered and often fitted on site. Figure 1.3 shows products you will learn to make during this course.

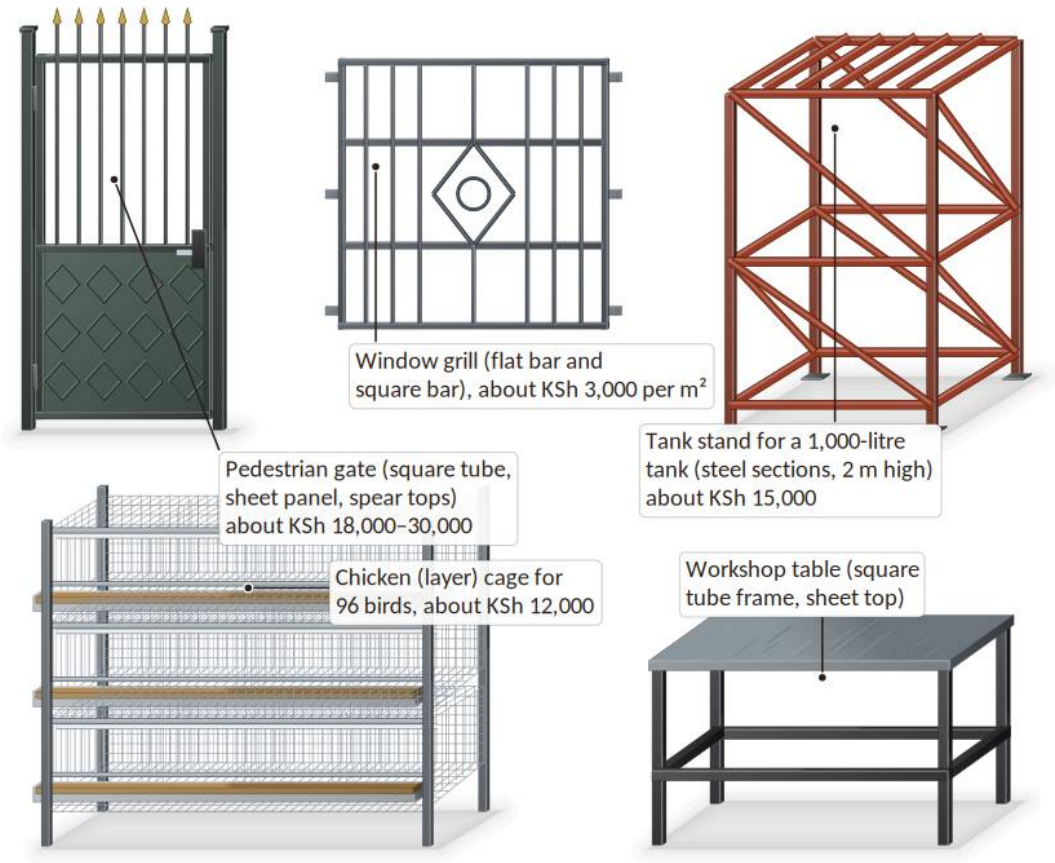


Figure 1.3 Common products of a Kenyan fabrication workshop, with typical 2026 selling prices. Prices change with size, design, steel prices and town.

Table 1.2 Typical products, materials and selling prices (approximate, 2026)

Product	Main materials	Typical price (KSh)
Pedestrian gate	Square tube 40 × 40 mm, flat bar, sheet or round bar infill	18,000–30,000
Window grill	Flat bar 25 × 3 mm, square tube or round bar	About 3,000 per m²
Burglar-proof door	Square tube, flat bar, sheet panel, hinges and lock box	About 25,000
Tank stand for a 1,000-litre tank (2 m high)	Angle line 40 × 40 × 4 mm with bracing	About 15,000
Chicken cage for 96 layers	Square tube or angle frame, weld mesh, galvanised feed troughs	About 12,000

Labour is often charged per item or per metre of weld. A fundi employed by the day earns about KSh 1,000–1,500 a day. A skilled fundi who prices jobs well, works neatly and finishes on time can earn much more running a workshop. Chapter 15 shows you how to cost a job, and Chapter 16 how to start a small business.

GREEN TIP

Welding is a green trade when done well. Plan your cutting list so that one 6 m length gives as many parts as possible, keep short offcuts for brackets and lugs, and sell scrap to licensed scrap dealers so it is melted and used again. Switch the welding machine off when you stop for tea or lunch: an idle old transformer machine still wastes power, while a modern inverter uses less electricity for the same weld.

1.4 Your career path

Level 3 is the start, not the end. The Kenya National Qualifications Framework (KNQF) has levels, and each level up means harder work, more responsibility and usually better pay. Figure 1.4 shows the ladder.

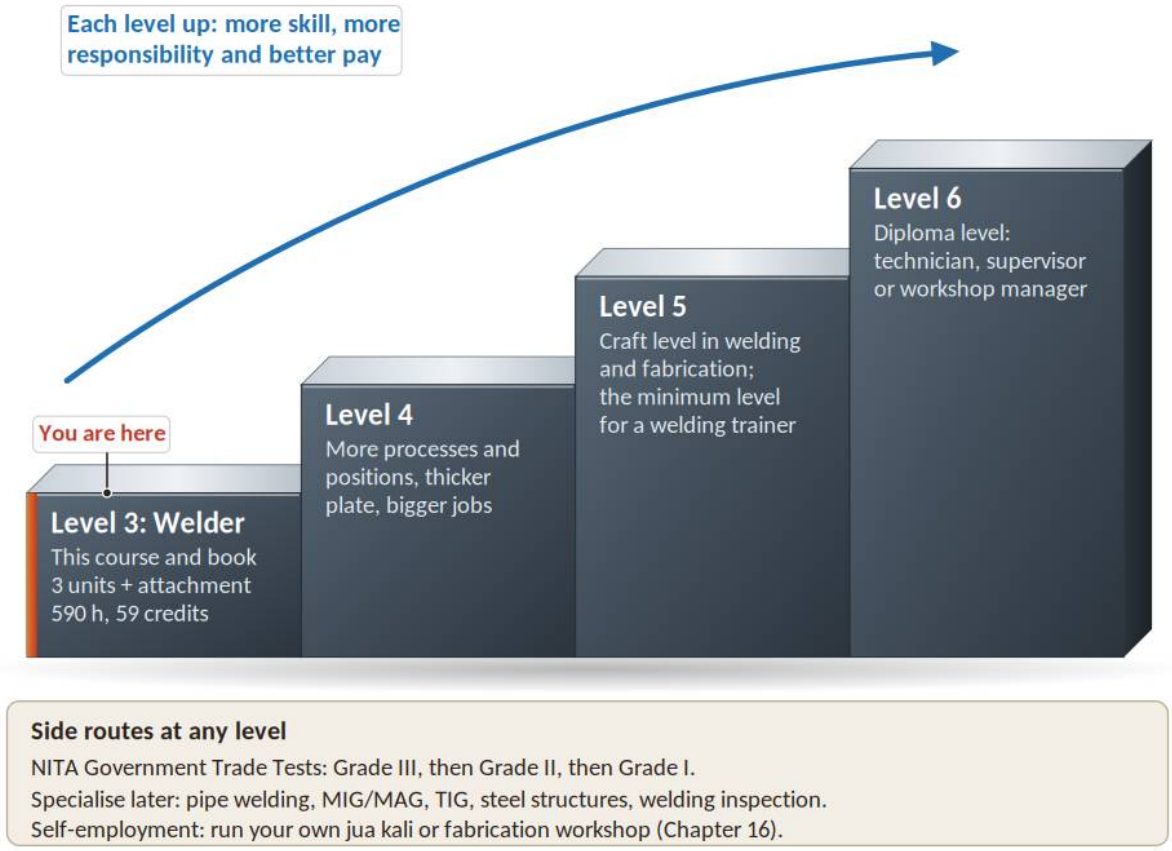


Figure 1.4 The career ladder in welding and fabrication. Ask your institution for the exact course names at each level.

- **Level 4:** more welding positions and processes, thicker plate and more complex fabrication.
- **Level 5:** craft level. A welding trainer must hold at least a Level 5 welding qualification (or equivalent), a TVETA licence and registration with EBK or KETRB.
- **Level 6:** diploma level, leading to work as a technician, supervisor or workshop manager.

You can also sit the National Industrial Training Authority (NITA) Government Trade Tests, starting with Grade III and moving up to Grades II and I. Many employers know these tests well. Later you can specialise in pipe welding, MIG/MAG and TIG welding, steel structures or welding inspection. Each specialism needs further training and testing.

> **TRAINER'S TIP**
>
> Start your portfolio on the first day. Photograph every job you make, from your first filed block to your last welded gate. Note the date, the material, the sizes and what you learned. A good portfolio helps you in assessment, in job interviews and when customers ask, "Have you made one like this before?"

1.5 How competency-based training works

This course follows the TVET CDACC competency-based modular curriculum for Welding, KNQF Level 3. It was built from an occupational standard that describes what a working welder must be able to do. In CBET you are not given marks for attendance or for remembering notes. You are judged on whether you can do real work to the standard.

1.5.1 Units, elements and performance criteria

The qualification is divided into **units of competency**. Each unit has a few **elements**, which are the main tasks. Each element has **performance criteria**: the checks the assessor ticks while watching you work and inspecting your job. For example, in an arc welding element the assessor checks that you prepared the material correctly, set the current, welded to the drawing, cleaned the weld and kept the work area tidy.

