Unit 23: Welding Technology

Unit code: R/600/0274

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit gives learners an understanding of manual, mechanised and machine-based welding processes, including laser, friction and resistance welding.

Unit introduction

A diverse range of welding processes is used within the manufacturing engineering industry, including manual, mechanised and machine-based techniques. The selection and application of these joining processes is vital in terms of the weld quality, and the economic viability of the finished product.

The learner will appreciate the need to produce high-quality welded joints in components based on the selection of the most appropriate process. To enable learners to make an informed choice they will be required to select joining processes to satisfy a given application. The unit is appropriate for work-based learners where their industrial environment utilises welding as an integral part of the manufacturing process. It is also suited to learners who are being prepared for employment in the welding industry.

Learners will perform a range of formative practical tasks that will include planning and preparing for work and ensuring that health and safety legislation and safe working practices are understood and followed at all times. Learners will select and check the condition of appropriate equipment, which is particularly important considering that learners could be working with electric currents, combustible gas mixtures or parts rotating at high speed.

Continuous formative assessment allows learners to develop their practical skills and knowledge which lead to summative assessments. Assignments will require them to report and record the development of their skills in the preparation and production of welded joints. Learners will inspect their work with reference to relevant quality standards, ensuring that they are capable of producing welded joints and are able to recognise defects.

Learning outcomes

On completion of this unit a learner should:

1 Know about health and safety legislation, regulations and safe working practices in the welding industry

2 Be able to prepare for welding operations

3 Be able to produce welded joints to a quality standard

4 Understand how quality inspection processes are applied to welded joints in components.

Unit content

1 Know about health and safety legislation, regulations and safe working practices in the welding industry

Legislation and regulations: legislation eg Health and Safety at Work Act 1974, Employment Act 2002, Factories Act 1961, regulations eg The Fire Precautions (Workplace) Regulations 1997, Management of Health and Safety at Work Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER)1998, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Lifting Operations and Lifting Equipment Regulations (LOLER)1998, Manual Handling Operations Regulations 1992, Personal Protective Equipment at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Control of Noise at Work Regulations 2005, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Working Time Regulations 1998, The Workplace (Health, Safety and Welfare) Regulations 1992, Health and Safety (First Aid) Regulations 1981, Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007, Simple Pressure Vessels (Safety) Regulations 1994

Safe working practices: fire prevention; accident prevention and reporting; risk assessment; manual handling eg materials, safe handling of gas cylinders; checking conditions eg gas leaks, voltage and amperage, correct fuses, circuit breakers, leads, earthing of equipment; personal protective equipment (PPE); ventilation and extraction; closing down eg equipment safety, storing equipment, safe disposal of waste materials; emergency procedures eg within the learning environment and the workplace; hazards associated with welding eg burns, electric shock, radiation

2 Be able to prepare for welding operations

Information sources: safety instructions; job instructions; engineering drawings; quality control documentation eg weld procedure specification (WPS), record and reporting sheets

Tools and equipment: check equipment availability; function and condition relevant to the welding process eg cables, hoses, torches and electrode holders, gas pressure regulators, flow meters; working environment eg workshop, site work, conditions for machinery and plant; assembling welding equipment eg cables, weld return clamps, electrode holders, gas cylinders, regulators, valves, safety devices

Welding parameters: setting and adjusting eg:

- for manual processes: gas pressure, flow rates, voltage, current (either alternating (AC) or direct (DC)), according to electrode or filler size
- for mechanised processes: safety devices, welding speed, other parameters (electrical parameters, flux dispensing and recovery mechanisms, wire feed rate, filler diameter, gas shielding system, mechanical functions (handling, loading, workholding, transfer))
- for resistance welding machines: welding current, welding and squeeze times, electrode pressure cycle, electrode size, welding speed (seam), weld pitch (spot), mechanical functions, electrode diameter and condition
- for laser welding machines: electrical parameters, welding speed, weld alignment and characteristics, beam tracking, beam characteristics (focal spot), gas shielding, mechanical mechanisms for workholding, traversing and transfer
- for friction welding machines: friction and forge cycle time, friction and forge loads (forces), rotational speed or other friction conditions (orbital, frictional burn-off characteristics, forge displacement, braking effort), weld appearance (correct upset)

