City & Guilds Level 3 Diploma in Engineering (2850-30-36, 38)

Qualification handbook for centres

QAN 600/0882/9

www.cityandguilds.com
April 2022
Version 2.2

About City & Guilds

As the UK's leading vocational education organisation, City & Guilds is leading the talent revolution by inspiring people to unlock their potential and develop their skills. We offer over 500 qualifications across 28 industries through 8500 centres worldwide and award around two million certificates every year. City & Guilds is recognised and respected by employers across the world as a sign of quality and exceptional training.

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Level 3 Diploma in Engineering – Welding (2850-30)
Level 3 Diploma in Engineering – Fabrication (2850-31)
Level 3 Diploma in Engineering – Fabrication and Welding (2850-32)
Level 3 Diploma in Engineering – Maintenance, Installation and Commissioning (2850-33)
Level 3 Diploma in Engineering – Mechanical Manufacturing Engineering (2850-34)
Level 3 Diploma in Engineering – Electrical and Electronic Engineering (2850-35)
Level 3 Diploma in Engineering – Shipbuilding (2850-36)
Level 3 Diploma in Engineering – Composites Engineering (2850-38)

Version and date	Change detail	Section
1.1 March 2012	Amended test spec	4.2 Test Specifications
1.2 Feb 2013	Amended range detail	Unit 325
1.3 Jun 2013	Add unit 341 to units and update structure	About this document Units
2.0 September 2013	Additional pathway (2850-38)	1.1 Qualification Structure 5.0 Units (339 and 340)
2.1 August 2017	Added TQT details Deleted QCF	Qualification at a glance, Structure Throughout
2.2 April 2022	Added City & Guilds to qualification title City & Guilds address updated	Cover, footer Throughout

Contents

1 About this document

This document contains the information that centres need to offer for the following qualification:

Qualification title and level	City & Guilds Level 3 Diploma in Engineering
GLH	480
TQT	540
City & Guilds qualification number	2850-30/31/32/33/34/35/36/38
Qualification accreditation number	600/0882/9
Registration and certification	See the online catalogue/Walled Garden for last dates

These awards are designed to contribute towards the knowledge and understanding for the NVQ Diploma in Engineering Maintenance (City & Guilds 1788), NVQ Diploma in Mechanical Manufacturing Engineering (City & Guilds 1712), NVQ Diploma in Fabrication and Welding (City & Guilds 1781) and NVQ Diploma in Technical Support (City & Guilds 1786).

This qualification is aimed at learners who:

- intend to follow Apprenticeship and Advanced Modern Apprenticeship programmes
- wish for career progression within the Engineering industry
- wish to develop the skills learnt from other qualifications
- require evidence towards the underpinning knowledge of the N/SVQ.

It is expected that learners should have the Level 2 Certificate in Engineering (2800), Level 2 Diploma in Engineering (2850) or equivalent in order to be able to satisfactorily complete the course of study.

Advanced mathematics and science is an optional unit within the qualification- its purpose is to facilitate progression to a higher level qualification. Centres will need to carry out an initial assessment of learners' literacy and numeracy skills in order to make a judgement about their ability to successfully achieve this unit.

This award is designed to contribute towards the knowledge and understanding for the N/SVQs in Engineering Level 3 (City & Guilds 1788), while containing additional skills and knowledge which go beyond the scope of the National Occupational Standards. It provides a valuable alternative for those learners who do not have access to the N/SVQ.

Learners must follow **one** of **eight** engineering pathways. Successful learners will receive a certificate endorsed with their chosen pathway.

1.1 Qualification structure

To obtain the **Level 3 Diploma in Engineering** a learner must successfully complete six units, two of which must be Units 301 and 302 (Engineering industry and Engineering technology).

The full list of units is as follows:

City & Guilds unit number	Title	UAN number	Credit value	GLH	Level
301	Engineering health and safety	Y/503/0334	9	80	3
302	Engineering principles	D/503/0433	9	80	3
303	Principles of welding	D/503/0335	9	80	3
304	Principles of fabrication	H/503/0336	9	80	3
305	Principles of fabrication and Welding	K/503/0337	9	80	3
306	Principles of engineering maintenance, installation and commissioning	M/503/0338	9	80	3
307	Principles of mechanical manufacturing engineering	T/503/0339	9	80	3
308	Principles of electrical & electronic engineering	K/503/0340	9	80	3
309	Principles of shipbuilding	M/503/0341	9	80	3
310	Manual metal arc welding of materials	F/503/0344	9	80	3
311	MIG welding of materials	R/503/0347	9	80	3
312	TIG welding of materials	D/503/0349	9	80	3
313	Plate work fabrication of materials	F/503/0375	9	80	3
314	Sheet metalwork fabrication of materials	A/503/0374	9	80	3
315	Fabrication and erection of structural steelwork	J/503/0376	9	80	3
316	Pattern development for fabrication	Y/503/0379	9	80	3
317	Maintenance of machine systems	R/503/0381	9	80	3
318	Maintenance of utility systems	D/503/0383	9	80	3
319	Maintenance of plant services	H/503/0384	9	80	3
320	Maintenance of hydraulic systems	T/503/0390	9	80	3
321	Maintenance of pneumatic systems	R/503/0395	9	80	3
322	Power generation systems and ancillary equipment	K/503/0435	9	80	3
323	Machining materials by turning	T/503/0437	9	80	3
324	Machining materials by milling	M/503/0436	9	80	3
325	Machining materials by grinding	A/503/0438	9	80	3
326	CNC machining of materials	D/503/0416	9	80	3
327	Detailed fitting of materials	M/503/0419	9	80	3
328	Maintenance of electrical equipment and systems	H/503/0420	9	80	3
329	Produce drawings using CAD	M/503/0422	9	80	3
330	Organising and managing engineering operations	A/503/0424	9	80	3
331	Advanced mathematics and science	K/503/0449	9	80	3

City & Guilds unit number	Title	UAN number	Credit value	GLH	Level
332	Mechatronics systems principles and fault finding	R/503/0428	9	80	3
333	Computer automated and robotic systems principles and control	R/503/0431	9	80	3
334	Power supply, and analogue and digital circuit principles and fault finding	Y/503/0432	9	80	3
335	Electronic power control principles and practice	H/503/0434	9	80	3
336	MIG welding of aluminium	H/503/0353	9	80	3
337	TIG welding of aluminium	Y/503/0351	9	80	3
338	Flux-cored arc welding of materials	K/503/0354	9	80	3
339	Principles of composite materials	L/505/2427	9	80	3
340	Principles of composites manufacture	D/505/2433	9	80	3
341	Pipe and tube fabrication	T/505/2728	9	68	3

The following certificate will be awarded to successful learners on completion of the required combinations of units and credits. Learners completing one or more units, rather than the full qualification, will receive a Certificate of Unit Credit (CUC).

Learners must follow one of the **eight** Engineering pathways that are available at Level 3. These are:
Level 3 Diploma in Engineering – Welding
Level 3 Diploma in Engineering – Fabrication
Level 3 Diploma in Engineering – Fabrication and Welding
Level 3 Diploma in Engineering – Maintenance, Installation and Commissioning
Level 3 Diploma in Engineering – Mechanical Manufacturing Engineering
Level 3 Diploma in Engineering – Electrical and Electronic Engineering
Level 3 Diploma in Engineering – Shipbuilding
Level 3 Diploma in Engineering – Composites Engineering

To gain the full 2850 Level 3 Diploma in Engineering, learners will be required to successfully complete **54** credits made up of six units under their chosen pathway.

Mandatory units – Learners must take **two** units (301 and 302)
Engineering health and safety (9 credits)
Engineering principles (9 credits)

Plus **one** 'principles of' dependent on the chosen pathway (**both** units 339 and 340 if taking the Composites Engineering pathway)
303 – Principles of Welding (9 credits)
304 – Principles of Fabrication (9 credits)
305 – Principles of Fabrication and Welding (9 credits)
306 – Principles of Engineering Maintenance, Installation and Commissioning (9 credits)
307 – Principles of Mechanical Manufacturing Engineering (9 credits)
308 – Principles of Electrical and Electronic Engineering (9 credits)
309 – Principles of Shipbuilding (9 credits)
339 – Principles of Composite Materials (9 credits)
340 – Principles of Composites Manufacture (9 credits)

Of the final two/three units, **one** must be a specialist unit from their chosen pathway (**two** for Fabrication and Welding; N/A for the Composites pathway) and any **two** further optional units (**one** for Fabrication and Welding; **two** for Composites).

Level 3 Diploma in Engineering Welding (2850-30)	**Level 3 Diploma in Engineering Fabrication (2850-31)**	**Level 3 Diploma in Engineering Fabrication & Welding (2850-32)**	**Level 3 Diploma in Engineering Engineering Maintenance, Installation & Commissioning (2850-33)**
Engineering health and safety Engineering principles	Engineering health and safety Engineering principles	Engineering health and safety Engineering principles	Engineering health and safety Engineering principles
Principles of welding	Principles of fabrication	Principles of fabrication & welding	Principles of engineering maintenance, installation and commissioning
Plus any one from (9 credits) Manual metal arc welding of materials MIG welding of materials TIG welding of materials	**Plus one from** (9 credits) Platework fabrication of materials Sheet metalwork fabrication of materials Fabrication and erection of structural steelwork Pattern development for fabrication Pipe and tube fabrication	**Plus one from** (9 credits) Manual metal arc welding of materials MIG welding of materials TIG welding of materials **And one from** (9 credits) Platework fabrication of materials Sheet metalwork fabrication of materials Fabrication and erection of structural steelwork Pattern development for fabrication Pipe and tube fabrication	**Plus one from** (9 credits) Maintenance of machine systems Maintenance of utility systems Maintenance of plant services Maintenance of Hydraulic Systems Maintenance of Pneumatic Systems Power generation systems and ancillary equipment

Level 3 Diploma in Engineering Mechanical Manufacturing Engineering (2850-34)	**Level 3 Diploma in Engineering Electrical & Electronic Engineering (2850-35)**	**Level 3 Diploma in Engineering Shipbuilding (2850-36)**	**Level 3 Diploma in Composites Engineering (2850-38)**
Engineering health and safety	Engineering health and safety	Engineering health and safety	Engineering health and safety
Engineering principles	Engineering principles	Engineering principles	Engineering principles
Principles of mechanical manufacturing engineering	Principles of electrical & electronic engineering	Principles of shipbuilding	Principles of composite materials
			Principles of Composites manufacture
Plus any one from	**Plus any one from**	**Plus any one from**	**N/A**
(9 credits)	(9 credits)	(9 credits)	
Machining materials by turning	Maintenance of electrical equipment and systems	Manual metal arc welding of materials	
Machining materials by milling	Mechatronics systems principles and fault finding	MIG welding of materials	
Machining materials by grinding	Computer automated and robotic systems principles and control	TIG welding of materials	
CNC machining of materials	Power supply and analogue and digital circuit principles and fault finding	Platework fabrication of materials	
Detailed fitting of materials	Electronic power control principles and practice	Sheet metalwork fabrication of materials	
		Fabrication and erection of structural steelwork	
		Pattern development for fabrication	
		Maintenance of machine systems	
		Maintenance of utility systems	
		Maintenance of plant services	
		Maintenance of hydraulic Systems	
		Maintenance of pneumatic Systems	
		Power generation systems and ancillary equipment	

Plus any two units from below (only one required for learners following the Fabrication & Welding pathway) (9 credits each)

- Manual metal arc welding of materials
- MIG welding of materials
- TIG welding of materials
- Platework fabrication of materials
- Sheet metalwork fabrication of materials
- Fabrication and erection of structural steelwork
- Pattern development for fabrication
- Maintenance of machine systems
- Maintenance of utility systems
- Maintenance of plant services
- Maintenance of hydraulic systems
- Maintenance of pneumatic systems
- Power generation systems and ancillary equipment
- Machining materials by turning
- Machining materials by milling
- Machining materials by grinding
- CNC machining of materials
- Detailed fitting of materials
- Maintenance of electrical equipment and systems
- Produce drawings using CAD
- Organising and managing engineering operations
- Advanced mathematics and science
- Mechatronics systems principles and fault finding
- Computer automated and robotic systems principles and control
- Power supply and analogue and digital circuit principles and fault finding
- Electronic power control principles and practice
- MIG welding of aluminium
- TIG welding of aluminium
- Flux-cored arc welding of materials

Total Qualification Time

Total Qualification Time (TQT) is the total amount of time, in hours, expected to be spent by a Learner to achieve a qualification. It includes both guided learning hours (which are listed separately) and hours spent in preparation, study and assessment.

Title and level	GLH	TQT
City & Guilds Level 3 Diploma in Engineering	480	540

1.2 Opportunities for progression

The qualification provides knowledge and practical skills related to the Level 3 NVQ Diploma in Engineering Maintenance, Level 3 NVQ Diploma in Mechanical Manufacturing Engineering, Level 3 NVQ Diploma in Fabrication & Welding and the Level 3 NVQ Diploma in Technical Support.

1.3 Qualification support materials

City & Guilds will provide the following learning and support resources which will be posted on our website.

Description	How to access
Assignment guide for centres	**www.cityandguilds.com**
Assignments 303 to 340	**www.cityandguilds.com** (password protected)
SmartScreen	**www.smartscreen.co.uk**

Apprenticeship frameworks

The Level 2 Certificate/Diploma in Engineering and the Level 3 Diploma in Engineering have been approved by SEMTA as technical certificates for the Apprenticeship in Engineering in England, Wales and Northern Ireland.

Full details of the requirements of the apprenticeship framework for the Engineering Sector are available from:

Name of SSC SEMTA
Address 14 Upton Road, Watford, WD17 0JT
Telephone 01923 238441
Fax 01923 256086
URL www.semta.org.uk/

2 Centre requirements

2.1 Approval

Centres approved to offer the qualification 2800 Certificate in Engineering will be given automatic approval to run the new Level 3 Diploma in Engineering (2850).

If there is no fast track approval for this qualification, existing centres who wish to offer this qualification must use the **standard** Qualification Approval Process.

To offer these qualifications new centres will need to gain both centre and qualification approval. Please refer to the *Centre Manual – Supporting Customer Excellence* for further information. Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualifications before designing a course programme.

2.2 Resource requirements

Centres must have access to sufficient equipment in the centre or workplace to ensure learners have the opportunity to cover all of the practical activities. It is acceptable for centres to use specially designated areas within a centre for some of the units, for example to assess the installation of specialised electrical systems, alignment and setting up of electric motors and driven devices (pumps, compressors, generators).

Centre staff

Centre staff must satisfy the requirements for occupational expertise for these qualifications. Staff should be technically competent in the areas for which they are delivering training and/ or should also have experience of providing training.

Assessor and verifier requirements

While the Assessor/Verifier (A/V) units are valued as qualifications for centre staff, they are not currently a requirement for the qualifications.

Continuing professional development (CPD)

Centres are expected to support their staff in ensuring that their knowledge of the occupational area and of best practice in delivery, mentoring, assessment and verification remains current, and takes account of any national or legislative developments.

2.3 Learner entry requirements

No specific prior qualifications, learning or experience are required for leaners undertaking the qualification(s). However, centres will need to make an initial assessment of each leaner to ensure that the level of the scheme is appropriate. The nature of both the learning and assessment required for the qualification is such that leaners will need basic literacy and numeracy skills ie the ability to read and interpret written tasks and to write answers in a legible and understandable form. Leaners will also need to be able to organise written information clearly and coherently, although they will not be assessed for spelling or grammatical accuracy unless this is part of the assessment criteria.

There are no restrictions on entry for this award. City & Guilds recommend that leaners should not enter for a qualification of the same level and the same content as that of a qualification they already hold.

Details of the availability of assessments and of the general regulations for their conduct are given in the 'Directory of Assessments and Awards'. If there is any inconsistency between the scheme regulations in this pamphlet and the Directory of Assessments and Awards, the Directory **shall** prevail.

For leaners with particular requirements, centres should refer to City & Guilds policy document Access to assessment, leaners with particular requirements. This also applies to leaners who wish to seek examinations in language other than English.

Age restrictions

City & Guilds cannot accept any registrations for leaners under the age of 16 as these qualifications are not approved for under 16s.

3 Course design and delivery

Tutors/assessors should familiarise themselves with the structure and content of the award before designing an appropriate course; in particular they are advised to consider the knowledge and understanding requirements of the relevant N/SVQ.

City & Guilds does not itself provide courses of instruction or specify entry requirements. As long as the requirements for the award are met, tutors/assessors may design courses of study in any way that they feel best meets the needs and capabilities of the leaners. Centres may wish to introduce other topics as part of the programme which will not be assessed through the qualifications, e.g. to meet local needs.

It is recommended that centres cover the following in the delivery of the course, where appropriate:

- Health and safety considerations, in particular the need to impress to leaners that they must preserve the health and safety of others as well as themselves
- Key Skills (such as Communication, Application of Number, Information technology, Working with others, Improving own learning and performance, Problem solving)
- Equal opportunities
- Spiritual, moral, social and cultural issues
- Environmental education, related European issues.

Access to assessment

City & Guilds' guidance and regulations on access to assessment are designed to facilitate access for assessments and qualifications for leaners who are eligible for adjustments to assessment arrangements. Access arrangements are designed to allow attainment to be demonstrated. For further information, please see *Access to assessment and qualifications*, available on the City & Guilds website.

Appeals

Centres must have their own, auditable, appeals procedure that must be explained to leaners during their induction. Appeals must be fully documented by the quality assurance co-ordinator and made available to the external verifier or City & Guilds.

Further information on appeals is given in *Centre Manual – Supporting Customer Excellence*. There is also information on appeals for centres and learners on the City & Guilds website or available from the Customer Relations department.

4 Assessment

The mandatory core units 301 – Engineering health and safety and 302 Engineering principles are assessed by a City & Guilds online multiple-choice assessment. The remaining 'Principles of' units are assessed by a short-answer question paper. All other units are assessed by assignment which contains practical and knowledge tasks.

The practical aspect of the assignments are centre devised with guidance provided by City & Guilds, confirmation that the centre devised practical aspect is acceptable is required from the City & Guilds External Verifier. The knowledge aspect of the assignments (short-answer questions) is provided by City & Guilds. As assignments are designed to sample practical activities, it is essential that the centres ensure that leaners cover the content of the whole unit.

Assessment components are graded (Pass, Merit, Distinction). A pass is the achievement level required for the knowledge and understanding in an NVQ and generally represents the ability to follow instructions and procedures. Merit and distinction represent increasing levels of ability to adapt to changing circumstances and to independently resolve problems.

4.1 Summary of assessment requirements

For these qualifications, leaners will be required to complete the following assessments:

- **one** online test for **each** mandatory unit
- **one** short-answer question paper for **each** 'Principles of' unit
- **one** assignment for **each** chosen optional unit

City & Guilds provides the following assessments:

Unit	Title	Assessment method	Where to obtain assessment materials
2850-301	Engineering health and safety	Online multiple-choice assessment The assessment covers all of the outcomes.	**www.walled-garden.com**
2850-302	Engineering principles	Online multiple-choice assessment The assessment covers all of the outcomes.	**www.walled-garden.com**
2850-303	Principles of welding	Assignment 2850-303 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-304	Principles of fabrication	Assignment 2850-304 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-305	Principles of fabrication and Welding	Assignment 2850-305 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**

Unit	Title	Assessment method	Where to obtain assessment materials
2850-306	Principles of engineering maintenance, installation and Commissioning	Assignment 2850-306 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-307	Principles of mechanical manufacturing engineering	Assignment 2850-307 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-308	Principles of electrical and electronic engineering	Assignment 2850-308 The assessment includes short answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-309	Principles of shipbuilding	Assignment 2850-309 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-310	Manual metal arc welding of materials	Assignment 2850-310 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-311	MIG welding of materials	Assignment 2850-311 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-312	TIG welding of materials	Assignment 2850-312 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-313	Platework fabrication of materials	Assignment 2850-313 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**

Unit	Title	Assessment method	Where to obtain assessment materials
2850-314	Sheet metalwork fabrication of materials	Assignment 2850-314 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-315	Fabrication and erection of structural steelwork	Assignment 2850-315 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-316	Pattern development for fabrication	Assignment 2850-316 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-317	Maintenance of machine systems	Assignment 2850-317 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-318	Maintenance of utility systems	Assignment 2850-318 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-319	Maintenance of plant services	Assignment 2850-319 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-320	Maintenance of hydraulic systems	Assignment 2850-320 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**

Unit	Title	Assessment method	Where to obtain assessment materials
2850-321	Maintenance of pneumatic systems	Assignment 2850-321 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-322	Power generation systems and ancillary equipment	Assignment 2850-322 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-323	Machining materials by turning	Assignment 2850-323 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-324	Machining materials by milling	Assignment 2850-324 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-325	Machining materials by grinding	Assignment 2850-325 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-326	CNC machining of materials	Assignment 2850-326 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	www.cityandguilds.com
2850-327	Detailed fitting of materials	Assignment 2850-327 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**

Unit	Title	Assessment method	Where to obtain assessment materials
2850-328	Maintenance of electrical equipment and systems	Assignment 2850-328 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-329	Produce drawings using CAD	Assignment 2850-329 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-330	Organising and managing engineering operations	Assignment 2850-330 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-331	Advanced mathematics and science	Assignment 2850-331 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-332	Mechatronics systems principles and fault finding	Assignment 2850-332 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-333	Computer automated and robotic systems principles and control	Assignment 2850-333 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-334	Power supply and analogue and digital circuit principles and fault finding	Assignment 2850-334 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**

Unit	Title	Assessment method	Where to obtain assessment materials
2850-335	Electronic power control principles and practice	Assignment 2850-335 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-336	MIG welding of aluminium	Assignment 2850-336 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-337	TIG welding of aluminium	Assignment 2850-337 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-338	Flux-cored arc welding of materials	Assignment 2850-338 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**
2850-339	Principles of composite materials	Assignment 2850-339 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-340	Principles of composites manufacture	Assignment 2850-340 The assessment includes short-answer questions to verify coverage of the underpinning knowledge in the unit.	**www.cityandguilds.com**
2850-341	Pipe and tube fabrication	Assignment 2850-338 The assessment covers the practical activities for all outcomes and will also sample underpinning knowledge to verify coverage of the unit. Centre devised assignment, internally marked, externally verified.	**www.cityandguilds.com**

Time allowance for assessments

The following time allowance must be applied to the assessment of this qualification:

- Each assignment has specific time constraints; please refer to the individual assignments. Centre staff should guide leaners to ensure excessive evidence gathering is avoided. Centres finding that assignments are taking longer, should contact the external verifier for guidance.

- All assignments must be completed and assessed within the leaners period of registration. Centres should advise leaners of any internal timescales for the completion and marking of individual assignments.

4.2 Test specifications

The test specifications for the units assessed by an online multiple-choice assessment are listed below.

2850-301: Engineering health and safety
Duration: 1 hour

Outcome		No. of questions	%
1	Understand compliance with statutory health and safety regulations and organisational requirements	13	32.5
2	Understand compliance with statutory environmental regulations and organisational requirements	7	17.5
3	Know how to implement accident and emergency procedures	9	22.5
4	Understand safe working practices and procedures	11	27.5
	Total	**40**	**100**

2850-302 Engineering principles
Duration: 1 hour 10 minutes

Outcome		No. of questions	%
1	Know how to interpret engineering information	11	24.5
2	Know how to differentiate between common engineering materials	10	22
3	Know how to perform engineering calculations	10	22
4	Understand quality control in engineering	14	31.5
	Total	**45**	**100**

The test specifications for the 'Principle of' units will be available on **www.cityandguilds.com**

4.3 Recognition of prior learning (RPL)

Recognition of prior learning (RPL) recognises the contribution a person's previous experience could contribute to a qualification.

5 Units

Structure of units

The units in these qualifications are written in a standard format and comprise the following:

- City & Guilds reference number
- unit accreditation number (UAN)
- title
- level
- credit value
- unit aim
- relationship to NOS, other qualifications and frameworks
- information on assessment
- learning outcomes which are comprised of a number of assessment criteria
- notes for guidance.

Where there are references to British, European and International standards the current version should be used.

Unit 301 Engineering health and safety

Level: **3**
Credit value: **9**
UAN: **Y/503/0334**

Unit aim

This unit is concerned with the requirements that are essential to enable engineering activities to be carried out safely and effectively. It includes dealing with statutory and organisational requirements in accordance with approved regulations, codes of practice and procedures. It covers responsibilities relating to accident reporting and the identification of hazards and risks.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand compliance with statutory health and safety regulations and organisational requirements
2. Understand compliance with statutory environmental regulations and organisational requirements
3. Know how to implement accident and emergency procedures
4. Understand safe working practices and procedures

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ Level 3 Unit No 1: Complying with Statutory Regulations and Organisational Safety Requirements

Assessment

This unit will be assessed by an online multiple-choice assessment.

Unit 301 Engineering health and safety

Outcome 1 Understand compliance with statutory health and safety regulations and organisational requirements

Assessment Criteria

The learner can:

1. describe the health and safety **regulations** applicable to engineering operations
2. explain **employers' responsibilities** to maintain health and safety
3. describe essential **operator and bystander** health and safety requirements
4. explain the Reportable Diseases and Dangerous Occurrences Regulations (**RIDDOR**) relevant to engineering
5. explain the procedures for **reporting accidents**
6. explain how the **management of health and safety** regulations are implemented
7. state the roles, responsibilities and powers of **health and safety personnel**
8. explain the sources of health and safety literature/advice and how to access it
9. describe how to carry out a **risk assessment** identifying potential health hazards
10. state the general rules for the observance of **safe practices**

Range

Regulations: Health and Safety at Work etc. Act, Control of Substances Hazardous to Health Regulations (COSHH), Provision and Use of Work Equipment Regulations (PUWER), Electricity at Work Regulations, Control of Major Accident Hazards Regulations (COMAH), Control of Noise at Work Regulations, Lifting Operations and Lifting Equipment Regulations (LOLER)

Employers' responsibilities:

Safe: place of work, plant and equipment, system of work, working environment, methods of handling, storing and transporting goods and materials

Reporting of accidents (RIDDOR), information, instruction, training and supervision of employees, a health and safety policy

Operator and bystander: Personal Protective Equipment (PPE), Respiratory Protective Equipment (RPE)' secure areas

Reporting accidents: summary of accident, name of victim(s), summary of events prior to accident, details of witnesses, information on injury or loss sustained, conclusions, recommendations, supporting material (photographs, video), diagrams, date, signature of person(s) responsible for report

Management of Health and Safety: including the four C's of positive health and safety (Competence, Control, Co-operation, Communication)

Health and safety personnel: Health and Safety Advisors, Health and Safety Representatives, Health and Safety Executive Inspectors, Environmental Health Officers

Risk assessment: potential hazards, slippery or uneven surfaces, spillages, scrap or waste material, inflammable materials, faulty or missing machine guards, faulty electrical connections or damaged cables, material ejection, pressure and stored energy, unshielded processes, volatile and

toxic materials, dust and fumes, contaminants and irritants, materials handling and transportation, working at heights

Safe practices: be alert, maintain personal hygiene, protect yourself and other people, know emergency procedures, report all hazards

Unit 301 Engineering health and safety

Outcome 2 Understand compliance with statutory environmental regulations and organisational requirements

Assessment Criteria

The learner can:

1. describe the differences between the **human and environmental conditions** leading to accidents in the workplace and the means of **controlling** them
2. describe the Environmental Management Systems standard ISO 14001 in terms of the engineering industry
3. describe the implementation of **environmental legislation** as it applies to engineering industries
4. identify health and safety **signs** and explain their purpose

Range

Human and environmental conditions:

Causes of accidents

Human: lack of management control, carelessness; improper behaviour and dress; lack of training, supervision and experience; fatigue; drug-taking and alcohol intake, **Environmental**: unguarded or faulty machinery or tools; inadequate ventilation; untidy, dirty, overcrowded workplace; inadequate lighting

Controlling: Eliminate the hazard, replace the hazard with something less dangerous, guard the hazard, personal protection, health and safety education and publicity

Environmental legislation: Environmental Protection Act, Pollution Prevention and Control Act, Clean Air Act, Radioactive Substances Act, Controlled Waste Regulations, Dangerous Substances and Preparations and Chemicals Regulations, Hazardous Waste Regulations

Signs: Warning, prohibition, mandatory, information, fire

Unit 301 Engineering health and safety

Outcome 3 Know how to implement accident and emergency procedures

Assessment Criteria

The learner can:

1. explain the need for the provision of **first aid** treatment
2. explain the **health and safety procedures** that prevent injury or discomfort to skin, eyes, hands and limbs
3. explain the appropriate **emergency action** to be taken in cases of electric shock
4. explain precautions to be taken to avoid **electric shock**
5. explain the causes of **asphyxiation** and the appropriate emergency action to be taken
6. state what is meant by a dangerous occurrence and hazardous malfunction
7. describe the procedures to be followed in the event of the sounding of an **emergency alarm**
8. describe methods of **fire prevention**

Range

First aid: location of facilities, location of qualified first aiders

Health and safety procedures: personal hygiene, skin protection and care, care of eyes, use of eye and face protectors which are to current EN specifications, use of respirators, dangers of hair and loose clothing getting caught in machinery, means of avoiding such dangers, benefits and use of protective clothing, use of safety guards, screens and fences

Emergency action: isolate electrical supply, removal from electricity supply, basic resuscitation procedures

Electric shock: hazards arising from the use of electrical equipment, general health and safety rules: checking and inspection of cables, leads and plugs; earthing; problems associated with the use of portable equipment; use of reduced voltage equipment; health and safety training; warning signs and notices; isolation procedures

Asphyxiation: confined working space, inadequate ventilation

Emergency alarm; evacuation system, escape routes, assembly points (reporting to assembly points, not to return until authorised)

Fire prevention: risk assessments, methods of controlling fires, fire procedures, adhering to fire safety legislation

Additional Guidance

Fire prevention: fire risk assessments, causes of fire, fire prevention, spread of fire, methods of controlling fires, conditions required for combustion and extinction, the fire triangle, fire procedures (fire drills, fire fighting equipment for different types of fires, extinguishers (types classification for types of fire), automatic equipment, adhering to fire safety legislation)

Unit 301 Engineering health and safety

Outcome 4 Understand safe working practices and procedures

Assessment Criteria

The learner can:

1. describe the range of Personal Protective Equipment (PPE) available and relate its use to the operations that will be undertaken
2. explain use of Respiratory Protective Equipment (**RPE**) when undertaking tasks involving exposure to hazardous substances and the range available
3. describe how to carry out a risk assessment for using mechanical lifting equipment
4. state the requirements of the Lifting Operations and Lifting Equipment Regulations **(LOLER)**
5. explain the health and safety rules for the use of mechanical lifting equipment
6. explain the purpose and methods of use of **accessories** to lifting gear
7. describe the Manual Handling Operations Regulations as they apply to engineering industries
8. explain the necessity of a **permit to work procedure**
9. explain the necessity of 'lock-off' procedures
10. state the procedures used to notify/report hazards to **appropriate people**
11. state situations in which it is unadvisable or unsafe to **work in isolation**

Range

RPE: chemicals and solvents, fumes, dust or harmful particulates, heat

Accessories: hooks, slings, eyebolts, shackles, chains, rings, special-to-purpose equipment, rules for the use of slings

Appropriate people: supervisors, health and safety advisors, health and safety representatives, fire marshals, works/site rescue team

Work in isolation: in confined spaces, above ground or in trenches, in close proximity to unguarded machinery, when a fire risk exists, with toxic or corrosive substances, on site

Additional Guidance

LOLER: as a general rule loads over 20kg need powered lifting gear, never exceed the maximum safe working load (SWL) indicated on the equipment and the accessories, avoid shock loading the lifting equipment, swinging and twisting, estimate the centre of gravity, position the lifting hook above the centre of gravity of the load to maintain an even balance, avoid pushing or pulling the load to adjust the balance, do not transport loads over the heads of people or walk under a load, do not leave a load hanging unnecessarily and, in any event, have someone to watch over it, always lower the load gently into position; make sure it will not move once the lifting equipment is removed, check date of equipment tests

Accessories: hooks (materials, design and certification) slings (materials, design and certification, the importance of the angle at the top, forces in the legs proportional to the angle at the top, design and construction of rope slings [natural and man-made fibres, steel wire slings]), eyebolts (design and construction to published standards, use when lifting engines, gearboxes, the importance of ensuring that the eyebolt shoulder is screwed flush to face of component) shackles (design and construction to published standards, the importance of SWL for different sizes) chains (design and construction; the importance of regular checking and testing to avoid failure from damage and metal fatigue) rings (design and construction to published standards; importance of use with slings

and chains), special-to-purpose equipment (use for lifting special equipment, regular lifting eg oil drums, production components) rules for the use of slings (never bend around sharp corners and edges and avoid overbending, use of protective covers on corners of loads, never twist or kink the sling never use a worn or damaged sling, always observe the safe working load (SWL))

Permit to work: purpose, description, content, types (including: 'hot working', electrical, maintenance operations, pressure testing, etc), procedure for use

Unit 302 Engineering principles

Level: 3
Credit value: 9
UAN: D/503/0433

Unit aim

This unit is concerned with those engineering principles that enhance the performance of engineering operations. This includes the extraction, interpretation and use of a range of technical information sources. It includes the use of basic calculations and engineering science that enables the leaner to better understand the behaviour and properties of engineering materials in order that appropriate materials may be selected to satisfy specifications. The identification and application of quality control measures that are relevant to engineering activities are also covered.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Know how to interpret engineering information
2. Know how to differentiate between common engineering materials
3. Know how to perform engineering calculations
4. Understand quality control in engineering

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ Level 3 Unit No 1: Complying with Statutory Regulations and Organisational Safety Requirements

Assessment

This unit will be assessed by an online multiple-choice assessment.