Each unit also has a **range** (the machines, materials and conditions you must handle) and **required knowledge** (what you must understand and explain). Your trainer teaches the unit through **learning outcomes**, each with suggested hours.

1.5.2 Certificates you can earn

- **Certificate of Competency:** awarded for each core unit in which you are found competent.
- **Statement of Attainment:** may be awarded when you prove competence in a certifiable element within a unit.
- **Kenya National TVET Certificate in Welding Level 3:** awarded when you are competent in all the units of the qualification.

TVET CDACC awards these certificates. Because each unit is certified separately, you can leave the course with a part qualification, work for a while and come back later to finish. This is called multiple entry and exit.

1.5.3 Recognition of Prior Learning (RPL)

Many fundis learned on the job without formal training. Through RPL they can be assessed against the same standard. If they show competence, they can be awarded a part or full qualification. If you already have workshop experience, ask your trainer about RPL.

To join this course you need a Kenya Certificate of Primary Education (KCPE), or an equivalent qualification accepted by TVETA.

1.6 The course map

The course has three core units and an industrial attachment. Figure 1.5 shows them to scale by hours, with the learning outcomes and the chapters of this book that cover them. Chapters 1 to 3 hold the knowledge that all units share: the trade, safety, metals, drawings and measuring.

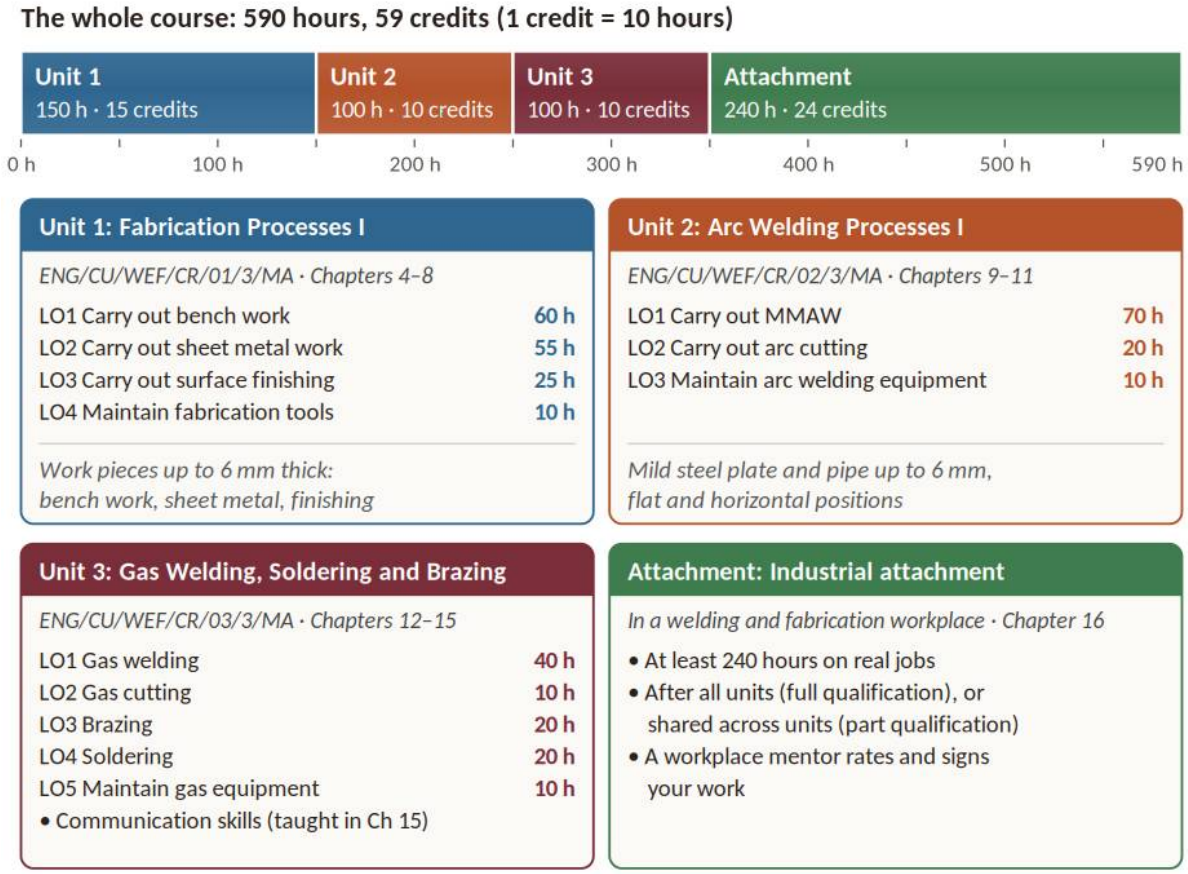


Figure 1.5 Course map. The bar is drawn to scale: the attachment is the longest single part of the course.

Table 1.3 The units of the Welder Level 3 qualification

Unit	CDACC code	Hours	Credits
Fabrication Processes I	ENG/CU/WEF/CR/01/3/MA	150	15
Arc Welding Processes I	ENG/CU/WEF/CR/02/3/MA	100	10
Gas Welding, Soldering and Brazing Processes	ENG/CU/WEF/CR/03/3/MA	100	10
Industrial attachment	—	240	24
Total		**590**	**59**

The industrial attachment is at least 240 hours in a welding and fabrication workplace. If you take the full qualification, it usually comes after all the units. If you take a part qualification, it may be shared equally across the units you take. A workplace mentor guides you and records your progress (see Chapter 16).

WORKED EXAMPLE 1.1: HOURS, CREDITS AND ATTACHMENT WEEKS

Question: (a) How many hours is one credit worth? (b) How many working weeks is the 240-hour attachment if you work 8 hours a day, 5 days a week?

(a) Total hours ÷ total credits = 590 h ÷ 59 credits = **10 hours per credit**. Check: Unit 1 is 150 h ÷ 10 = 15 credits, which matches Table 1.3.

(b) Hours per week = 8 h × 5 days = 40 h. Weeks = 240 h ÷ 40 h = **6 weeks** (30 working days).

1.7 How you will be assessed

Assessment in CBET is open and fair: you are told the standard before you are assessed. Your trainer and the assessor use tools based on the occupational standard and the performance-criteria weighting.

1.7.1 The rules

- **Theory to practical is 10:90** in every unit. Ninety per cent of your marks come from what you do with your hands: the quality, accuracy and safety of your work.
- **Formative assessment** happens throughout training. Every performance criterion is assessed, using the weighting.
- **Summative assessment** comes at the end of the unit. It is mainly practical and focuses on the critical parts of the unit.
- Formative and summative assessment are combined in the ratio **60% : 40%** to give your overall unit score.
- You may be assessed by practical tests, project work, written tests, oral questions and your portfolio of evidence.

1.7.2 Where the marks are

Figure 1.6 shows how the marks are shared in each unit. Notice how heavily practical work counts, and which elements carry the most marks. In Unit 1, sheet metal work alone carries half the marks. In Unit 2, MMAW carries half. In Unit 3, the four processes carry roughly equal marks.

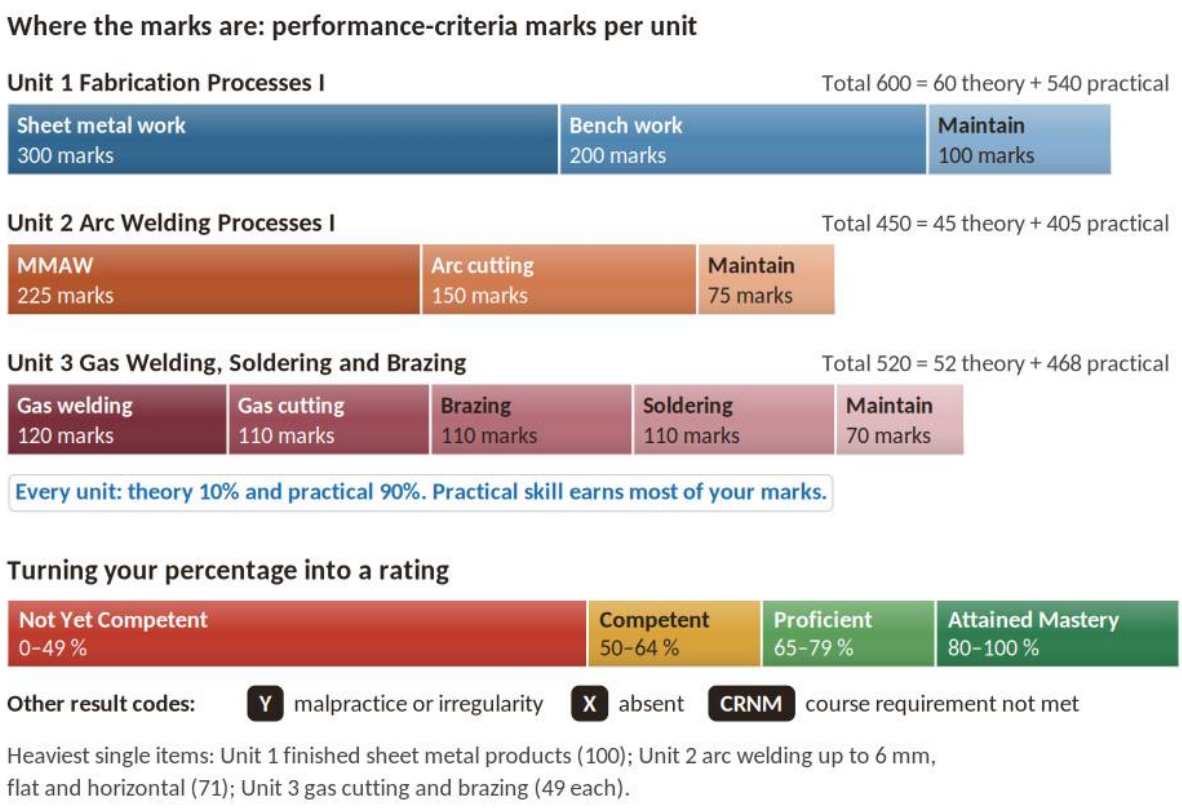


Figure 1.6 How the marks are shared in each unit, and the rating scale used for every unit of competency.