Welding processes: manual eg manual metal-arc (MMA), metal inert gas (MIG), metal active gas (MAG), metal-arc gas shielded, flux cored wire, tungsten inert gas (TIG), plasma-arc, gas welding; mechanised eg MIG/MAG, cored wire, TIG, plasma-arc, submerged arc; machine based eg resistance welding machines (spot, seam, projection), laser welding machines, friction welding machines

Consumables: appropriate to process eg electrode (rutile, basic, nickel alloy, cellulosic, stainless steel, other electrodes), filler wire, gases (oxygen, acetylene, shielding gases), inert and active gases, flux/agglomerated flux, forms of supply, care when handling flux; safe storage of consumables

3 Be able to produce welded joints to a quality standard

Safely: fire prevention; accident prevention and reporting; using risk assessment; manual handling; equipment maintenance; checking conditions eg gas leaks, voltage and amperage, fuses, circuit breakers, leads; wearing PPE; fumes; using ventilation and extraction; closing down equipment safely after use

Joints/components: eg

- for manual processes: butt, fillet, autogeneous weld (without filler wire)
- for mechanised processes: two different joint configurations, two different material groups
- for resistance welding machines: two different material thicknesses, two different joint configurations
- for laser and friction welding machines: two different components, two different material groups

Welding positions: to a relevant standard eg British Standard (BS) EN 287 flat (PA), horizontal vertical (PB), horizontal (PC), vertical upwards (PF), vertical downwards (PG), overhead (PE), inclined tube/pipe (H-L045 or J-L045); welding technique eg torch angle, filler angle

Material: forms eg plate (thickness appropriate to process, up to 6 mm for resistance welding), section, pipe/tube, sheet (<3 mm), other forms; types eg carbon steel, stainless steel, aluminium

Quality standard: minimum weld quality standard equivalent to the level given in the relevant standard eg European/International Standard BS EN ISO 5817, BS EN ISO 10042, BS EN ISO 13919-2; meet the required accuracy as specified eg dimensions, tolerances, weld quality, spot and projection welds are correctly located

4 Understand how quality inspection processes are applied to welded joints in components

Quality standard: safety in the use of test equipment and chemicals; minimum weld quality standard equivalent to the level given in the relevant standard eg European and International Standard BS EN ISO 5817, BS EN ISO 10042, BS EN ISO 13919-2, BS EN 12062; meet the required accuracy as specified eg dimensions, tolerances, weld quality, spot and projection welds are correctly located

Testing: non-destructive inspection eg dye penetrant, ultrasonic, radiographic (x-ray, gamma ray), pressure tests (hydraulic, pneumatic), fluorescent particle, magnetic particle; destructive eg macroscopic examination, nick break (fracture) tests, bend tests visual inspection; weld gauges eg fillet, leg length, undercut and hi-lo gauges

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 identify aspects of health and safety legislation, regulations and safe working practices applicable to welding	**M1** analyse the effect of using incorrect welding parameters for a selected welding process including the effects on quality and safety when producing welded components	**D1** justify the selection of a welding process for a given application when producing welded components
P2 use information sources to select a welding process for a given application, and suggest suitable parameters for the welding process [IE4]	**M2** discuss the advantages and disadvantages of two welding processes considering consumables, equipment, technique and quality for a given welding application.	**D2** evaluate the benefits and limitations of using a non-destructive inspection methods on welded components.
P3 produce a list of consumables that are required for a selected welding process		
P4 plan the tools and equipment needed to produce welded components safely using a selected welding process [SM3, SM4]		
P5 use appropriate welding positions and materials to produce two welded joints safely with a manual or mechanised welding process [SM3, SM4]		
P6 produce two welded joints/ components to a quality standard using a manual or mechanised welding process [SM3, SM4]		
P7 use appropriate welding positions and materials to produce two welded joints safely with a machine-based welding process [SM3, SM4]		