Unit 302 Engineering principles

Outcome 1 Know how to interpret engineering information

Assessment Criteria

The learner can:

1. explain the relevance of **engineering information**
2. describe the difference between the **abbreviations and notation** used on various standard engineering drawings, circuit diagrams or piping layouts
3. interpret the information that can be extracted from **reference charts, tables, graphs and BS EN standards**
4. explain the use of CAD systems to produce engineering drawings
5. explain the use of databases and spreadsheets to display information
6. explain the basic principles of **document control**
7. interpret **drawings, dimensioning and labelling**
8. describe how to use charts, tables, graphs and BS EN standards
9. describe how to extract information from drawings
10. describe how to use engineering drawings to produce material lists
11. describe how to use engineering drawings to determine quality requirements

Range

Engineering information: BS EN standards, instruction manuals, technical handbooks, tables, charts (including: flow, Gantt, tally), graphs (including histograms, scatter diagrams), Ishikawa diagrams (fishbone diagrams or cause-and-effect diagrams), data sheets, text books and reference materials, computer applications

Abbreviations and notation: symbols and abbreviations, application to: engineering drawings, machining, welded joints, circuit diagrams and piping layouts

Reference charts, tables, graphs and BS EN standards: tapping sizes and threads, feeds and speeds, cable sizing, PIN configurations, component ratings, welding symbols, machining symbols and tolerances, piping components

Drawings, dimensioning and labelling: projections (orthographic [first angle, third angle], isometric [including exploded], oblique); reference points, lines, edges and surfaces, continuous dimensions, baseline dimensions

Additional Guidance

Document control: where documents are obtained from, how distribution and use of documents is controlled, the relevance of document issue numbers, document approval and authorisation procedures, procedure to be adopted if documents are lost or damaged

Unit 302 Engineering principles

Outcome 2 Know how to differentiate between common engineering materials

Assessment Criteria

The learner can:

1. describe the difference between a range and form of **supply of materials** commonly used in engineering
2. describe the difference between **characteristics** of metallic and non-metallic materials used in engineering
3. describe how carbon and alloying elements affect the properties of carbon and low alloy steels
4. describe how **heat treatments** can affect the properties of carbon and low alloy steels
5. explain the causes of **corrosion** in materials
6. state the **defects** that can occur in materials/products and explain the importance of controlling them
7. select materials to meet specification requirements in a typical engineering environment

Range

Supply of materials: ferrous metals (low, medium and high carbon steels; low alloy steels; stainless steels; cast irons), non-ferrous metals (aluminium and aluminium alloys, copper, brass, bronze, nickel, lead, titanium), non-metallic (hard and soft woods, composites, plastics: thermoplastic, thermosetting), ceramics, reinforcing materials (glass fibre, carbon fibre, aramid fibre)

Characteristics: selection of materials for engineering applications, strength, rigidity, temperature stability (heat resistance, thermal conductivity, electrical conductivity and insulation), wear resistance, acoustic absorption, shock absorption, corrosion resistance, influence of physical properties of materials on processing techniques (cutting, forming, joining), identification of engineering materials (colour, surface texture, appearance, density, magnetic/non-magnetic, spark test)

Heat treatments: iron-carbon thermal equilibrium diagram, annealing, normalising, hardening, tempering

Corrosion: pitting, intergranular, galvanic, leaching, oxidation

Defects: critical, major, minor or non-critical

Additional Guidance

Characteristics: selection of materials for engineering applications, strength, rigidity, temperature stability (heat resistance, thermal conductivity, electrical conductivity and insulation), wear resistance, acoustic absorption, shock absorption, corrosion resistance, influence of physical properties of materials on processing techniques (cutting, forming, joining), identification of engineering materials (colour, surface texture, appearance, density, magnetic/non-magnetic, spark test), factors influencing the choice of materials (properties, cost, testing of materials (non-destructive: visual, penetrant [dye and fluorescent], magnetic particle [dye and fluorescent], radiography, ultrasonic; destructive: tensile, shear, hardness [Brinell, Vickers, Rockwell], toughness [Charpy, Izod], creep, fatigue, bending.

Unit 302 Engineering principles

Outcome 3 Know how to perform engineering calculations

Assessment Criteria

The learner can:

1. express numerical solutions to a **degree of accuracy** that is appropriate to the value being calculated
2. use a calculator to raise a number to a power and determine square roots
3. use formulae to complete **transpositions** and solve problems
4. use **algebraic expressions**
5. plot and interpret **straight line graphs**
6. apply Pythagoras' Theorem
7. explain how to use **Sine, Cosine and Tangen**t to solve typical engineering problems
8. define density and relative density and solve related problems using formula
9. define **moments of a force** and **solve related problems using formula**
10. define **work, power and energy** and solve related problems using formula
11. define **friction** and solve related problems using formula
12. describe the relationship between **temperature** changes and changes in length
13. define types of **heat** and solve related problems using formula

Range

Degree of accuracy: correct to three significant figures, correct to two decimal places, express a decimal fraction in standard form, express tolerance in terms of limits of size

Transpositions: involving addition, subtraction, multiplication and division in any combination using a maximum of three terms, for example Ohm's Law solve problems: substitution of known values

Algebraic expressions: represent numerical quantities using symbols, apply laws of precedence in the use of precedence (BODMAS)

Straight line graphs: determining suitable scales from given data, defining and correctly labelling axes, determine the gradient, determine the intercept, prove the law of the straight line graph is $y = mx + c$

Sine, Cosine and Tangent: state their ratios for angles up to 90°, determine their values for given angles up to 90°, solve simple problems

Moments of a force: define and apply the 'Principle of Moments', define the meanings of the terms 'torque' & 'couple'

Solve problems: associated with levers and couples work, power and energy define work done in terms of force and distance moved

Work, power and energy: explain what is meant by energy; state that the unit of energy is the joule (J), the unit of power is the watt (W) and the unit of work is the joule (J); define power in terms of voltage/current and work done per second, perform calculations for work, power and energy

Friction: definition, explain coefficient of friction, explain how friction can be reduced, select materials that will rotate, or slide together with low frictional value, perform calculations for friction

Temperature: define coefficient of expansion, solve numerical problems to determine the change in length due to temperature.

Heat: define: specific heat capacity, specific latent heat (fusion, evaporation) solve numerical problems associated with specific heat capacity, specific latent heat of fusion, specific latent heat of evaporation

Unit 302 Engineering principles

Outcome 4 Understand quality control in engineering

Assessment Criteria

The learner can:

1. state what is meant by the term **quality** and apply quality to contexts/perceptions
2. define the terms **inspection and quality control**
3. explain the principles of **quality control and inspection**
4. explain the need for materials and components, **inward inspection** and correct documentation
5. state the function of an incoming raw materials inspection department
6. explain the need for **validating and calibrating** test and measuring equipment
7. explain how to **check equipment is approved** for use and how to take appropriate action to return/report equipment that has passed its approval date
8. explain the use of engineering standards in determining the fitness of purpose of items/equipment used in engineering production, construction and maintenance
9. describe the appropriate **action** to take when required standards of performance are not met
10. explain limits of authority in respect of re-working, adjusting or scrapping a component/product
11. explain the need to inform a responsible person of the variation from the stated standard
12. state the need to document all actions agreed upon and taken
13. explain the importance of **quality records** and the type of inspection records needed
14. explain the purpose of the ISO 9000 series of standards
15. describe how to complete quality documents/records of work carried out and record test/inspection results
16. interpret results from quality measurements and compare them with stated parameters
17. make recommendations whether to re-work, adjust or scrap items/components that do not meet required standards

Range

Quality: components, products or services being fit for purpose, customer expectation, product, component or service reliability, the need for interchangeability with regard to supplying spare parts, product life cycle

Quality control and inspection: inspection: covering the examination, measurement, testing and judgement of a product for conformation to a predetermined requirement i.e. fitness for purpose, quality control: activities embracing all stages of manufacture from initial design, raw material and finished products, principles of inspection (random sampling, sampling frequency)

Inward inspection: dimensional accuracy, correct documentation for incoming goods/materials, importance of release and advice notes, faults that may arise in documentation and storage of incoming goods, methods of checking for faults in documentation, spot checks, random checks; sampling (quarantine inspection) in terms of: importance of release and advice notes, the reason for clear, identification of materials with relevant batch numbers, procedures to be followed before batch material is released into stores in accordance with storage recommendations – tests to be applied, identification of acceptance/rejection criteria and the recording procedures involved, remedial action to be taken when components/materials prove defective

Validating and calibrating: need for regular and controlled calibration and validation of measuring equipment, need for traceable records of calibration checks, use of international standards

Check equipment is approved: Equipment such as: torque wrenches, lifting equipment, pressure gauges, micrometers, vernier instruments

Action: re-work, adjust, scrap

Quality records: record all test results, record all inspections carried out, procedures to be taken upon completion of task (place into stores, pass it to another department, mark it for re-work, adjust, mark it for scrap or salvage

Unit 303 Principles of welding

Level: **3**
Credit value: **9**
UAN: **D/503/0335**

Unit aim
This unit enables the leaner to understand the underlying principles that enable effective welding to take place, without focusing on specific welding processes.

Welding metallurgy, the physical science of welding, weld symbols, joint design, distortion, defects and testing: non-destructive (NDT) and destructive (mechanical) are included.

Learning outcomes
There are **five** learning outcomes to this unit. The learner will be able to:
1. Understand the fundamentals of welding
2. Know how to apply welding symbols to joint preparations
3. Understand the affects of distortion and residual stresses due to welding
4. Understand the metallurgical effects of welding
5. Know how to determine the integrity of welded joints

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering

Assessment
This unit will be assessed by a short-answer question paper.

Unit 303 Principles of welding

Outcome 1 Understand the fundamentals of welding

Assessment Criteria

The learner can:

1. explain the characteristics of an **electric arc** used for welding purposes
2. explain the purpose of **electrode coverings** used for welding purposes
3. explain the **effects** of fluxes and electrode coverings/cores upon welding processes
4. explain the purpose of **shielding gases** used for welding purposes

Range

Electric arc: voltage distribution across the arc, heat generation at the cathode and anode, arc characteristics (alternating current [a.c.], direct current [d.c.]), effects and influence of magnetic fields, factors that influence metal transfer (surface tension, gravity, electromagnet [Lorentz] force, hydrodynamic forces due to gas flow, pinch effect

Electrode coverings: rutile, basic, cellulosic, iron powder

Effects: facilitates arc striking, stabilises and directs the arc, assists control of the size and frequency of filler metal globules/droplets, protects filler metal from atmospheric contamination during transfer, protects deposited metal from contamination, provides appropriate weld contour, prevents rapid cooling of weld metal (thermal blanket effect), provides a flux for the molten pool to remove oxides and impurities, supplies additional metal to weld pool

Shielding gases: tungsten inert gas (TIG) welding, metal inert gas (MIG) welding, inert gases (argon, helium), inert gas mixtures (CO_2, Ar/CO_2, Ar/O_2/CO_2, Ar/He/O_2/CO_2, Ar/O_2, Ar/H_2, N_2, Ar/N_2) [where: Ar = argon, He = helium, O_2 = oxygen, H_2 = hydrogen, N_2 = nitrogen, CO_2 = carbon dioxide]; influence of shielding gases (protection from gases in the atmosphere, composition of atmosphere, arc characteristics, mode of metal transfer, penetration, weld bead profile, speed of welding, wetting/undercutting tendency, cleaning action, weld metal mechanical properties

Additional Guidance

Electrode coverings: processes manual metal arc (MMA) welding, types of covering (rutile, basic, cellulosic, iron powder)

Unit 303 Principles of welding

Outcome 2 Know how to apply welding symbols to joint preparations

Assessment Criteria

The learner can:

1. describe the difference between the **features** of welded joints
2. describe how to apply BS EN 22553 to **types of joints**
3. describe how to apply **weld dimensions** to weld symbols

Range

Features: face, toes, root, HAZ (heat affected zone), convex fillet profile, concave fillet profile, mitred fillet profile, root face, root gap, root radius ('U' butt profile), land ('U' butt profile), bevel angle, included angle, weld width, throat thickness, leg length(s), fusion zone (depth of fusion), excess weld metal, penetration, fusion line (boundary)

Types of joints: Welded, brazed and soldered joints — symbolic representation on drawings, symbols for the communication of the designation of welded joints; types of joint (butt, tee, lap, corner); types of weld preparation (square butt [open], square butt [closed], flanged butt, single-vee butt, double-vee butt, single 'U' butt, double 'U' butt, fillet, single-bevel butt, double-bevel butt, single 'J' butt, double 'J' butt, spot, seam, projection, surfacing, plug, edge, surface, inclined, fold); application of types of weld preparation (arrow line, reference line, identification line, symbol, non-symmetrical welds, symmetrical welds); supplementary and complimentary symbols (finished flush by grinding, finished flush by machining, convex, concave, backing [sealing] run, permanent backing strip, removable backing strip, toes blended smoothly, peripheral welds, field or site welds, numerical indication of welding process [EN 24063 — Welding, brazing, soldering and braze welding of metals — nomenclature of processes and reference numbers for symbolic representation on drawings]

Weld dimensions: leg length, throat thickness, fillet welds, square butt welds, root gaps, intermittent fillet welds, staggered intermittent fillet welds

Unit 303 Principles of welding

Outcome 3 Understand the affects of distortion and residual stresses due to weldingg

Assessment Criteria

The learner can:

1. explain the **reasons for distortion** due to welding
2. classify **types of distortion**
3. explain the methods of **distortion control**
4. explain the methods of **distortion rectification**
5. explain the **residual stress** effects of welding

Range

Reasons for distortion: uneven expansion and contraction, degree of restraint

Types of distortion: longitudinal, transverse, angular, buckling, bowing, dishing, twisting

Distortion control: presetting, pre-bending, weld sequencing, skip welding, back-stepping, balanced welding, intermittent welding, tack welding, pre and post weld heat treatment, joint design, chills, restraint (clamping, jigs, back-to-back assembly)

Distortion rectification: mechanical methods (peening, jacking, pressing, bending, rolling, hammering, planishing); thermal methods (use of heat strips, use of heat triangles); combination of mechanical and thermal methods (hot working)

Residual stress: causes (restraint due to uneven expansion and contraction [natural], restraint due to distortion control methods [clamping, jigs, back-to-back assembly, balanced welding]), effects (pattern across joint cross-section [areas of tension, areas of compression], influence upon mechanical properties in service), stress relieving methods (normalising, thermal stress relief)

Unit 303 Principles of welding

Outcome 4 Understand the metallurgical effects of welding

Assessment Criteria

The learner can:

1. explain the **heat distribution** during welding
2. explain the **effects of heat** due to welding
3. explain the relationship between the iron-carbon (Fe-C) **thermal equilibrium diagram** for plain carbon steels and welded joints
4. explain the reasons for **cracking** due to welding
5. explain the effects of **dilution** on fully fused joints in dissimilar metals

Range

Heat distribution: thermal gradients, heat flow, weld thermal cycle, effects upon the structure of the weld metal, effects upon the structure of the parent metal (heat-affected zone [HAZ], HAZ sub-zones [overheated, refining, transition]

Effects of heat: temperature, methods of heat production (electric arc, electrical resistance, combustion), determination of heat input during arc welding (J/s, [k]J/mm), pre and post weld heat treatment, stress relief, methods of temperature measurement (pyrometer, temperature indicating crayons), means of heat transfer/loss (conduction, convection, radiation)

Thermal equilibrium diagram: influence of percentage carbon content in iron, influence of temperature, upper critical point, lower critical point, eutectoid, relationship to heat treatment processes, relationship to weld and HAZ

Cracking: cold-cracking due to hydrogen in steels, definition, conditions necessary for cold cracking, influence of hydrogen, influence of stresses, influence of susceptible microstructure, methods of avoiding, reheat cracking, definition, types of steels sensitive to reheat cracking, reheat cracking due to heat treatment, reheat cracking due to multi-pass welding

Dilution: determine the amount of dilution in a weld deposit, factors affecting dilution, welding procedure, methods of reducing dilution, use of solid phase welding processes

Additional Guidance

Cracking: cold-cracking due to hydrogen in steels, definition, conditions necessary for cold cracking, influence of hydrogen (sources of hydrogen, control of hydrogen in the deposited weld metal) influence of stresses (nature of stresses, methods of avoiding) influence of susceptible microstructure (nature, methods of avoiding), cracking mechanism in the weld metal and the HAZ, effect of preheating, use of stainless steel weld metal; lamellar tearing, definition, causes (through thickness properties, inclusions) methods of avoiding (influence of joint design, bead sequence, influencing factors [manganese/sulphur ratio, copper content, oxygen content, depth to width ratio of the weld, crack susceptibility); reheat cracking, definition, types of steels sensitive to reheat cracking, reheat cracking due to heat treatment, reheat cracking due to multi-pass welding

Dilution: determine the amount of dilution in a weld deposit, factors affecting dilution, welding procedure (welding process, welding technique), methods of reducing dilution (buttering, control of heat input [including welding current {use of small electrodes at low current, allowing the work to cool between runs/layers, fast travel speed, avoiding the use of pre-heat (not always possible), careful selection of welding process}], use of solid phase welding processes

Unit 303 Principles of welding

Outcome 5 Know how to determine the integrity of welded joints

Assessment Criteria

The learner can:

1. classify the types of **weld defects** (EN 26520)
2. explain the application of **visual examination** methods to welded joints
3. explain the application of **penetrant testing** methods to welded joints
4. explain the application of **magnetic particle testing** methods to welded joints
5. explain the application of **radiography** methods to welded joints
6. explain the application of **ultrasonic testing** methods to welded joints
7. explain the application of **mechanical testing** methods to welded joints
8. explain the methods of **container testing**

Range

Weld defects: cracks (longitudinal, transverse, edge, HAZ, crater, centreline, fusion zone, underbead), lack of fusion (root, side wall, inter-run), porosity (scattered, cluster, isolated pore, root, blow holes, worm holes), piping (craters), solid inclusions (slag, copper, tungsten, oxide), lack of penetration, undercut, oxidation, excessive weld metal (including penetration), underfill, concavity, overlap, burn-through, possible causes, remedial action

Visual examination: applications, requirements (equipment, personnel) benefits, limitations

Penetrant testing: dye, fluorescent, test procedure, applications, equipment requirements, limitations

Magnetic particle testing: magnetic flow (types of magnet [horseshoe, yoke]), current flow (a.c. [skin effect], d.c., types of magnetisation [prods, bar, coil, tubular, kettle element]), test procedure, applications, equipment requirements, benefits, limitations

Radiography: sources of radiation (x-ray, gamma ray), principle, applications, equipment requirements, benefits, limitations, radiation hazards (effects of radiation on the human body, radiation monitoring, personal monitoring, radiation enclosures, precautions for site radiography), radiographic techniques (plate, pipe [single wall – single image {including panoramic}, double wall – single image, double wall – double image [ellipse, superimposed])

Ultrasonic testing: applications, procedure, applications, equipment requirements (ultrasonic testing set [cathode ray tube {oscilloscope}, controls, calibration], probes [normal, angle, probe index, selection criteria, beam spread, far zone, near zone, dead zone], leads, calibration blocks, couplant), benefits, limitations, techniques (thickness testing, lamination testing, transmission method, reflection method), determination of geometry (beam angle, skip distance), procedures for reporting and recording flaws in welded components

Mechanical testing: impact tests (izod, charpy), bend tests (root, face, side), tensile (determination of tensile strength, determination of yield stress, determination of percentage elongation, transverse, all weld metal, tensile/shear [application to lap joints, application to double lap joints]), fracture (nick break), macro examination (specimen preparation, magnification), micro examination

(specimen preparation, magnification), hardness surveys (weld zone, HAZ, parent metal, location of indents, testing methods (Vickers, Brinell, Rockwell), testing of spot welded joints (peel test, tensile/shear, cross tensile, 'U' tensile, twist or torsion

Container testing: hydraulic pressure, pneumatic pressure, by filling, by immersion, health and safety considerations

Unit 304 Principles of fabrication

Level: 3
Credit value: 9
UAN: H/503/0336

Unit aim

This unit enables the leaner to understand the underlying principles that apply to the selection of materials and mechanical joining processes used in fabrication, without focusing on specific fabrication disciplines. Included is fabrication materials, allowances for bending and rolling, the principles of shearing, joining using non-thermal methods and finishing

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Know how to classify common materials used in fabrication engineering
2. Know how to determine the bending and rolling allowances for fabricated forms and the principles of shearing
3. Understand the difference between different non-thermal joining methods
4. Understand different methods used for finishing fabricated components

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering: Unit 026: Heat Treating Materials for Fabrication Activities; Unit 028: Joining Fabricated Components using Mechanical Fasteners

Assessment

This unit will be assessed by a short-answer question paper.

Unit 304 Principles of fabrication

Outcome 1 Know how to classify common materials used in fabrication engineering

Assessment Criteria

The learner can:

1. critically compare **materials** from a range found in fabrication engineering
2. explain the commercial **forms of supply** of materials available
3. state the criteria used for the **selectio**n of materials for a given application
4. explain the different material **structures**
5. explain the variation in properties that result from different types of **metallic structures**
6. explain the requirements for the **heat treatment** of metals

Range

Materials: metallic (low-carbon steel, low alloy steels, high yield steels, austenitic stainless steels, clad and coated materials [galvanised steel, tin plated steel, plastic coated steel, clad steels, anodised aluminium], aluminium/aluminium alloys, copper/copper alloys, titanium/ titanium alloys), polymers (thermoplastics, thermosetting), composites (glass fibre, carbon fibre, aramid fibre)

Forms of supply: sheet, plate, section (RSJ, channel, column, beam, tee, angle (equal leg, unequal leg), hollow section (square, rectangular, round [tubular]), pipe, fibre reinforcing materials (FRP)

Selection: strength/weight ratio, resistant properties (heat, corrosion, wear), cost, weldability, malleability

Structures: crystalline, chain molecules, amorphous

Metallic structures: fine grained structure, coarse grained structure, effect of grain size upon working properties

Heat treatment: annealing (steels, stainless steels, non-ferrous metals), normalising of steels, hardening of steels, tempering of steels, precipitation hardening of aluminium alloys

Unit 304 Principles of fabrication

Outcome 2 Know how to determine the bending and rolling allowances for fabricated forms and the principles of shearing

Assessment Criteria

The learner can:

1. explain the **mechanics of bending**
2. define the term **neutral line**
3. explain the purpose of **bending allowances** and apply bending allowance formulas
4. explain the purpose of **rolling allowances** and apply rolling allowance formulas
5. calculate the included angle of patterns of right cones using formula
6. explain the **principles of shearing**

Range

Mechanics of bending: tensile stresses, compressive stresses, neutral plane, springback, compensation for springback

Neutral line: principle, application to bending and rolling

Bending allowances: definition, radius of bend, application (thin sheet materials, thick plate materials, pipe, circular forms, 'U' bends, right-angle bends, non-right-angle bends, compound forms)

Rolling allowances: definitions (diameter of cylinder, length/height of cylinder, circumference of cylinder), application (circular cylinders, elliptical cylinders, taking into account material thickness, determination of the length of presetting required to avoid 'flats' when rolling

Principles of shearing: shear angle, rake angle, clearance, shearing action (area under shear, shear force required), mechanical advantage of lever system for hand-operated shears (bench, hand), principle of moments for lever system for hand-operated shears (bench, hand), piercing and blanking (area under shear, shear force required)

Unit 304 Principles of fabrication

Outcome 3 Understand the difference between different non-thermal joining methods

Assessment Criteria

The learner can:

1. classify **bolting** methods from a range found in fabrication engineering
2. classify **mechanical fastenings** applied to thin plate fabrication engineering
3. explain the reasons for and the methods available to protect metal surfaces prior to and after assembly
4. classify **joint configurations** from a range found in fabrication engineering
5. explain the benefits of using **jigs and fixtures**
6. explain the use of **adhesive bonding** in the joining of fabricated assemblies
7. calculate **joining allowances**

Range

Bolting: black bolts, high strength friction grip (HSFG), close tolerance bolts, fitted bolts, load indicating bolts, torshear, importance of cleanliness of contact surfaces, correct tensioning, hole diameters, tolerances and alignment of holes to produce satisfactory bolted connections

Mechanical fastenings: bolts, captive nuts, studs, self-tapping screws, special thin plate fastenings, solid and tubular rivets, blind rivets (pop rivets)

Joint configurations: self secured, lap joints, flanged joints, thermal/mechanical bonded, grooved seams, double grooved seams, knocked up, panned down, slip joints, flexible joints, threaded joints

Benefits of using jigs and fixtures: position of component(s), joint alignment, mass production/repetitive work, distortion control/dimensional accuracy, economy of operation

Adhesive bonding: methods available (heat activated, solvent activated, impact activated), preparation of surfaces, applications, health and safety considerations

Joining allowances: joints joined by: riveting, bolting, adhesive bonding

Unit 304 Principles of fabrication

Outcome 4 Understand different methods used for finishing fabricated components

Assessment Criteria

The learner can:

1. explain the methods of removal of **surface contaminants** prior to finishing
2. explain the common **causes of corrosion** and degradation of common engineering materials
3. classify the methods of **corrosion prevention** or retardation commonly found in fabrication engineering
4. classify the **methods of application** for common surface coatings
5. evaluate the **merits and suitability** of purpose of the various surface preparations and protections

Range

Surface contaminants: for: scale, oxide, slag, excessive build up and weld metal penetration, spatter

Causes of corrosion: oxidation of ferrous materials, direct chemical attack on metals, electrolytic corrosion, conditions and regions that can be conducive to corrosive activity (bi-metallic joints, immersed in aqueous solutions, adjacent to changes in grain structure [heavily worked material-stress corrosion], surface flaws, increased temperature

Corrosion prevention: painting, cladding with corrosion and/or heat resistant materials, cladding with plastics, metallic coatings, cathodic protection, anodic protection, fouling and anti-fouling coatings, corrosion inhibitors

Methods of application: painting (brush, dip, spray), metallic coatings (metal spraying, hot dip galvanising, electroplating)

Merits and suitability: cost, portability, functional effectiveness (influence upon: environmental performance, application of surface coatings, aesthetic appeal, material selection)

Unit 305 Principles of fabrication and welding

Level: **3**
Credit value: **9**
UAN: **K/503/0337**

Unit aim
This unit enables the leaner to understand the underlying principles of fabrication and welding, without focusing on specific fabrication disciplines or welding processes.

Fabrication materials, joining using non-thermal methods, weld symbols, joint design, distortion, weld defects and testing: non-destructive (NDT) and destructive (mechanical) are included.

Learning outcomes
There are **five** learning outcomes to this unit. The learner will:
1. Understand how to classify common materials used in fabrication engineering
2. Know how to apply welding symbols to joint preparations
3. Know the difference between non-thermal joining methods
4. Understand the affects of distortion and residual stresses due to welding
5. Know how to determine the integrity of welded joints

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering: Unit 026: Heat Treating Materials for Fabrication Activities; Unit 028: Joining Fabricated Components using Mechanical Fasteners

Assessment
This unit will be assessed by a short-answer question paper.