1.7.3 Ratings and result codes

Your score in each unit is changed to a percentage and then to a rating: **80–100 Attained Mastery**, **65–79 Proficient**, **50–64 Competent**, and **49 and below Not Yet Competent**. A result slip may also show **Y** (assessment malpractice or irregularity), **X** (absent) or **CRNM** (course requirement not met, for example a missing attachment or portfolio). Not Yet Competent is not failure for ever: you get more training and are assessed again.

WORKED EXAMPLE 1.2: FROM MARKS TO A RATING

Question: In Unit 2 (out of 450) a trainee scores 33 out of 45 in theory and 290 out of 405 in practical. (a) What is the percentage and rating? (b) Another trainee scores 68% in formative assessment and 74% in summative assessment. What is the overall score?

(a) Total = 33 + 290 = 323 marks. Percentage = 323 ÷ 450 × 100 = **71.8%**. 71.8 lies between 65 and 79, so the rating is **Proficient**.

(b) Overall = (0.60 × 68) + (0.40 × 74) = 40.8 + 29.6 = **70.4%**, which is also **Proficient**.

COMMON MISTAKES

- Thinking the written test is what matters most. Theory is only 10% of each unit; neat, accurate, safe practical work is 90%.
- Forgetting housekeeping. Cleaning up, returning tools and sorting scrap carry marks in every unit.
- Leaving the portfolio to the last week. Photos, drawings and records must be collected as you go.
- Missing a practical assessment. You will be marked X (absent) and must arrange to be assessed later.
- Copying another trainee's work or answers. This is malpractice (Y) and can stop your certification.

1.8 Professional behaviour

Skill with the welding machine is only half the job. Customers return to a fundi who is reliable, honest and pleasant to deal with. Employers keep workers who are safe and careful. Build these habits from your first week:

- **Safety first.** Wear your PPE every time, keep others away from the arc and report hazards. Chapter 2 covers this fully.
- **Punctuality and time keeping.** Arrive on time and finish jobs when you promised. If you will be late, tell the customer early.
- **Quality.** Check sizes, squareness and welds before you hand over a job. A gate that does not swing freely costs you your name.
- **Honesty.** Give fair quotations, use the materials you quoted and return the customer's balance and offcuts if agreed.
- **Care of tools and materials.** Return tools clean, report damage and do not waste electrodes, discs or steel.
- **Teamwork and respect.** Help others, listen to your supervisor and treat all workmates and customers with respect.

- **Communication and records.** Write down measurements, cutting lists and costs. Use WhatsApp photos to confirm designs with customers, politely and clearly.
- **Keep learning.** Ask questions, read the electrode packet and machine manual, and practise until your welds are consistent.

SAFETY FIRST

Your first day in the workshop is also your first day of safety. Do not touch a welding machine, grinder or gas cylinder until your trainer has shown you how. Never look at a welding arc without a proper filter, even for a second, and never stand near someone grinding without eye protection. Under the Occupational Safety and Health Act 2007 every worker must follow safety instructions and use the PPE provided.

Practical task 1.1: Workshop visit and job study

Tools and equipment

- Notebook and pen
- Phone camera (ask permission before taking photos)
- Steel tape measure
- Your PPE: overall, safety boots, safety glasses

Materials

- Job study form from your trainer, or a page ruled into the headings in step 3
- Portfolio file or folder

Steps

1. With your trainer, arrange a visit to a jua kali shed, a fabrication workshop or your institution's welding workshop.
2. Introduce yourself politely, explain the purpose of the visit and ask the person in charge for permission to watch and take photos.
3. Record: the products being made; the machines and tools in use; the steel sections and sizes in stock; the PPE each worker uses; how scrap and offcuts are handled.
4. Choose one finished product. Measure its main sizes and make a neat sketch with the dimensions.
5. Ask (politely) what the product sells for and how long it took to make. Compare the price with Table 1.2.
6. List three good safety practices and three hazards you saw. Do not point out hazards in a rude way; discuss them later with your trainer.
7. Thank the workshop owner. Write a one-page report and file it, with your sketch and photos, as the first entry in your portfolio.

Safety

- Wear your overall, boots and safety glasses. Stay behind welding screens and out of the path of grinding sparks.
- Do not touch machines, hot metal or gas equipment in the workshop you visit.
- Keep at least 10 m from any hot work unless you are behind a screen.

Chapter summary

- A Level 3 welder measures, marks out, cuts, shapes, fits, welds, finishes and maintains, working on mild steel up to 6 mm, mostly flat and horizontal.
- Welders work in jua kali sheds, fabrication companies, construction sites, garages, factories, government works and their own businesses.
- Typical products include gates, window grills, burglar-proof doors, tank stands and chicken cages.
- The career ladder runs from Level 3 to Level 6, with NITA trade tests and specialisms alongside.
- CBET judges what you can do. Units contain elements, and elements contain performance criteria.
- The course is three units (150 + 100 + 100 h) plus 240 h of attachment: 590 h and 59 credits.
- Theory to practical is 10:90; formative and summative combine 60:40; ratings run from Not Yet Competent to Attained Mastery.
- Professional behaviour (safety, punctuality, quality, honesty, respect) is part of being competent.

Check your competence

- [ ] I can describe the main tasks of a Level 3 welder and fabricator.
- [ ] I can name at least five workplaces where welders are employed in Kenya.
- [ ] I can list typical products and give their approximate selling prices.
- [ ] I can explain the career ladder from Level 3 to Level 6 and the NITA trade tests.
- [ ] I can explain units, elements, performance criteria, Certificate of Competency and Statement of Attainment.
- [ ] I can name the three core units with their hours, and the length of the attachment.
- [ ] I can convert a mark to a percentage and a competence rating.
- [ ] I can explain the codes Y, X and CRNM.
- [ ] I have started my portfolio of evidence.

Practice questions

1. List six tasks a Level 3 welder and fabricator carries out in a normal working week.
2. Name five types of workplace in Kenya where a welder can be employed, and give one typical job for each.
3. Name the three core units of the Welder Level 3 qualification and give the hours and credits for each.
4. Explain the difference between a Certificate of Competency, a Statement of Attainment and the Kenya National TVET Certificate in Welding Level 3.
5. What is Recognition of Prior Learning (RPL)? Who can benefit from it?
6. (Oral) Explain to a new trainee what "theory to practical 10:90" means for how they should spend their training time.
7. A trainee scores 412 marks out of 600 in Unit 1. Work out the percentage and give the competence rating.

8. A trainee scores 58% in formative assessment and 47% in summative assessment in Unit 3. Using the 60:40 rule, find the overall score and rating.
9. What do the codes Y, X and CRNM mean on a result slip?
10. (Practical) Visit a fabrication workshop as in Practical task 1.1. Sketch one product with its main dimensions, list the steel sections used and record the selling price. Add the report to your portfolio.

CHAPTER 10

Manual Metal Arc Welding in Flat and Horizontal Positions

WHAT YOU WILL LEARN

- Prepare mild steel plates and pipes up to 6 mm: clean, cut, bevel, set the root gap and tack.
- Name the main weld joints and the flat (1G, 1F) and horizontal (2G, 2F) positions.
- Strike the arc, run straight and weaved beads, restart, fill craters and remove slag safely.
- Weld butt and T-joints in the flat and horizontal positions.
- Recognise weld defects and distortion, and prevent them.
- Inspect, finish and clean up after welding.

Unit: Arc Welding Processes I · ENG/CU/WEF/CR/02/3/MA · Learning outcome 1 · About 70 hours (shared with Chapter 9)

This is the chapter where you stop reading about the arc and start using it. Every gate, window grill, tank stand and chicken cage depends on the skills here: a clean fit-up, a steady arc and a sound bead. It is also where the marks are. In Unit 2, arc welding up to 6 mm in the flat and horizontal positions carries 71 of the 450 marks, the largest single item, and material preparation carries another 43.5. Machines, electrodes and current settings were covered in Chapter 9.

Key words

Bead
One line of weld metal laid down by one pass of the electrode.

Run (pass)
One trip along the joint. Thick joints need a root, fill and cap run.

Arc length
The gap between the electrode tip and the weld pool.

Root gap
The space left between the plates at the bottom of a butt joint.

Root face
The small flat strip left at the bottom of a bevelled edge.

Penetration
How deep the weld melts into the joint.

Tack weld
A short weld that holds parts in place before the full weld.

Fillet weld
A weld of triangular section joining two surfaces at an angle.

Weave
A side-to-side movement of the electrode to make a wider bead.

Crater
The hollow left at the end of a bead when the arc is broken.

Undercut
A groove melted into the plate along the edge (toe) of a weld and left unfilled.