Assessment and grading criteria			
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P8	produce two welded joints/ components to a quality standard using a machine-based welding process [SM3, SM4]		
P9	explain the results of a destructive and non-destructive test on a given joint/component when welded to a quality standard.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit could be delivered using tutor-led demonstrations followed by practical tasks where learners gain experience of working with appropriate tools and equipment used in the welding industry. Underpinning knowledge can be delivered by integrating practical demonstrations, classroom-based theory sessions and directed research, using a variety of learning resources including information technology. Centres may wish to consider industrial visits so that learners can investigate and observe joining processes not generally available within the centre (for example laser and friction welding machines). Learners may benefit from the use of DVD footage, while the internet may also be used for information and video clips of the various welding processes.

Tutors must ensure that learners understand the hazards and safe working practices associated with welding equipment before they are allowed to use the processes. Learners should be introduced to the processes using a series of graded formative tasks to enable them to develop their skills and demonstrate their competence before attempting the summative tasks.

Learners should be encouraged to evaluate their performance in the formative tasks using a combination of tutor, self and peer assessment methods. The inspection of welded joints and components within the workshop will encourage self, and peer assessment. Learners can relate the results of the inspection process to the adjustment of process parameters to enable them to experiment, in an attempt to improve weld quality. This should be supported with formative feedback from the tutor.

The four learning outcomes follow a natural progression which should enable learners to develop an understanding of the fundamental stages involved in the production of welded joints and components, irrespective of the process used. Job instructions should be written in a logical format that will lead learners to consider all aspects of the task from safety, selection of tools, equipment and materials, process set-up and operation through to the production and inspection of welded joints in components.

The summative tasks will assess learners' competence in the use of certain welding processes and their ability to control process parameters to produce welded components that meet a specified quality standard.

Work-based learners should be encouraged to relate the learning outcomes to the processes and techniques used in the workplace. They should also be provided with a wider knowledge of welding processes used in industry, and not just those in their own place of work. Centres should relate tasks to the needs of local industries to prepare learners for employment and to provide them with appropriate skills and knowledge.

Learners will require instruction in the safe application of welding processes and need access to a wide range of publications, reference data, manufacturers' products/information and computer facilities. The centre should have access to an appropriate range of welding equipment.

There is scope within the content of this unit to link the assessment of this unit with *Unit 22: Fabrication Processes and Technology* and *Unit 27: Welding Principles.* Care should be taken to ensure that the learning outcomes of these units are met if synoptic assessment is used.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit, scheme of work and assessment methods • introduction to welding for producing permanent joints • introduction to health and safety related to welding • introduction to health and safety legislation and regulations • explain safe working practices.
Preparation for and carrying out **Assignment 1: Safe Working Practices when Welding** (P1).
Whole-class teaching: • describe information sources – drawings, job specifications, quality documentation • explain use of information required when welding • explain selection of welding processes for different applications • explain and demonstrate use of tools and equipment required during welding • explain and demonstrate use of manual, mechanised, and machine-based processes. *Workshop practical session*: • overview of relevant processes and process selection • introduction to welding equipment used • parameters for manual, mechanised, and machine-based processes • preparation for use, shutdown procedures and storage of equipment.
Preparation for and carrying out **Assignment 2: Using Information and Preparing for Work** (P2, P3, P4, M1, D1).
Whole-class teaching: • explain welding theory and demonstrate use of welding techniques for different joints, materials and positions • explain weld quality standards for materials, joints and components • describe common defects and irregularities in welded joints. *Workshop practical session*: • safety in welding workshops (manual, mechanised, and machine-based processes) • use of correct techniques when welding different joints and process constraints • use of correct techniques when welding different materials – process specific • use of correct techniques when welding different positions – process specific • ensuring weld quality and application of weld standards in inspection.
Preparation for and carrying out **Assignment 3: Producing Quality Welded Joints** (P5, P6, P7, P8, M2).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain weld testing theory and demonstrate visual, destructive and non-destructive testing techniques • explain use of test standards – variety of standards, tolerances, dimensions, weld quality • explain and demonstrate test procedures – visual, destructive and non-destructive • explain methods of reporting. *Workshop practical session*: • safe practice for preparing joints and using equipment • preparation of joints for testing • testing of welded joints • reporting results of weld tests.
Preparation for and carrying out **Assignment 4: Inspecting Welded Joints** (P9, D2).
Feedback and unit evaluation.