Unit 305 Principles of fabrication and welding

Outcome 1 Understand how to classify common materials used in fabrication engineering

Assessment Criteria

The learner can:

1. critically compare **materials** from a range found in fabrication engineering
2. explain the commercial **forms of supply** of materials available
3. state the **criteria** used to select materials for a given application
4. explain the different material **structures**
5. explain the variation in properties that result from different types of **metallic structures**
6. explain the requirement for the **heat treatment** of metals

Range

Materials: metallic (low-carbon steel, low alloy steels, high yield steels, austenitic stainless steels, clad and coated materials [galvanised steel, tin plated steel, plastic coated steel, clad steels, anodised aluminium], aluminium/aluminium alloys, copper/copper alloys, titanium/ titanium alloys), polymers (thermoplastics, thermosetting), composites (glass fibre, carbon fibre, aramid fibre)

Forms of supply: sheet, plate, section (RSJ, channel, column, beam, tee, angle (equal leg, unequal leg), hollow section (square, rectangular, round [tubular]), pipe, fibre reinforcing materials (FRP)

Criteria: strength/weight ratio, resistant properties (heat, corrosion, wear), cost, weldability, malleability

Structures: crystalline, chain molecules, amorphous

Metallic structures: fine grained structure, coarse grained structure, effect of grain size upon working properties

Heat treatment: annealing (steels, stainless steels, non-ferrous metals), normalising of steels, hardening of steels, tempering of steels, precipitation hardening of aluminium alloys

Unit 305 Principles of fabrication and welding

Outcome 2 Know how to apply welding symbols to joint preparations

Assessment Criteria

The learner can:

1. describe the difference between **features** of welded joints
2. describe how to apply BS EN 22553 to **types of joints**
3. describe how to apply **weld dimensions** to weld symbols

Range

Features: face, toes, root, HAZ (heat affected zone), convex fillet profile, concave fillet profile, mitred fillet profile, root face, root gap, root radius ('U' butt profile), land ('U' butt profile), bevel angle, included angle, weld width, throat thickness, leg length(s), fusion zone (depth of fusion), excess weld metal, penetration, fusion line (boundary)

Types of joint: Welded, brazed and soldered joints — symbolic representation on drawings, symbols for the communication of the designation of welded joints; types of joint (butt, tee, lap, corner); types of weld preparation

Weld dimensions: leg length, throat thickness, fillet welds, square butt welds, root gaps, intermittent fillet welds, staggered intermittent fillet welds

Additional Guidance

Types of joint: Welded, brazed and soldered joints — symbolic representation on drawings, symbols for the communication of the designation of welded joints; types of joint (butt, tee, lap, corner); types of weld preparation (square butt [open], square butt [closed], flanged butt, single-vee butt, double-vee butt, single 'U' butt, double 'U' butt, fillet, single-bevel butt, double-bevel butt, single 'J' butt, double 'J' butt, spot, seam, projection, surfacing, plug, edge, surface, inclined, fold); application of types of weld preparation (arrow line, reference line, identification line, symbol, non-symmetrical welds, symmetrical welds); supplementary and complimentary symbols (finished flush by grinding, finished flush by machining, convex, concave, backing [sealing] run, permanent backing strip, removable backing strip, toes blended smoothly, peripheral welds, field or site welds, numerical indication of welding process [EN 24063 — Welding, brazing, soldering and braze welding of metals — Nomenclature of processes and reference numbers for symbolic representation on drawings]

Unit 305 Principles of fabrication and welding

Outcome 3 Know the difference between non-thermal joining methods

Assessment Criteria

The learner can:

1. classify **bolting** methods from a range found in fabrication engineering
2. classify **mechanical fastenings** applied to thin plate fabrication engineering
3. explain the reasons for and the methods available to protect metal surfaces prior to and after assembly
4. classify **joint configurations** from a range found in fabrication engineering
5. explain the benefits of using **jigs and fixtures**
6. explain the use of **adhesive bonding** in the joining of fabricated assemblies
7. calculate **joining allowances**

Range

Bolting: black bolts, high strength friction grip (HSFG), close tolerance bolts, fitted bolts, load indicating bolts, torshear, importance of cleanliness of contact surfaces, correct tensioning, hole diameters, tolerances and alignment of holes to produce satisfactory bolted connections

Mechanical fastenings: bolts, captive nuts, studs, self-tapping screws, special thin plate fastenings, solid and tubular rivets, blind rivets (pop rivets)

Joint configurations: self secured, lap joints, flanged joints, thermal/mechanical bonded, grooved seams, double grooved seams, knocked up, panned down, slip joints, flexible joints, threaded joints

Jigs and fixtures: position of component(s), joint alignment, mass production/repetitive work, distortion control/dimensional accuracy, economy of operation

Adhesive bonding: methods available (heat activated, solvent activated, impact activated), preparation of surfaces, applications, health and safety considerations

Joining allowances: joints joined by: riveting, bolting, adhesive bonding

Unit 305 Principles of fabrication and welding

Outcome 4 Understand the affects of distortion and residual stresses due to welding

Assessment Criteria

The learner can:

1. explain the **reasons for distortion** due to welding
2. classify **types of distortion**
3. explain the methods of **distortion control**
4. explain the methods of **distortion rectification**
5. explain the **residual stress** effects of welding

Range

Reasons for distortion: uneven expansion and contraction, degree of restraint

types of distortion: longitudinal, transverse, angular, buckling, bowing, dishing, twisting

Distortion control: presetting, pre-bending, weld sequencing, skip welding, back-stepping, balanced welding, intermittent welding, tack welding, pre and post weld heat treatment, joint design, chills, restraint (clamping, jigs, back-to-back assembly)

Distortion rectification: mechanical methods (peening, jacking, pressing, bending, rolling, hammering, planishing); thermal methods (use of heat strips, use of heat triangles); combination of mechanical and thermal methods (hot working)

Residual stress: causes (restraint due to uneven expansion and contraction [natural], restraint due to distortion control methods [clamping, jigs, back-to-back assembly, balanced welding]), effects (pattern across joint cross-section [areas of tension, areas of compression], influence upon mechanical properties in service), stress relieving methods (normalising, thermal stress relief)

Unit 305 Principles of fabrication and welding

Outcome 5 Know how to determine the integrity of welded joints

Assessment Criteria

The learner can:

1. classify the types of **weld defects** (EN 26520) and identify possible causes and remedial action
2. explain the application of **visual examination** methods to welded joints
3. explain the application of **penetrant testing** methods to welded joints
4. explain the application of **magnetic particle testing** methods to welded joints
5. explain the application of **radiography** methods to welded joints
6. explain the application of **ultrasonic testing** methods to welded joints
7. explain the application of **mechanical testing** methods to welded joints
8. explain the methods of **container testing**

Range

Weld defects: cracks (longitudinal, transverse, edge, HAZ, crater, centreline, fusion zone, underbead), lack of fusion (root, side wall, inter-run), porosity (scattered, cluster, isolated pore, root, blow holes, worm holes), piping (craters), solid inclusions (slag, copper, tungsten, oxide), lack of penetration, undercut, oxidation, excessive weld metal (including penetration), underfill, concavity, overlap, burn-through, possible causes, remedial action

Visual examination: applications, requirements (equipment, personnel) benefits, limitations

Penetrant testing: dye, fluorescent, test procedure, applications, equipment requirements, limitations

Magnetic particle testing: magnetic flow (types of magnet [horseshoe, yoke]), current flow (a.c. [skin effect], d.c., types of magnetisation [prods, bar, coil, tubular, kettle element]), test procedure, applications, equipment requirements, benefits, limitations

Radiography: sources of radiation (x-ray, gamma ray), principle, applications, equipment requirements, benefits, limitations, radiation hazards (effects of radiation on the human body, radiation monitoring, personal monitoring, radiation enclosures, precautions for site radiography), radiographic techniques (plate, pipe [single wall – single image {including panoramic}, double wall – single image, double wall – double image [ellipse, superimposed])

Ultrasonic testing: applications, procedure, applications, equipment requirements (ultrasonic testing set [cathode ray tube {oscilloscope}, controls, calibration], probes [normal, angle, probe index, selection criteria, beam spread, far zone, near zone, dead zone], leads, calibration blocks, couplant), benefits, limitations, techniques (thickness testing, lamination testing, transmission method, reflection method), determination of geometry (beam angle, skip distance), procedures for reporting and recording flaws in welded components

Mechanical testing: impact tests (izod, charpy), bend tests (root, face, side), tensile (determination of tensile strength, determination of yield stress, determination of percentage elongation, transverse, all weld metal, tensile/shear [application to lap joints, application to double lap joints]), fracture (nick break), macro examination (specimen preparation, magnification), micro examination (specimen preparation, magnification), hardness surveys (weld zone, HAZ, parent metal, location of

indents, testing methods (Vickers, Brinell, Rockwell), testing of spot welded joints (peel test, tensile/shear, cross tensile, 'U' tensile, twist or torsion

Container testing: hydraulic pressure, pneumatic pressure, by filling, by immersion, health and safety considerations

Unit 306 Principles of engineering maintenance, installation and commissioning

Level: 3
Credit value: 9
UAN: M/503/0338

Unit aim

This unit enables the leaner to understand the underlying principles that apply to all commonly used processes and elements that are essential to most maintenance, installation and commissioning activities. It takes into account the fact that some industries and organisations employ engineering personnel that perform both of these activities, whereas others, particularly specialist contractors for installation and commissioning, may only cover a limited range. The content of this unit can be applicable to both situations as it is considered essential for all learners to have a wide range of engineering knowledge and experience.

It covers the maintenance, installation and commissioning requirements, including equipment and lubrication that are commonly associated with the maintenance, installation and commissioning of plant and machinery and the ways in which they are used or applied.

Leaners are not expected to have an in-depth understanding of all maintenance and installation and commissioning strategies, but they should become familiar with the events, terminology and practices that they will need as part of their normal work.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand how to plan maintenance, installation and commissioning activities
2. Know how to install and commission instruments and components
3. Understand how to evaluate methods to overcome friction and corrosion
4. Know how to evaluate connection methods

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1684 Level 3 – Installation and Commissioning and NVQ 1688 Level 3 – Engineering Maintenance

Assessment

This unit will be assessed by a short-answer question paper.

Unit 306 Principles of engineering maintenance, installation and commissioning

Outcome 1 Understand how to plan maintenance, installation and commissioning activities

Assessment Criteria

The learner can:

1. explain the reasons for carrying out **maintenance activities**
2. explain the methods and **procedures** necessary to make an area safe
3. describe the contents of a **maintenance plan**
4. explain how to carry out **installation activities**
5. describe the contents of a **report** completed following maintenance or installation activities
6. describe the difference between symptoms and the causes of faults

Range

Maintenance activities: upholding or improving safety standards, maintaining production output at the required levels and quality, maximising the useful working life of engineering assets, increasing production efficiency (reduction of rejected work or downtime), activities include: carrying out routine servicing schedules or planned preventative maintenance, repair and replacement following breakdowns, monitoring and performance testing

Procedures: using barriers and/or tapes, placing warning signs in appropriate positions, informing any persons who may be affected, isolating power or pressure sources, obtaining official clearance (permit to work), cleaning work areas after spillage, leakage or contamination (absorbent substances, detergents and solvents, approved waste disposal methods)

Maintenance plan: tools and equipment, materials and spares (minimising downtime [avoid loss of production, avoid poor customer relations {internal and external}], wage overheads), estimate the length of time needed for maintenance

Installation activities: installing machinery and systems into new sites or locations, replacement of machinery and equipment following or extending facilities, monitoring and performance testing, factors to consider: site conditions and locations of components, storage of parts and materials, tools and equipment, provision of services – electricity, compressed air, water and drainage, minimising disruption to adjacent work areas, how to estimate the length of time needed for the installation and commissioning

Report: work undertaken, location(s), dates/times (commencement, completion and handover), parts and consumables used, test data, permit to work or certification references

Unit 306 Principles of engineering maintenance, installation and commissioning

Outcome 2 Know how to install and commission instruments and components

Assessment Criteria

The learner can:

1. explain the applications of **instruments** used for testing and monitoring the condition of systems and machinery
2. explain the methods used to **set-up and align components**
3. describe how to perform installation and commissioning operations of instruments and/or components

Range

Instruments: terms: range, sensitivity, response, accuracy, repeatability, analogue and digital signals, transducers and amplifiers; pressure: manometers, Bourdon tube based instruments; temperature: expansion types, electrical resistance types and thermocouples, thermal paints and crayons; flow: direct (bellows and piston types), inferential (rotameters, venturi and orifice plates, and turbine types); rate and speed: tachometers (mechanical and electrical), stroboscopes, pulse counters; content: direct (dipsticks and sight glasses), indirect (load cells and electrical transducers); electrical multimeters (megameters, multimeters); vibration, data recorders; need for regular calibration of instruments and the methods used; methods of mounting instruments and the ways in which they can be protected from: external damage or unauthorised interference, excess loads and surges (use of snubbers and reservoirs), heat and vibration

Set-up and align components: straight edges and squares, feeler gauges and test indicators, plumb lines and spirit levels, taut wire, optical and laser based instruments

Unit 306 Principles of engineering maintenance, installation and commissioning

Outcome 3 Understand how to evaluate methods to overcome friction and corrosion

Assessment Criteria

The learner can:

1. explain the nature of surfaces and the effects of these on **friction**
2. explain the purpose of **lubrication** to reduce the effects of **friction**
3. explain the **nomenclature** used to describe lubricant properties
4. evaluate types of **oils** and **greases** for given applications
5. explain the nature and causes of **corrosion** and methods of minimising the effects

Range

Friction: actual surface contact area (on 'peaks') and hence causes of 'cold welding', surface wear (breaking of 'peaks'), generation of heat, forces required to overcome friction (static and dynamic); reducing the adverse effects by use of: low friction materials, material combinations that control wear to only one of the two contacting elements, partial lubrication, full film lubrication

Lubrication: hydrodynamic wedge principle – requirements: bearing types and design, clearances, points of oil admission; lubrication methods: total loss, recirculatory (construction and component parts of reservoirs, filtration methods and positioning, heat exchangers, pressure controls and warning devices), splash, grease guns and nipples, self lubricating (cast iron and impregnated metals)

Nomenclature: viscosity, viscosity index, emulsions, foaming, compatibility (with other oils, seals and bearing material), pour and flash points, additives

Oils: mineral, animal and vegetable, synthetic; properties (load, temperature) environmental considerations, reasons for deterioration (excess heat, oxidation, contamination, breakdown of structure due to prolonged overloading, poor storage conditions)

Greases: the base (matrix), lubricants, methods of application, including the need to prevent over-packing and churning

Corrosion: types: oxidation, electrolytic; methods of minimising effects: selection of materials to suit conditions, insulation of dissimilar metals, use of sacrificial anodes, use of protective coatings, paint, galvanising and anodising, plating and coating; methods of releasing corroded nuts (release and penetrating oils, application of heat, nut splitters or similar techniques)

Unit 306 Principles of engineering maintenance, installation and commissioning

Outcome 4 Know how to evaluate connection methods

Assessment Criteria

The learner can:

1. explain the purposes of **bearings** and their applications
2. explain the methods available for **removal and fitting** of bearings
3. explain the purposes of **threaded joints** and their applications

Range

Bearings: plain bearings, roller bearings, ball bearings, shielded and sealed forms of roller and ball

Removal and fitting: onto shafts and into housings

Threaded joints: thread forms (pitch and lead, major and root diameters, truncation), identification using screw pitch gauges and charts, applications, methods of insertion and extraction of studs, dealing with sheared studs (extractors, drilling and re-tapping), use of rawlbolts and ragbolts for masonry and concrete (hole preparation and fitting, health and safety aspects in relation to reinforced concrete)

Additional Guidance

Bearings: plain bearings (materials used [including non-ferrous alloys, non-metallic], split and solid forms and their housing methods, shell and white-metalled types), roller bearings (cylindrical, tapered, double row, spherical, needle), ball bearings (single row deep groove and angular contact, double row deep groove and angular contact, self-aligning), shielded and sealed forms of roller and ball bearings

Removal and fitting: methods of removing and fitting bearings (special extractors and mandrels, hand (mandrel) and hydraulic presses, appropriate lubricants or grease

Unit 307 Principles of mechanical manufacturing engineering

Level: **3**
Credit value: **9**
UAN: **T/503/0339**

Unit aim

This unit enables the leaner to understand the underlying principles that apply to all common machine tool systems, covering: the alignment of machine tools, power transmission, an evaluation of the application of CNC to machine tools and the understanding of maintenance requirements for machine tool systems. Within the unit leaners are expected to prepare a maintenance programme, prepare a lubrication chart, produce a CNC part-programme and critically compare CNC machining to non-CNC machining.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand how to determine the alignment of machine tools
2. Know how to differentiate between methods of power transmission in machine tools
3. Understand how to evaluate the application of CNC to machine tools
4. Understand the maintenance requirements for machine tool systems

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1682 Level 3 – Mechanical Manufacturing Engineering

Assessment

This unit will be assessed by a short-answer question paper.

Unit 307 Principles of mechanical manufacturing engineering

Outcome 1 Understand how to determine the alignment of machine tools

Assessment Criteria

The learner can:

1. describe the range of **machine tools** available in terms of size, capacity, accuracy and production capability
2. explain the **structural requirements** of a range of common machine tools
3. explain the common methods of **mounting** machine tools
4. explain the importance of **alignment** in machine tools and methods to achieve it

Range

Machine tools: lathes (centre, turret), milling machines (horizontal, vertical, universal), drilling machines (bench, pedestal, radial arm, multi-spindle, co-ordinate table, special purpose), grinding machines (surface [horizontal spindle, vertical spindle], cylindrical [plain, universal], internal, special purpose), electro machining (electrodischarge machining [EDM] {ram feed, wire feed}, ultrasonic machining [USM], electrochemical machining [ECM], laser machining, computer numerical control (CNC)

Structural requirements: strength, rigidity, stability, control of movement, materials (cast iron, cast steel, steel plate), structures (box column, rib and box bed, fabricated base)

Mounting: cork pad, adjustable mounting, rag bolt, expanding nut

Alignment:

slideways: flat, vee, dovetail, cylindrical, comparison of their capabilities, main features, accuracy of movement, means of adjustment, lubrication, protection

stick-slip: definition, recirculating ball leadscrews, hydrostatic slides

typical checks: coaxial alignment between main spindle axis, coaxial alignment between two spindles, alignment of spindle to guideway, squareness of slideways movement, concentricity and end float of spindle, squareness of planes to spindle, setting of guards, stops and automatic safety cut-outs

bearings: plain bush (radial, radial and axial) ball (radial, axial, radial and axial) roller (radial, axial, radial and axial)

methods of alignment: standard tests, straight edge, precision level, autocollimator and reflector, roundness measuring machine

Unit 307 Principles of mechanical manufacturing engineering

Outcome 2 Know how to differentiate between methods of power transmission in machine tools

Assessment Criteria

The learner can:

1. explain the methods used to achieve **rotational movement**
2. explain the methods used to achieve **linear movement**
3. explain the methods used to **change speeds**
4. explain the methods used to **control feed speeds**
5. explain the methods used to control feeds and speeds of **hydraulic components** on machine tools
6. explain the application of **pneumatic systems** to the operation and control of machine tools

Range

Rotational movement: belt drives (flat, vee and tooth), gears, hydraulic actuators

Linear movement: screw and nut (vee, square [including multi-start], ACME, relationship between the lead of a screw and the motion transmitted, engaging screw drives [fixed nuts, split nuts]), rack and pinion, recirculating ball-screw, crank and connecting rod, cams (lift, dwell and types of motion produced) hydraulic actuator

Change speeds: sliding gears, cone pulleys, clutch operated, infinitely variable, electrical/electronic

Control feed speeds: sliding gears (Norton gearbox), leadscrew and nut, hydraulic drives

Hydraulic components: variable capacity pump, filter, pressure gauge, pressure relief valve, directional control valve, actuator, signal elements, one way flow control valve, differential cylinders, meter in, meter out, bleed off, pressure control valves, sequence valves, electrical and electro- magnetic control systems (switching devices, solenoids, interlock systems, timing shafts and cams, coded information, stepper motors), advantages and limitations of hydraulic actuation and control, common defects which may occur on a hydraulic system and methods of repair

Pneumatic systems: variable output compressor, service unit, pressure gauge, signal elements, directional control valves, actuator, supply air throttling, exhaust air throttling, pressure reducing valve, pressure operated valves, time delay valve, electrical and electro- magnetic control systems (switching devices, solenoids, interlock systems, timing shafts and cams, coded information, stepper motors), advantages and limitations of pneumatic actuation and control, common failures which may occur on a pneumatic system and methods of repair

Additional Guidance

Rotational movement: flat belts, vee belts (single and matched sets) toothed belts, chain drives, correct tensioning belts and chains, friction clutches, dog clutches, gears: worm and wheel, bevel gear, spur, gear nomenclature (addendum, dedendum, clearance, diametral pitch, circular pitch, module), gear materials (cast iron alloy steels [including surface hardened], non-ferrous alloys [brass and bronze derivations], plastics), calculate simple and compound gear ratios, relationship between torque and power transmitted and the loads on gear teeth, gear box layouts and means of selecting different output speeds, gear defects (pitting, flaking, scoring and scuffing, likely causes); hydraulic actuators

Unit 307 Principles of mechanical manufacturing engineering

Outcome 3 Understand how to evaluate the application of CNC to machine tools

Assessment Criteria

The learner can:

1. explain the **operating principles** of computer numerically controlled machine tools
2. describe how to produce a **part-programme** to demonstrate the relative work/tool movement of a CNC machine tool
3. describe how to prove the part-programme using simulation software
4. **critically compare** CNC machine tools against non-CNC machine tools
5. describe how to evaluate **cutting tools materials** for given applications (CNC and non-CNC)

Range

Operating principles: open loop system, closed loop system, control systems (closed loop servo motors and associated transmission, stepper motors and associated transmission), types and function of position transducers (rotary type, optical gratings), digital control

Part-programme: co-ordinate positioning (absolute, incremental), use of sub routines, macros and canned cycles, role of CADCAM

Critically compare: production (mass, flow, batch, job), ease of programming, repeatability, prototypes, skill levels and other factors

Cutting tools materials: high carbon steel (HCS), high speed steel (HSS) tungsten carbide, ceramic

Unit 307 Principles of mechanical manufacturing engineering

Outcome 4 Understand the maintenance requirements for machine tool systems

Assessment Criteria

The learner can:

1. describe the differences between **types of maintenance** carried out on machine tools
2. describe a **maintenance programme** for a typical machine tool
3. describe what would be included in a **lubrication chart** for a typical machine tool workshop
4. classify **coolants and lubricants** applicable to machine tool systems
5. classify the methods of application for common surface coatings
6. explain the **commissioning/maintenance procedures** carried out on machine tools

Range

Types of maintenance: running, preventive, breakdown, routine

Maintenance programme: inspection, lubrication, adjustment, rectification, overhaul

Lubrication chart: machine designation, types of lubricant, quantities of lubricant, frequency

Coolants and lubricants: types of coolant pump, strainers and filtration methods (including separating tanks and magnetic drum), filters, lubrication of headstock/gearbox assemblies of splash and pressurised feed (lead and feed screws, separation of coolant from lubricants in the lathe cross slides/carriage assemblies)

Commissioning/maintenance procedures: checks, operational function, compare checks and operational functions with manufacturers' or production departments requirements, complete reports and job sheets, submit report

Additional Guidance

Commissioning/maintenance procedures: checks (alignment and levels, electrical power supplies/insulation, safety switches/devices and interlocking, security of pipes and couplings, oil levels), operational function (run at light load: check, oil temperature, oil pressure, cooling/coolant system as appropriate; run at full load and carry out the same checks again), compare checks and operational functions with manufacturers' or production departments requirements, complete reports and job sheets (work carried out to commission/restore machine tool to operational condition, complete maintenance schedule, report and recommendation on system condition), submit report

Unit 308 Principles of electrical and electronic engineering

Level: 3
Credit value: 9
UAN: K/503/0340

Unit aim

This unit enables the leaner to understand the underlying principles that apply across electrical and electronics engineering. The unit covers supply systems, protection and earthing, electronic measurement, functions of electrical machines, transformers and switchgear and electronic components and circuits.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand electrical supply systems, protection and earthing
2. Understand the function of electrical and electronic components
3. Know how to carry out electronic measurement
4. Understand functions of electrical machines.

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

NVQ 1788 Level 3 – Engineering Maintenance: Unit 311: Carrying Out Fault Diagnosis on Electrical Equipment and Circuits

Assessment

This unit will be assessed by a short-answer question paper.

Unit 308 Principles of electrical and electronic engineering

Outcome 1 Understand electrical supply systems, protection and earthing

Assessment Criteria

The learner can:

1. explain electricity **supply systems**
2. explain the function of **transformers** and switchgear
3. explain the purpose of earthing systems
4. explain **protection systems**

Range

Supply systems: from generation to utilisation, generation, transmission and distribution voltages, star and delta connections, single and 3 phase power.

Transformers: principle of operation, input, output and losses, transformer rating in kVA, auto transformer; LV & HV switchgear.

Protection systems: short circuits, overloads, earth leakage, fuses, circuit breakers, residual current devices, residual current breakers (RCD's) with overload (RCBO)

Unit 308 Principles of electrical and electronic engineering

Outcome 2 Understand the function of electrical and electronic components

Assessment Criteria

The learner can:

1. apply basic electrical **units**
2. describe **resistors**
3. describe **magnetism** and magnetic circuits
4. describe **inductance** and inductive components
5. describe **capacitors** and capacitance.
6. describe graphically inductance and capacitance when connected to **d.c. supplies**
7. state the effects of resistance, inductance and capacitance connected to an **a.c. circuit**.
8. describe **semiconductor** devices
9. describe **electronic circuits** and components including applications.

Range

Units: energy, current, charge, voltage, power and resistance

Resistors: resistance depends upon dimensions, material and temperature, resistivity Ohms law, series and parallel d.c circuits

Magnetism: fields and flux paths, relationship between flux, area and flux density

Inductance: inductors as wound components, self and mutual induction, Lenz's law, force on a conductor

Capacitors. electric field and stress, Ddelectrics, relate potential difference charge and capacitance, construction and types, series parallel connections

d.c. supplies: C & L connected to d.c circuits, series circuits, charge and discharge, time constants

a.c. circuit: R,L & C in a.c circuits. R,L & C in series / parallel, power, power factor, kW, kVA & kVAr

Semiconductor devices: action of semiconductor devices, thyristors, bridge rectifiers, smoothing circuits

Electronic circuits: function of amplifier, oscillator, filter, power supply, application of common components, photocell, photodiode etc

Unit 308 Principles of electrical and electronic engineering

Outcome 3 Know how to carry out electronic measurement

Assessment Criteria

The learner can:

1. describe how to use **multimeters** to measure current, voltage and resistance
2. describe how to use **oscilloscope**s in different modes
3. describe how to use electronic instruments for **component testing** and prepared circuits
4. describe how to use electronic instruments as **signal sources** for prepared circuits
5. describe the use of **computers** in component testing**.**

Range

Multimeters: auto range, data capture and transfer, correct range settings

Oscilloscopes: use to carry out a range of tests and measurements, real time and storage

Component testing: transistors, a series RLC circuit: a resistor, inductor and capacitor (L,C & R), power gain or loss in dB, voltage/current gain

Signal sources: advantages and disadvantages of oscilloscopes

Computers: diagnostic information, technical information, websites, use and function as digital multimeter, oscilloscope, spectrum analyser

Unit 308 Principles of electrical and electronic engineering

Outcome 4 Understand functions of electrical machines.

Assessment Criteria

The learner can:

1. describe the principles of rotating **electrical machines**
2. describe the function of **3 phase induction motors**
3. describe the function of **single phase** a.c motors

Range

Electrical machines: a.c and d.c generators, interdependence of frequency, speed, pole pairs, EMF and field strength. d.c motor, dynchronous and asynchronous machines, rotating magnetic field

3 phase induction motors: cage rotor, wound rotor

Single phase: Series Universal, split phase, permanent capacitor, capacitor start/ run

Unit 309 Principles of shipbuilding

Level: **3**
Credit value: **9**
UAN: **M/503/0341**

Unit aim
This unit provides the skills required to work within a shipbuilding/ship repair establishment and is concerned with ship design the identity of types in typical forms and major components linked to design features.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1 Understand shipbuilding technical drawings and computer aided engineering
2 Know how to identify ship types, design features and major components
3 Know how to identify the principal structural components of a ship
4 Understand the assembly and erection of ship parts

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
N/A

Assessment
This unit will be assessed by a short-answer question paper.

Unit 309 Principles of shipbuilding

Outcome 1 Understand shipbuilding technical drawings and computer aided engineering

Assessment Criteria

The learner can:

1. explain the **terminology** used on marine industry drawings and specifications
2. interpret **abbreviations** used on marine industry technical drawings and data
3. interpret shipbuilding technical **drawings, plans and tables**
4. interpret lines plans and offset tables
5. explain the work of the **mould loft**
6. explain the purpose of **templates**
7. explain computer aided engineering (**CAE**) techniques used and their application in shipbuilding
8. critically compare the benefits and limitations of computer aided engineering (**CAE)** to conventional techniques

Range

Terminology: outboard of, inboard of, in way of, scantlings, length (overall, between perpendiculars and on summer load waterline), forward and after perpendiculars, breadth and depth (moulded and extreme), draught, freeboard, freeboard marks, displacement, deadweight, rise of floor, camber, flare, bilge, bilge radius, bilge keel, flat of bottom, tumblehome, superstructure, forecastle, tank top, stringer, floor, bulkhead, shell, frame/frame station, deck, deckhead, longitudinal, transverse, butt seam, gross, net and displacement tonnage

Abbreviations: PSFA, LOA, LBP, LBP, (L), FP, AP, B, D, SLWL, TF, F, T, S, W, WNA

Lines plans and offset tables: lines plan, displacement stations, frame stations and their relationship; tables of offsets to produce ship shapes, illustrating fairing of form in three dimensions: frames, waterlines, buttocks; shell expansion plans; draught and freeboard markings

Mould loft: full scale lofting, scale lofting, numerical control (computer) lofting

Templates: avoidance of repetitive marking and measuring, material optimisation, checking angles, contours etc., guidance for repetitive profile cutting, nesting, materials suitable for templates

CAE: computer aided design, computer aided draughting, computer aided manufacture, Industrial robots; productivity, quality, competitiveness, profit, storage space, impact upon working practices, impact upon society, security of data; application in mould lofts (purpose, benefit of computer aided lines fairing, various stages in the production of tapes to control cutting and forming machinery, benefits of numerical control compared to the production and use of templates)

Additional Guidance

Drawings, plans and tables: role of shipbuilding detail and assembly drawings, block plans and location drawings, listed plans and tables (body plans, lines plans, sheer profile, off-set tables), relationship between listed plans and tables

Unit 309 Principles of shipbuilding

Outcome 2 Know how to identify ship types, design features and major components

Assessment Criteria

The learner can:

1. critically compare **ship types** in terms of applications, forms and profiles
2. describe **design features** of ships
3. describe **major components** of ships
4. explain **fore and after end construction**.

Range

Ship types: cargo (general, bulk carrier, oil tanker, container, liquefied natural gas, refrigerated), naval vessels (aircraft carrier, troop carrier, submarine, fleet oiler), passenger vessels (passenger liner, ferry, cruise liner, roll on – roll off), service craft (oil support vessel, tug, ice breaker)

Design features: cargo (double bottom arrangements, decks, bulkheads, engine room space, cargo spaces, fore and after peaks, accommodation spaces), naval vessels (watertight sub – divisions, accommodation spaces, armament and equipment spaces, operations area), passenger vessels (loading and unloading arrangements, accommodation areas, recreation areas, crew accommodation, access routes) service craft (divisions for: engines, operations, crew, storage, etc.)

Major components: cargo space, double bottom tanks, peak tanks, engine rooms, accommodation spaces, deep tanks, cofferdams, pump rooms, chain locker, cargo access arrangements, cargo handling equipment

Fore and after end construction: fore peak construction (collision bulkhead, floors, types of stem, bulbous bows, deep tanks: construction and usage, chain locker and hawse pipes, bow thrust units and supporting structure, access and egress from fore peak), after peak construction (stern construction [types]; flats, floors and wash plates; steering gear flat, construction and supporting structure; stern frame connections; function, construction and operation of rudders; types of rudder)

Unit 309 Principles of shipbuilding

Outcome 3 Know how to identify the principal structural components of a ship

Assessment Criteria

The learner can:

1. describe the **factors influencing the strength of a ship's structure**
2. explain the **principal structural components** of a ship

Range

Factors influencing the strength of a ship's structure: main forces acting on a ship's structure, the variation of liquid pressure with head and its effect on a ship's structure, forces on submerged surfaces (calculations of: internal loads from cargo, fuel oil; external loads from sea), reaction of the ship to applied forces (hogging and sagging, panting, racking)

Principal structural components: double bottoms, tank top, framing, bulkheads, transverses, shell, pillars and girders, superstructure, decks deckhouses, forecastle, bridge, poop, workshop flats; transverse, longitudinal and combined framing systems of ships; components of transverse and longitudinal framed double bottoms, components of deck structure, pillars and girders, deck openings; constructional features of different types of transverse and longitudinal bulkheads; hatches and doors, function and methods of construction, constructional features and methods of attachment to the hull of bulwarks and guard rails; methods of obtaining continuity of strength, the avoidance of abrupt changes in contour, rudder

Additional Guidance

Principal structural components: double bottoms, tank top, framing, bulkheads, transverses, shell, pillars and girders, superstructure, decks deckhouses, forecastle, bridge, poop, workshop flats; transverse, longitudinal and combined framing systems of ships; components of transverse and longitudinal framed double bottoms: watertight, plate and bracket floors, bottom and tank top stiffening and connections, centre and side girders, margin plate, tank top; shell structure for transversely and longitudinally framed ships, connections to deck and bottom structure; components of deck structure, pillars and girders, deck openings; constructional features of different types of transverse and longitudinal bulkheads; hatches and doors, function and methods of construction (deck openings and supporting structure, side and end hatch coamings, hatch closing arrangements, oil tanker hatches, watertight hatches and doors fitted in naval vessels); constructional features and methods of attachment to the hull of bulwarks and guard rails; methods of obtaining continuity of strength, the avoidance of abrupt changes in contour

Unit 309 Principles of shipbuilding

Outcome 4 Understand shipbuilding technical drawings and computer aided engineering

Assessment Criteria

The learner can:

1. explain the importance of **accuracy and alignment** throughout the ship's construction cycle
2. explain the need for **inspection**
3. explain the main procedure for **erection**
4. describe the **lifting procedures and safety precautions** for fabricated units
5. explain the methods used to secure the sections in the initial position
6. explain the purpose and operation of self-propelled modular transporters (SPMT)
7. describe structural behaviour of assemblies and sub assemblies evidenced from case studies and historical records

Range

Accuracy and alignment: structure, methods of avoiding accumulation of error, personal responsibility for accuracy, carry out alignment checks using levelling equipment (laser, dumpy level)

Inspection: function of a datum surface and datum line; standard measuring equipment; define tolerance with regard to accuracy; methods of checking accuracy of dimensions, alignment, form, squareness and freedom from twist or distortion

Erection: equipment and instruments necessary for fairing, joining, plumbing and levelling, sequence of erection and methods used to temporary fasten and maintain shape, need for continual alignment checks

Lifting procedures and safety precautions: lift large fabricated units considering centre of gravity, safe working loads, swinging loads; importance of determining centre of gravity of regular and irregular shaped units; problems associated with the lifting of large units; health and safety hazards associated with the lifting of large fabricated units SPMT: types, capacity, operation, communication, power

Additional Guidance

Erection: equipment and instruments necessary for fairing, joining, plumbing and levelling, (reasons for datum lines in ship construction; procedure for the assembly of plates and sections; reasons for assembling thick plate fabrications on a level surface; preparing a level surface; reasons for part assemblies and trial erections), sequence of erection and methods used to temporary fasten and maintain shape (logical sequence of erection for ship construction, methods used to avoid twist and distortion, use of assembly jigs and fastening devices, use of tack bolts and tack welds); need for continual alignment checks

Unit 310 Manual metal arc welding of materials

Level: **3**
Credit value: **9**
UAN: **F/503/0344**

Unit aim

This unit sets out the requirements for manual metal arc welding in a modern engineering environment, in terms of what needs to be achieved by the learner, ie: welding a series of challenging joint configurations across in a wide range of positions that are compliant to welding procedure specifications.