Distortion
Unwanted change of shape caused by weld metal shrinking as it cools.

10.1 Weld joints

A **joint** is where two parts meet. The joint decides how you prepare the edges and which weld you make. The curriculum names five joints: butt, lap, corner, T and cruciform. The edge joint is used on thin sheet (Figure 10.1).

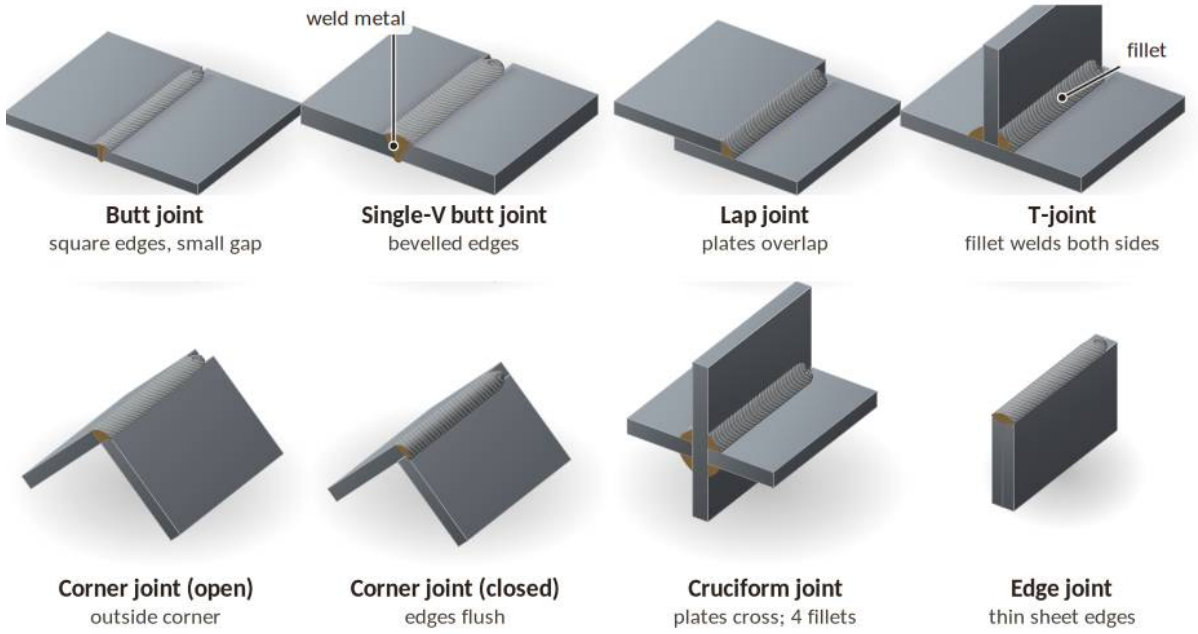


Figure 10.1 The main weld joints in mild steel plate. The cut end of each joint shows the weld metal in section.

- **Butt joint:** plates edge to edge in the same plane. Up to about 4 mm the edges stay square with a small gap; 5–6 mm plate is bevelled to a V. Uses: tank bottoms, joining plate, lengthening flat bar and pipe.
- **Lap joint:** one plate overlaps the other by at least about five times the thickness (and not less than about 25 mm), with a fillet weld along the edge. No edge preparation. Uses: gussets, brackets, patches on lorry bodies.
- **T-joint:** one plate square on the face of another, with fillet welds in one or both corners. The most common joint in fabrication. Uses: stiffeners, gate posts and tank-stand legs on base plates.
- **Corner joint:** plates meet at their edges to form an L, either open (a V to fill) or closed (edges flush). Uses: boxes, cabinets, troughs, frame corners.
- **Cruciform joint:** two plates meet a third from opposite sides, like a plus sign, with four fillet welds. Uses: heavy brackets and crossing members.

10.2 Welding positions

The **welding position** describes how the joint lies. Gravity pulls on the molten pool, so the position changes your technique. The number in the code gives the position and the letter the weld type: G for groove (butt), F for fillet.

- **Flat (1G, 1F):** you weld from above and the pool lies level. It is the easiest and fastest position, so turn the job flat whenever you can.

- **Horizontal (2G, 2F):** in 2G the plates stand upright and the joint runs sideways; in 2F you weld the corner of a T-joint with one plate flat and one upright. Gravity pulls the pool down, so angle the rod slightly upwards and keep the pool small.

For pipe, 1G means the pipe lies horizontally and is rolled while you weld on top; 2G means the pipe stands upright and you weld around it. Vertical and overhead come at higher levels.

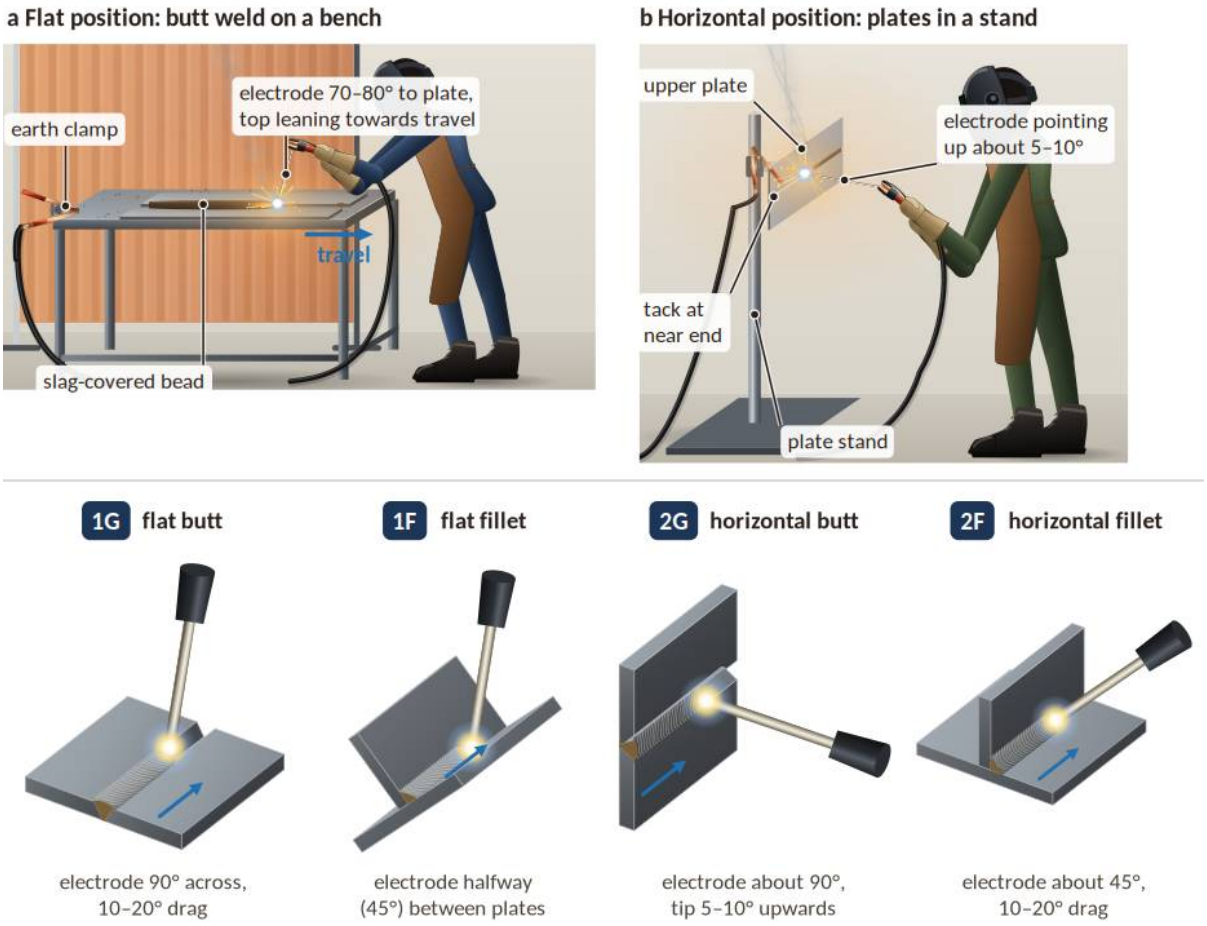


Figure 10.2 Flat and horizontal welding positions. (a) A flat butt weld at the bench. (b) A horizontal butt weld with the plates held upright in a stand. Below: the four position codes for Level 3 with their electrode angles. Vertical (3G) and overhead (4G) come at higher levels.

Table 10.1 Electrode angles and current for flat and horizontal positions (E6013)

Position	Work angle (across)	Travel angle	Current	Watch for
1G butt	90° to the plate	70–80° (10–20° drag)	Normal	Both edges melting in
1F fillet	45°, halfway between plates	70–80°	Normal	Equal legs
2G butt	About 90°, tip 5–10° upwards	70–80°	5–10% below flat	Sagging; undercut on the top edge
2F fillet	About 45°, aimed a little at the lower plate	70–80°	5–10% below flat	Undercut on the upright plate; overlap

A drag angle means the electrode top leans towards the direction of travel, so the tip points back at the finished weld. This keeps the slag behind the pool.

10.3 Preparing material (up to 6 mm)

Good welds start before the arc is struck. Material preparation is the second-heaviest item in the MMAW element, so work carefully and let the assessor see each step.