Assessment

Assessment of this unit could be through the use of four assignments.

The first assignment could cover P1 where learners are asked to produce a written report. Evidence for P1 must be specific to welding and the processes used within the industry. Learners will need clear guidelines in respect of what they should present. There is a large amount of generic material that learners will need to access. Care should be taken to ensure that what is presented is properly referenced and not directly copied from the internet or any other source.

A second assignment covering P2, P3 and P4 could be used to demonstrate the preparatory requirements for welding. Evidence could be presented in the form of a written report or by an oral presentation, supported by diagrams and photographs of formative practical work. Learners will need to select and describe a welding process for a given application. The expectation within this task is that all areas of the process will be described and the stated quality standards will be taken into account. The practical experience will influence learners' ability to answer this task. M1 and D1 can also be achieved by analysing the effect of incorrect welding parameters and justifying a selected process for a given welding application. Learners will need to demonstrate their knowledge of both joining processes and the properties of engineering materials.

Criteria P5 and P6 are assessed through a third practical assessment. The evidence for the practical investigations will be in a written report format, or may be assessed as part of a logbook or portfolio that records the types of joint, materials and positions used, and the consumables required for the process. This may be supported by witness statements or observation records used to show the evidence required. This will provide evidence of the joints produced using either a manual or mechanised welding process. The choice of whether a manual or mechanised process should be used is left to the centre and may be decided by the pathway that learners are following in their workplace. More freedom of choice may exist with centre-based learners but attention should be given to likely local employment opportunities.

Criteria P7 and P8 require joints to be welded using machine-based processes which should be assessed in a similar format to P5 and P6. Care must be taken to consult the content section of the unit to ensure that the range of welding positions, joints, materials and consumables appropriate to the joining process being assessed for the manual, mechanised and machine-based welding processes. M2 can be achieved by the learner comparing two processes, which could be the processes used in P6 and P8, and demonstrating further knowledge of the processes. Care will be required when selecting the given application to ensure learners have opportunities to carry out this comparison. Although it is not compulsory to have a manual and mechanised process, this is where opportunities may be maximised during a comparison.

A fourth assignment could be in assessing P9 where the learner uses a report to explain the results of quality inspection processes used for the joints produced in P6 and P8. Learners should include their findings, and refer to the standards, accuracy, destructive, non-destructive and visual inspection methods used. Reference should be made to the original guidelines for the given application and any quality standards that are indicated. D2 will require learners to use the results of the practical work carried out to achieve P6 and P8. The information in the written outcome from M2 may also be of use in enabling them to evaluate non-destructive inspection.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1	Safe Working Practices when Welding	Learners need to produce an information poster on health and safety requirements and safe working practices applicable to the welding industry.	A written report that describes the legislation and safe working practices used in the welding industry with clear referencing to appropriate sources of information.
P2, P3, P4, M1, D1	Using Information and Preparing for Work	Learners have to select a suitable process and welding parameters, identify consumables and plan the tools and equipment needed for a given welding application (eg a number of welded joints to form a simple component).	A written report could be used to assess the pass criteria using diagrams and photographs of relevant information. Further analysis and justification would assess M1 and D1. It may be considered that an oral presentation, supported with appropriate graphics, may be more suitable in the assessment of all criteria in this assignment. The tutor should consider the method of maintaining evidence of the presentation.