The unit is concerned with the technology and practices involved in the application of manual metal arc welding. The unit is demanding in terms of technological content and the complexity of the welding that leaners are expected to achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (i.e. electrodes) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Be able to apply safe working practices to manual metal arc welding
2 Be able to prepare equipment for performing manual metal arc welding
3 Be able to perform manual metal arc welding operations to meet welding procedure specification requirements
4 Be able to evaluate welded joints for welding procedure specification conformance

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 4: Welding Materials by the Manual Metal Arc Process

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 310 Manual metal arc welding of materials

Outcome 1 Be able to apply safe working practices to manual metal arc welding

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** in a welding environment and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, PUWER (scope within the welding environment), RIDDOR, Management of Health and Safety at Work Regulations, Personal Protective Equipment At Work Regulations, Noise at Work Regulations

Hazards and risks: fume, fire, electricity, arc radiation, hot metal/slag

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to welding process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection (Personal Protective Equipment (PPE), screening, warnings [verbal, notices], hot metal/slag (methods of avoiding)

Unit 310 Manual metal arc welding of materials

Outcome 2 Be able to prepare equipment for performing manual metal arc welding

Assessment Criteria

The learner can:

1. list the range of welding equipment available
2. describe the functions of **welding equipment**
3. prepare the **welding equipment** for a range of given applications

Range

Welding equipment: power sources, transformer/rectifier, inverter, generator, measurement of electrical output and continuity, methods of current regulation, power source characteristics,, leads, electrode holders, return clamps, ancillary equipment

Additional Guidance

Welding equipment: power sources (output [alternating current [a.c.], direct current [d.c.], transformer [function, winding ratio, input/output ratio, construction], transformer/rectifier [function, operation, construction {diodes, thyristors} function of smoothing capacitors], inverter [function, operation, construction], generator [fuel driven, motor driven, function, operation, construction], rated output [duty cycle]), measurement of electrical output and continuity (voltage – use of voltmeter/multi-meter, current – use of ammeter/shunts/coils, continuity – use of continuity tester/ohmmeter), methods of current regulation (tapped reactor, moving core, moving coil, moving shunt, saturable reactor, variable resistance), power source characteristics (volt/ampere graph, drooping characteristic, constant current output), leads used (welding, return, earth, construction, rated output [duty cycle]), electrode holders (types, fully insulated, partially insulated), return clamps (types, clamping mechanisms), ancillary equipment (angle grinders, chipping hammer, wire brushes, hammer and chisel)

Unit 310 Manual metal arc welding of materials

Outcome 3 Be able to perform manual metal arc welding operations to meet welding procedure specification requirements

Assessment Criteria

The learner can:

1. critically compare **welding consumables** for a range of given applications
2. differentiate between **welding consumables** by their classification
3. produce complex welded joints in a range of positions in accordance with welding procedure specification (**WPS**) parameters
4. **restore work areas** to a clean and safe condition on completion of welding operation.

Range

Welding consumables: electrode coverings to current BS EN standard (strength and elongation properties, impact properties, chemical composition, type of the covering, recovery rate and current type, welding positions, hydrogen content of the deposit), electrode coverings (cellulosic, rutile, basic, iron powder, composition, applications, baking requirements, hydrogen content, determination of electrode efficiency), function of coverings (facilitates arc striking, stabilises and directs the arc, assists control of the size and frequency of filler metal globules/droplets, protects filler metal from atmospheric contamination during transfer, protects deposited metal from contamination, provides appropriate weld contour, prevents rapid cooling of weld metal [thermal blanket effect], provides a flux for the molten pool to remove oxides and impurities, supplies additional metal to weld pool [including alloying elements], core wire composition (carbon steel, low alloy steel, stainless steel, non-ferrous metals, cast iron), electrode coverings to current AWS standard (strength and elongation properties, position, usability, suffix)

WPS: welding process, parent metal, consumables, pre welding activities (cleaning, edge preparation, assembly, pre-heat), welding parameters, welding positions (EN ISO 6947 – PA, PB, PC, PD, PE, PF, PG), number and arrangement of runs to fully fill/weld joints, electrode sizes for joint thicknesses, techniques used when welding with electrodes (cellulosic, rutile, basic, iron powder), electrical conditions required (type of current, alternating [a.c.], direct [d.c.], electrode polarity (positive, negative), welding current ranges, voltage (open circuit, arc), control of heat input, interpass/run cleaning/back gouging methods, post welding activities (slag removal, spatter removal, wiring brushing, removal of excess weld metal where required), post-weld heat treatment (normalising, stress relief)

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 310 Manual metal arc welding of materials

Outcome 4 Be able to evaluate welded joints for welding procedure specification conformance

Assessment Criteria

The learner can:

1. explain the implications of quality specifications used to determine the **integrity of welded joints**
2. **visually evaluate** welded joints for conformance
3. prepare and **destructively test** joints to evaluate sub-surface for conformance

Range

Integrity of welded joints: classification of defects, quality specification (BS EN 25817 – arc welded joints in steel – guidance on quality levels for imperfections), methods of avoiding, rectification methods

Visually evaluate: use of visual techniques, lighting, low powered magnification, fillet weld gauges, dye penetrant testing, preparation for inspection, qualitive (defect levels, appearance), quantitive (extent, size, dimensional accuracy)

Destructively test: nick-break (fracture), macroscopic examination (x5) bend tests (butt welds, side, face, root), methods of preparation for testing

Unit 311 MIG welding of materials

Level: **3**
Credit value: **9**
UAN: **R/503/0347**

Unit aim

This unit sets out the requirements for metal inert gas (MIG) welding in a modern engineering environment, in terms of what needs to be achieved by the leaner, ie: welding a series of challenging joint configurations across in a wide range of positions that are compliant to welding procedure specifications.

The unit is concerned with the technology and practices involved in the application of MIG welding. The unit is demanding in terms of technological content and the complexity of the welding that leaners are expected to achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (i.e. electrodes) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Be able to apply safe working practices to MIG welding
2 Be able to prepare equipment for performing MIG welding
3 Be able to perform MIG welding operations to meet welding procedure specification requirements
4 Be able to evaluate welded joints for welding procedure specification conformance

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 5: Welding Materials by Manual MIG/MAG and other Continuous Wire Processes

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 311 MIG welding of materials

Outcome 1 Be able to apply safe working practices to MIG welding

Assessment Criteria

The learner can:

1. apply the **health and safety regulations** relevant to welding
2. assess **hazards and risks** in a welding environment and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow **safe working practices**

Range

Health and safety r**egulations:** Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: fume, fire, electricity, arc radiation, hot metal, hazards associated with the storage, handling and use of pressurised gas cylinders

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance cylinders (safe storage conditions, safe handling/moving, safe use)

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to welding process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render PPE provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection [PPE, screening, warnings {verbal, notices}]), hot metal (methods of avoiding), hazards associated with the storage, handling and use of pressurised gas cylinders

Unit 311 MIG welding of materials

Outcome 2 Be able to prepare equipment for performing MIG welding

Assessment Criteria

The learner can:

1. list the range of **welding equipment** available
2. describe the functions of welding equipment
3. prepare the **welding equipment** for a range of given applications
4. prepare the welding **shielding gases** for a range of given applications

Range

Welding equipment: power sources, inverter , generator, rated output, measurement of electrical output and continuity, relationship between wire feed speed control and welding current, power source characteristics, function of induction, return, earth, construction, rated output, welding guns, contact tip, return clamps, wire feed control, ancillary equipment

Shielding gases: cylinders, manifold systems, regulators (fixed, single-stage, two-stage), gas flow meters, gas tubes and connectors, use of solenoid valves, heaters for CO_2

Additional Guidance

Welding equipment: power sources (output direct current [d.c.], transformer/rectifier [function, operation, construction {diodes, thyristors} function of smoothing capacitors], inverter [function, operation, construction], generator [fuel driven, function, operation, construction], rated output [duty cycle]), measurement of electrical output and continuity (voltage – use of voltmeter/multi-meter, current – use of ammeter/shunts/coils, continuity – use of continuity tester/ohmmeter), relationship between wire feed speed control and welding current, power source characteristics (volt/ampere graph, flat characteristic, constant voltage output), function of induction (principle, effect, fixed, stepped, variable control, leads used (welding [water cooled, air cooled, harness construction], return, earth, construction, rated output [duty cycle]), welding guns/torches (water cooled, air cooled, construction, types [push, pull, reel-on-gun] swan neck design, pistol design, nozzles [dip, spray], contact tip [functions, material, sizes, clearing a burn-back), return clamps (types, clamping mechanisms), wire feed control (variable speed motor, direct control of wire feed rate, indirect control of welding current, solenoid valves [shielding gas, water], relay for electrical power, jog-feed control, gas purge control) ancillary equipment (angle grinders, wire brushes, linishers, hammer and chisel)

Unit 311 MIG welding of materials

Outcome 3 Be able to perform MIG welding operations to meet welding procedure specification requirements

Assessment Criteria

The learner can:

1. critically compare **welding consumables** for a range of given applications
2. differentiate between **welding consumables** by their classification
3. produce complex welded joints in a range of positions in accordance with welding procedure specification (WPS) parameters
4. **restore work areas** to a clean and safe condition on completion of welding operation.

Range

Welding consumables:

Electrode wires: BS EN 440: Welding consumables: wire electrodes and deposits for gas shielded metal arc welding of non alloy and fine grain steels, classification: (sizes [diameters, reel sizes available], strength and elongation of the weld metal, impact properties of the weld metal, chemical composition of the weld metal, deoxidisers, function of copper coating, protection of bare wires), non-ferrous metals (types, availability, typical sizes), storage (storage, identification, segregation (classification, size)

Shielding gases: BS EN 439: Welding consumables: shielding gases for arc welding and cutting, effects of shielding gases/gas mixtures (weld pool/arc area protection, heat input, weld geometry, penetration profile, travel speed, mode of metal transfer), applications for shielding gases/gas mixtures (argon, helium, carbon dioxide, argon/carbon dioxide mixtures, argon/oxygen/carbon dioxide mixtures, argon/oxygen mixtures, helium/argon/oxygen/carbon dioxide mixtures), gas pressure requirements, flow rates for applications

WPS: welding process, parent metal, consumables, pre welding activities (cleaning, edge preparation, assembly, pre-heat), welding parameters, welding positions (EN ISO 6947 – PA, PB, PC, PD, PE, PF, PG), number and arrangement of runs to fully fill/weld joints, electrode sizes for joint thicknesses, mode of metal transfer (dip [short-circuiting, globular, spray, pulse), electrical conditions required (type of current, direct [d.c.], electrode polarity (positive), wire feed speed ranges, voltage (open circuit, arc), control of heat input, shielding gas (type, flow rate) interpass/run cleaning/back gouging methods, post welding activities (spatter removal, wiring brushing, removal of excess weld metal where required), post-weld heat treatment (normalising, stress relief)

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 311 MIG welding of materials

Outcome 4 Be able to apply safe working practices to MIG welding

Assessment Criteria

The learner can:

1. explain the implications of quality specifications used to determine the **integrity of welded joints**
2. **visually evaluate** welded joints for conformance
3. prepare and **destructively test** joints to evaluate sub-surface for conformance

Range

Integrity of welded joints: classification of defects, quality specification (BS EN 25817 – arc welded joints in steel – guidance on quality levels for imperfections), methods of avoiding, rectification methods

Visually evaluate: use of visual techniques, lighting, low powered magnification, fillet weld gauges, dye penetrant testing, preparation for inspection, qualitive (defect levels, appearance), quantitive (extent, size, dimensional accuracy)

Destructively test: nick-break (fracture), macroscopic examination (x5) bend tests (butt welds, side, face, root), methods of preparation for testing

Unit 312 TIG welding of materials

Level: 3
Credit value: 9
UAN: D/503/0349

Unit aim

This unit sets out the requirements for tungsten inert gas (TIG) welding in a modern engineering environment, in terms of what needs to be achieved by the leaner, ie: welding a series of challenging joint configurations across in a wide range of positions that are compliant to welding procedure specifications.

The unit is concerned with the technology and practices involved in the application of TIG welding. The unit is demanding in terms of technological content and the complexity of the welding that leaners are expected to achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Be able to apply safe working practices to TIG welding
2 Be able to prepare equipment for performing TIG welding
3 Be able to perform TIG welding operations to meet welding procedure specification requirements
4 Be able to evaluate welded joints for welding procedure specification conformance

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 6: Welding Materials by Manual TIG and Plasma-arc Processes

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 312 TIG welding of materials

Outcome 1 Be able to apply safe working practices to TIG welding

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** in a welding environment and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow **safe working practices**

Range

Regulations: Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: fume, fire, electricity, arc radiation, hot metal, hazards associated with the storage, handling and use of pressurised gas cylinders

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance cylinders (safe storage conditions, safe handling/moving, safe use)

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to welding process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render PPE provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection [Personal Protective Equipment (PPE), screening, warnings {verbal, notices}]), hot metal (methods of avoiding), hazards associated with the storage, handling and use of pressurised gas cylinders

Unit 312 TIG welding of materials

Outcome 2 Be able to prepare equipment for performing TIG welding

Assessment Criteria

The learner can:

1. list the range of **welding equipment** available
2. describe the functions of welding equipment
3. prepare the **welding equipment** for a range of given applications
4. prepare the welding **shielding gases** for a range of given applications

Range

Welding equipment: power sources, direct current [d.c.], transformer, transformer/rectifier, inverter, generator, measurement of electrical output and continuity, methods of current regulation, power source characteristics, torches, collet, collet holder, gas lens, electrodes, return clamps, ancillary equipment

Shielding gases: cylinders, manifold systems, regulators (fixed, single-stage, two-stage), gas flow meters, gas tubes and connectors, use of solenoid valves

Additional Guidance

Welding equipment: power sources (output [alternating current [a.c.], direct current [d.c.], transformer [function, winding ratio, input/output ratio, construction], transformer/rectifier [function, operation, construction {diodes, thyristors} function of smoothing capacitors], inverter [function, operation, construction], generator [fuel driven, motor driven, function, operation, construction], rated output [duty cycle]), measurement of electrical output and continuity (voltage – use of voltmeter/multi-meter, current – use of ammeter/shunts/coils, continuity – use of continuity tester/ohmmeter), methods of current regulation (tapped reactor, moving core, moving coil, moving shunt, saturable reactor, variable resistance), power source characteristics (volt/ampere graph, drooping characteristic, constant current output), leads used (welding [water cooled, air cooled, harness] return, earth, construction, rated output [duty cycle]), torches (types, water cooled air cooled, pencil, construction, connections, contactor/switch, foot pedal/amptrol, back caps [long. medium, short, applications], nozzles [long. medium, short, applications], collet, collet holder, gas lens [construction, effects, benefits, limitations, applications), electrodes (thoriated, zironiated, ceriated, lananathed, compositions, sizes, identification, applications, preparation [grinding: techniques, equipment, health and safety implications {dust, particulates, extraction, radioactivity for thoriated}), return clamps (types, clamping mechanisms), ancillary equipment (angle grinders, linishers, wire brushes, oxide removal, degreasers)

Unit 312 TIG welding of materials

Outcome 3 Be able to perform TIG welding operations to meet welding procedure specification requirements

Assessment Criteria

The learner can:

1. critically compare **welding consumables** for a range of given applications
2. differentiate between **welding consumables** by their classification
3. produce complex welded joints in a range of positions in accordance with welding procedure specification (WPS) parameters
4. explain the effects of the **electrical characteristics** of the TIG welding arc
5. **restore work areas** to a clean and safe condition on completion of welding operation.

Range

Welding consumables: *Electrode wires:* BS EN 1668: Welding consumables: rods, wires and deposits for tungsten inert gas welding of non alloy and fine grain steels, classification: BS EN 12072: Welding consumables: wire electrodes, wires and rods for arc welding of stainless and heat-resisting steels., classification: (sizes [diameters, lengths], strength and elongation of the weld metal, impact properties of the weld metal, chemical composition of the weld metal, deoxidisers, function of copper coating, protection of bare wires), non-ferrous metals (types, availability, typical sizes), storage (storage, identification, segregation (classification, size)

Shielding gases: BS EN 439: welding consumables, shielding gases for arc welding and cutting, effects of shielding gases/gas mixtures (weld pool/arc area protection, heat input, weld geometry, penetration profile, travel speed), applications for shielding gases/gas mixtures (argon, helium, argon/helium mixtures, helium/argon mixtures, argon/hydrogen mixtures, nitrogen, argon/nitrogen mixtures), gas pressure requirements, flow rates for applications

WPS: Welding process, parent metal, consumables, pre welding activities (cleaning, edge preparation, assembly, pre-heat), welding parameters, welding positions (EN ISO 6947 – PA, PB, PC, PD, PE, PF, PG), number and arrangement of runs to fully fill/weld joints, electrode sizes for joint thicknesses, electrode, filler wire, electrical conditions required (type of current, alternating [a.c.] direct [d.c.], electrode polarity (negative), welding current ranges, methods of arc ignition (scratch, high frequency, lift start), shielding gas (type, flow rate, pre-weld gas flow, post-weld gas flow), techniques (including autogenous), control of heat input, interpass/run cleaning/back gouging methods, post welding activities (wiring brushing, removal of excess weld metal where required), post-weld heat treatment (normalising, stress relief)

Electrical characteristics: effects of types of current (a.c./d.c.) and electrode polarity (d.c.: positive, negative) upon: heat input/distribution, electrode, weld bead profile, penetration; methods of a.c. arc stabilisation (including: square wave); welding current features (pulse current, slope in, slope out) voltage (open circuit, arc)

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 312 TIG welding of materials

Outcome 4 Be able to evaluate welded joints for welding procedure specification conformance

Assessment Criteria

The learner can:

1. explain the implications of quality specifications used to determine the **integrity of welded joints**
2. **visually evaluate** welded joints for conformance
3. prepare and **destructively test** joints to evaluate sub-surface for conformance

Range

Integrity of welded joints: classification of defects, quality specification (BS EN 25817 – arc welded joints in steel – guidance on quality levels for imperfections), methods of avoiding, rectification methods

Visually evaluate: use of visual techniques, lighting, low powered magnification, fillet weld gauges, dye penetrant testing, preparation for inspection, qualitive (defect levels, appearance), quantitive (extent, size, dimensional accuracy)

Destructively test: nick-break (fracture), macroscopic examination (x5) bend tests (butt welds, side, face, root), methods of preparation for testing

Unit 313 Platework fabrication of materials

Level: **3**
Credit value: **9**
UAN: **F/503/0375**

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the fabrication of platework, including bolted and welded fabrications, developed platework, tubular node connection, boxed girder construction and pressure vessels.

It covers health and safety aspects of fabrication, necessary planning and template development lay outs, marking out, cutting and forming and joining for the production of platework fabrications.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Be able to apply safe working practices to platework fabrication
2 Be able to prepare equipment for platework cutting
3 Be able to prepare the equipment for platework forming
4 Be able to produce fabrications using platework techniques

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 22: Marking Out Components for Metalwork; Unit 32: Cutting Plate and Sections using Shearing Machines; Unit 35: Bending and Forming Platework using Press Brakes or Bending Machines; Unit 36: Forming Platework using Rolling Machines; Unit 38: Producing Platework Assemblies

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 313 Platework fabrication of materials

Outcome 1 Be able to apply safe working practices to platework fabrication

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** associated with hot working and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: hot working (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), arc radiation (visible light, infra-red, ultra-violet, effects, protection (Personal Protective Equipment (PPE), screening, warnings [verbal, notices], hot metal/slag from (thermal cutting process, welding processes, grinding)

Safe working practices: thermal cutting and welding: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to fabrication process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Unit 313 Platework fabrication of materials

Outcome 2 Be able to prepare equipment for platework cutting

Assessment Criteria

The learner can:

1. prepare fabrication **cutting equipment** for a range of given applications
2. prepare **thermal cutting equipment** for a range of given applications
3. **critically compare** methods of cutting thick plate using thermal and mechanical methods

Range

Cutting equipment: drills (twist drill nomenclature, drilling machines [pedestal, bench, radial arm, portable, hand, electric power, pneumatic]), tank cutters, hole saws, rotary shears (portable shears, nibblers [shear type, punch type, combination shears]), guillotines (mechanical, pneumatic, CNC control, back stops, front stops, guides), universal shearing machine, power punch (including CNC control), cold sawing (circular saws, band saws [vertical, horizontal], reciprocating, friction), portable angle grinders/sanders

Thermal cutting equipment: oxy-fuel gas cutting (principle, manual cutting of plate and sections, machine cutting of plate, reason for 'three-point' support of plate, control of distortion), electric arc process (plasma-arc, laser cutting)

Critically compare: cost of equipment, suitability, versatility, accuracy, quality of cut

Unit 313 Platework fabrication of materials

Outcome 3 Be able to prepare the equipment for platework forming

Assessment Criteria

The learner can:

1. prepare fabrication **forming equipment** for a range of given applications
2. **critically compare methods of forming** thick plate mechanical methods

Range

Forming equipment: rolling machines (pyramid type, pinch type [three and four pinch], mechanical, angle-ring bending, section rolls), folding machines (horizontal, vertical, double arm folder) press brake (tooling [dies, forming tools], mechanical, electro-hydraulic, up-stroking, down-stroking, CNC control), fly press (tooling [dies, forming tools]); methods of spring-back control for bending and folding, tooling design for air bending techniques, specialised tooling for press brake, use of polyurethane block for use with double arm folder, methods of pre-setting plate edges for rolling

Methods of forming: cylinders, methods of conical and helical rolling, methods of rolling sectional material, stops, guides fitted to aid production; guarding (interlocking devices, fail safe circuits, light guards, gates)

Critically compare: cost of equipment, suitability, versatility, accuracy, quality of finish

Unit 313 Platework fabrication of materials

Outcome 4 Be able to produce fabrications using platework techniques

Assessment Criteria

The learner can:

1. perform **fabrication assembly** operations to produce square, rectangular and circular forms from thick plate to ± 2.0 mm tolerance
2. perform **joining** operations to produce fabricated platework assemblies to ± 2.0 mm tolerance
3. **restore work areas** to a clean and safe condition on completion of the operation.

Range

Fabrication assembly: transfer of patterns to metal, use of level surfaces for assembling, methods used for alignment (strong backs and wedges, draw cleats/lugs, draw bolts), methods of avoiding twist, methods of controlling distortion, use of stays to maintain shape, use of jigs and fixtures and clamping devices, use of tack bolts and tack welds, care and use of lifting tackle, importance of close contact surfaces, removal of all temporary tack weld and the reinstatement of a good surface.

Joining:

Thermal joining techniques: manual metal arc welding, MIG welding, procedures, settings and consumables to produce sound and effective tacking, interpret weld symbols to BS EN 22553, range of joint configuration used in thick platework ('open' square corner joints, lap fillets, tee fillets, cruciform joints, single and double vee butts, welding techniques (single and multi-run, stringer beads and weaving), joint design and welding sequence (weld strength, distortion control, weld economics), jigs and fixtures to aid assembly; manipulators, positioners, rotators to facilitate welding and control distortion/ maintain dimensional accuracy;

Mechanical methods of joining: bolting (bolts: [black bolts, high strength friction grip bolts, close tolerance bolts, fitted bolts], bolting requirements [cleanliness of contact surfaces, correct tensioning, hole clearance, tolerances, alignment of holes])

Dimensional accuracy: function of a datum line or surface, measuring equipment to check dimensional accuracy, specific tolerances, methods of checking accuracy (dimensions, alignment, form, squareness, freedom from twist and distortion, surface condition)

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 314 Sheet metalwork fabrication of materials

Level: 3
Credit value: 9
UAN: A/503/0374

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the fabrication of thin plate, including developed thin plate components, ducting, double curvature work and light sheetmetal fabrication. It covers the health and safety aspects of fabrication work, cutting and forming of sheet metal and the production of fabrications using sheet metalwork techniques, including joining by soldering (soft and hard) and resistance welding (spot, seam and projection).

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Be able to apply safe working practices to sheet metalwork fabrication
2 Be able to prepare and use equipment and tools for sheetmetal cutting
3 Be able to prepare the equipment and tools for sheetmetal forming
4 Be able to produce fabrications using sheet metalwork techniques

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 22: Marking Out Components for Metalwork; Unit 23: Cutting Sheetmetal to Shape using Hand and Machine Tools; Unit 24: Forming Sheetmetal using Hand and Machine Tools; Unit 25: Producing Sheetmetal Assemblies

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 314 Sheet metalwork fabrication of materials

Outcome 1 Be able to apply safe working practices to sheet metalwork fabrication

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** associated with hot working and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: hot working (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers)

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to fabrication process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Unit 314 Sheet metalwork fabrication of materials

Outcome 2 Be able to prepare and use equipment and tools for sheetmetal cutting

Assessment Criteria

The learner can:

1. prepare fabrication **cutting equipment** for a range of given applications
2. prepare fabrication **cutting tools** for a range of given applications

Range

Cutting equipment: drills (twist drill nomenclature, drilling machines [pedestal, bench, portable, hand, electric power, pneumatic]), trepanning, tank cutters, hole saws, rotary shears (portable shears, nibblers [shear type, punch type, combination shears]), guillotines (treadle, mechanical, pneumatic, CNC control, back stops, front stops, guides), universal shearing machine, fly press, power punch (including CNC control), portable angle grinders/sanders

Cutting tools: hand shears (straight, left hand, right hand, universal), bench shears (hand-lever, throatless, corrugated), tinman's hand-level punch

Unit 314 Sheet metalwork fabrication of materials

Outcome 3 Be able to prepare the equipment and tools for sheetmetal forming

Assessment Criteria

The learner can:

1. prepare fabrication **forming equipment** for a range of given applications
2. prepare fabrication **forming tools** for a range of given applications

Range

Forming equipment: jennys (tooling), rolling machines (pyramid type, pinch type, slip rolls, hand-operated, mechanical, cone rolls, angle-ring bending), folding machines (box and pan, universal swing-beam, angle bending, simple bench mounted bending), press brake (tooling [dies, forming tools], mechanical, electro-hydraulic, up-stroking, down-stroking, CNC control), fly press (tooling [dies, forming tools]), stretch forming/shrinking machines, vibratory forming machines

Forming tools: types and sizes of hammers, planishing hammers, stretching hammers, blocking hammers, hollowing hammers, mallets, wedge shaped mallets, wooden blocks, sand bags, range of bench stakes

Unit 314 Sheet metalwork fabrication of materials

Outcome 4 Be able to produce fabrications using sheet metalwork techniques

Assessment Criteria

The learner can:

1. perform **fabrication techniques** to produce square, rectangular, cylindrical, conical forms (including offsets) and transition pieces from sheetmetal to ± 2.0 mm tolerance
2. perform **joining** operations to produce fabricated sheetmetal assemblies to ± 2.0 mm tolerance
3. evaluate fabrications for **dimensional accuracy** and fitness for purpose
4. **restore work areas** to a clean and safe condition on completion.

Range

Fabrication techniques: transfer of patterns to metal/plastics, stiffening techniques (swaging, beading, wired edges [including false], folds, flanging), forms (square, rectangular, cylindrical, conical: offset: square, rectangular, cylindrical, conical; boxed, curved panels, double curvatures, segmental bends), techniques used to produce transition pieces (square to round, round to square, breeches), stretching and shrinking techniques (hand forming, machine forming), hand forming techniques (hollowing, raising, planishing, flanging, double curvature, 'split and weld' methods), wheeling techniques

Joining: methods of fabrication assembly, use of joints, including self-secured, soldering and hard solder, types of fluxes, heat sources, braze welding, resistance welding processes

Dimensional accuracy: function of a datum line or surface, measuring equipment to check dimensional accuracy, specific tolerances, methods of checking accuracy (dimensions, alignment, form, squareness, freedom from twist and distortion, surface condition)

Additional Guidance

Joining: methods of fabrication assembly (holding methods, clamping, distortion control methods), use of joints, including self-secured (lap, grooved seam, lock-formed, Pittsburgh lock, panned down, knocked-up, jointing allowances, junctions that require notched corners), soldering and hard solder (brazing) techniques (principles of soldering, benefits and limitations, joint design, preparing the joint, cleaning the joint, types of soft solder [melting points, applications], types of fluxes, heat sources [copper bit, flame, hot plate, furnace, induction, resistance, dip], cleaning the soldered joint), braze welding, resistance welding processes (spot, seam, projection, principles of resistance welding [power source, generation of heat, electrodes [sizes, types, functions, methods of cooling, electrode arms)

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 315 Fabrication and erection of structural steelwork

Level: 3
Credit value: 9
UAN: J/503/0376

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the fabrication and erection of structural steelwork.

The unit is broadly divided into structural materials, fixtures and fastenings, structural fabrication, site work and safe working practices during fabrication and on site.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Be able to apply safe working practices to steelwork fabrication and erection
2 Know how to prepare structural materials for steelwork fabrication
3 Be able to perform marking out and cutting operations on structural materials
4 Be able to produce fabricated steelwork structures

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 22: Marking Out Components for Metalwork; Unit 33: Cutting and Shaping Materials using Portable Thermal Cutting Equipment; Unit 37: Producing and Finishing Holes using Drilling Machines; Unit 28: joining Fabricated Components using Mechanical Fasteners; Unit 42: Producing Major Structural Components/Sub-assemblies

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 315 Fabrication and erection of structural steelwork

Outcome 1 Be able to apply safe working practices to steelwork fabrication and erection

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** associated with hot working and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: hot working (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), arc radiation (visible light, infra-red, ultra-violet, effects, protection (PPE, screening, warnings [verbal, notices], hot metal/slag from (thermal cutting process, welding processes, grinding)

Safe working practices: thermal cutting and welding: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to fabrication process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Unit 315 Fabrication and erection of structural steelwork

Outcome 2 Know how to prepare structural materials for steelwork fabrication

Assessment Criteria

The learner can:

1. critically compare **structural steels** used in fabrication engineering
2. explain the commercial **forms of supply** of materials available
3. explain the forms of **pre-fabricated sections** and **fixtures** commercially available

Range

Structural steels: low carbon steel, low alloy steels, high yield alloy steels, weather resistant steels (WR 55 grades); applications, limitations, load bearing capabilities, ease of fabrication (marking out, cutting, joining), density; application for: (access) platforms, decking and walkways, stairways and hooped ladders, handrailings; (support) saddles, brackets and cleats, frameworks, bracings and ties

Forms of supply: sections (rolled steel angle [RSA] {equal leg, unequal leg}, universal beam [UB], universal column [UC], rolled steel channel [RSC], rolled steel joist [RSJ], tee bar) hollow sections (circular hollow section [CHS], rectangular hollow section [RHS]) plates (plain, non-slip [durbar and chequer], expanded, pierced and punched), flat bars

Pre-fabricated sections: plate birders, box girders, lattice girders, castellated beams, cambered beams, laced stanchions, battened stanchions, portal frames

Fixtures: cleats (beam to beam connections, beam to column connections), columns (base plates, end plates, splice plates), gusset plates

Unit 315 Fabrication and erection of structural steelwork

Outcome 3 Be able to perform marking out and cutting operations on structural materials

Assessment Criteria

The learner can:

1. perform **marking out** operations on structural steelwork to meet specification
2. perform **cutting** operations on structural material to meet specification
3. **critically compare** methods of cutting structural steelwork using thermal and mechanical methods

Range

Marking out: directly onto steelwork, using templates (types: plate, sections, cleats; application of templates: box, battened, part), datum, centre lines, set out points, avoidance of cumulative error in marking out by the avoidance of string dimensions, non-slip plate (chequer) avoiding 'wrong hand' or 'mirror image' errors, setting out a camber, derive the shapes of bolted gusset plates from standard hole pitch and edge distance

Cutting:

Mechanical: drills, tank cutters, hole saws, rotary shears, guillotines, universal shearing machine, power punch, cold, portable angle grinders/sanders, reasons for reaming punched holes

Thermal: oxy-fuel gas cutting, electric arc process

Critically compare: cost of equipment, suitability, versatility, accuracy, quality of cut

Additional Guidance

Cutting:

Mechanical: drills (twist drill nomenclature, drilling machines [pedestal, bench, radial arm, portable, hand, electric power, pneumatic]), tank cutters, hole saws, rotary shears (portable shears, nibblers [shear type, punch type, combination shears]), guillotines (mechanical, pneumatic, CNC control, back stops, front stops, guides), universal shearing machine, power punch (including CNC control), cold sawing (circular saws, band saws [vertical, horizontal], reciprocating, friction), portable angle grinders/sanders, reasons for reaming punched holes

Thermal: oxy-fuel gas cutting (principle, manual cutting of plate and sections, machine cutting of plate, reason for 'three-point' support of plate, control of distortion), electric arc process (plasma-arc, laser cutting)

Unit 315 Fabrication and erection of structural steelwork

Outcome 4 Be able to produce fabricated steelwork structures

Assessment Criteria

The learner can:

1. perform **fabrication assembly** operations to produce welded beam to beam connection from structural steelwork to ± 2.0 mm tolerance
2. explain the form and applications of **joining methods** used in structural steelwork
3. evaluate fabrications for **dimensional accuracy** and fitness for purpose
4. perform a trial **erection** of fabricated sections
5. tension bolts to the recommended torque
6. set out a roof truss and determine which members are struts and which are ties
7. **restore work areas** to a clean and safe condition on completion.