10.3.1 Read, measure, mark and cut

Read the job drawing (Chapter 3) and write a cutting list: part, size, number off and material. Plan cuts to keep offcuts large and few. Measure from a square edge, mark with a scriber or soapstone and check with a try square. Cut 6 mm plate with a cutting disc, by gas cutting, or by arc cutting (Chapter 11). Remove all burrs and check every piece against the drawing.

10.3.2 Clean the joint

Clean at least 20 mm each side of the joint to bright metal. Remove mill scale, rust, paint, oil and grease with a flap disc or wire brush. Dirt in the joint causes porosity and slag inclusions.

10.3.3 Edge preparation and root gap

Edge preparation shapes the plate edges so the weld can reach the full depth of the joint (Figure 10.3, Table 10.2).

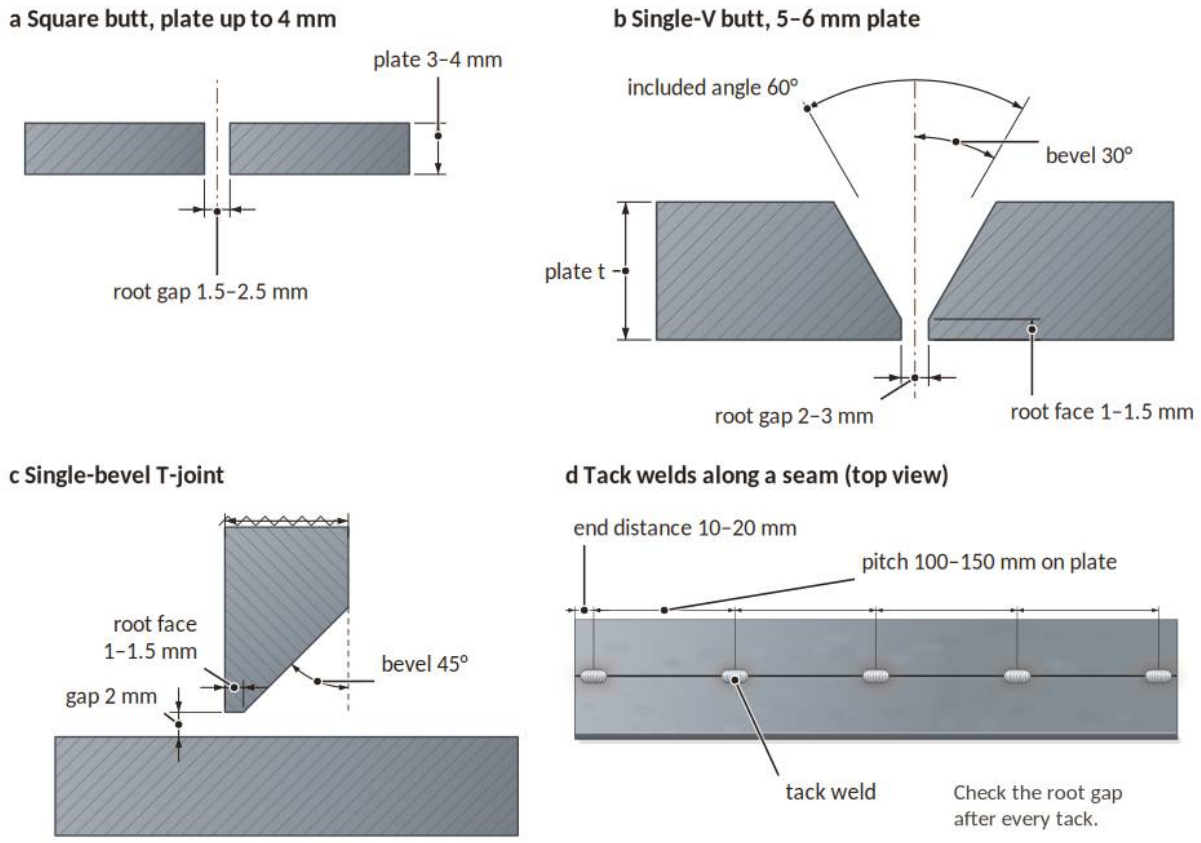


Figure 10.3 Edge preparation and tacking for MMAW of mild steel up to 6 mm. Sections are not to scale. The values are typical starting points; always follow the job drawing.

Table 10.2 Typical joint preparation for mild steel up to 6 mm (E6013)

Thickness	Joint and edge	Root gap	Electrode and starting current	Runs
2–3 mm	Square butt	0–1.5 mm	2.5 mm, low end of 75–100 A	1
3–4 mm	Square butt	1.5–2.5 mm	2.5 mm, 75–100 A	1, plus back run if needed
5–6 mm	Single-V, 60° included, root face 1–1.5 mm	2–3 mm	Root 2.5 mm, 75–90 A; fill and cap 3.2 mm, 100–125 A	2–3
3–6 mm	T or lap, square edges, tight fit	0–1 mm	3.2 mm, 100–125 A	1 per side, leg up to about 6 mm

These currents follow the Chapter 9 rule of thumb (30–40 A per mm of electrode diameter). They are starting points: check the electrode packet and test on scrap of the same thickness. To bevel a 6 mm edge, mark the bevel line and grind a 30° bevel (measured from the square edge) down to it, leaving a 1–1.5 mm root face. Too thin a root face burns through; too thick will not penetrate. A short length of bare 2.5 mm core wire makes a handy gap gauge.

10.3.4 Tack welding

A good tack is short (10–20 mm on plate), well fused and small enough to melt into the main weld. Set the gap, tack one end, check the gap again, then tack the other end. Longer seams need tacks every 100–150 mm on plate or 50–75 mm on thin sheet. Chip each tack and grind its ends to a taper so the main weld blends in.

10.3.5 Pipes up to 6 mm wall

Cut pipe ends square and bevel walls of 4 mm and over to 30–35° with a 1.5 mm root face; thinner walls can be square-butted with a 1.5–2 mm gap. Line the pieces up in a length of angle iron and tack at 12, 3, 6 and 9 o'clock. For a rolled 1G weld, weld a short length near the top, stop, roll the pipe and continue. For 2G, stand the pipe upright and weld around it in short sections. Tank-stand legs on base plates are pipe-to-plate fillets made in the 2F position.

> **SAFETY FIRST**
>
> Before you strike: helmet with the correct filter (typically shade 10–11 for 2.5 mm rods and shade 11 for 3.2 mm rods; see Chapter 9), clear glasses under the helmet, gauntlets, leather apron, cotton overall with sleeves down and no turn-ups, and safety boots. Close the screens. Check the cables, holder and earth clamp, and fix the clamp close to the weld. Keep gloves and clothes dry. Never weld galvanised or painted steel without removing the coating and using extraction: zinc fume causes metal fume fever. Keep a CO2 or dry powder extinguisher by the bay and combustibles 10 m away. Never weld a drum or tank that held fuel; refer it to your supervisor.

10.4 Striking the arc and running beads

10.4.1 Striking the arc

Fit the electrode at 90° in the holder jaws, steady your hand, and lower your helmet *before* the arc starts. There are two methods (Figure 10.4):

- **Scratch start:** drag the tip lightly across the plate for 20–25 mm, like striking a match, then lift to the arc length. Easiest for beginners and on AC.
- **Tap start:** touch the tip straight down on the plate and lift at once. Use it in tight spaces or where scratch marks would show.

Strike inside the joint, never on the plate surface beside it: stray arc strikes leave hard spots. If the electrode sticks, twist and snap it free with the holder; if it will not come free, release it from the jaws. Keep your helmet down until it is free.