Criteria covered	Assignment title	Scenario	Assessment method
P5, P6, P7, P8, M2	Producing Quality Welded Joints	Learners need to produce welded joints to a required quality standard.	A written report supported by a logbook or portfolio that records the range of consumables, joints, materials and welding positions used. Evidence of the weld quality may include photographs, diagrams, witness statements, and quality reports. The report should identify the quality standards used and compliance to that standard. A comparison of two welding processes clearly identifying the processes and the advantages and disadvantages of each process for a given application should be included.
P9, D2	Inspecting Welded Joints	Learners test welded joints that they have previously made in a material or component.	A practical activity evidenced by a report that discusses the quality inspection processes used for the joints produced in P6 and P8 and the results. The report can further investigate the benefits and limitations of using non-destructive testing techniques on welded components.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
	Application of Welding Processes	Fabrication Processes and Technology
		Welding Principles

This unit also covers some of the knowledge and understanding associated with the SEMTA Level 3 National Occupational Standards in Fabrication and Welding Engineering, particularly:

- Unit 4: Welding Materials by the Manual Metal Arc Process
- Unit 5: Welding Materials by the Manual MIG/MAG and other Continuous Wire Processes
- Unit 6: Welding Materials by the Manual TIG and Plasma Arc Welding Process
- Unit 7: Welding Materials by the Manual Gas Welding Process
- Unit 16: Welding Materials with Mechanised Arc Welding Equipment
- Unit 17: Welding Materials using Resistance Spot, Seam and Projection Welding Machines
- Unit 18: Welding Materials using Laser Welding Machines
- Unit 20: Welding Materials using Friction Welding Machines
- Unit 65: Inspecting Welded Components or Structures for Visual Quality and Dimensional Accuracy.

Essential resources

Centres delivering this unit will need access to appropriate welding equipment, consumables and materials as outlined in the unit. Centres must also have access to appropriate destructive and non-destructive test equipment.

Employer engagement and vocational contexts

The materials and processes used in the delivery of this unit should be in the context of the learners' workplace or may be based on case studies of local employers. Learners may benefit from industrial visits to provide an understanding of welding processes in an industrial context, and to also appreciate the range of processes and materials used in industry.

The use of vocational contexts is essential in the delivery and assessment of this unit. Much of the investigative activity can be set in the context of learners' work placements supported by case studies of local employers and well known national companies. All four learning outcomes lend themselves well to visits or input from visiting speakers from local employers.

There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Davies A C – *Science and Practice of Welding, Volume 1* (Cambridge University Press, 1993) ISBN 9780521435659

Davies A C – *Science and Practice of Welding, Volume 2* (Cambridge University Press, 1993) ISBN 9780521435666

Raj B, Shankar V and Bhaduri A – *Welding Technology for Engineers* (Alpha Science International Ltd, 2005) ISBN 9781842651940

Smith B – *Welding Practice* (Arnold, 1995) ISBN 9780340614068

Timings R – *Fabrication and Welding Engineering* (Newnes, 2008) ISBN 978075066916

Weman K – *Welding Processes Handbook* (Woodhead Publishing, 2003) ISBN 9780849317736

Zhang H – *Resistance Welding* (CRC Press, 2005) ISBN 9780849323461

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	analysing and evaluating information sources to select welding processes
Self-managers	selecting materials, processes and consumables for a given application planning the tools and equipment needed for a given application anticipating, taking and managing risks when welding.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	analysing the outcome of changing welding parameters and experimenting with a range of settings.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Find and select information	
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	researching health and safety information and safe working practices used in the welding industry
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	speaking and listening to peers and tutors when reviewing weld quality, weld parameters and the results of weld testing
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	selecting, reading and using sources of information during welding tasks and when researching health and safety information
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	reporting on health and safety information and safe working practices writing reports to effectively communicate plans, process parameters, techniques and test results of welding processes and welded components.