Range

Fabrication assembly: forming processes (plate rolls [pinch, pyramid], section rolls, beam bender), use of level surfaces for assembling, methods used for alignment (strong backs and wedges, draw cleats/lugs, draw bolts), methods of avoiding twist, methods of controlling distortion, use of stays to maintain shape, use of jigs and fixtures and clamping devices, use of tack bolts and tack welds, care and use of lifting tackle, importance of close contact surfaces, removal of all temporary tack weld and the reinstatement of a good surface, reasons for part assemblies, trial erections and sub-assemblies

Joining methods:

Thermal joining techniques*:* manual metal arc welding, MIG welding, procedures, settings and consumables to produce sound and effective tacking, interpret weld symbols to BS EN 22553, range of joint configuration used in thick steelwork ('open' square corner joints, lap fillets, tee fillets, cruciform joints, single and double vee butts, welding techniques (single and multi-run, stringer beads and weaving), joint design and welding sequence (weld strength, distortion control, weld economics), jigs and fixtures to aid assembly; manipulators, positioners, rotators to facilitate welding and control distortion/ maintain dimensional accuracy (restraint, welding sequence, pre-setting) methods of rectifying excessive distortion in welded structures (mechanical force, heat)

Mechanical methods of joining*:* bolting – bolts (black, high tensile, high strength friction grip [HSFG], load indicating, close tolerance, torshear), washers (plain, hardened steel, load indicating, taper, tab, anti-vibration), shear connectors, factors that contribute to the quality of bolted connections (cleanliness of surfaces in contact, alignment of holes, correct tensioning [torque wrench, impact wrench])

Dimensional accuracy: function of a datum line or surface, measuring equipment to check dimensional accuracy, specific tolerances, methods of checking accuracy (dimensions, alignment, form, squareness, freedom from twist and distortion, surface condition)

Erection: levelling steelwork and steelwork bases, plumbing vertical members, checking alignment, handle, move and lift structural sections safely, use of ancillary equipment used on site to lift, move or adjust the position of steelwork (pulleys, block and tackle, pull-lifts, hydraulic jacks, podger spanners, drifts, wedges, temporary props and bracings, falsework, modification techniques to steelwork on site (misaligned holes, incorrect sized members, maximum thickness of packings, fouling existing steelwork or services), consequences of cutting holes in beams to facilitate service piping or ducting

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 316 Pattern development for fabrication

Level: **3**
Credit value: **9**
UAN: **Y/503/0379**

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for obtaining flat layouts of 3D forms that can be used for producing templates to mark out the material for fabrication to the required form.

Learning outcomes

There are **five** learning outcomes to this unit. The learner will:

1 Be able to determine lines of intersection
2 Be able to develop patterns using parallel line techniques
3 Be able to develop patterns using radial line techniques
4 Be able to develop patterns using triangulation
5 Be able to produce templates of developed patterns

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 27: Developing and Marking Out Templates for Metalwork

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 316 Pattern development for fabrication

Outcome 1 Be able to determine lines of intersection

Assessment Criteria

The learner can:

1. determine lines of intersection using projection
2. determine lines of intersection using the principle of the **common central sphere**
3. determine lines of intersection using the method of cutting planes
4. determine **joint lines of ducts**

Range

Common central sphere: right cylindrical branches onto transformer pieces, oblique cones to right cones, oblique cones to oblique cones, inclined right cylinder branches on right cones on and off centre, cylindrical and rectangular branch intersections onto rectangular hoppers, cylindrical and rectangular branches on spherical, doomed or dished ends

Joint lines of ducts: where the centre lines lie on centre and in the same plane, a right angled tee piece of equal cross-section, a right angled tee piece of unequal cross-section, junctions of three cylinders

Unit 316 Pattern development for fabrication

Outcome 2 Be able to develop patterns using parallel line techniques

Assessment Criteria

The learner can:

1. apply the **parallel line** method of pattern development
2. apply the **parallel line** method of pattern development to **complex forms**

Range

Parallel line: segmental bends (right cylindrical and oblique), square or rectangular ducts cut obliquely, right cylinders cut obliquely, oblique cylinders cut obliquely

Complex forms: branch pipes on to boiler, shells, dished ends and domed ends, cylindrical branches onto right and cylindrical segmental bends to include interpenetration of the branch pipe, square and rectangle branches onto right and oblique cones, swan neck transition pieces, rectangle to rectangle in angular planes, transition pieces of apparently twisted sides with openings at right angles and different levels

Unit 316 Pattern development for fabrication

Outcome 3 Be able to develop patterns using radial line techniques

Assessment Criteria

The learner can:

1. apply the **radial line** method of pattern development
2. apply the radial line method of pattern development to **complex forms**

Range

Radial line: right cones and frusta, oblique cones and frusta, oblique cones cut by a flat surface, oblique cones cut by a curved surface, two way breeches piece made from right cones, two-way breeches piece made from oblique cones

Complex forms: right cones in multiple connections of right cylinders and right cones, breeches pieces involving oblique cones, tapered segmental bends ('lobster back bends')

Unit 316 Pattern development for fabrication

Outcome 4 Be able to develop patterns using triangulation

Assessment Criteria

The learner can:

1. apply the **triangulation** method of pattern development
2. apply the triangulation method of pattern development to **complex forms**

Range

Triangulation: hoppers based on square or rectangular based pyramids, square or rectangle to round transformers, round to square or rectangle transformers, transformers and hoppers on and off centre, between parallel planes, transformers and hoppers between parallel and non-parallel planes, right cylinders, oblique cylinders, right cones, oblique cones

Complex forms: rectangular to round off-set transformers on a roof apex, breeches pieces branching from cylindrical main to equal and unequal diameter ducts, rectangular kinked sided hoppers (kinked to produce maximum volume, kinked to produce minimum volume), spiral blade segments by triangulation

Unit 316 Pattern development for fabrication

Outcome 5 Be able to produce templates of developed patterns

Assessment Criteria

The learner can:

1. apply pattern development techniques to prepare **templates** for the marking out of a fabrication
2. perform **calculations** to produce dimensions for checking templates
3. review and revise layouts to accommodate **material thickness**
4. **restore work areas** to clean and safe condition on completion of the operation

Range

Templates: purpose, means of checking, types and applications, use of CAD packages, specialist packages, template production techniques, tools used, materials, information contained on templates, drilling requirements, cutting instructions, assembly reference mark, datum[s]

Calculations: length of cylinder (πd), angle at the apex of a developed right cone/frustra pattern/half pattern, use of triangles, use of trigonometry, application of the neutral line

Material thickness: methods of marking out from templates, including: external forms, internal forms, holes, back marks, pitch, use of datums; determine modified set-outs to accommodate plate thickness (application of the neutral line), use of instructions added to templates and patterns produced by the triangulation method enabling them to be used effectively

Additional Guidance

Templates: purpose (avoid repetitive measurements, avoid unnecessary material wastage, act as a guide to cutting process[es], means of checking [lengths, angles, shapes, forms], precise method of marking hole positions, reliable means of assuring repeatability), types and applications (pattern development, internal, external, roof truss, gusset, back-marks, hole, bushed, box), use of CAD packages (standard CAD [eg AutoCAD], specialist packages [pattern development software]), template production techniques (template shop/loft, setting out floor), tools used (saws, planes, drills, marking gauge, steel rule, compasses, dividers, trammels, protractor, engineers square, flat (plate) square, straight edge, hammers, centre/dot/nipple punches, chalk line and soft chalk, french chalk, coloured and indelible pencils/crayons), materials (template paper, hardboard, timber, sheetmetal, steel plate), information contained on templates (job/contract number, size/thickness of material, steel section and length, quantity required, bending/folding instructions, orientation [eg 'this side up', 'left side', 'right hand', etc], drilling requirements, cutting instructions, assembly reference mark, datum[s]

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 317 Maintenance of machine systems

Level: 3
Credit value: 9
UAN: R/503/0381

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the routine maintenance, repair and modifications to all types of manufacturing machine systems. This consists of machine tools: drills, lathes, millers, grinders (precision and off-hand), power saws and boring machines. It includes the mechanical and fluid power features of NC and CNC machines and robots, but not the control systems.

It also covers extrusion equipment and presses: filling, bottling and packaging plant and conveying and transfer equipment (but not fork lift trucks and cranes or other mobile devices).

Leaners will not usually be expected to know the constructional features of the components of hydraulic, pneumatic or refrigeration systems, or other specialist equipment, only the function of each. However they should be able to apply general engineering principles to identify the causes of a fault and safely carry out any replacements needed to bring the equipment back on line.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1 Understand the function of machine systems
2 Be able to prepare for maintenance of machine systems
3 Be able to perform inspections and maintenance tasks
4 Be able to reinstate machine systems

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Engineering Maintenance; Unit 6: Maintaining Mechanical Equipment

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 317 Maintenance of machine systems

Outcome 1 Understand the function of machine systems

Assessment Criteria

The learner can:

1. explain the **structural requirements** of a range of common machine systems
2. explain the importance of **alignment** in machine systems and methods to achieve it
3. explain the methods used to achieve **rotational movement**
4. explain the methods used to achieve **linear movement**
5. explain the methods used to **change speeds**
6. explain the methods used to **control feed speeds**
7. classify **coolants and lubricants** applicable to machine systems
8. explain the application of **hydraulic and pneumatic systems** to the operation and control of machine systems

Range

Structural requirements: strength, rigidity, stability, control of movement, materials (cast iron, cast steel, steel plate), structures (box column, rib and box bed, fabricated base)

Alignment:

Slideways: flat, vee, dovetail, cylindrical, comparison of their capabilities, main features, accuracy of movement, means of adjustment, lubrication, protection, friction related to applied loads and surface finish

Typical checks: coaxial alignment between main spindle axis, coaxial alignment between two spindles, alignment of spindle to guideway, squareness of slideways movement, concentricity and end float of spindle, squareness of planes to spindle, setting of guards, stops and automatic safety cut-outs

Bearings: plain bush (radial, radial and axial) ball (radial, axial, radial and axial) roller (radial, axial, radial and axial)

Methods of alignment: standard tests, straight edge, precision level, autocollimator, reflector, laser, roundness measuring machine

Rotational movement: flat belts, vee belts, toothed belts, chain drives, correct tensioning belts and chains, friction clutches, dog clutches, gears: worm and wheel, bevel gear, spur, gear nomenclature, gear materials, non-ferrous alloys, calculate simple and compound gear ratios, relationship between torque and power transmitted and the loads on gear teeth, gear box layouts and means of selecting different output speeds, gear defects, hydraulic actuators

Linear movement: screw and nut (vee, square [including multi-start], ACME, relationship between the lead of a screw and the motion transmitted, engaging screw drives [fixed nuts, split nuts]), rack and pinion, recirculating ball-screw, crank and connecting rod, cams (lift, dwell and types of motion produced) hydraulic actuator

Change speeds: sliding gears, cone pulleys, clutch operated, infinitely variable, electrical/electronic

Control feed speeds: sliding gears (Norton gearbox), leadscrew and nut, hydraulic drives

Coolants and lubricants: types of coolant pump, strainers and filtration, filters, lubrication of headstock/gearbox assemblies of splash and pressurised feed

Hydraulic and pneumatic systems: hydraulic reservoirs and pumps, actuators (rotary and linear), valves and the methods of operation, pneumatic/hydraulic pressure intensifiers, pneumatic silencers, methods of providing clean, dry air to a machine tool from air mains

Additional Guidance

Rotational movement: flat belts, vee belts (single and matched sets) toothed belts, chain drives, correct tensioning belts and chains, friction clutches, dog clutches, gears: worm and wheel, bevel gear, spur, gear nomenclature (addendum, dedendum, clearance, diametral pitch, circular pitch, module), gear materials (cast iron alloy steels [including surface hardened], non-ferrous alloys [brass and bronze derivations], plastics), calculate simple and compound gear ratios, relationship between torque and power transmitted and the loads on gear teeth, gear box layouts and means of selecting different output speeds, gear defects (pitting, flaking, scoring and scuffing, likely causes); hydraulic actuators

Hydraulic and pneumatic systems: hydraulic reservoirs and pumps, actuators (rotary and linear), valves and the methods of operation (mechanical, pilot, solenoid, directional control, flow control, pressure control, uni-directional), pneumatic/hydraulic pressure intensifiers, pneumatic silencers, methods of providing clean, dry air to a machine tool from air mains

Unit 317 Maintenance of machine systems

Outcome 2 Be able to prepare for maintenance of machine systems

Assessment Criteria

The learner can:

1. evaluate type and extent of work to be carried out
2. develop a **plan** that includes assessing any risks, securing the area and isolating equipment
3. estimate the **tools, materials, equipment and information** that will be needed
4. set-up to carry out the maintenance activity

Range

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system, procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination, fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Additional Guidance

Plan: to include- emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system (isolating switches, removal of fuses, closing and 'locking off' of valves, removal of valves and blanking of pipes) procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination (including any special Personal Protective Equipment (PPE) such as breathing apparatus), fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Tools, materials, equipment and information: specific implications of statutory regulations, codes of practice related to installing or maintaining systems, special considerations as prescribed by the manufacturer

Unit 317 Maintenance of machine systems

Outcome 3 Be able to perform inspections and maintenance tasks

Assessment Criteria

The learner can:

1. perform **dismantling and assembling** operations to ensure effective operation on completion
2. perform **inspections of components** and draw conclusions **regarding** its repair or replacement

Range

Dismantling and assembling: to allow for reassembly, identification of parts (layout of parts), reassemble in correct order for recommissioning of the system.

Testing of parts and system to establish effectiveness of repair/replacement.

Additional Guidance

Dismantling and assembling: make identification (witness) marks on components so that they can be correctly reassembled/re-aligned, label and safely store parts that have been removed methods used to avoid distortion and damage to, or leakage from, pipework (disconnecting, aligning, connecting), precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from: misalignment, use of wrong tools, excessive force, uncontrolled release of springs, scoring of surfaces; protection of dismantled components from contamination (blanking off open ports, use of correct cleaning agents and lint-free cloths), sequence for tightening bolts and applying specified torque, application of lubrication to seals, precautions to be taken when refilling systems with specified oils, methods of safely bleeding systems to eliminate air locks and avoid spillage, how to remove; fit and replace: bearings, seals, springs, circlips, keys, brushes; prepare or make new gaskets or joints (including preparation of surfaces and/or housings) and repack glands

Inspections: bearing surfaces, erosion and pitting, split or worn seals, signs of overheating (discolouration); condition of filters for: signs of metallic or other particles, indications of emulsions or oil deterioration, correctly labelling re-built components for replacement in a system or returning to stores, checking oil for signs of oxidation and acidity, bench testing re-assembled components, pressure testing pipework and pressure vessels, presenting information that can be used to appraise the outcome of a maintenance or installation activity

Unit 317 Maintenance of machine systems

Outcome 4 Be able to reinstate machine systems

Assessment Criteria

The learner can:

1. perform **re-commissioning** operations to brings system on-line and adjust as required until the working requirements have been fully met
2. **restore work areas** to a clean and safe condition on completion of maintenance and re-commissioning

Range

Re-commissioning: bring system back on-line and test/trial run to establish full functionality

Additional guidance

Re-commissioning: refilling or recharging systems, opening up the system to the sources of pressure, methods to safely drain, bleed and purge systems to avoid undue leakage or contamination, set up and test interlocks, sensors and limit switches, sequence of bringing systems back to the specified working conditions (removal of protective covers and blanks, opening appropriate valves or switches, operating the system under gradually increasing pressures or loads, state the methods of securing pipework and safety fittings (guards, handrails), methods of replacing insulation, lagging and other protective coverings, applying identification markings to different parts of a system (colour identification of pipework to BS 1710, using appropriate and approved codings for electrical connections and components)

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 318 Maintenance of utility systems

Level: **3**
Credit value: **9**
UAN: **D/503/0383**

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the maintenance and/or installation requirements of utilities systems needed for industrial purposes. These include compressed air, electricity and steam (but not boilers).

The unit will cover system layouts and their main components, the selection and use of appropriate tools and equipment, the procedures and techniques involved with safely installing and isolating systems, removing or replacing components, commissioning, or restoring, a system to a fully operative condition.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will

1. Understand the function of utility systems
2. Be able to prepare for maintenance of utility systems
3. Be able to perform inspections and maintenance tasks
4. Be able to reinstate utility systems

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Engineering Maintenance; Unit 6: Maintaining Mechanical Equipment within an Engineering System

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 318 Maintenance of utility systems

Outcome 1 Understand the function of utility systems

Assessment Criteria

The learner can:

1. explain the nature and behaviour of **air** under pressure
2. differentiate between the different types of air **compressor** and their performance
3. explain the features of **pipework and systems** used for supplying compressed **air**
4. explain the nature and properties of **steam** under pressure
5. explain the nature and effects of **electricity**
6. explain the applications of **electrical systems**

Range

Air: compressed air hazards, relationships between force, area and pressure and how to use them for calculations, relationships between volume, temperature and pressure and how to use them for calculations, relationships between volume, temperature and pressure and how to use them for calculations, relative humidity and its relationship with air pressure and temperature

Compressor: performance capability in terms of pressure and volumetric output of free air delivered (FAD): piston types – single stage and multi-stage, screw, centrifugal, basic component parts and layout of each type of compressor, intercoolers and aftercoolers construction and layout, air receivers (function, associated essential equipment fitted to receivers, legal requirements for installation, inspection and testing), air dryers (absorption, adsorption, refrigerant types [super dryers])

Pipework and systems

Air: factors affecting pressure drops and flow rates and the relationships between these and pipe sizes, how information can be obtained by the use of nomograms, pipework materials and applications, methods of connecting and supporting different forms of pipework with respect to access and vibration, mains layouts – methods of isolating, draining (including slope) and 'take off' arrangements, the costs associated with air leaks, service units – filters, pressure regulators and lubricators

Steam: hazards, heat transfer principles and the applications to heat exchangers, calculation of heat flows (temperature difference x surface area x heat transfer coefficient), heat content of steam, relationships between pressure and temperature (use of steam tables), types of steam and applications (saturated, dry saturated, superheated)

Pipework and systems – steam: materials and applications, connecting methods for HP and LP systems, flanged joints (screwed and welded), pipe support systems to allow for expansion and vibration, jointing materials (fibre based, corrugated metallic and spiral wound), lagging and insulation, causes and prevention of water hammer, drainage methods, manual cocks and steam traps, functions and main features of drain coolers, condensers and condensate return systems, types and main features of steam valves used for (system isolation and safety, pressure reduction and control, flow control), uses of LP and exhaust steam for fan heaters, calorifiers and economisers

Electricity: meaning of common electrical terms and state their units and relationships as applicable (voltage, current and resistance [Ohm's law], power, voltage and current [relationship between electrical and mechanical power], heating and magnetic effects, a.c. and d.c. voltages differences and applications)

Electrical systems: electrical supply systems and their applications and limitations (supply from grid, 3 phase 4 wire, single phase, 12V and 24V requirements and uses), types and uses of transformers (fixed and portable), isolating and control methods (isolators and circuit breakers, switchgear and distribution panels, fuses, no-volt release and residual current detectors), methods of electrical distribution, their applications and limitations (cable forms and selection [size, insulation, including IMS and screened], cable protection methods including conduit and armoured, bus bars, extension reels [heating effects on coiled cable]), meters for testing continuity, voltage and resistance

Unit 318 Maintenance of utility systems

Outcome 2 Be able to prepare for maintenance of utility systems

Assessment Criteria

The learner can:

1. evaluate type and extent of work to be carried out
2. develop a **plan** that includes assessing any risks, securing the area and isolating equipment
3. estimate the **tools, materials, equipment and information** that will be needed
4. set-up to carry out the maintenance activity

Range

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system, procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination, fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Additional Guidance

Plan: to include- emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system (isolating switches, removal of fuses, closing and 'locking off' of valves, removal of valves and blanking of pipes) procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination (including any special Personal Protective Equipment (PPE) such as breathing apparatus), fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Tools, materials, equipment and information: specific implications of statutory regulations, codes of practice related to installing or maintaining systems, special considerations as prescribed by the manufacturer

Unit 318 Maintenance of utility systems

Outcome 3 Be able to perform inspections and maintenance tasks

Assessment Criteria

The learner can:

1. perform **dismantling and assembling** operations to ensure effective operation on completion
2. perform **inspections** of components and draw conclusions regarding its repair or replacement

Range

Dismantling and assembling: to allow for reassembly, identification of parts (layout of parts), reassemble in correct order for recommissioning of the system.

Testing of parts and system to establish effectiveness of repair/replacement.

Inspections: bearing surfaces, erosion and pitting, split or worn seals, signs of overheating (discolouration); condition of filters for: signs of metallic or other particles, indications of emulsions or oil deterioration, correctly labelling re-built components for replacement in a system or returning to stores, checking oil for signs of oxidation and acidity, bench testing re-assembled components, pressure testing pipework and pressure vessels, presenting information that can be used to appraise the outcome of a maintenance or installation activity, methods of testing electrical equipment/circuitry for insulation and continuity

Additional Guidance

Dismantling and assembling: make identification (witness) marks on components so that they can be correctly reassembled/re-aligned, label and safely store parts that have been removed methods used to avoid distortion and damage to, or leakage from, pipework (disconnecting, aligning, connecting), precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from: misalignment, use of wrong tools, excessive force, uncontrolled release of springs, scoring of surfaces; protection of dismantled components from contamination (blanking off open ports, use of correct cleaning agents and lint-free cloths), sequence for tightening bolts and applying specified torque, application of lubrication to seals, precautions to be taken when refilling systems with specified oils, methods of safely bleeding systems to eliminate air locks and avoid spillage, how to remove; fit and replace: bearings, seals, springs, circlips, keys, brushes; prepare or make new gaskets or joints (including preparation of surfaces and/or housings) and repack glands

Unit 318 Maintenance of utility systems

Outcome 4 Be able to reinstate utility systems

Assessment Criteria

The learner can:

1. perform **re-commissioning** operations to brings system on-line and adjust as required until the working requirements have been fully met
2. **restore work areas** to a clean and safe condition on completion of maintenance and re-commissioning

Range

Re-commissioning: bring system back on-line and test/trial run to establish full functionality

Additional Guidance

Re-commissioning: refilling or recharging systems, opening up the system to the sources of pressure, methods to safely drain, bleed and purge systems to avoid undue leakage or contamination, set up and test interlocks, sensors and limit switches, sequence of bringing systems back to the specified working conditions (removal of protective covers and blanks, opening appropriate valves or switches, operating the system under gradually increasing pressures or loads, state the methods of securing pipework and safety fittings (guards, handrails), methods of replacing insulation, lagging and other protective coverings, applying identification markings to different parts of a system (colour identification of pipework to BS 1710, using appropriate and approved codings for electrical connections and components)

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 319 Maintenance of plant services

Level: **3**
Credit value: **9**
UAN: **H/503/0384**

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the maintenance and/or installation requirements of systems commonly used in industrial plant and premises. These include heating and ventilation, fresh water and waste, low water systems, fuel and gas storage and distribution.

The unit will cover system layouts and their main components, the selection and use of appropriate tools and equipment, the procedures and techniques involved with safely isolating systems, removing and replacing components and restoring a system back to a full working condition.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand the function of plant services
2. Be able to prepare for maintenance of plant services
3. Be able to perform inspections and maintenance tasks
4. Be able to reinstate plant services

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Engineering Maintenance; Unit 43: Carry Out Planned Maintenance on Service Systems and Equipment

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 319 Maintenance of plant services

Outcome 1 Understand the function of plant services

Assessment Criteria

The learner can:

1. describe the difference between the cold, **hot and process water supply and disposal methods**
2. explain the properties and requirements of **fuel oil systems**
3. explain the properties and requirements of **gases and supply systems**
4. explain the principles of **heating and ventilating systems**

Range

Hot and process water supply and disposal methods: nature of water and the treatments required, storage requirements and methods – including cleansing and testing services, types of water pump, types of valve, pressure control including relief, flow control, pipework requirements, heat exchangers, water sprinkler systems, detector types and testing, storage and settling tanks, arrangements for the disposal of clean and contaminated waters, toxic liquid waste

Fuel oil systems: fuel characteristics and combustion principles, precautions when storing, handling and supplying fuels, types of fuel pump, types of valve, pressure control, flow control, pipework requirements, identification, protection – lagging and tracing

Gases and supply systems: gases for fuel and processing applications storage methods and requirements, safe practices for filling and distribution, procedures for evacuating pipework and disposal of contents removed according to current legislation, methods of testing for gas presence and leaks, procedures to be followed when detected gas levels are unsafe, line purging and pressure testing techniques, types of valve used for plant and services equipment

Heating and ventilating systems: the requirements for acceptable habitability, recommended number of air changes, the relationships between air velocity, ducting area and volume of air delivered using simple calculations or data tables, 'U' values of common construction materials, factors affecting pressure drops and losses in a system; factors affecting pressure drops and losses in a system; specific heat values for air and water and steam; sources of heat into an area, heating and ventilating components and their symbols according to current BS and ISO standards, circulating pumps, heating and cooling units components, fans [centrifugal and axial], the effect of fan speed and power needed for different airflow rates, filtration units, large particle extraction, methods of mounting and fixing; types of pipework and ducting; layouts of hot water central heating systems, layouts of single and double duct systems, monitoring and control of, automatic recorders for the analysis of system operation and efficiency

Additional Guidance

Hot and process water supply and disposal methods: nature of water and the treatments required (acidic and alkaline – corrosive effects, dissolved solids – effects and softening processes, bacterial content and treatment, un-dissolved solids – erosion), storage requirements and methods – including cleansing and testing services, types of water pump (positive displacement, centrifugal), types of valve (isolating [gate and screw down], pressure control including relief, flow control), pipework requirements (materials, joining methods and fittings by means of flanged and screwed connectors, the use of elbows and tee pieces, identification [to BS 1710], identification and protection – lagging and tracing), heat exchangers (single and multi-pass, calorifiers), water sprinkler systems, detector types and testing, storage and settling tanks, arrangements for the disposal of: clean and contaminated waters, toxic liquid waste

Fuel oil systems: fuel characteristics and combustion principles (air/fuel mixture, flammability and exclusivity, viscosity and flow characteristics, light and heavy types, applications), precautions when storing, handling and supplying fuels (types of tank and content measuring methods, need for barrier walls and spillage trenches, isolating and emergency procedure, warning and information signs and notices), types of fuel pump (positive displacement, centrifugal), types of valve (isolating [gate and screw down], pressure control, flow control), pipework requirements (materials, joining methods and fittings (elbows, 'Y' pieces, tee pieces), identification (to BS 1710), protection – lagging and tracing

Gases and supply systems: gases for fuel and processing applications (propane, acetylene, oxygen, ammonia, nitrogen, argon) storage methods and requirements (identification of cylinders and lines, ventilation, flame proof switches, securing cylinders, security of access), safe practices for filling and distribution, procedures for evacuating pipework and disposal of contents removed according to current legislation, methods of testing for gas presence and leaks, procedures to be followed when detected gas levels are unsafe, line purging and pressure testing techniques, types of valve used for plant and services equipment (isolating [gate and screw down], pressure control, flow control)

Heating and ventilating systems: the requirements for acceptable habitability in terms of temperatures, humidity, airborne particles, fumes, odours and bacterial content; recommended number of air changes for welding shops, general workshops, office blocks, stores and warehouses; the relationships between air velocity, ducting area and volume of air delivered using simple calculations or data tables, 'U' values of common construction materials - wood, bricks, concrete, insulation; factors affecting pressure drops and losses in a system; factors affecting pressure drops and losses in a system; specific heat values for air and water and steam; sources of heat into an area (external from solar radiation, internal from electrical equipment and occupants); heating and ventilating components and their symbols according to current BS and ISO standards (changeover, bypass and isolating valves and their methods of actuation [manual, mechanical, electrical], circulating pumps, heating and cooling units components [including drainage systems], fans [centrifugal and axial], the effect of fan speed and power needed for different airflow rates, filtration units, large particle extraction [wood chips and similar particulates]; methods of mounting and fixing; types of pipework and ducting (materials for construction and insulation, flange connecting methods, noise reduction baffles); layouts of hot water central heating systems, layouts of single and double duct systems [with heater and cooler elements, etc]; monitoring and control of systems (from a central control point, local sensors and overrides, testing of cooling water sources for bacterial content (legionella), automatic recorders for the analysis of system operation and efficiency

Unit 319 Maintenance of plant services

Outcome 2 Be able to prepare for maintenance of plant services

Assessment Criteria

The learner can:

1. evaluate type and extent of work to be carried out
2. develop a **plan** that includes assessing any risks, securing the area and isolating equipment
3. estimate the **tools, materials, equipment and information required**
4. set-up to carry out the maintenance activity

Range

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system, procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination, fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Additional Guidance

Plan: to include- emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system (isolating switches, removal of fuses, closing and 'locking off' of valves, removal of valves and blanking of pipes) procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination (including any special Personal Protective Equipment (PPE) such as breathing apparatus), fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Tools, materials, equipment and information: specific implications of statutory regulations, codes of practice related to installing or maintaining systems, special considerations as prescribed by the manufacturer

Unit 319 Maintenance of plant services

Outcome 3 Be able to perform inspections and maintenance tasks

Assessment Criteria

The learner can:

1. perform **dismantling and assembling** operations to ensure effective operation on completion
2. perform **inspections** of components and draw conclusions regarding its repair or replacement

Range

Dismantling and assembling: to allow for reassembly, identification of parts (layout of parts), reassemble in correct order for recommissioning of the system.

Testing of parts and system to establish effectiveness of repair/replacement.

Additional Guidance

Dismantling and assembling: make identification (witness) marks on components so that they can be correctly reassembled/re-aligned, label and safely store parts that have been removed methods used to avoid distortion and damage to, or leakage from, pipework (disconnecting, aligning, connecting), precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from: misalignment, use of wrong tools, excessive force, uncontrolled release of springs, scoring of surfaces; protection of dismantled components from contamination (blanking off open ports, use of correct cleaning agents and lint-free cloths), sequence for tightening bolts and applying specified torque, application of lubrication to seals, precautions to be taken when refilling systems with specified oils, methods of safely bleeding systems to eliminate air locks and avoid spillage, how to remove; fit and replace: bearings, seals, springs, circlips, keys, brushes; prepare or make new gaskets or joints (including preparation of surfaces and/or housings) and repack glands

Inspections: bearing surfaces, erosion and pitting, split or worn seals, signs of overheating (discolouration); condition of filters for: signs of metallic or other particles, indications of emulsions or oil deterioration, correctly labelling re-built components for replacement in a system or returning to stores, checking oil for signs of oxidation and acidity, bench testing re-assembled components, pressure testing pipework and pressure vessels, presenting information that can be used to appraise the outcome of a maintenance or installation activity

Unit 319 Maintenance of plant services

Outcome 4 Be able to reinstate plant services

Assessment Criteria

The learner can:

1. perform **re-commissioning** operations to brings system on-line and adjust as required until the working requirements have been fully met
2. **restore work areas** to a clean and safe condition on completion of maintenance and re-commissioning

Range

Re-commissioning: bring system back on-line and test/trial run to establish full functionality

Additional guidance

Re-commissioning: refilling or recharging systems, opening up the system to the sources of pressure, methods to safely drain, bleed and purge systems to avoid undue leakage or contamination, set up and test interlocks, sensors and limit switches, sequence of bringing systems back to the specified working conditions (removal of protective covers and blanks, opening appropriate valves or switches, operating the system under gradually increasing pressures or loads, state the methods of securing pipework and safety fittings (guards, handrails), methods of replacing insulation, lagging and other protective coverings, applying identification markings to different parts of a system (colour identification of pipework to BS 1710, using appropriate and approved codings for electrical connections and components)

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 320 Maintenance of hydraulic systems

Level: **3**
Credit value: **9**
UAN: **T/503/0390**

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the maintenance and/or installation requirements of hydraulic power transmission systems. It involves identifying hydraulic components and their symbols and the interpretation of circuit diagrams. It also covers the procedures and techniques involved with isolating systems safely, the ability to install or rebuild circuits from given information, removing and replacing components in a circuit and restoring a system back to a full working condition it also covers causes of common faults in hydraulic systems.