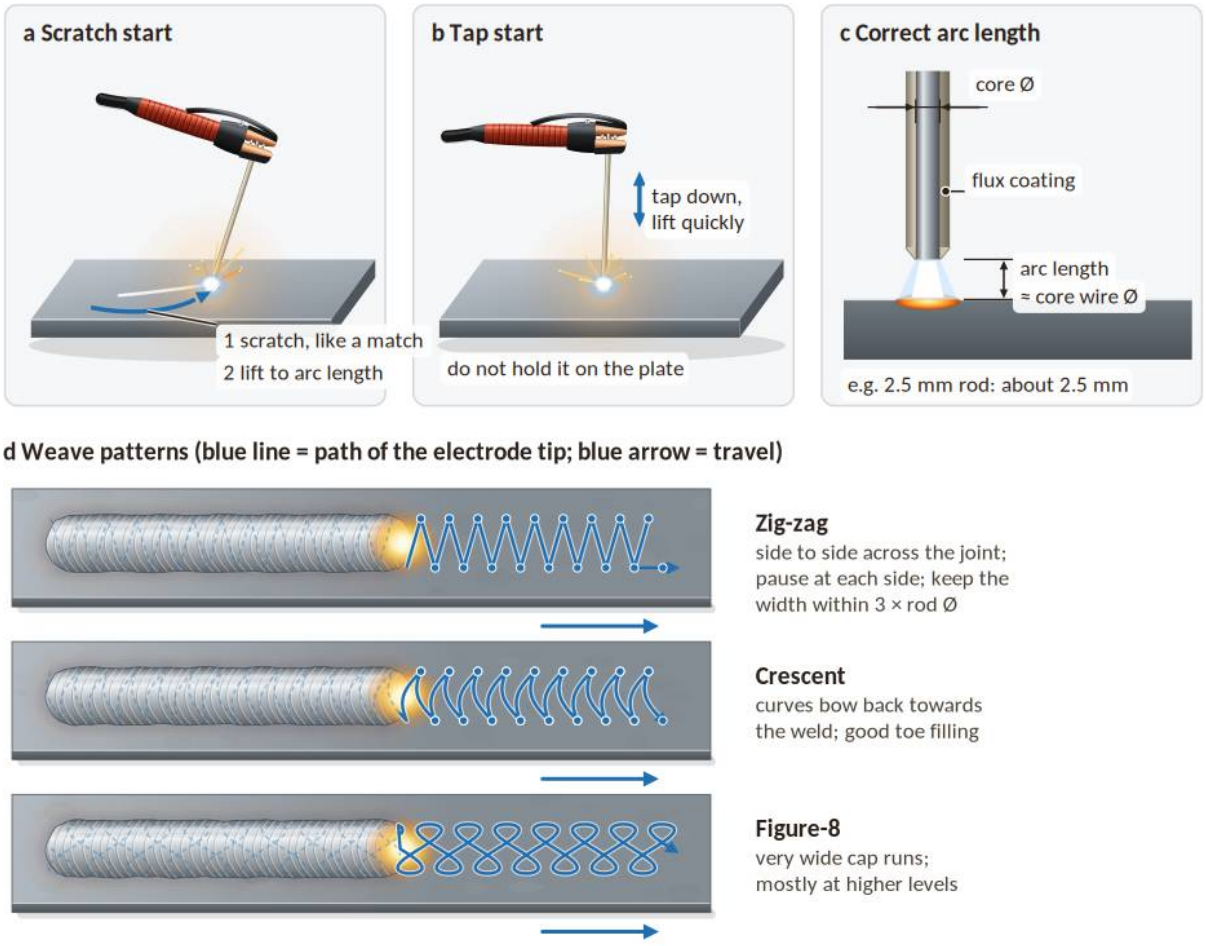


Figure 10.4 Starting the arc by (a) the scratch method and (b) the tap method; (c) correct arc length; (d) the three weave patterns.

10.4.2 Current, arc length, angle and speed

- **Current:** too low and the rod sticks and the bead sits on top; too high and the rod glows red, spatter flies and the plate undercuts.
- **Arc length:** about the core wire diameter. Keep feeding the rod down as it burns. A correct arc crackles steadily, like frying; a long arc hisses, pops and wanders.

- **Angle:** 10–20° drag and the work angles in Table 10.1.
- **Travel speed:** aim for a bead two to three times the core diameter wide with even ripples. Watch the pool, not the arc.

Arc force is the push of the arc into the pool. Many inverters have an arc force (dig) control; more helps stop a short root arc from sticking. Leave it mid-range unless your trainer advises otherwise.

10.4.3 Stringers and weaving

A straight bead with no side movement is a **stringer**. Use stringers for root runs, thin plate and all horizontal welds. For a wider bead, such as the cap on a flat 6 mm V-butt, **weave**: pause briefly at each side so the edges fill without undercut, and cross the middle quickly. Keep the weave within about three times the rod diameter; wider weaves trap slag.

10.4.4 Restarts and craters

To restart, chip the end of the bead, strike 10–15 mm ahead of the crater, move back into the crater, let it fill, then carry on. At the end of a run, slow down or step back over the bead until the crater is full, then break the arc with a quick flick. Unfilled craters are thin and often crack. Burn each rod to a stub of about 40–50 mm.

> **TRAINER'S TIP**
>
> Before you strike, do a dry run along the joint with the machine off. Can you reach the whole length without changing your stance? Is the cable free? Most wobbly beads come from running out of arm halfway. Rest your free hand on the bench to steady the holder hand.

10.4.5 Chipping, brushing and reading the bead

Remove the slag after every run. Wait until the bead stops glowing, then chip with the chisel end of the hammer, away from your face and from other people, and finish with the wire brush. Hold hot pieces with pliers or tongs. Do not quench test pieces in water; sudden cooling can harden the weld zone and cause cracks. Then read the bead using Figure 10.5.

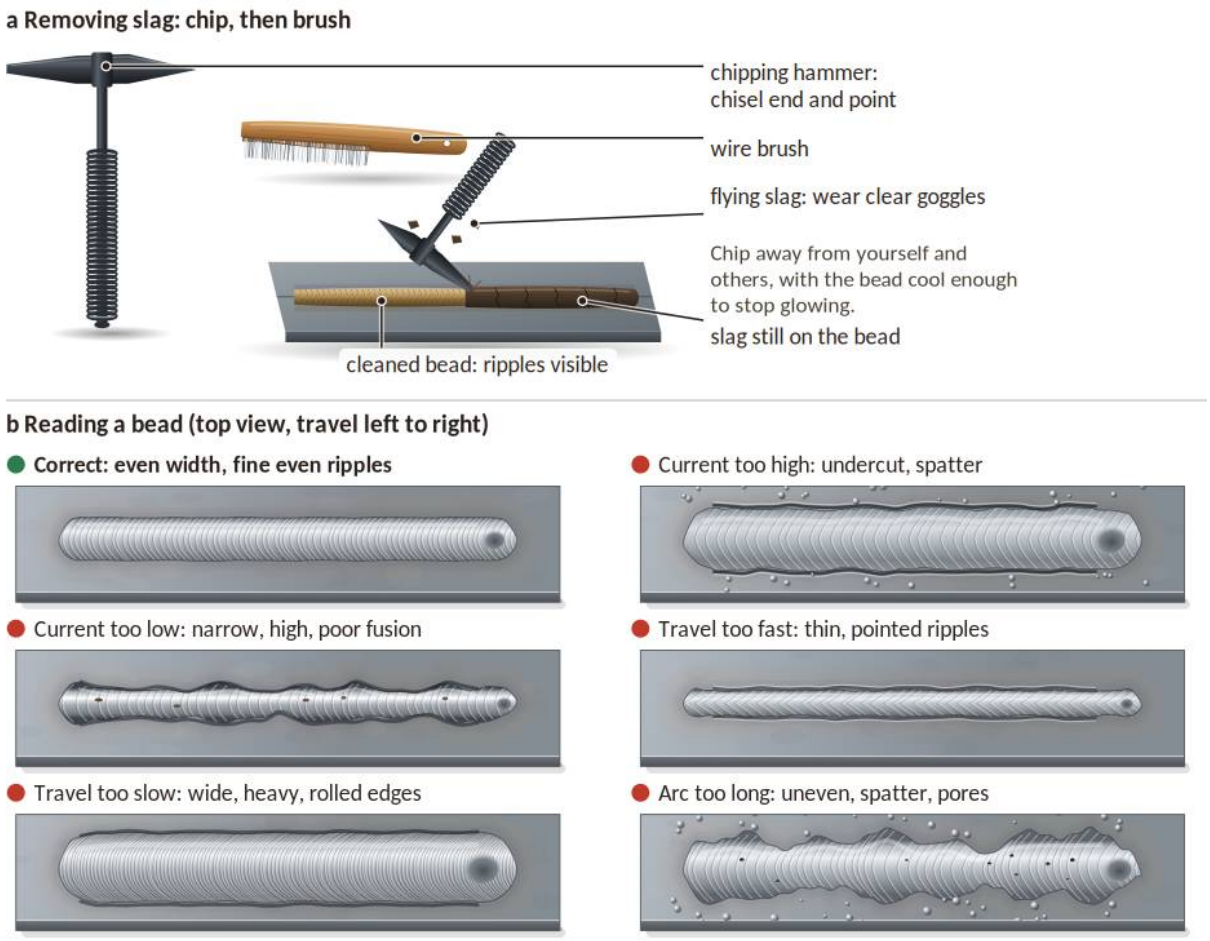


Figure 10.5 (a) Removing slag with the chipping hammer and wire brush. (b) What a bead tells you about current, travel speed and arc length.

WORKED EXAMPLE 10.1: ELECTRODES AND COST FOR A T-JOINT EXERCISE

A trainee welds four T-joints, each 150 mm long, with a single-run fillet on both sides, using 3.2 mm E6013. One rod gives about 150 mm of fillet. Allow 25% extra for restarts. How many rods, and what cost?

Weld length = 4 × 2 sides × 150 mm = 1,200 mm. Rods = 1,200 ÷ 150 = 8; with 25% extra, 8 × 1.25 = 10 rods.

Cost per rod = KSh 1,850 ÷ 160 = KSh 11.56. Ten rods = 10 × 11.56 = **about KSh 116**.

Power: about 1 minute of arc per rod, so 10 minutes. At about 110 A the machine draws roughly 3 kW: 3 × 10/60 = 0.5 kWh × KSh 30 = **about KSh 15**. Total about KSh 131. Check the length one rod gives in *your* workshop by running a rod on a test joint.

10.5 Welding in the flat position

10.5.1 Butt weld (1G)

Lay the tacked plates on two pieces of angle so the root is clear of the bench. For a 6 mm single-V:

1. **Root run:** 2.5 mm rod at about 80 A, short arc on the joint centre. Watch for a small "keyhole" just ahead of the pool: it shows both root faces are melting. If it grows, speed up; if it disappears, slow down.
2. **Clean:** chip and brush; grind off high spots or trapped slag.

3. **Fill:** 3.2 mm rod at about 110 A with a slight weave, to about 1 mm below the surface.
4. **Cap:** weave just wider than the V so it covers each edge by 1–2 mm and stands 1–2 mm high.
5. **Check the back:** an even penetration bead about 0.5–2 mm high along the full length.

On 3–4 mm square butts one run with a 2.5 mm rod is usually enough; add a back run if the root is not fully fused.

10.5.2 Fillet weld (1F)

Set the T-joint in a V-block or between two angles so the corner forms a level trough. Hold the rod upright, halfway between the plates, with a 10–20° drag, at 110–120 A with a 3.2 mm rod. Aim for equal legs of about 6 mm on 6 mm plate. Weld one side, chip, turn the job and weld the other.

10.6 Welding in the horizontal position

10.6.1 Fillet weld (2F)

This is the T-joint as it usually sits on the bench, and the weld you will make most often, for example a gate post on its base plate. Hold the rod about 45° between the plates, aimed slightly at the lower plate, with a 10–20° drag and a short arc. If the upright plate undercuts, lower the current or aim lower. If metal rolls onto the bottom plate without fusing (overlap), travel faster or raise the current slightly. Do not weave; for a larger leg, lay two or three stringers: first in the corner, then one on the bottom plate and one on the upright, each overlapping the last by half.

10.6.2 Butt weld (2G)

Clamp the tacked plates in a stand with the joint horizontal at about chest height. Reduce the current by 5–10%. Hold the rod about 90° to the plate with the tip 5–10° upwards so the arc pushes metal up against gravity, and use a 10–20° drag. Run the root as a stringer, then fill and cap with stringers stacked from the bottom up, each overlapping half of the one below. Weaving here makes the pool sag and undercut the top edge.

COMMON MISTAKES

- Watching the arc instead of the pool, so the bead wanders off the joint.
- Letting the arc grow long as the rod burns down.
- Welding over slag from the previous run.
- Using one current for every position and thickness without testing on scrap.
- Snapping the arc away at the end and leaving a crater.
- Weaving in the horizontal position.
- Too few or weak tacks, so the gap closes or a tack cracks.

10.7 Distortion and its control

Weld metal shrinks as it cools and pulls the plates with it. The result is **distortion**: plates that are not flat, frames out of square and gates that will not close (Figure 10.6). **Longitudinal shrinkage** shortens the joint along the weld; **transverse shrinkage** pulls the plates together across it; **angular distortion** lifts the outer edges because the wide top of a V or fillet shrinks more than the root; and **bowing** curves a long bar welded on one face.

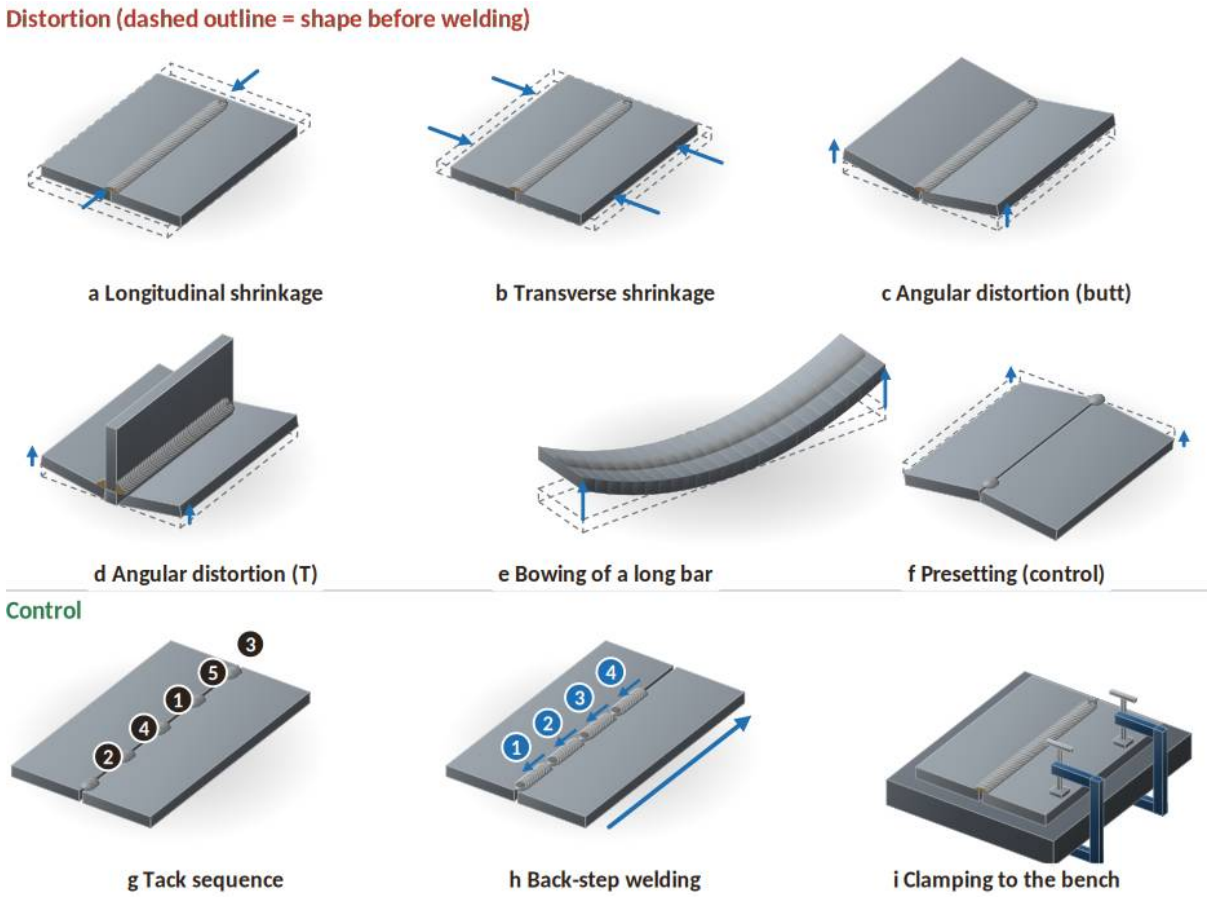


Figure 10.6 Types of distortion (a–e) and ways to control it (f–i), exaggerated so they are easy to see. In (g) the numbers give the tack order. In (h) each numbered segment is welded back towards the start (small arrows) while the work moves on in the direction of the long arrow.

To control distortion:

- **Do not over-weld,** and fit up tightly so you do not fill large gaps.
- **Tack in sequence:** for example centre first, then the ends, then the spaces between.
- **Preset** the plates about 1–2° the opposite way so shrinkage pulls them flat.
- **Balance the welding:** weld opposite sides or opposite corners of a frame in turn.
- **Back-step:** weld short lengths (50–75 mm) against the overall direction to spread the heat.
- **Clamp** the job to a flat steel bench or jig and leave it clamped until cool.

IN THE KENYAN WORKSHOP

In a busy jua kali shed you will see gates laid out on a flat steel table, the frame clamped down and the corners welded opposite after opposite, then checked by measuring the diagonals. That is distortion control learnt on the job. Know the reasons behind these habits and you will need less straightening. A customer who gets a gate that will not hang straight goes to another welder next time.

10.8 Weld defects: causes and prevention

A **defect** is any fault that makes a weld weak or unacceptable. Some show on the surface; others hide inside and appear only when a test piece is cut or bent (Figure 10.7, Table 10.3).

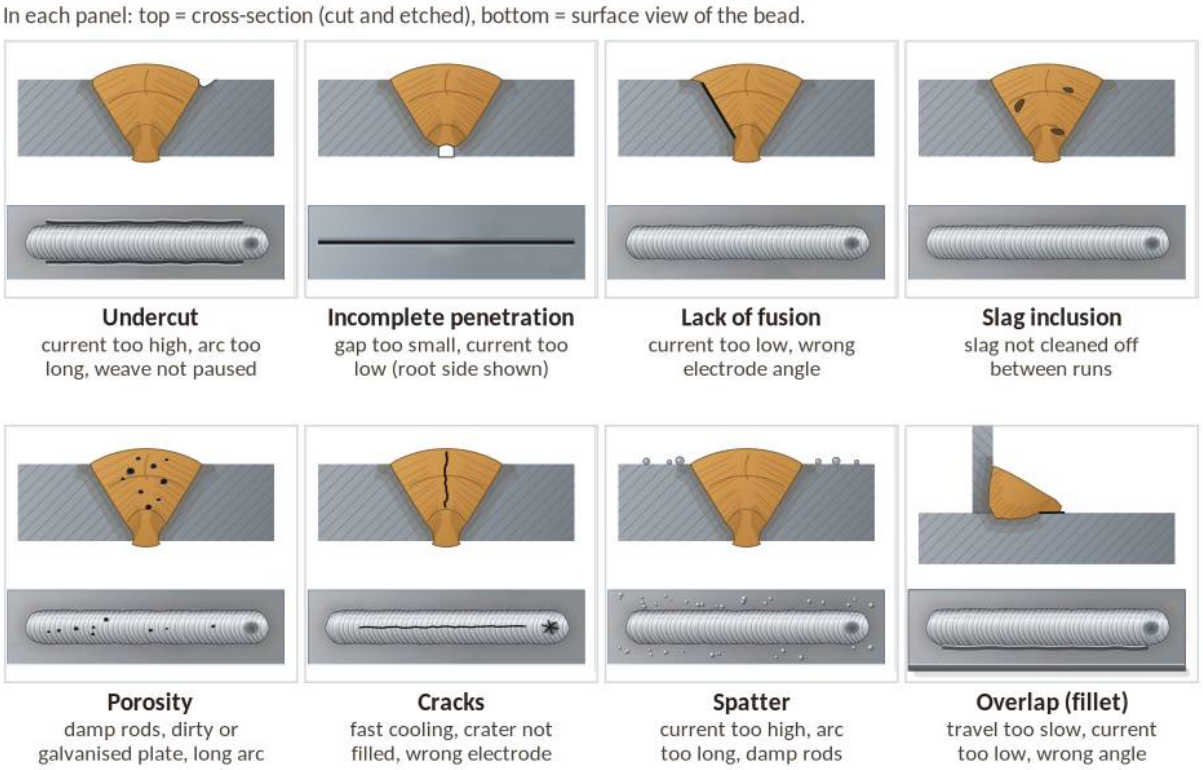


Figure 10.7 Common MMAW defects, each shown cut through and etched (top) and from the surface (bottom), with their main causes. The sections are of a multi-run single-V butt weld, except overlap, which is a horizontal fillet weld.