When training rigs are used then a method of safely applying reasonable loads to fully test the operation of a circuit must be provided i.e. not simply that the specified actuator movements are obtained.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will be able to:

1. Understand the function of hydraulic systems
2. Be able to prepare for maintenance of hydraulic systems
3. Be able to perform inspections and maintenance tasks
4. Be able to reinstate hydraulic systems

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Engineering Maintenance; Unit 20: Maintaining Fluid Power Equipment; Unit 22: Testing Fluid Power Equipment and Systems

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 320 Maintenance of hydraulic systems

Outcome 1 Understand the function of hydraulic systems

Assessment Criteria

The learner can:

1. explain the relationships between force, pressure and area and carry out simple calculations
2. explain the reasons for pressure drops and losses in a system
3. explain the effect of fluid flow rate on actuator speed and power produced
4. explain the characteristics of **hydraulic fluids**
5. explain the function of **hydraulic components** and their current standard symbols
6. describe the difference between the **constructional features** of hydraulic components
7. explain the methods used for connecting pipework and hoses and how systems are installed to minimise pressure drops and flow restriction
8. describe the selection of components for particular purposes
9. explain the **relative positions of components** in a circuit
10. explain the possible causes of **common faults**

Range

Hydraulic fluids: viscosity, density and lubricity (including effects of temperature and aeration), flash point and fire resistant forms, purpose of oil additives, causes of deterioration of hydraulic oils, procedures for storing and handling of hydraulic fluids, potential hazards

Hydraulic components: pumps, gear types, vane types, actuators, rotary, non-return, pressure, auxiliary components

Constructional features: types of seals and their applications (static and dynamic), seal materials, compatibility and methods of assembly, methods of mounting and fixing valves and actuators, attachment of connectors and pipework

Relative positions of components: counterbalance, unloading and offloading, meter-in, meter-out and bleed off speed control, sequential operation

Common faults: slow, erratic and intermittent motion of actuators, lack of specified system pressure, cavitation, overheating of oil

Additional Guidance

Hydraulic fluids: viscosity, density and lubricity (including effects of temperature and aeration), flash point and fire resistant forms, purpose of oil additives, causes of deterioration of hydraulic oils (chemical changes due to oxidation overheating, contamination by suspended solids and moisture, incorrect storage conditions), procedures for storing and handling of hydraulic fluids, potential hazards (toxicity, harmful effects on skin)

Hydraulic components: BS 2917, ISO 1219-1; pumps (piston types [axial, radial and variable delivery – swash plate], gear types [internal and external], vane types [fixed and variable capacity]); actuators (linear – single acting, double acting, telescopic and differential [ram] type cylinders] uncushioned and cushioned forms], rotary – [hydraulic motors] piston and sliding vane types; valves and their methods of actuation [manual, mechanical, electrical and pilot] (rotary and spool directional control valves – 2/2, 3/2, 4/2, 5/2 and 4/3 [including all neutral position variants of 3 position types], non-return [plain and pilot operated], pressure control – pressure regulating and

relief [simple and compound], flow control – simple restrictors, uni-directional and pressure compensated types, modular [stacker] and cartridge valve assemblies, identification of valve ports using current systems [PABT and numeric]); auxiliary components (reservoirs, accumulators, pressure intensifiers, filters)

Unit 320 Maintenance of hydraulic systems

Outcome 2 Be able to prepare for maintenance of hydraulic systems

Assessment Criteria

The learner can:

1. evaluate type and extent of work to be carried out
2. develop a **plan** that includes assessing any risks, securing the area and isolating equipment
3. estimate the **tools, materials, equipment and information** that will be needed
4. set-up to carry out the maintenance activity

Range

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system, procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination, fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Additional Guidance

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system (isolating switches, removal of fuses, closing and 'locking off' of valves, removal of valves and blanking of pipes) procedures for de-pressurising systems and testing them to be in a safe condition (including reservoirs and storage vessels), procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination (including any special PPE such as breathing apparatus), fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Tools, materials, equipment and information: specific implications of statutory regulations, codes of practice related to installing or maintaining systems, special considerations as prescribed by the manufacturer

Unit 320 Maintenance of hydraulic systems

Outcome 3 Be able to perform inspections and maintenance tasks

Assessment Criteria

The learner can:

1. perform **dismantling and assembling** operations to ensure effective operation on completion
2. perform **inspections** of components and draw conclusions regarding its repair or replacement

Range

Dismantling and assembly: to allow for reassembly, identification of parts (layout of parts), reassemble in correct order for recommissioning of the system, Testing of parts and system to establish effectiveness of repair/replacement.

Additional Guidance

Dismantling and assembling: make identification (witness) marks on components so that they can be correctly reassembled/re-aligned, label and safely store parts that have been removed methods used to avoid distortion and damage to, or leakage from, pipework (disconnecting, aligning, connecting), precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from: misalignment, use of wrong tools, excessive force, uncontrolled release of springs, scoring of surfaces; protection of dismantled components from contamination (blanking off open ports, use of correct cleaning agents and lint-free cloths), sequence for tightening bolts and applying specified torque, application of lubrication to seals, precautions to be taken when refilling systems with hydraulic oil, methods of safely bleeding systems to eliminate air locks and avoid spillage, procedures for charging gas filled accumulators

Inspections: bearing surfaces, erosion and pitting (e.g. of gear teeth or vane edges), split or worn seals, signs of overheating (discolouration); condition of filters for: signs of metallic or other particles, indications of emulsions or oil deterioration, correctly labelling re-built components for replacement in a system or returning to stores, checking oil for signs of oxidation and acidity, bench testing re-assembled components, pressure testing pipework and pressure vessels, presenting information that can be used to appraise the outcome of a maintenance or installation activity

Unit 320 Maintenance of hydraulic systems

Outcome 4 Be able to reinstate hydraulic systems

Assessment Criteria

The learner can:

1. perform **re-commissioning** operations to bring system on-line and adjust as required until the working requirements have been fully met
2. **restore work areas** to a clean and safe condition on completion of maintenance and re-commissioning

Range

Re-commissioning: bring system back on-line and test/trial run to establish full functionality

Additional Guidance

Re-commissioning: refilling or recharging systems, opening up the system to the sources of pressure, methods to safely drain, bleed and purge systems to avoid undue leakage or contamination, set up and test interlocks, sensors and limit switches, sequence of bringing systems back to the specified working conditions (removal of protective covers and blanks, opening appropriate valves or switches, operating the system under gradually increasing pressures or loads, state the methods of securing pipework and safety fittings (guards, handrails), methods of replacing insulation, lagging and other protective coverings, applying identification markings to different parts of a system (colour identification of pipework to BS 1710, using appropriate and approved codings for electrical connections and components)

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 321 Maintenance of pneumatic systems

Level: 3
Credit value: 9
UAN: R/503/0395

Unit aim

This unit enables the leaner to develop the skills and the underlying process technology required for the maintenance and/or installation requirements of pneumatic power transmission systems.

It involves identifying pneumatic components and their symbols and the interpretation of circuit diagrams. It also covers the procedures and techniques involved with isolating systems safely, the ability to install or rebuild circuits from given information, removing and replacing components in a circuit and restoring a system back to a full working condition and causes of common faults in pneumatic systems.

When training rigs are used then a method of safely applying reasonable loads to fully test the operation of a circuit must be provided i.e. not simply that the specified actuator movements are obtained.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand the function of pneumatic systems
2. Be able to prepare for maintenance of pneumatic systems
3. Be able to perform inspections and maintenance tasks
4. Be able to reinstate pneumatic systems

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Engineering Maintenance; Unit 20: Maintaining Fluid Power Equipment; Unit 22: Testing Fluid Power Equipment and Systems

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 321 Maintenance of pneumatic systems

Outcome 1 Understand the function of pneumatic systems

Assessment Criteria

The learner can:

1. explain the relationships between force, pressure and area and carry out simple calculations
2. explain the use of nomograms for pipe selection
3. explain the reasons for **pressure drops** and losses in a system
4. explain the effect of fluid flow rate on actuator speed and power produced
5. explain the changes in energy throughout a system
6. explain the function of **pneumatic components** and their current standard symbols
7. describe the difference between the **constructional features** of pneumatic components
8. explain the methods used for **connecting pipework** and hoses and how systems are installed to minimise pressure drops and flow restriction
9. describe the selection of components for particular purposes
10. explain the **relative positions of components** in a circuit
11. explain the possible causes of **common faults**
12. explain the application of circuits with **electro pneumatic** operation

Range

Pressure drops: leaks, changes in temperature, venting, etc.

Pneumatic components: actuators, rotary, rotary and spool directional control valves, non-return, pressure control, simple restrictors and by-pass forms, two pressure and shuttle valves [OR and AND logic], quick exhaust, impulse generators, identification of valve ports using current systems; auxiliary components

Constructional features: types of seals and their applications (static and dynamic), seal materials, compatibility and methods of assembly, methods of mounting and fixing valves and actuators

Connecting pipework: attachment of connectors and pipework to components, types of pipework and connecting methods (rigid, flexible and push-in), factors for efficient and safe routing of pipes to minimise pressure drops and flow restriction

Relative positions of components: components needed for particular purposes and their relative positions in a circuit to obtain speed control and sequential operation, reasons for held (maintained) signals and methods of overcoming this problem for circuits requiring up to three group cascade layouts

Common faults: slow, erratic and intermittent motion of actuators, lack of specified system pressure

Electro pneumatic: types of sensor or contact (induction, magnetic, reed switches), relays, rotary switches; principles of programmable logic controllers (PLCs) using a 'black box' treatment only; basic the programming methods and the need for requiring feedback signals

Additional Guidance

Pneumatic components: BS 2917, ISO 1219-1: actuators (linear – single acting, double acting, telescopic and differential [ram] type cylinders] uncushioned and cushioned forms], rotary – [air motors] piston and sliding vane types; valves and their methods of actuation [manual, mechanical, electrical and pilot], rotary and spool directional control valves [including all neutral position variants of 5/3 position types], non-return [plain and pilot operated], pressure control – pressure regulating and relief, flow control – simple restrictors and by-pass forms, two pressure and shuttle valves [OR and AND logic], quick exhaust, impulse generators, identification of valve ports using current systems; auxiliary components (reservoirs, accumulators, pressure intensifiers, filters, silencers,)

Unit 321 Maintenance of pneumatic systems

Outcome 2 Be able to prepare for maintenance of pneumatic systems

Assessment Criteria

The learner can:

1. evaluate type and extent of work to be carried out
2. develop a **plan** that includes assessing any risks, securing the area and isolating equipment
3. estimate the **tools, materials, equipment and information** that will be needed
4. set-up to carry out the maintenance activity

Range

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system, procedures for de-pressurising systems and testing them to be in a safe condition, procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination, fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Additional Guidance

Plan: to include - emergency shut down and evacuation procedures for the work, methods of isolating the equipment or system (isolating switches, removal of fuses, closing and 'locking off' of valves, removal of valves and blanking of pipes) procedures for de-pressurising systems and testing them to be in a safe condition (including reservoirs and storage vessels), procedure for draining oil or other such substances and their safe and legitimate disposal, spillage and contamination (including any special Personal Protective equipment (PPE) such as breathing apparatus), fire, personal injury, disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts, working at heights and in confined spaces, electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations: methods of lifting, supporting, or otherwise making system components safe, how the work to be undertaken may interact with or affect other systems or production facilities

Tools, materials, equipment and information: specific implications of statutory regulations, codes of practice related to installing or maintaining systems, special considerations as prescribed by the manufacturer

Unit 321 Maintenance of pneumatic systems

Outcome 3 Be able to perform inspections and maintenance tasks

Assessment Criteria

The learner can:

1. perform **dismantling and assembling** operations to ensure effective operation on completion
2. perform **inspections** of components and draw conclusions regarding its repair or replacement

Range

Dismantling and assembling: to allow for reassembly, identification of parts (layout of parts), reassemble in correct order for recommissioning of the system, testing of parts and system to establish effectiveness of repair/replacement.

Additional Guidance

Dismantling and assembling: make identification (witness) marks on components so that they can be correctly reassembled/re-aligned, label and safely store parts that have been removed methods used to avoid distortion and damage to, or leakage from, pipework (disconnecting, aligning, connecting), precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from: misalignment, use of wrong tools, excessive force, uncontrolled release of springs, scoring of surfaces; protection of dismantled components from contamination (blanking off open ports, use of correct cleaning agents and lint-free cloths), sequence for tightening bolts and applying specified torque, application of lubrication to seals, precautions to be taken when refilling systems with hydraulic oil, methods of safely bleeding systems to eliminate air locks and avoid spillage, procedures for charging gas filled accumulators

Inspections: bearing surfaces, erosion and pitting (e.g. of gear teeth or vane edges), split or worn seals, signs of overheating (discolouration); condition of filters for: signs of metallic or other particles, indications of emulsions or oil deterioration, correctly labelling re-built components for replacement in a system or returning to stores, checking oil for signs of oxidation and acidity, bench testing re-assembled components, pressure testing pipework and pressure vessels, presenting information that can be used to appraise the outcome of a maintenance or installation activity

Unit 321 Maintenance of pneumatic systems

Outcome 4 Be able to reinstate pneumatic systems

Assessment Criteria

The learner can:

1. perform **re-commissioning** operations to brings system on-line and adjust as required until the working requirements have been fully met
2. **restore work areas** to a clean and safe condition on completion of maintenance and re-commissioning

Range

Re-commissioning: bring system back on-line and test/trial run to establish full functionality

Additional Guidance

Re-commissioning: refilling or recharging systems, opening up the system to the sources of pressure, methods to safely drain, bleed and purge systems to avoid undue leakage or contamination, set up and test interlocks, sensors and limit switches, sequence of bringing systems back to the specified working conditions (removal of protective covers and blanks, opening appropriate valves or switches, operating the system under gradually increasing pressures or loads, state the methods of securing pipework and safety fittings (guards, handrails), methods of replacing insulation, lagging and other protective coverings, applying identification markings to different parts of a system (colour identification of pipework to BS 1710, using appropriate and approved codings for electrical connections and components)

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 322 Power generation systems and ancillary equipment

Level: **3**
Credit value: **9**
UAN: **K/503/0435**

Unit aim
This unit is concerned with power generation and associated systems, in terms of: planning and preparation, components, carrying out inspections, maintenance and installation tasks and commissioning the system.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Be able to identify the components and features of utilities
2. Be able to plan and prepare for the maintenance or installation operation
3. Be able to carry out inspections and general maintenance tasks
4. Be able to commission or re-commission the system

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 322 Power generation systems and ancillary equipment

Outcome 1 Be able to identify the components and features of utilities

Assessment Criteria

The learner can:

1. identify the components and sub-systems needed for **power generation** units from drawings that use standard symbols
2. identify the **function of the essential components** needed for power generation plant or sub-systems
3. select **components** or equipment to meet specified functions in terms of required volumes (fuel, air and steam), pressures and temperatures using manufacturers' catalogues or other data

Range

Power generation: principles of combustion of hydrocarbon fuels and the products of combustion, need for the correct proportions of air and fuel for complete combustion, ways in which energy forms can be achieved (chemical to heat, heat to mechanical, kinetic to mechanical); principles and factors affecting heat transfer by conduction, convection and radiation, basic four stroke, two stroke cycle for spark, compression ignition (CI) systems, valve timing diagrams (for all types) defining lead, lag and overlap, ignition and combustion requirements [obtaining the correct air pressures and temperatures, uniform mixtures of air and fuel in the required proportions, effects of incorrect mixtures, use of pressure/volume and crank angle/pressure diagrams to show the stages in combustion process]

Function of the essential components: general layouts of the following types of engine: on-line, vee, methods of supplying air to IC engines, main features of electrical systems

Components : parts of cooling water supply systems, water treatment for preventing scaling, corrosion and freezing, relationship between pressure and boiling point and resultant danger, parts of lubricating systems, splash methods of lubricating cylinder walls and valve mechanisms, types of oil and grease used specifically for IC engines, starting methods for IC engines, general construction details of reciprocating IC engines, bearing types and application, ball and roller solid bush, split bearings, principles and construction of turbines, stages of a gas turbine engine and the associated components, compressor-blade materials, changes in air pressure and temperatures, compression chambers, power take off arrangements, control methods for safe and efficient running, dispersal methods for exhaust gases in accordance with current regulations and good practice, stages of steam turbines and the associated components, control nozzle arrangements, speed governing and overspeed trips, exhaust steam arrangements and condensers, materials used for different components and power units and the reasons for their selection, possible causes of corrosion in IC engines, possible causes of commonly observed symptoms related to IC engines

Additional Guidance

Function of the essential components: general layouts of the following types of engine (in-line, vee, engine capacity in terms of bore, stroke and number of cylinders, meaning of torque and its relationship with engines speed and power produced, factors affecting the efficiency of power generating systems, systems for supplying fuels to power units (from storage point to engine, by carburettors, venture, throttle control, main and idling jets, injection pumps, injectors [types and spray patterns] gas flow regulating valves]) methods of supplying air to IC engines (normally aspirated, under pressure [supercharged and turbo-charged[,construction and positioning of

chargers, need for correct operating procedures to avoid damage during start up and shut down, air filtration [wet and dry types]), main features of electrical systems (coil ignition and components-switch, coil, condensers, contact breakers, distributors, spark plug types, suppressors, magneto-rotating armature, rotating magnet, contact breakers and mechanisms, a.c. alternators and generators and including voltage regulators, d.c. batteries-checking of condition and recharging)

Components : parts of cooling water supply systems (closed circulation via heat exchangers [radiators], pump types, temperature control methods [thermostats], water treatment for preventing scaling, corrosion and freezing, relationship between pressure and boiling point and resultant dangers), parts of lubricating systems – (pressurised: pump types, filters, pressure control and warning systems, oil coolers), splash methods of lubricating cylinder walls and valve mechanisms, types of oil and grease (and additives) used specifically for IC engines, starting methods for IC engines (electric, compressed air, hydraulic, manual, starting aids, volatile gas injection, heater plugs, excess fuel [choke], decompression devices), general construction details of reciprocating IC engines (cylinder blocks and heads [use wet and dry liners], crankshafts and bearing arrangements, cam shafts and valve timing arrangements, piston assemblies [gudgeon pins and types of piston ring], bearing types and application, ball and roller solid bush, split bearings [white metalled and shell types], principles and construction of turbines (rotor and stator blade configurations, blade shapes-impulse and reaction types-multi staging, methods of attaching blades onto rotor discs, need to allow for expansion of gases and steamand gas), stages of a gas turbine engine and the associated components, compressor-blade materials, changes in air pressure and temperatures, compression chambers (materials, fuel injection and mixing arrangements [primary and secondary], internal and external combustion zones, blade materials, attachment methods [including shrouding], power take off arrangements (reduction gearing), control methods for safe and efficient running (acceleration control units, steady speed governors, overspeed and temperature trips, use of exhaust gases to preheat air inlet to combustion zones), dispersal methods for exhaust gases in accordance with current regulations and good practice, stages of steam turbines and the associated components, control nozzle arrangements), speed governing and overspeed trips, exhaust steam arrangements and condensers, materials used for different components and power units and the reasons for their selection, possible causes of corrosion in IC engines (cooling water, condensation, reactions with combustion products, requirements and checks needed for standard maintenance and installation routines associated with the components and systems listed, possible causes of commonly observed symptoms related to IC engines (smoke from exhaust, overheating, knocking or pinking, misfiring or loss of power, excessive consumption [of fuel or oil])

Unit 322 Power generation systems and ancillary equipment

Outcome 2 Be able to plan and prepare for the maintenance or installation operation

Assessment Criteria

The learner can:

1. evaluate the type and **extent of work** to be carried out
2. describe how **current legislation** and codes of practice relate to the given tasks
3. carry out a **risk assessment** by listing the procedures and requirements for setting up safe working conditions
4. select manufacturers information, related records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment required

Range

Extent of work: layout, function of components and operational features of the pneumatic system to be installed or maintained (special considerations as prescribed by the manufacturer, methods of lifting, supporting or otherwise making system components safe, work to be undertaken may interact with or affect other systems or production facilities)

Current legislation: specific implications of Statutory regulations, Codes of practice related to installing or maintaining steam generating systems, disposal of toxic waste and other substances as defined by COSHH and environmental protection acts, pressure systems and portable gas containers and working at heights and in confined areas legislation

Risk assessment: methods of isolating the equipment or system (isolating switches, removal of fuses, closing or locking off of valves, removal of valves and blanking of pipes, procedures for de-pressurising systems and testing them to be in a safe condition, procedures for draining oil and other substances and their safe and legitimate disposal, need for providing equipment to deal with spillage and contamination (including any special Personal Protective Equipment (PPE) such as breathing apparatus), fire and personal injury, emergency shut down and evacuation procedures for the work area

Unit 322 Power generation systems and ancillary equipment

Outcome 3 Be able to carry out inspections and general maintenance tasks

Assessment Criteria

The learner can:

1. carry out an **inspection**
2. **diagnose system faults and rectify components**
3. reassemble system following repair

Range

Inspection: on power generation equipment or system

Inspection: methods used to avoid distortion and damage to, or leakage from, pipework (disconnecting, aligning, connecting), precautions needed to safely and effectively dismantle components, make identification (witness)marks on components so they can be correctly re assembled or re-aligned, label and safely store parts that have been removed, precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from misalignment, use or wrong tools or excessive force, uncontrolled release of springs and scoring of surfaces; protect dismantled components from contamination (blanking off open ports, use of correct cleaning agents and lint free cloths)

Diagnose system faults and rectify components: rectify by repair or replace, essential points to be checked when inspecting pneumatic components (bearing surfaces, erosion and pitting, split or worn seals, signs of overheating (colour changes), condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration

Re-assembly: procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals, need for correctly labelling re-built components for replacement in a system or returning to stores, checking oil for signs for oxidation and acidity, bench testing re-assembled components, pressure testing pipework and pressure vessels, precautions to be taken when refilling systems with hydraulic oil, methods of safely bleeding systems to eliminate air locks and avoid spillage, procedures for charging gas filled accumulators, present information that can be used to appraise the outcome of a maintenance or installation activity

Unit 322 Power generation systems and ancillary equipment

Outcome 4 Be able to commission or re-commission the system

Assessment Criteria

The learner can:

1. bring the system **online and adjust** as required until the working parameters have been fully met
2. **restore the work area** to a clean and safe condition on completion of maintenance or installation
3. identify **hazardous substances** that may have been used or discovered during the work and give the approved method of disposal for each such substance
4. describe the reasons for **handing over** the system to the authorised persons
5. complete a report on the action taken.

Range

Online and adjust: precautions to be taken when refilling or recharging the systems and opening up the system to the sources of pressure, methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination, set up and test interlocks, sensors and limit switches, removal of protective covers and blanks, opening appropriate valves or switches, operating the system under gradually increasing pressure or loads

Hazardous substances: materials used that are classified as hazardous and those that can be recycle

Handing over: necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person, procedure for terminating any 'permits to work' that have been

Additional Guidance

Restore the work area: methods of securing pipework and safety fittings (guards, handrails), methods of replacing insulation, lagging or other protective coverings, identification markings to different parts of a system: colour identification of pipework to BS1710; using appropriate and approved codings for electrical connections and components

Unit 323 Machining materials by turning

Level: 3
Credit value: 9
UAN: T/503/0437

Unit aim

This unit is concerned with the underlying process of machine alignment and producing complex components whilst following safe working practices.

The unit is designed to enable leaners to carry out a full alignment test and record the results, produce internal and external tapers, measure angles and inspect with taper gauges, cut internal threads external multi start threads, form profiles and identify cutting tool shapes and describe the materials.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Be able to carry out alignment tests and machine to required dimensions
2. Be able to produce self-holding and quick release tapers
3. Be able to produce single and two start threads
4. Be able to differentiate between cutting methods

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1682 Level 3 – Mechanical Manufacturing Engineering; Unit 4: Setting Centre Lathes for Production and Unit 5: Machining Components using Centre Lathes

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 323 Machining materials by turning

Outcome 1 Be able to carry out alignment tests and machine to required dimensions

Assessment Criteria

The learner can:

1. perform **safety checks**
2. use inspection **equipment** to perform full **alignment tests**
3. explain the functions and layout of the **headstock** gearbox
4. **machine by turning** to required dimensions

Range

Safety checks: risk assessment, inspect equipment prior to test, lock-off system. re-instatement procedures, Personal Protective Equipment (PPE), manual handling, emergency stops, COSHH requirements (lubricants, cutting fluids, cleaning materials)

Equipment: mandrills (headstock, tailstock) dial test indicators (lever, plunger) precision levels (spirit [vee grooved base], square block), straight edge

Alignment tests: headstock, tailstock, bed, guideways, centres

Headstock: shafts, gear clusters, ratios, gear systems (shaft [drive, driven, lay], gears [straight, involute, rack], lubrication systems [drip, splash, pump]) system of lubrication, calculations (geometric gear progression [including produce graph], spindle speeds for each gear ratio)

Machining by turning: external, internal, faces, recesses, undercuts, between centres, parting off, drilling holes (centre drilling, pilot drilling, through holes, blind holes, flat bottom holes), reamed holes, bored holes, chamfers, parting off, knurling, types of chip produced (continuous [materials, prevention, hazards], discontinuous [materials]), relationship between feed rate and depth of cut and the effect on material removal rate

Unit 323 Machining materials by turning

Outcome 2 Be able to produce self-holding and quick release tapers

Assessment Criteria

The learner can:

1. use **workholding** devices when setting up for turning operations
2. perform turning operations to produce self-holding and quick-release **tapers** to BS EN ISO 286 and surface finish 1.6 μm
3. explain methods of **manufacture**
4. evaluate tapers using engineers' blue, measuring and gauging **inspection** techniques

Range

Workholding: between centres, faceplate, catch plates and carriers, collets, magnetic and pneumatic devices, mandrels, steadies, fixtures, spigots, bar feed, purpose

Tapers: morse, international, boring tools and holders, drills (twist, core), reaming (purpose, types [machine, chucking, taper], nomenclature, accessories [extension sockets, reduction sleeves, machine tapers, floating reamer])

Manufacture: form tool, compound slide, offset tailstock, taper turning attachment

Inspection: measure/gauge internal and external tapers (taper plug gauge, taper ring gauge), engineers' blue, gauge blocks, sine bar and surface table/plate

Additional Guidance

Workholding: between centres (centres and sleeves: dead, running, live) faceplate (hold work directly on plate, hold work via a fixture, balancing) catch plates and carriers, chucks (three jaw, hard jaws, soft jaws, four jaw [normal reverse, regular shapes, irregular shapes, balancing), collets (parallel, expanding), magnetic and pneumatic devices, mandrels (plain, expanding), steadies (fixed, travelling), fixtures, spigots, bar feed, purpose (locate workpiece, restrain workpiece against cutting forces)

Unit 323 Machining materials by turning

Outcome 3 Be able to produce single and two start threads

Assessment Criteria

The learner can:

1. identify different standard **thread forms**
2. perform **grinding** operations to produce cutting tools to match methods of thread cutting
3. perform **lathe setting** operations to produce internal and external threads
4. produce multi-start **threads** to medium fit specification
5. **evaluate** threads against the specification

Range

Thread forms: metric (course, fine, special) unified (course, fine) British Standard (whitworth, fine, B.A.) square, acme

Grinding: tool grinder, profile, high speed steel, stellite

Lathe setting: on centre, square using gauge, half included angle, pitch movement (compound slide, rotate spindle)

Threads: internal, external, cutting (plunge, half included angle, chasers), calculate depth of flank angle, sine bar gauge blocks, surface plate/table, precision balls, depth micrometer

Evaluate: three wire, thread measuring machine, shadow graph projector, thread profile gauge, contour gauge, thread measuring (effective diameter, major diameter, minor diameter)

Assessment Guidance

Thread should be retained to ensure that the thread is not produced with a die and finished with a die-nut.

Unit 323 Machining materials by turning

Outcome 4 Be able to differentiate between cutting methods

Assessment Criteria

The learner can:

1. describe **tool and tip shape**
2. perform calculations to determine the cutting speeds in relationship to **tool material** and **materia**l being cut
3. perform calculations to determine **cutting** speeds and feeds
4. describe form, oblique and orthogonal **cutting**
5. diagnose any **problems** encountered

Range

Tool and tip shapes: solid bits, brazed tips and inserts (disposable), indexable tip tool shapes (square, triangular, diamond, round), tool holding (clamp and cap screw, pin and wedge, pin and lever, screwed, single post, quick-change tool post, four way tool post)

Tool material: high speed steel, alloyed carbon steel, stellite, tungsten and ceramic carbides, diamond, temperature charges tool materials, tool geometry (clearance, rake [positive, negative]), chip breakers, tip tool colour coding

Materials: range of carbon steels, cast iron, aluminium, copper and copper alloys

calculations: speed formula, feed in millimetres per revolution, factors affecting choice of cutting speed (work material being cut, cutting tool material, type of cutting operation, surface finish required, type of cutting fluid), factors affecting choice of feed (finish required, rate of material removal, type of cutting tool material, power of machine, type of cutting operation)

Cutting: rake and clearance angles for form tool, cutting and feed forces (tangential, feed, back, calculate the forces acting on a cutting tool) types of cutting (oblique, orthogonal), types and properties of cutting fluid (aqueous, oil-type, chemical, synthetic, gases)

Problems: oversize/undersize components (tool wear, slackness in slides, deflection), inconsistency of product shape (deflection, clamping, stops, alignment of fixtures), vibration (condition of machine, tooling, set-up, speeds and feeds), surface damage to component (blunt tools, clamping)

Unit 324 Machining materials by milling

Level: 3
Credit value: 9
UAN: M/503/0436

Unit aim
This unit is concerned with the underlying process used in producing complex components whilst following safe working practices and using advanced milling operations to a high level of precision.