Table 10.3 MMAW defects: causes and prevention

Defect	Usual causes	Prevention
Undercut	Current too high; long arc; travel too fast; wrong angle; no pause at the edges	Lower current; short arc; steady speed; pause at the toes; in 2F aim lower
Incomplete penetration	Gap too small or root face too thick; current low; travel fast	Gauge the gap; 1–1.5 mm root face; 2.5 mm root rod; watch the keyhole
Lack of fusion	Current low; wrong angle; arc riding on the pool	Correct current; aim at the bevel faces; keep the arc ahead of the pool
Slag inclusion	Slag left between runs; notches at run edges; weave too wide	Chip and brush every run; grind out notches; limit the weave
Porosity	Damp rods; rust, oil, paint or zinc on the joint; long arc	Dry rods (Chapter 9); clean to bright metal; short arc
Spatter	Current high; long arc; damp rods; arc blow on DC	Correct settings; dry rods; move the earth clamp
Cracks	Crater not filled; fast cooling or quenching; root run too small; damp rods (hydrogen)	Fill craters; never quench; make the root run large enough; use dry rods
Distortion	Too much weld; unbalanced welding; poor tacking	See Section 10.7

Cracks are the most serious defect because they grow in service. Grind a crack out completely and reweld; never weld over it.

10.9 Visual inspection

Clean the weld and inspect it in good light, with a magnifier for cracks and a fillet gauge for size. Check that:

- fillet legs are equal and to the drawing; butt caps are 1–2 mm high with even ripples;
- the toes blend smoothly, with no undercut you can catch with a fingernail and no overlap;
- there are no cracks, pores, slag, unfilled craters or arc strikes, and little spatter;
- butt welds show an even root bead along the full length;
- the job is to size, square and flat.

Your trainer may also cut, etch or bend a test piece to find hidden defects such as lack of fusion.

10.10 Finishing and housekeeping

Finish only as far as the job needs. Remove all slag and spatter. On gates and furniture, dress the weld with a flap disc but never grind below the plate surface, which thins the joint. Prime with red oxide the same day, then top coat (Chapter 8).

Housekeeping carries 21 marks in the MMAW element of Unit 2, and more in the arc cutting and maintenance elements. After each task: switch off the machine; hang the holder where it cannot touch earthed metal; coil the cables without kinks; put stubs in the stub tin, never on the floor; sweep up cold slag; return unused rods to the dry store; and put away tools and PPE. Useful offcuts go to the offcut rack and scrap to a licensed scrap dealer. Paint and thinner waste is handled under NEMA rules.

GREEN TIP

A correct bead needs little grinding, which saves discs, power and time. Switch the machine off during breaks. Cut practice coupons from offcuts and use every face and edge before scrapping them. Sell stubs and scrap for recycling.

WORKED EXAMPLE 10.2: STEEL FOR A SET OF TEST COUPONS

Practical task 10.2 needs eight pieces of 6 mm plate, 150 × 75 mm each. Find their mass and cost if an 8 ft × 4 ft sheet costs KSh 26,000 (steel density 7,850 kg/m³).

Area = 8 × 0.150 × 0.075 = 0.09 m². Volume = 0.09 × 0.006 = 0.00054 m³. Mass = 0.00054 × 7,850 = **about 4.2 kg**.

Sheet area = 2.4384 × 1.2192 = 2.973 m², so steel costs 26,000 ÷ 2.973 = KSh 8,746 per m². Coupons = 0.09 × 8,746 = **about KSh 787**, before cutting waste. For 25 trainees that is about KSh 19,700, which is why workshops use offcuts.

Practical task 10.1: Striking the arc and running beads on plate (flat)

Tools and equipment

- MMAW machine, holder, cables, earth clamp
- Booth with screens and extraction
- Chipping hammer, wire brush, pliers
- Steel rule, soapstone; full PPE

Materials

- Mild steel plate 6 mm, 200 × 150 mm (offcut)
- E6013 electrodes 2.5 mm and 3.2 mm, dry

Steps

1. Check cables, holder and clamp. Clean the plate and mark lines 25 mm apart.
2. Fix the earth clamp and set about 80 A for a 2.5 mm rod.
3. Practise ten scratch starts and ten tap starts, holding each arc for 2–3 seconds.
4. Run stringer beads along the lines. Chip, brush and compare each with Figure 10.5.
5. Run beads at 65 A and 100 A on scrap and compare; return to the best setting.
6. Stop mid-bead, change rods and make a smooth restart; fill the end crater.
7. With 3.2 mm at about 110 A, run zig-zag weave beads 8–10 mm wide.
8. Pad the plate with stringers, each overlapping half of the last. Show your trainer, then clean up.

Safety

- Helmet down before every strike; screens closed.
- Clear glasses on while chipping; chip away from your face.

- Handle hot plate with pliers; do not quench it.

Practical task 10.2: Butt and T-joints in the flat and horizontal positions

Tools and equipment

- MMAW machine and accessories; plate stand
- Angle grinder with cutting, grinding and flap discs; face shield
- Rule, try square, scriber, fillet gauge, G-clamps
- Chipping hammer, wire brush, pliers; full PPE

Materials

- Eight pieces of 6 mm plate, 150 × 75 mm
- E6013 electrodes 2.5 mm and 3.2 mm
- Job drawing

Steps

1. Read the drawing; check and deburr all pieces.
2. Bevel one long edge of four pieces to 30° with a 1–1.5 mm root face.
3. Clean the joint areas. Tack two butt joints with a 2–3 mm gap and 1–2° preset, and two T-joints square and tight.
4. **1G:** root with 2.5 mm, then fill and cap with 3.2 mm. Check the root bead.
5. **1F:** set one T-joint as a trough; weld both sides.
6. **2F:** weld both sides of the second T-joint with the base flat on the bench.
7. **2G:** clamp the second butt horizontal in the stand; lower the current 5–10%; stack stringers bottom to top.
8. Clean and inspect all welds with the fillet gauge; record defects and likely causes. Mark each coupon with your name and position code, hand in, and clean up.

Safety

- Face shield over glasses when grinding; check the disc rating and guard.
- In horizontal welding spatter falls towards you: apron on, collar closed.
- Make sure the stand is stable and the earth clamp tight.

Chapter summary

- The main joints are butt, lap, corner, T and cruciform, each with its own preparation and uses.
- Flat (1G, 1F) is easiest; horizontal (2G, 2F) needs a smaller pool, 5–10% less current and stringer beads.
- Clean to bright metal, bevel 5–6 mm butts to a 60° V with a 1–1.5 mm root face, set a 2–3 mm gap and tack well.
- Control current, arc length (about the core diameter), angle (10–20° drag) and travel speed.
- Restart into the crater, fill end craters, and chip and brush every run.
- Reduce distortion with tight fit-up, correct weld size, tack sequence, presetting, balanced welding, back-stepping and clamping.
- Know the causes and prevention of the common defects, inspect every weld and leave the bay clean.

Check your competence

- [ ] I can name the main joints and say where each is used.
- [ ] I can set up the 1G, 1F, 2G and 2F positions.
- [ ] I can cut, clean, bevel and tack plates up to 6 mm.
- [ ] I can strike the arc both ways and free a stuck electrode safely.
- [ ] I can run even stringer and weave beads and make smooth restarts.
- [ ] I can weld butt and T-joints in the flat and horizontal positions.
- [ ] I can explain the causes and prevention of weld defects and distortion.
- [ ] I can inspect and finish my welds and carry out housekeeping.

Practice questions

1. Name five weld joints and give a Kenyan workshop product that uses each.
2. What do the codes 1G, 1F, 2G and 2F mean?
3. Why is a 6 mm butt joint bevelled but a 3 mm one is not? Give the included angle, root face and root gap for the 6 mm joint.
4. Describe the scratch and tap starts. What do you do if the electrode sticks?
5. A bead is narrow and high with cold, sharp edges. What is the likely cause and the fix?
6. Why is the electrode pointed 5–10° upwards in a 2G weld, and why should you not weave?
7. Give the causes and prevention of (a) undercut, (b) slag inclusion, (c) porosity.
8. Using 30–40 A per mm of diameter, find the current range for a 3.2 mm electrode. What would you start with for a 2F fillet?
9. A job needs 3 m of single-run fillet. One 3.2 mm rod gives about 150 mm. How many rods with 20% extra, and what do they cost at KSh 1,850 per 5 kg packet of about 160 rods?
10. Practical/oral: Prepare, tack, preset and weld two pieces of 6 mm plate, 300 × 150 mm, as a 1G single-V butt, then inspect it and explain each step. What is the mass of the two plates?

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