The unit is designed to enable leaners to set and operate a universal dividing head, carry out differential indexing, establish spindle speeds and feeds for individual operations, machine multiple faces in a single pass, mill straight and curved gears.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Be able to prepare for milling operation
2. Be able to machine components using a universal dividing head
3. Be able to machine components by reaming and boring
4. Be able to reinstate the work area

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1682 Level 3 – Mechanical Manufacturing Engineering; Unit 8: Setting Milling Machines for Production and Unit 9: Machining Components using Milling Machines

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 324 Machining materials by milling

Outcome 1 Be able to prepare for milling operation

Assessment Criteria

The learner can:

1. explain the range, type and capabilities of **milling machines** available
2. explain the **checks** required prior to machining
3. define cutting speed as relative speed between tool point and work surface
4. explain the factors affecting choice of **cutting speed**
5. define and calculate **feed rates**
6. critically compare the types and properties of **cutting fluid**
7. explain the **relationship between rotation of cutter and feed direction**
8. describe the range, setting, methods of use and characteristics of **workholding** methods and devices
9. explain the types and applications of **spindle held cutters**
10. explain the types and applications and methods of securing of **other cutters**
11. explain the **tool geometry** of milling cutter
12. explain the factors to be considered for **effective production of components**
13. explain the possible production **problems** encountered and possible remedies
14. perform milling machine set up to meet component and production specifications
15. perform relevant alignment checks and check machine for defects
16. produce a speeds and feeds table
17. set required speeds and feeds
18. prepare and mount cutting tools for complex milling operations

Range

Milling machines: horizontal, vertical, universal, construction, parts, applications, reasons for the choice of milling machine type; horizontal milling operations: milling flat surfaces (horizontal, vertical), production of slots, slitting thin plate, gang milling, straddle milling, cutting keyways, gear cutting; vertical milling operations: milling flat surfaces (horizontal, vertical), production of slots (tee, dovetail), sunk and recessed surfaces, keyway cutting, including woodruff

Checks: safety switches, interlock devices, emergency stops, guarding, alignment tests (table, vertical spindle/quill), operating and care procedures (methods of starting, stopping, including emergency stop procedure)

Cutting speed: work material being cut, cutting tool material, type of cutting operation, type of cutter, surface finish required, type of cutting fluid required, calculate cutting speeds for milling

Feed rates: cut/tooth, table feed rate (mm/min), calculate feed, formula (feed/tooth x number of teeth x rev/min); factors affecting choice of feed rate: finish required, rate of material removal (type of cutting tool material, power of machine), type of cutting operation being carried out, type of cutter; calculate feed rates for milling

Cutting fluid: types (aqueous, oil-type, chemical, synthetic), purpose (provision of lubrication at tool point, absorption and removal of heat from the cutting zone, maintaining clean cutting zone, washing away chips

Relationship between rotation of cutter and feed direction: up-cut milling, down-cut milling

Workholding: clamping work to machine table, machine vice, tilting table, sine table, rotary table, angle plate, vee blocks, dividing head [plain and universal] (methods of workholding, indexing calculations [simple, compound, differential and angular]), fixtures; purpose (locate workpiece, restrain workpiece against cutter forces); potential movement of the workpiece along and around the x, y, and z axes of the machine

Spindle held cutters: face mills, inserted blade

Other cutters: drills, parallel and taper shank, machine reamers, machine taps, boring tools

Tool geometry: factors affecting penetration of material by cutting edge (hardness of cutting tool material in relation to material being cut, sharpness of cutter, wedge form of cutter); angle of wedge shape and their function and terminology (rake angle: positive, negative, neutral), clearance angles; relationship between depth of cut and feed rate and effect on material removal rate

Effective production of components: correct sequence of machining operations to maximise production, eliminating unnecessary tool changes, eliminate unnecessary materials handling (fixtures, stops and guides), adjust parameters to improve quality and production efficiency

Problems: oversize/undersize products (tool wear, slackness in slides, deflection), inconsistency of product shape (deflection, clamping, stops, alignment of fixtures), vibration (condition of machine, tooling, set-up, speeds and feeds), surface damage of component (blunt tools, clamping), product schedules not being met

Unit 324 Machining materials by milling

Outcome 2 Be able to machine components using a universal dividing head

Assessment Criteria

The learner can:

1. select and set **workholding devices** square and central to cutter and set adjustable angle plate to prescribed angle
2. set-up **universal dividing head** for differential milling operations
3. perform **calculations** the indexing movement and gearing required
4. produce machined holes and slots around an external diameter
5. produce machined **gears** and cutter teeth around an external diameter
6. machine arcs and angles, to within specified dimensions and measure accuracy to ± 0.1mm, angular ± 1° and surface finish 1.6 μm
7. produce machined teeth on the peripheral of **bevelled blanks**
8. apply milling machine **equipment** to complex machining operations
9. apply **milling cutters** and perform complex machining operations to BS EN ISO286, angles ± 0.5° and surface finish 1.6 μm
10. perform **inspection** of components to determine the level of accuracy by measuring and gauging

Range

Workholding devices: rotary table (indexing, scales (rotary, vernier), swizzle vice, angle plate (fixed and adjustable), methods of securing and centralising work

Universal dividing head: 40:1

Calculations: simple and differential indexing

Gears: straight and curved teeth for gear wheels and teeth for cutters, straight, involute, splined hafts, serrated shafts

Bevelled blanks: end of shaft and/or bored

Equipment: tailstock, chuck, catch plate mandrel dial test indicator and base

Milling cutters: end mills, slot drills, angle cutters and drills

Inspection: external micrometers (0 -25, 25-50 and 50-150mm), internal micrometer, vernier callipers & protractor, surface texture gauges, gauge blocks, sine bar

Unit 324 Machining materials by milling

Outcome 3 Be able to machine components by reaming and boring

Assessment Criteria

The learner can:

1. set up **machines and equipment** to perform reaming and boring operations
2. check and reset machines **alignment**
3. apply **cutting tools** to complex machining operations
4. mount cutters prior to multi facet milling in a single pass
5. produce precision holes by boring and reaming to within H8
6. perform **inspection** of components to determine the level of accuracy by measuring and gauging

Range

Machines and equipment: vertical, horizontal, universal, off-set boring head

Alignment: table, spindle

Cutting tools: reamers (machine, chucking, stub, shell, boring heads)

Inspection: internal micrometer, depth micrometer, vernier callipers and protractor, surface texture gauges, gauges: plug, sine bar (construction, size, calculations)

Unit 324 Machining materials by milling

Outcome 4 Be able to reinstate the work area

Assessment Criteria

The learner can:

1. explain the health and safety and environmental legislations for waste disposal, and implications of not following legal requirements
2. explain the importance of **maintaining the safety and cleanliness** of machinery, tools equipment and the work area
3. explain the correct procedures for dealing with waste materials
4. explain the potential problems that may occur during restoring the work area and actions to be taken
5. explain the actions to be taken in the event of a **spillage**
6. **restore work area** after machining operations

Range

Maintaining the safety and cleanliness: isolate machines, manual cleaning, machine assisted cleaning, use and correct storing of cleaning agents, identify and label products, inspection of components, tools and equipment on the completion of work, sort items into reusable, rework and waste, clean and store Personal Protective Equipment (PPE)

Spillage: barriers and safety signs, use of personal protective equipment, aids to containment and prevention of spillage reaching watercourse, aides for cleaning, who should be notified

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 325 Machining materials by grinding

Level: 3
Credit value: 9
UAN: A/503/0438

Unit aim
This unit is concerned with the underlying process of producing high quality surface textures on a range of components by grinding whilst following safe working practices.

The unit is designed to enable leaners to carry out a range of surface grinding operations safely, carry out a range of cylindrical grinding operations both internally and externally, set and operate a tool and cutter grinding machine to re-grind milling cutters, lathe tools, test, inspect and replace abrasive wheels and carry out an inspection of surface texture.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Understand how to perform manufacturing operations safely on grinding machines
2. Be able to perform manufacturing operations to produce precision finishes using surface grinding
3. Be able to perform manufacturing operations to produce precision finishes using cylindrical grinding
4. Be able to perform tool and cutter grinding operations

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1682 Level 3 – Mechanical Manufacturing Engineering; Unit 22: Setting Grinding Machines for Production and Unit 23: Machining Components using Grinding Machines

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 325 Machining materials by grinding

Outcome 1 Understand how to perform manufacturing operations safely on grinding machines

Assessment Criteria

The learner can:

1. explain the **training requirements** for removal and changing of abrasive wheels
2. describe the methods of **inspection and testing** abrasive wheels for damage
3. explain the wheel **marking** system
4. explain the **characteristics** of abrasive wheels

Range

Training requirements: reference to Provision and Use of Work Equipment Regulations, appointed person responsibilities, mandatory signs, Personal Protective Equipment (PPE), guarding, manual handling

Inspection and testing: safety checks (wheel speed, spindle speed, visual, ring test), safety factors (centrifugal stress, operating stress [heat, mechanical]), machine checks (oil levels [wheelhead, workhead], lubrication points), ensure no end play in spindle, security of pipes and couplings, safety devices and interlocks are working, emergency stops, alignment , traverse stops are functional, guards in position and secure, type and care of cutting fluids (purpose: absorption and carry away heat from the cutting zone, rapid cooling, maintain clean cutting zone, flood contact zone, remove dust and particles), filtering system for the cutting fluid, dust extraction equipment (purpose and function, checking, removal of waste), care of grinding wheels

Marking: types (1, 2, 3, 4, 5, 6, 11, 12, 13, 27, 27A)abrasives (aluminium oxide, silicon carbide, cubic boron nitride [CBN]), grain size, grade, structure and bond, wheels larger than Ø80 mm (rpm, dimensions, specifications) wheels less than Ø80 mm (colour coded stripes, expiry date), factors affecting wheel selection (material to be ground, amount of material to be removed, arc/area of contact, type and condition of machine, wheel and work speeds, dry or wet cutting

Characteristics: cutting action, hazards (bursting wheel, flying particles, abrasive burns)

Unit 325 Machining materials by grinding

Outcome 2 Be able to perform manufacturing operations to produce precision finishes using surface grinding

Assessment Criteria

The learner can:

1. perform **surface grinding operations to produce precision flat and parallel surfaces**
2. use **workholding devices** when setting up for grinding operations
3. valuate the **dimensional accuracy** to BS EN ISO 286 and 0.2 μm surface texture
4. perform wheel **balancing**, truing and dressing operations
5. describe the possible **faults** in grinding wheels and ways of rectifying them

Range

Surface grinder: horizontal spindle, vertical spindle, need for dust extraction, feed systems, determination of wheel and work speeds, reason for 'sparkout', reasons for the 'warm up' period, settings

Workholding: magnet chuck,table, magnet blocks, double sided tape, direct clamping, vices, fixtures, purpose

Surface grinding: dry grinding, wet grinding, guards (wheel, table), machine movements and methods of setting (wheel, table)

Dimensional accuracy: co-ordinate measuring machine, micrometers (external) surface measuring machine and charts

Balancing: false spindle, balancing stand compound slide, dressing (diamond, stone)

Faults: wheel chatter, rough finish, wheel loading, short wheel life, effects of heat when grinding, possible problems and remedies

Additional Guidance

Surface grinder: horizontal spindle (reciprocating table, down feed and cross traverse, rotary table, down feed and cross traverse), vertical spindle (reciprocating table and down feed, rotary table and down feed), need for dust extraction, feed systems (table – reciprocating and cross, wheel), determination of wheel and work speeds, reason for 'sparkout', reasons for the 'warm up' period, settings (traverse stops, centres, rests, guides, control wheel)

Workholding: magnet chuck (truing of surface), table, magnet blocks, double sided tape, direct clamping, vices, fixtures, purpose (restrain workpiece against wheel force, locate workpiece)

Faults: wheel chatter (true wheel, increase feed, use softer grade) rough finish (finer grit wheel, use harder grade, increase work traverse) wheel loading (use coarser grit, dress wheel, increase work traverse), short wheel life, effects of heat when grinding (expansion/dimensional accuracy, overheating/wheel life and additional costs) possible problems and remedies (over and undersize components: wheel wear, slackness inslides deflection; inconsistency of component shape: deflecting and stops; vibration: condition of machine, set up, speeds and feeds; surface finish of component: wheel fault and clamping)

Unit 325 Machining materials by grinding

Outcome 3 Understand how to perform manufacturing operations safely on grinding machines

Assessment Criteria

The learner can:

1. perform external and internal grinding operations using a cylindrical grinder to produce precision parallel and tapered bores and shafts
2. use **workholding devices** when setting up for grinding operations
3. evaluate the **dimensional accuracy** to BS EN ISO 286 and 0.2 μm surface texture
4. perform wheel **mounting**, balancing, truing and dressing operations
5. **restore work areas** to a clean and safe condition on completion.

Range

Cylindrical grinder: machine parts, drive pin, face plate, table traverse stops, guarding, table, grinding fluids

Workholding: between centres, faceplate, carriers, chucks, collets, spigots

External and internal grinding: centralising, work setting, setting table traverse stops, steady rests, steady rest shoes, guarding, nomograms, effects of arc area contact

Dimensional accuracy: co-ordinate measuring machine, micrometers (external, internal) surface measuring machine and charts

Mounting: handling and storage of wheels, truing and dressing (fixed installation diamond, portable diamond), wheel balancing (parallel ways, overlapping discs), hub flanges, effects of an unbalanced wheel, function and construction of control wheel

Additional Guidance

Cylindrical grinder: machine parts (work head, tailstock, table, wheel head [external internal), feed systems (table, wheel head), drive pin, face plate, table traverse stops, guarding (external wheels, internal wheels), table, grinding fluids (cooling, chip and dust removal, non-corrosive, supply [pump, flow control, filtration])

External and internal grinding: centralising (work head, tailstock), work setting (between centres, three jaw self centring chuck), setting table traverse stops, steady rests, steady rest shoes, guarding (external wheels, internal wheels, table), nomograms (work head speed, table traverse speed), effects of arc area contact

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled

Unit 325 Machining materials by grinding

Outcome 4 Be able to perform tool and cutter grinding operations

Assessment Criteria

The learner can:

1. perform safe operation of **tool and cutter grinders** to re-grind lathe tools and milling cutters
2. explain the **tool geometry** nomenclature for lathe tools and milling cutters
3. **calculate** the off set for different angles

Range

Tool and cutter grinders: machine parts (wheel head, cutter head, stub arbor, setting gauge, centres tailstock, tool rest), wheel dressing (off-hand), principle parts (grinding wheel, tooth rest blade), directional movements (work), types of feed (how feed is accomplished)

Tool geometry: range of lathe tools and milling cutter, collet held and arbour mounted, methods of grinding (milling cutters, linear setting, angular setting) clearance angles (primary, secondary), addition equipment: gauges, tooth rest, and cutter heads/collets

Calculate: linear setting to obtain clearance angle

Unit 326 CNC machining of materials

Level: 3
Credit value: 9
UAN: D/503/0416

Unit aim

This unit enables the leaner to develop the skills and knowledge necessary to successfully machine by Computer Numerical Control (CNC), it includes part-programming, preparation of the machine, selection and the preparing of the required methods of workholding, the selection and the correct mounting of tooling.

It also covers the operations required and safe working practices to complete the machining operations.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Be able to produce CNC part-programs
2. Be able to set-up CNC machine tools
3. Be able to produce parts using CNC machine tools
4. Be able to reinstate the work area

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1682 Level 3 – Mechanical Manufacturing Engineering; Unit 30: Loading and Proving NC/CNC Machine Tool Programs; Unit 31: Carry Out NC/CNC Machine Tool Programming; Unit 32: Setting NC/CNC Turning Machines for Production; Unit 34: Setting NC/CNC Milling Machines for Production; Unit 33: Machining Components using NC/CNC Turning Machines; Unit 35: Machining Components using NC/CNC Milling Machines

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 326 CNC machining of materials

Outcome 1 Be able to produce CNC part-programs

Assessment Criteria

The learner can:

1. interpret engineering component drawings to determine CNC part-programming requirements
2. explain the principles of computer numerical control as the control of machine movements and management functions through coded instructions
3. explain the **types of program format**
4. explain the meaning of the **part programming terms**
5. select a suitable datum to the component to be machined
6. describe the factors to be considered when **planning** a part program
7. produce tables of co-ordinate dimension taken from specified datum positions in the form of **part program** operation sheets
8. produce an **instruction set** to machine and engineering component to size
9. explain **tool geometry** requirements for effective material removal
10. calculate **speeds and feeds** for CNC machine tools
11. explain the importance of modifying feed rates when profiling internal and external radii
12. explain the constant surface speed mode for turning operations
13. explain the benefits of using tool nose radius compensation for turning operations
14. explain circular interpolation and arc programming commands
15. apply **trigonometry** to calculate component cutter path co-ordinates
16. describe different programming formats including ISO word address and other formats used by Fanuc, Heidenhain and other controllers
17. describe word address, conversational and graphical programming

Range

Types of program format: fixed sequence/block, word address

Part-programming terms: character, word, block, modal and non-modal functions

Planning: component material, dimensions and tolerances, required surface finish, appropriate datum settings, roughing and finishing operations, grouping of similar operations, relevant canned cycles, loops, macros and subroutines, workholding methods to give accurate location and secure (CNC milling: direct clamping, vices, fixtures, devices modified for CNC operations; CNC turning: three jaw chucks, including the use of soft jaws, four jaw chucks, collets)

Part program: work material, work datum position, workholding requirements, tooling requirements including pre-setting data, sequence of operations, miscellaneous functions

Instruction set: factors to be considered when planning safe tool paths to ensure: operator safety, collisions with component and workholding equipment are avoided, safe work and tool changing positions are specified, defined areas to prevent collisions, cutter diameter compensation for milling operations, assigned canned cycles, user-defined canned cycles, translation and transformation commands for: mirror imaging, rotation, scaling, datum offset; canned cycles for turning operations

Tool geometry: milling cutters, turning tools, characteristics and applications, principles of mounting/clamping systems

Speeds and feeds: spindle speed (define cutting speed as relative linear speed between work surface and tool point, use cutting tool manufacturers data for work/tool combinations allowing for: type of cutting operation, surface finish requirements, use of coolant); feed rate (define feed rate as distance moved per minute (mm/min) or distance moved per revolution (mm/rev), use of manufacturers feed rate data allowing for: type of cutting operation, surface finish requirements, cutting tool geometry, work/tool material combinations, delicacy of work piece and workholding method

Trigonometry: Pythagoras' theorem, trigonometric ratios, sine rule

Additional Guidance

Part program: work material, work datum position, workholding requirements, tooling requirements including pre-setting data, sequence of operations [part program] (X, Y, Z, dimensional information, machine management information [preparatory functions: rapid movement, time dwell, zero shift, feed rates, absolute/incremental dimensions, inch/metric units]; miscellaneous functions [end of program, spindle forward/reverse, tool change, coolant on/off]; speeds and feeds; tooling requirements)

Instruction set: factors to be considered when planning safe tool paths to ensure: operator safety, collisions with component and workholding equipment are avoided, safe work and tool changing positions are specified, defined areas to prevent collisions (safe zone, warning zone, prohibited zone); cutter diameter compensation for milling operations, assigned canned cycles (role and benefits; milling: circular interpolation, rectangular/circular pocket milling, slot mill; drilling: drill, drill and dwell, deep hole drilling); user-defined canned cycles (role and benefits; loops, macros, subroutines); translation and transformation commands for: mirror imaging, rotation, scaling, datum offset; canned cycles for turning operations (stock removal in turning, stock removal in facing, thread cutting, peck drilling in Z axis)

Unit 326 CNC machining of materials

Outcome 2 Be able to set-up CNC machine tools

Assessment Criteria

The learner can:

1. use the precautions to be taken to prevent accidents when setting and operating CNC machines
2. explain the potential hazards when setting and operating CNC machines input part-program
3. **input data** to CNC machine controls
4. check that guards, interlocking devices and fail safe mechanisms are operating
5. set work datums and tool length offset values
6. describe the characteristics of preset and qualified tooling
7. describe the advantages of performing a **trial run**

Range

Input data: manual data input, portable systems, direct computer link, via data storage devices

Trial run: (dummy run) finding any unwanted rapid tool movements, make adjustments to speeds and feeds, adjustments to compensate for errors, reduce unnecessary tool movements, rearrange the machining sequence; methods of editing the part program: manual data input (MDI), off line using a text editor

Unit 326 CNC machining of materials

Outcome 3 Be able to produce CNC part-programs

Assessment Criteria

The learner can:

1. produce block diagrams showing the elements of open and closed loop control systems
2. produce line diagrams to identify primary and secondary **axes of motion** for vertical and horizontal spindle CNC machines indicating positive and negative movement
3. compare work and tool holding/changing systems on CNC machine tools
4. explain the principles of **tooling** systems, libraries and monitoring
5. explain the function of **workholding and setting devices** used on CNC machine tools
6. explain the **construction and operation** of CNC machine tools and recognise the importance to accurate performance in milling and turning
7. explain problems of **swarf removal** and the methods used to overcome them
8. differentiate between different types of **machine control** and the application to which they are suited
9. use the precautions to be taken to prevent accidents when setting and operating CNC machines
10. explain the potential **hazards** when setting and operating CNC machines input part-program
11. check that, guards, interlocking devices and fail safe mechanisms are operating
12. prove part programs to check for program errors and edit to achieve optimum production performance
13. explain the importance of **optimising production** during program proving
14. produce suitable components to required specifications
15. inspect finished component against specifications

Range

Axes of motion: X Y and Z conventions used for primary axis motion for various CNC machine configurations; U V and W conventions used for secondary axis motion for various CNC machine configurations; A B and C conventions used for rotation about the primary axes

Tooling: systems: preset, qualified, modular cutting unit, tool adapter; libraries: tool identification, geometry, offset values, speed, feed and tool life data; monitoring: sensing devices and electronic probes – tool life and cutting conditions, tool breakage detection, tool offset measurements, tool identification, torque variations, acoustic emissions

Workholding and setting devices: conventional workholding devices modified to suit CNC operation; positioning work datum relative to machine datum, the need for zero shift controls and how they are used, the use of air and hydraulic workholding devices for gripping delicate components; methods of setting workholding devices accurately relative to machine slide movements

Construction and operation: structural requirements: strength, rigidity, vibration damping; correct alignment, feedback transducers, re-circulating ball and leadscrew; operating principles of linear and rotary transducers used in CNC systems, differences between open and closed loop control systems (positional feedback, drive method)

Swarf removal: volume produced, conveyor systems, slant bed design, cutting fluid reclamation

Machine control: typse: point to point control, linear (paraxial) control, continuous path control; applications: point to point drilling and tapping operations, linear profiles and slots, curved profiles and slots

Hazards: tool collisions, swarf/chips, rapid movement of machine parts and tooling, entrapment, etc.; avoidance using machine over-ride controls, hazards when using the constant surface speed function on CNC lathes, location and function of emergency stop and program stop controls, guards, interlocking devices and fail safe mechanisms

Optimising production: adjusting speeds and feeds to give maximum metal removal rates considering: surface finish requirements, tool life requirements; reducing unnecessary tool movements; rearranging the machining sequence; adjustments to compensate for errors and tool wear (tool offsets and length offset values, cutter radius/diameter compensation)

Unit 326 CNC machining of materials

Outcome 4 Be able to reinstate the work area

Assessment Criteria

The learner can:

1. **restore the work area** to agreed requirements
2. describe the difference between waste and reusable or recyclable materials
3. explain the actions to be taken in the event of a **spillage**

Range

Waste and reusable or recyclable materials: types of waste produced, storage and waste removal, disposal methods (recycling, solid waste, liquid waste)

Spillage: barriers and safety signs, use of Personal Protection Equipment (PPE), aids to containment and prevention of spillage reaching the watercourse, aides for cleaning, who should be notified

Additional Guidance

Restore the work area: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identifying and recording finished work, manual cleaning machine tools, machine assisted cleaning, use and storage of cleaning agents, labelling/identifying products, inspecting components, tools and equipment on completion of work, cleaning and storing personal protection equipment

Unit 327 Detailed fitting of materials

Level: 3
Credit value: 9
UAN: M/503/0419

Unit aim
This unit enables the leaner to develop the skills and knowledge that are essential for detailed fitting being carried out safely and efficiently.

It includes the preparation of equipment, materials, service supplies, works areas, together with production and quality requirements.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Be able to determine tooling and equipment requirements
2. Be able to prepare to perform detailed fitting operations
3. Be able to perform detailed fitting operations
4. Be able to reinstate the work area

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1682 Level 3 – Mechanical Manufacturing Engineering; Unit 60: Producing Components using Hand Fitting Techniques

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 327 Detailed fitting of materials

Outcome 1 Be able to determine tooling and equipment requirements

Assessment Criteria

The learner can:

1. follow **safe working practices** and procedures when carrying out maintenance activities
2. explain the **hazards** associated with bench fitting activities
3. interpret information from **engineering drawings**
4. identify the **tools and equipment** required to undertake a bench fitting activity
5. describe the functions of **equipment and systems**
6. explain the **factors affecting accuracy**
7. explain the forces exerted on pins and keys

Range

Safe working practices: wearing appropriate protective clothing and equipment (overalls, safety footwear, eye protection, hearing protection, use of barrier cream), maintaining a clean and tidy work area, preparing the work area, leaving the work area in a safe and clean condition, risk assessments

Hazards: handling of coolants and cutting oils/compounds, misuses of tools, use of damaged or badly maintained tools

Engineering drawings: dimensional, geometrical, materials

Tools and equipment: marking out, hand tools, measuring instruments, gauges, dial test indicators, surface finish/texture, cutting and shaping, scrapers, levers and pullers, drills, taps, use of charts for selecting tapping sizes and dies, reamers, forms of power supply, powered hand tools, forming equipment, guillotines, folders

Equipment and systems: bearings, bushes and seals; shafts and couplings; pins and keys; power transmission and pulley mechanisms; fabrications and castings; gaskets; locking devices; springs; linkages/rollers

Factors affecting accuracy: environmental, equipment, human

Forces exerted on pins and keys: axial, radial, shear

Additional Guidance

Tools and equipment: marking out (scribers, scribing block, punches pin [centre and dot], surface plate/table, angle plate, parallels and vee blocks) hand tools (files, screwdrivers, hammers and mallets, spanners (open-ended, socket sets, ring, torque wrenches), measuring instruments (rules, inside and outside calipers, protractor, micrometers (external, depth), verniers (height gauge, protractor, callipers), gauges (feeler, blocks/slip, radius, thread) dial test indicators, surface finish/texture (comparison plates, tactile machines), cutting and shaping (saws [hand, mechanical], scrapers, levers and pullers, drills (high speed steel [HSS] carbide tips drill speed tables, cutting speed formula [cutting speed = $\pi dN/1000$]), taps (spiral flute, straight flute [taper, second, bottoming], use of charts for selecting tapping sizes) and dies (circular split, rectangular loose, solid die nut, pipe thread), reamers (hand, taper), forms of power supply (230V, 110V, pneumatic,

battery), powered hand tools (drills, screwdrivers, angle grinders, saws), forming equipment (bench folders, fly press), guillotines, folders

Equipment and systems: bearings, bushes and seals; shafts and couplings; pins and keys; power transmission and pulley mechanisms (gears, chains and sprockets, belts and pulleys); fabrications and castings; gaskets; locking devices; springs; linkages/rollers

Factors affecting accuracy: misalignment of work and measuring equipment, parallax error; affects of temperature variation upon: measuring, joining by co-efficient of expansion/contraction

Unit 327 Detailed fitting of materials

Outcome 2 Be able to prepare to perform detailed fitting operations

Assessment Criteria

The learner can:

1. explain the purpose of **workholding**
2. describe the different types and features of **machines**
3. explain the meaning and applications of different **threads**
4. explain the purpose of **reaming holes**
5. explain the purpose of **scraping**
6. explain the purpose of **shafts and plain bearings**
7. explain the type, construction and purpose of **ball and roller bearing systems**
8. identify the different **type of seals**
9. explain the purpose of **flanges**
10. explain the purpose of **gear assemblies**
11. explain the purpose of **transmission systems**
12. explain the type, construction and purpose of **cylinders/actuators and auxiliary components**
13. critically compare **types of pump** available
14. critically compare **types of valve** available
15. explain the type, construction and purpose of auxiliary components
16. prepare to produce assemblies by detailed fitting

Range

Workholding: locate work, restrain the forces exerted by the tool, workholding devices

Machines: bench/pillar drills, portable drills (mains operated, battery, pneumatic) grinding machines (bench, angle)

Threads: terms: pitch and lead, left and right hand threads, single and multi-start; applications: fastening device, transmit motion; manual methods cutting threads: internal taps, internal special taps and thread inserts, external dies, external solid die nuts

Reaming holes: parallel through, blind, tapered

Scraping: flat surfaces, bearings

Shafts and plain bearings: correct clearances, checking clearance, lubrication and methods of distribution

Ball and roller bearing systems: factors influencing cleanliness, classes of fit (inner race fits tightly on shaft, outer race slides into housing, inner and outer races both tightly fitting), types of self-alignment bearings, distinguish between thrust bearings designed to take: axial loads only, axial and radial loads; tools used for fitting ball and roller bearings (drifts, special spanners, extractors), inspecting bearings for faults (pitting, crazing, discolouration, assessment of the necessity for replacement); sealing bearing assemblies lubricated by grease or lubricating oils (felt and synthetic

rubber ring seals, minimum machined clearance between bearing housing and shaft, labyrinth seals)

Type of seals: metallic, non-metallic, combination of metallic and non-metallic; selection: applications, temperature and pressure, speed of moving parts, replacement period and corrosion

Flanges: faces clean and flat, checking 'O' rings or gaskets for size, shape and depth/condition of recesses, tightening flange bolts in the correct sequence

Gear assemblies: how to obtain: contact area of tooth surfaces, alignment of gear faces, tooth surface clearance; methods of obtaining positive clearance

Transmission systems: tensioning belt/pulley systems, tensioning chain/sprocket systems

Cylinders/actuators and auxiliary components: single acting, double acting, auxiliary components: reservoirs, accumulators, filters

Types of pump: gear, vane, piston

Types of valve: manual, mechanical, pilot, directional control values spool and rotary, non-return, pressure control, flow control

Unit 327 Detailed fitting of materials

Outcome 3 Be able to perform detailed fitting operations

Assessment Criteria

The learner can:

1. use **workholding** devices safely
2. use drilling and grinding machines to shape material safely
3. **sharpen tools by grinding**
4. produce and apply internal and external **threads** for engineering uses
5. produce **reamed holes**
6. apply **scraping** technique to flat surfaces and bearings
7. assemble **component parts and sub systems**
8. isolate equipment
9. check **accuracy of components** against specification

Range

Workholding: locate work, restrain the forces exerted by the tool, workholding devices

Sharpen tools by grinding: cold chisels, twist drills

Machines: bench/pillar drills, portable drills (mains operated, battery, pneumatic) grinding machines (bench, angle)

Threads: manual methods cutting threads: internal taps, internal special taps and thread inserts, external dies, external solid die nuts

Reamed holes: parallel through, blind, tapered

Scraping: flat surfaces, bearings

Component parts and sub systems

Shafts and bearings: methods of obtaining clearances by: filing, scraping, shimming; checking clearance: feeler gauges, dial test indicator (DTI), lead wire, lubrication

Ball and roller bearings: cleanliness: personal cleanliness hands, tools and work surfaces, cleaning journals and housings prior to fitting, retaining bearings in protective wrapping until required; methods of positioning by: pressing into the housing, tapping, heating and sliding onto the shaft, cooling; use tools for fitting ball and roller bearings, inspect bearings for faults, seal bearing assemblies lubricated by grease or lubricating oils

Seals: metallic, non-metallic, combination of metallic and non-metallic; selection: applications, temperature and pressure, speed of moving parts, replacement period and corrosion

Flanges: faces clean and flat, checking 'O' rings or gaskets for size, shape and depth/condition of recesses, tightening flange bolts in the correct sequence

Gear assemblies: contact area of tooth surfaces, alignment of gear faces, tooth surface clearance; methods of obtaining positive clearance by: increasing the centre distance between gears, reducing tooth profile one gear, reducing tooth thickness of both gears; fitting gears on shafts: press fit, push fit

Transmission systems: methods of tensioning belt/pulley systems, tensioning chain/sprocket systems

Cylinders/actuators: single acting, double acting

Pumps: gear, vane, piston, auxiliary components: reservoirs, accumulators, filters

Valves: methods of activation: manual, mechanical, pilot, directional control values spool and rotary, non-return, pressure control, flow control

Isolating equipment: removal of fuses from electrical prime movers, disconnect drive shaft, closing and locking-off valves, closing auxiliary supplies, drain down pipework

Accuracy of components: factors affecting accuracy: misalignment of work and measuring equipment, parallax error

Additional Guidance

Component parts and sub systems

Shafts and bearings: methods of obtaining clearances by: filing, scraping, shimming; checking clearance: feeler gauges, dial test indicator (DTI), lead wire, lubrication

Ball and roller bearings: cleanliness: personal cleanliness hands, tools and work surfaces, cleaning journals and housings prior to fitting, retaining bearings in protective wrapping until required; methods of positioning by: pressing into the housing, tapping, heating and sliding onto the shaft (oil bath or electrically), cooling; use tools for fitting ball and roller bearings (drifts, special spanners, extractors), inspect bearings for faults (pitting, crazing, discolouration, assessment of the necessity for replacement); seal bearing assemblies lubricated by grease or lubricating oils (felt and synthetic rubber ring seals, minimum machined clearance between bearing housing and shaft

Transmission systems: methods of tensioning belt/pulley systems (idler pulleys, adjustment of the centres between shafts, hinged mounted pulleys), tensioning chain/sprocket systems (idler wheel, adjustment of sprocket by set screws)

Unit 327 Detailed fitting of materials

Outcome 4 Be able to reinstate the work area

Assessment Criteria

The learner can:

1. **restore the work area** to agreed requirements
2. identify **waste and reusable or recyclable materials**
3. explain the actions to be taken in the event of a spillage

Range

Waste and reusable or recyclable materials: types of waste produced, storage and waste removal, disposal methods (recycling, solid waste, liquid waste)

Actions to be taken in the event of a spillage: barriers and safety signs, use of personal protection equipment, aids to containment and prevention of spillage reaching the watercourse, aides for cleaning, who should be notified

Additional Guidance

Restore the work area: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identifying and recording finished work, isolate machines, manual cleaning machine tools, machine assisted cleaning, use and storage of cleaning agents, labelling/identifying products, inspecting components, tools and equipment on completion of work, cleaning and storing Personal Protection Equipment (PPE)

Unit 328 Maintenance of electrical equipment and systems

Level: 3
Credit value: 9
UAN: H/503/0420

Unit aim
The unit is concerned with basic electrical theory and electrical components associated with the maintenance of electrical equipment.

The leaner will understand the operations necessary for the planning and carrying out of maintenance in an industrial and commercial environment.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Understand the components and features of electrical systems
2. Be able to plan and prepare for the maintenance operation
3. Be able to carry out monitoring and inspection of maintenance work
4. Be able to re-commission the system and restore the work area.

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1788 Level 3 – Engineering Maintenance: Unit 315: Carrying Out Preventative Planned Maintenance on Electrical Equipment

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 328 Maintenance of electrical equipment and systems

Outcome 1 Understand the components and features of electrical systems

Assessment Criteria

The learner can:

1. explain **electrical system components** and units in conjunction with system drawings
2. explain the **function of electrical components** and the way in which they can be assembled
3. identify **components and systems** to meet required functions

Range

Function of electrical components: electromagnets, magnetic materials, iInductors capacitors, electrolytic capacitors, discharge resistors, semi-conductor devices, diodes, thyristor and triac, half and full wave rectification, heat sinks, smoothing circuits, single thyristor circuits, transformers

Components and systems containment systems, Busbar systems, underfloor ducting, rising mains, steel wire armoured (SWA) and Mineral Insulated Copper cable (MICC), circuit breakers switches, fuses, isolators supply systems, earthing arrangements TT, TN-S, TN-C-S, lightning protection, no-volt releases, residual current devices. d.c machines ratings, insulation and enclosures. d.c. generators excitation and voltage control. d.c motors, series, shunt & compound, alternating current machines, types- induction and synchronous, construction-cylindrical and salient pole, power factor correction equipment,single phase motors, series universal, split phase induction start, capacitor start, capacitor start and run, motor starters and motor speed controllers test equipment, insulation resistance testers, low resistance ohmmeters, wattmeters, earth loop impedance and prospective short circuit testers tachometers and stroboscopes.

Unit 328 Maintenance of electrical equipment and systems

Outcome 2 Be able to plan and prepare for the maintenance operation

Assessment Criteria

The learner can:

1. evaluate the **extent of work** to be carried out
2. describe the current legislation and codes of practice relating to electrical equipment and systems
3. carry out a **risk assessment** by listing the procedures and requirements for setting up safe working conditions
4. analyse manufacturers' information, related work records, circuit diagrams and other necessary **data**
5. identify **tools and equipment**
6. prepare works orders or requisitions

Range

Extent of work: area, safety requirements, equipment, barriers and enclosures, notification of personnel and other workers, Personal Protective Equipment (PPE)

Legislation: Electricity at Work Regulations, IEE Wiring Regulations, GS 38

Risk assessment: method statements, safe isolation procedure, Permit to Work

Data: manufacturers data, catalogues, internet, component data sheets, availability and assemble of materials, company stores, wholesalers and component suppliers

Tools and equipment: hand and power tools, battery operated drills, safety checks

Unit 328 Maintenance of electrical equipment and systems

Outcome 3 Be able to carry out monitoring and inspection of maintenance work

Assessment Criteria

The learner can:

1. carry out **inspection**
2. conduct **diagnosis** and carry out repairs
3. complete maintenance record

Range

Inspection: on equipment or systems.
eg visual inspection of plant, cables and containment

Diagnosis and carry out repairs – on faulty system and/or components

eg faults to lighting, plant containment and other components. Motors and Generators, safe dismantling, recording of faults, install range of electrical systems. containment of oils and greases, protection and storage of parts, wear due to corrosion, erosion and pitting, worn seals, removal and fitting bearings, seals, springs, circlips, manufacture and fitting of gaskets, bench testing of components , maintenance records

Unit 328 Maintenance of electrical equipment and systems

Outcome 4 Be able to re-commission the system and restore the work area.

Assessment Criteria

The learner can:

1. **re commissions the system** and adjust as required to working parameters
2. **restore work area** to a clean and safe condition upon completion of maintenance
3. classify **hazardous substances** and the state the approved method of disposal
4. produce a **report** to record the actions taken during hand over.

Range

Re commission system: safety before re-energising, check all systems in place and re-set, prescribed start up procedures, electrical, mechanical and pneumatic/hydraulic checks

Hazardous substances: oils, greases, cleaning agents, solvents, insulation, adhesives, fillers, packing, lagging

Report: complete maintenance schedules, clear permits to work and sign off, diaries, materials used, record likely future requirements, update maintenance schedule, hand over to authorised personnel

Additional Guidance

Restore work area: Return reusable materials to store, clean & check tools, return tools to store/storage

Unit 329 Produce drawings using CAD

Level: **3**
Credit value: **9**
UAN: **M/503/0422**

Unit aim
This unit enables the leaner to develop the skills and knowledge in computer aided design (CAD), in terms of producing 2D and 3D drawings, including the use of 3D modelling methods.

Although most of the commands referred to are generic and would apply to all CAD systems, some terms may be specific to one particular application (eg AutoCAD). Where this is the case an equivalent alternative application commands may be appropriate.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Be able to set-up to produce CAD drawings
2. Be able to produce 2D CAD drawings
3. Be able to produce 3D CAD drawings
4. Be able to produce hard copies of CAD drawings

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
This unit is linked to the NVQ 1686 Level 3 – Engineering Technical Support; Unit 5: Producing Engineering Drawings/Models using 3D Computer Aided Techniques

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 329 Produce drawings using CAD

Outcome 1 Be able to set-up to produce CAD drawings

Assessment Criteria

The learner can:

1. explain the function of **hardware** components used for CAD which are unique to CAD
2. explain the function of **data input devices** used in CAD
3. explain the function of **data output devices** used in CAD
4. explain CAD **software requirements**
5. evaluate methods of **data storage** and make recommendations for their use
6. explain the reasons for backup files and saving drawings at regular intervals
7. describe the role of drawings in communicating technical information
8. critically **compare CAD** systems with manual draughting methods
9. explain the purpose of prototype drawings and how they are used
10. set drawing aids
11. create layers
12. set drawing limits to suit component dimensions
13. set suitable drawing parameters
14. use main menu drawing commands to produce a variety of different shapes
15. create, save and load a range of library drawings

Range

Hardware: effects of hardware specifications on efficiency of the system, processor type and speed, available RAM, video processor card, VDU resolution and screen size, size of hard disk drive

Data input devices: keyboard, mouse, digitising tablet and puck, light pen, scanning, touch pad, track ball, CAD functions (command input, cursor movement, selecting menu items, picking points)

Data output devices: VDU, printers, plotters, transfer data to a computer-aided manufacturing (CAM), principles of CAD/CAM

Software requirements: memory allocation, driving input and output devices, CAD software, graphics creation, manipulation, manipulation, editing, storage, user software, customising menus and parameter, symbols library, macros, applications software including: parts listing, costing, stress analysis; operating system functions: create directories (folders), organise the contents of directories, locate, copy, delete and rename files

Data storage: hard disk drive, CD ROM, CD RW, DVD ROM, DVD RW, USB storage devices, other storage media (eg. Internet), maintaining careful filing systems for manual reference and data storage (creation and maintenance of manual reference files for ease of access, index system for storage of disks), methods of restricting user access using passwords where required

Compare CAD: speed of drawing creation, checking and editing, ease of creating modified revisions, quality and consistency of finished drawing, memory facility, storage and retrieval of finished drawings, cost, compatibility with CAM systems

Unit 329 Produce drawings using CAD

Outcome 2 Be able to produce 2D CAD drawings

Assessment Criteria

The learner can:

1. set drawing **parameters** on the CAD system
2. explain the reasons for using structured **layers** and how they are created
3. explain the function of the **commands** used in producing 2D CAD drawings
4. produce 2D CAD drawings that contain essential **technical information**
5. apply standard **conventions** to 2D CAD drawings
6. differentiate between absolute, relative (incremental) and polar co-ordinate systems
7. differentiate between world and user co-ordinate systems
8. review and revise 2D CAD drawings by **editing** and manipulating graphical data
9. produce **text** on 2D CAD drawings
10. import and position library items onto 2D CAD drawings
11. apply conventions relating to **dimensioning** to 2D CAD drawings
12. apply the conventions for **cross-hatching** areas to 2D CAD drawings
13. save drawings using appropriate file names
14. load and edit existing drawings
15. evaluate the process of producing a 2D CAD drawing and recommend improvements to the process

Range

Parameters: limits to suit component dimensions and paper size, drawing aids to draw entities accurately (grid spacing, snap interval, object snap mode, orthogonal mode, units benefits and limitations of using the drawing aids)

Layers: apply meaningful names, assign line types, assign colours, control the visibility of layers

Commands: line, polyline, circle, arc, polygon, rectangle, ellipse, doughnut, erase (single entities, multiple entities)

Technical information: projection type (pictorial: isometric, oblique; orthographic: first angle, third angle) units, scale, shape, size including tolerance, surface finish, number off, material requirements, special treatments

Conventions: BS 8888, types of line, representation of common features

Editing: zoom in/zoom out, pan, erase, copy, mirror, offset, move, array (rectangular and polar), trim, extend, scale, stretch, break, fillet, chamfer, modify properties **(**line type, colour, layer)

Text: position, font style, font height, rotation

Dimensioning: linear, aligned, angular, diameters, radii, leader, tolerances, limits, methods of edit existing dimensions, baseline, continuous, associative dimensions

Cross-hatching: simple and complex **areas,** pre-defined hatch patterns, user defined hatch patterns, application to cross-sectioning

Unit 329 Produce drawings using CAD

Outcome 3 Be able to produce 3D CAD drawings

Assessment Criteria

The learner can:

1. explain the role of detail and assembly drawings
2. critically compare the 3D CAD drawing **visual representation** methods available
3. explain the function of the **commands** used in producing 3D CAD drawings
4. produce 3D CAD drawings that contain essential technical information
5. review and revise 3D CAD drawings by editing and manipulating graphical data
6. apply the shading and rendering to 3D CAD drawings
7. save drawings using appropriate file names
8. load and edit existing drawings

Range

Visual representation: isometric projection, wire frame modelling, extruded forms, solid modelling (B-REP, CGS, hybrid) surface modelling, parametric and variational geometry

Commands: line, polyline, circle, arc, polygon, rectangle, ellipse, doughnut, erase (single entities, multiple entities), extrude, revolve, 3D primitives (box, cuboid, sphere, cylinder, cone, torus, wedge), combine primitives using Boolean operations (addition, union, join, subtraction, cut, intersection), surfacing commands, shade, hide, render, rotate, camera, 3D views, 3D viewports (multiple views), model space, paper space

Unit 329 Produce drawings using CAD

Outcome 4 Be able to produce hard copies of CAD drawings

Assessment Criteria

The learner can:

1. **print/plot** hard copies of different sized CAD drawings
2. print/plot hard copies of modified CAD drawings
3. critically compare types of printer/plotter available
4. import drawings into **presentation** software for demonstration purposes
5. transfer CAD data to a computer-aided manufacturing Computer Aided Manufacturing (CAM) system

Range

Print/plot: print/plot command, printer/plotter configuration settings, device selection, paper size (A4, A3, etc.), paper orientation (portrait, landscape) paper source, print quality, pen assignments where appropriate, display parameters, extents, limits, view, window, text resolution, units, scale, rotation and origin, print preview

Presentation: produce a presentation that fulfils one or more of the following criteria:

- demonstrates the stages of the drawing process
- shows the capabilities of the engineering item drawn
- presents the item from a sales and marketing perspective

Unit 330 Organising and managing engineering operations

Level: 3
Credit value: 9
UAN: A/503/0424

Unit aim

This unit enables the leaner to develop an understanding of the principles of organisation and management and the ways in which engineering activities can be efficiently planned and implemented. It covers the topics: relationships between installation, production and maintenance operations, the necessity for good planning in order to provide an efficient and cost effective service and why good recording processes are needed and how data is collected, used to forecast and/or solve problems.

The unit also covers the main sources of labour and physical resources and developing good relationships with all levels of personnel and the ways in which their duties need to be carried out. The leaner is not expected to have an in-depth understanding of all engineering activities and strategies but should be familiar with the events/terminology that they will come into contact with during normal working conditions.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Be able to organise engineering activities
2. Be able to schedule engineering activities
3. Be able to analyse the costs associated with engineering installation, production and maintenance
4. Be able to apply research methods to assist the installation, production or maintenance process

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1686 Level 3 – Engineering Technical Support; Unit 52: Scheduling Engineering Activities; Unit 57: Carry Out Project Management of Engineering Activities

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 330 Organising and managing engineering operations

Outcome 1 Be able to organise engineering activities

Assessment Criteria

The learner can:

1. explain the **organisational structures** employed in engineering
2. describe the function of **engineering sections**
3. explain the procedures for organising and running **meetings**

Range

Organisational structures: roles and responsibilities, lines of communication, decision making and implementation procedures, types of organisation chart

Engineering sections: installation, production, maintenance

Meetings: duties of the chair and secretary

Additional Guidance

Engineering sections: installation (site preparation, installing new or modified equipment and systems, commissioning machinery and systems), production (preparation of drawings and specifications, ensuring that appropriate machinery, manpower and materials are available, producing work allocations and rotas to ensure efficient operation, dealing with production problems and shortages), maintenance (carrying out routine servicing schedules, repair and replacement following breakdowns, monitoring and performance testing of machinery, equipment and systems)

Meetings: duties of the chair (preparation of agendas, allocating personnel to deliver agenda items, conduct and control meetings), duties of the secretary (arrange time, venue and catering requirements, take minutes during meeting, produce finalised minutes and distribute to concerned persons

Unit 330 Organising and managing engineering operations

Outcome 2 Be able to schedule engineering activities

Assessment Criteria

The learner can:

1. explain the factors that need to be considered when **planning operations**
2. explain the need for reviewing production and maintenance procedures at regular intervals in order to ensure maximum efficiency and economy
3. prepare flow and Gantt (bar) charts for planning, scheduling and checking on progress
4. produce worksheets or job cards for typical engineering tasks
5. explain the need for establishing priorities and the most effective **sequences of operations**
6. explain how **modification, repair or replace** policies are determined by considering
7. explain how **reliability** can be achieved and production targets maintained

Range

Planning: obtaining specialist tools and equipment, personnel requirements (existing staff, specialist skills available and possible training needs, temporary [sub contract, casual], contingencies and overtime), items that must be considered when preparing contracts (working conditions and health and safety implications, supervisory and legal responsibilities, penalties for non compliance with conditions, insurance cover), provision of materials and spares, effects on other departments or changes to working practices (permanent or temporary), estimation of time needed for different activities

Operations: production, maintenance or installation

Sequences of operations: Critical Path Analysis (CPA) and/or Performance Evaluation and Review Techniques (PERT) principles (using examples but without necessarily carrying out an analysis), contingency plans for: inclement conditions, shortage of materials or staff, equipment failure

Modification, repair or replace: plant history records, manufacturer's recommendations, changes in production output, age of plant or equipment, technological changes

Reliability: good maintenance, identification of recurring problems or faults, initiating or modifying new procedures, updating systems, equipment and machinery

Unit 330 Organising and managing engineering operations

Outcome 3 Be able to analyse the costs associated with engineering installation, production and maintenance

Assessment Criteria

The learner can:

1. analyse the cost-related information needed when **estimating/budgeting** for an **activity**
2. estimate the cost of an **activity**
3. estimate the **total life cycle costs** of machinery
4. describe the difference between **direct and indirect costs**
5. compare production performance, maintenance or installation costs using cost analysis
6. use bar and/or pie charts to identify the optimum levels of production or maintenance
7. explain how commonly used cost ratios are employed to determine the value of maintenance
8. evaluate the significant importance on costs of machinery and items held in stores as indicated by a Pareto analysis
9. explain the relationship between capital expenditure and depreciation for plant and equipment
10. explain the need manage stock levels in stores for economic and efficient operation and production

Range

Estimating/budgeting: extent of the task(s), time allowed for completion, the skills and experience of personnel to be involved, machinery, equipment, materials and spares that will be needed, purchase or hire of specialist equipment

Activity: production, maintenance or installation

Total life cycle costs: design features, maintenance, expected length of serviceable use, disposal value or costs that may be incurred during decommissioning and dismantling

Direct and indirect costs: direct costs (materials, labour [company employed and sub-contract], overheads [rent, rates, taxes, energy consumption]), indirect costs (organisation and management, lost production, depreciation of equipment, training)

Unit 330 Organising and managing engineering operations

Outcome 4 Be able to apply research methods to assist the installation, production or maintenance process

Assessment Criteria

The learner can:

1. describe the implications of using **computers** to access records and product information
2. explain how feedback data can be used to improve planning and scheduling
3. collect data and use it to report on installation, production or maintenance requirements
4. identify **the information required to determine the prime cause of a fault or production problem**
5. produce an algorithm to help trace a fault or production problem
6. explain the importance of collecting and recording information following the failure of equipment or machinery for calculation of Mean Time Between (or To) Failures (MTBF and MTTF)
7. evaluate available data to decide whether to repair or replace equipment

Range

Computers: increased number of access points, ease of updating, wide range of information available (including access to Internet), appropriate siting and cost of installation, maintaining security of data and limiting access to authorised persons only, training of personnel, automatic data collection and recording methods for controlling operations

Information required to determine the prime cause of a fault or production problem: to include detailed knowledge of the principles of the plant and equipment, observed and measured data, information obtained from operators, history of the equipment, details of changes in running conditions or modifications made, information from suppliers or manufacturers

Unit 331 Advanced mathematics and science

Level: **3**
Credit value: **9**
UAN: **K/503/0449**

Unit aim
This unit enables the leaner to develop the skills in and understanding of mathematics and science to facilitate progression onto awards that require a Level 3 mathematics and science component

It is primarily aimed at those leaners who wish to progress to higher education and has been applied to practical engineering principles of mathematics topics.

Learning outcomes
There are **ten** learning outcomes to this unit. The learner will:
1. Be able to perform calculations involving indices, logarithms and algebra
2. Be able to perform calculations using trigonometry
3. Be able to perform calculations using calculus
4. Be able to perform calculations involving statistics
5. Be able to perform tests to determine stress, strain and elasticity of materials
6. Be able to solve problems involving kinematics
7. Be able to solve problems involving dynamics
8. Be able to solve problems involving bending beams
9. Be able to solve problems involving fluids
10. Be able to demonstrate the effects of electromagnetism and alternating current

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 331 Advanced mathematics and science

Outcome 1 Be able to perform calculations involving indices, logarithms and algebra

Assessment Criteria

The learner can:

1. use **powers and roots** to solve problems
2. use **logarithms** to solve problems
3. use **number bases** to solve problems
4. use **algebra** to solve problems

Range

Powers and roots: meanings of the terms: base, index, power, root and reciprocal;
$a^0 = 1$, $a^{-n} = 1/a^n$, $a^{1/n} = \sqrt[n]{a}$, evaluate: $a^m a^n$, $a^{(n+m)}$, a^m/a^n, a^{m-n}, $(a^m)^n$, a^{mn}, $a^{m/n}$
express decimal fractions in standard form, solve algebraic problems involving transposition of terms with indices

Logarithms: define a logarithm as a power applied to a base number, logarithms to the base 10, logarithms to the base 'e' stating its application, logarithms to simplify calculations

Number bases: application of binary and hexadecimal numbering systems in data transmission, storage and progamming, calculations using binary and hexadecimal numbers, conversions of numbers between denary, binary and hexadecimal bases

Algebra: algebraic and graphical methods to solve simultaneous and quadratic equations, define the roots of an equation, simple arithmetic and geometric series, factorial notation for combinations and permutations

Unit 331 Advanced mathematics and science

Outcome 2 Be able to perform calculations using trigonometry

Assessment Criteria

The learner can:

1. perform calculations involving trigonometric ratios for the four quadrants
2. apply the Sine Rule (A/sina + B/sinb + C/sinc) to practical problems
3. apply the Cosine Rule ($a^2 = b^2 + c^2 - 2.b.c\ cosa$) to practical problems
4. plot graphs of the functions $y = R \sin(\omega t + \alpha)$ and $y = R \cos(\omega t + \alpha)$
5. perform calculations to solve problems involving **areas**
6. differentiate between different **trigonometric identities**
7. explain that a complex number is a combination of 'j' notation and a rational number
8. explain the graphical represent **vector quantities** and **polar quantities**

Range

Areas: non right-angled triangles, angles between lines, true length of lines, true angle between planes

Trigonometric identities: tan = sin/cos, cot = 1/tan, sec = 1/cos, cosec = 1/sin

Vector quantities: complex numbers, modulus, argument

Polar quantities: complex numbers, argand diagrams, rotating vector, polar to cartesian form and vice-versa

Unit 331 Advanced mathematics and science

Outcome 3 Be able to perform calculations using calculus

Assessment Criteria

The learner can:

1. apply the rules of **differentiation**
2. apply Simpson's Rule to the calculation of areas of irregular sections
3. apply the rules of **integration**
4. perform calculations that apply differentiation to problems such as velocity and acceleration
5. perform calculations involving maxima and minima to determine the minimum material required to produce a regular-shaped square or circular container of maximum volume
6. perform calculations that apply integration to problems such as summation of irregular areas, volumes of revolution, centroid of area and second moment of area

Range

Differentiation: $dy/dx = nx^{n-1}$, products, quotients, function of a function and algebraic expressions (polynomial expressions, exponential expressions, simple trigonometrical functions), calculations involving a second derivative

Integration: $\int ax^n dx = a/n+1(x^{n+1})$, polynomial expressions, exponential expressions, simple trigonometric functions, integration by substitution, integration by parts

Unit 331 Advanced mathematics and science

Outcome 4 Be able to perform calculations involving statistics

Assessment Criteria

The learner can:

1. calculate the **mean and standard deviation** for a sample of engineering components
2. perform estimates of failure rates of engineering artefacts or systems
3. define probability
4. define dependent and independent events, addition and multiplication laws of probability, permutations and combinations applied to probability, normal probability distribution, confidence limits and statistical testing

Range

Mean and standard deviation: gather and collate data from various sources and solve problems involving: frequency distributions (mean, median, mode, standard deviation), extrapolated data, interpolated data, use a calculator to perform statistical calculations

Unit 331 Advanced mathematics and science

Outcome 5 Be able to perform tests to determine stress, strain and elasticity of materials

Assessment Criteria

The learner can:

1. perform **tensile tests** on a range of materials and determine Young's Modulus for each material
2. perform **shearing tests** and determine the modulus of rigidity of materials

Range

Tensile tests: direct stress, direct strain, elastic limit, yield stress, tensile strength, breaking point, Modulus of Elasticity, factor of safety, calculations comparing the properties of different materials

Shearing tests: shear stress, shear strain, Modulus of Rigidity, Poisson's ratio, calculations comparing the properties of different materials

Unit 331 Advanced mathematics and science

Outcome 6 Be able to solve problems involving kinematics

Assessment Criteria

The learner can:

1. define velocity and acceleration
2. solve practical problems involving bodies in **linear motion** and trajectories
3. use **vector diagrams** to determine achieved tracks and relative velocities

Range

Velocity and acceleration: velocity as a vector quantity that is the rate of change of distance with respect to time, area under a velocity/time curve represents the distance travelled, acceleration is the rate of change of velocity with time, area under an acceleration/time curve represents velocity

Linear motion: solve problems for linear and rotary motion both graphically and using the formulae:

$s = {}^1/_2(u + v)t$, $\theta = {}^1/_2(\omega_1 + \omega_2)t$; $a = (v - u)/t$, $\alpha = (\omega_2 - \omega_1)/t$; $v = u + at$, $\omega_2 = \omega_1 + \alpha t$;

$s = ut + {}^1/_2at^2$, $\theta = \omega_1 t + {}^1/_2\alpha t^2$; $v^2 = u^2 + 2as$, $\omega_2{}^2 = \omega_1{}^2 + 2\alpha s$

Vector diagrams: velocities of bodies subjected to linear motion (ships in tides, aircraft in winds)

Unit 331 Advanced mathematics and science

Outcome 7 Be able to solve problems involving dynamics

Assessment Criteria

The learner can:

1. explain Newton's Laws of Motion
2. define the acceleration due to gravity as 9.81 ms^{-2}
3. define that 1 newton is the force required to accelerate a mass of 1 kg at the rate of 1 ms^{-2}
4. solve practical problems involving accelerating/decelerating masses both graphically and using the formulae f = ma
5. define momentum as the product of mass and velocity
6. solve practical problems involving colliding bodies by calculation
7. use calculations to find the moment of inertia of disks and rimmed flywheels
8. define radius of gyration
9. define potential energy and solve practical problems involving P.E = mgh
10. explain the relationship between work done in raising a body to potential energy
11. define linear and angular kinetic energy in terms of $^1/_2 mv^2$ and $^1/_2 I\omega^2$
12. solve energy conversion problems both graphically and using formulae
13. solve problems associated with stored energy both graphically and using the formulae SE = $^1/_2 fx$

Unit 331 Advanced mathematics and science

Outcome 8 Be able to solve problems involving bending beams

Assessment Criteria

The learner can:

1. construct shear force and bending moment diagrams for simply supported beams and cantilevers
2. perform calculations to determine **maximum bending moments**
3. define units of second moment of area as m^4
4. solve problems associated with the stresses produced in bending beams
5. compare the resistance in bending of tee, 'I' and channel beam cross-sections

Range

Maximum bending moments: point loads, uniformly distributed loads, combinations of point and uniformly distributed loads, identify points of contraflexure, assumptions made in calculating stress due to bending

Unit 331 Advanced mathematics and science

Outcome 9 Be able to solve problems involving fluids

Assessment Criteria

The learner can:

1. define Boyle's law
2. define Charles' law
3. define the combined gas laws
4. solve practical **gas law problems** by calculation
5. solve practical **fluid flow rate problems** by calculation

Range

Gas law problems: Boyle's law, Charles' law, combined gas laws

Fluid flow problems: velocity of flow, volume flow rate, mass flow rate, continuity equation for an incompressible liquid

Unit 331 Advanced mathematics and science

Outcome 10 Be able to demonstrate the effects of electromagnetism and alternating current

Assessment Criteria

The learner can:

1. demonstrate the effect of a magnetic field on a current carrying conductor
2. demonstrate the effect of a magnetic field on a moving conductor
3. apply Fleming's Left-hand Rule to establish the direction of the force on a current flowing at right angles to the direction of a magnetic field
4. perform calculations to determine the magnitude of the force on a current flowing at right angles to a magnetic field using the formula F = B.I./
5. explain the practical applications of **force exerted on a current in a magnetic field**
6. define **Faraday's law** of electromagnetic induction
7. explain the practical applications of **electromagnetic induction**

Range

Force exerted on a current in a magnetic field: electric motor, moving coil loudspeaker

Faraday's law: effect of moving a conductor across a magnetic field, use calculations the value of an induced e.m.f. using the formula E = Blv

Electromagnetic induction: electric generator, eddy-current brake, method of generating an alternating electro-motive force (emf), sketch the graph of instantaneous conductor emf against angular position of coil, define the period and frequency of an alternating current

Unit 332 Mechatronics systems principles and fault finding

Level: 3
Credit value: 9
UAN: R/503/0428

Unit aim

This unit is concerned with pneumatic, hydraulic, mechanical and electrical actuation systems. The topics covered will enable the leaner to interpret diagrams, explain the operation of circuits and systems and be able to identify and test electrical and mechanical components.

The leaner will also be able to perform diagnostic checks on prepared (simple) systems, and make deductions from the results of these checks which lead to a correct fault diagnosis.

Learning outcomes

There are **five** learning outcomes to this unit. The learner will be able to:

1. Understand the principles of the 'Total Engineering Approach' to production systems
2. Be able to apply the principles of typical sensors
3. Be able to apply the principles of pneumatic, hydraulic, mechanical and electrical actuation systems
4. Be able to apply the principles of embedded control
5. Be able to carry out fault finding on pneumatic, hydraulic, mechanical and electrical actuation systems

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1788 Level 3 – Engineering Maintenance: Unit 323: Carrying Out Fault Diagnosis on Engineered Systems

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 332 Mechatronics systems principles and fault finding

Outcome 1 Understand the principles of the 'Total Engineering Approach' to production systems

Assessment Criteria

The learner can:

1. classify the basic **building blocks** of industrial systems
2. explain, with the aid of block diagrams, the **architecture** of various types of industrial systems
3. describe the differences between the **features** of conventional and mechatronic systems.

Range

Building blocks: typical input devices, prime movers, gearing, controllers, typical output devices

Architecture: controller, correction element, process, outputs, logical sequence of events, construct block diagrams

Features: centralised control or distributed control, hard wiring or networks, sequence control or intelligent individual control, relay logic *or* software programming, plant maintenance or predictive maintenance

Unit 332 Mechatronics systems principles and fault finding

Outcome 2 Be able to apply the principles of typical sensors

Assessment Criteria

The learner can:

1. interface contact and non-contact **sensors** into a control system
2. explain the operation and application of **sensors**
3. explain typical connections and tuning arrangements for **sensors**
4. explain the action and importance of **signal conditioning systems**
5. explain the importance of **terms** applied to sensors used in an industrial system

Range

Sensors: micro switch, snap action limit switch, wobble stick, pressure mat, positively guided safety switch, inductive proximity, capacitive proximity, optical proximity, light curtain, thermocouple, strain gauge differential pressure, impeller flow, encoder (incremental and absolute), resolver

Signal conditioning systems: voltage to current, current to voltage, pressure to voltage, pressure to current, analogue to digital, digital to analogue, frequency to voltage, frequency to current, sink to source, source to sink

Terms: sensitivity, repeatability, resolution, dead band, alignment, compatibility, cross talk, grounding, calibration

Unit 332 Mechatronics systems principles and fault finding

Outcome 3 Be able to apply the principles of pneumatic, hydraulic, mechanical and electrical actuation systems

Assessment Criteria

The learner can:

1. design and implement **control and actuation systems**
2. explain the operation and application of each part of a **pneumatic power system**
3. explain the operation and application of **valves** employed in **pneumatic systems**
4. explain the operation and application of **actuators** employed in pneumatic systems
5. explain the operation and application of each part of a **hydraulic power system**
6. explain the operation and application of **valves** employed in **hydraulic systems**
7. explain the operation and application of **actuators** employed in hydraulic systems
8. classify **symbols** used in pneumatic, hydraulic, mechanical and electrical actuation systems
9. explain the operation and application of each part of a **mechanical system**
10. explain the operation and application of each part of a **electrical system**
11. explain the application of **components** in a fieldbus network

Range

Control and actuation systems: pneumatic, hydraulic, electrical

Pneumatic power system: prime mover (i.e., motor), compressor (i.e., two stage reciprocating), silencer, filter, pressure relief valve, cooler, filter and water trap, air receiver, pipe work distribution system

Valves - pneumatic systems:

Directional control valves (DCV) – spool, 3/2, 4/2, 5/2, directly operated, pilot operated, solenoid operated, poppet

Directional valves – one way, one way restrictor return

Pressure control valves – pressure regulating, pressure limiting, pressure sequence, proportional

Process control valves – pneumatic diaphragm actuator, linear contoured, equal, percentage

Actuators:

Linear actuators – single acting, double acting, fluid muscle, tandem, multi position, stick slip

Rotary actuators – use of linear actuator to produce rotation, vane-type semi-rotary, vane motor

Hydraulic power system: prime mover (i.e., motor), pump, non return valve, pressure relief valve, accumulator (i.e. bladder-type), sump, hydraulic oil, pipe work distribution system and return

Valves - hydraulic systems:

Directional control valves (DCV) – spool, 3/2, 4/2, 5/2, directly operated, pilot operated, solenoid operated, poppet

Directional valves – one way, one way restrictor return

Pressure control valves – pressure regulating, pressure limiting, pressure sequence, proportional

Symbols: flow path, flow shut-off, initial connections, push button operation, lever operation, roller operation, plunger operation, spring operation, solenoid operation, pedal operation, pilot operation, 2/2 valve, 3/2 valve, 4/2 valve, 5/2 valve, non return valve, pressure limiting valve, regulator, pressure source, exhaust, filter, single acting cylinder, double acting cylinder, rotary actuator

Mechanical system: prismatic motion, revolute motion, sliding joints, revolving joints, force amplification (i.e., levers), change of speed (i.e., gears), transfer of rotation (i.e., belts and chains), types of motion (i.e., quick return mechanism), cams and cam followers, change of direction (i.e., bevel and worm gear), linear to revolute / revolute to linear (i.e., rack and pinion), bearings (i.e., plain roller needle and ball)

Electrical system:

Switching devices – push buttons, relays, thyristor, triac, solid state relay

Solenoid devices

Motors – series d.c., shunt d.c., separately excited d.c., stepper, servo, single phase induction, three phase induction

Motor control – basic d.c. motor speed control (i.e., inverter drive), basic induction motor speed control (i.e., inverter drive), basic stepper motor controllers, basic servo motor controllers

Components: benefits over hard wired systems, communications interface to control system, basic requirements of wiring medium (i.e. CAT 5, grounding), types of distributed input / output modules (i.e., digital, analogue)

Termination - insulation displacement connection (IDC), RJ-45, DIN, BNC

Unit 332 Mechatronics systems principles and fault finding

Outcome 4 Be able to apply the principles of embedded control

Assessment Criteria

The learner can:

1. write simple expressions to describe **logic instructions**
2. explain the function of the main **components** in Programmable Logic Controller (PLC) architecture
3. explain **Ladder Logic programming** as used in PLC programming
4. explain the content of simple programs written using **Ladder Logic programming**
5. explain the function of the main **components** in Programmable Interface Controller (PIC) architecture
6. apply the content of programs written for simple **programme languages** PIC programming
7. explain the operation of **embedded control systems**
8. explain the logical function of **logic gates**

Range

Logic instructions: simple instructions to describe input/output conditions, correct terminology

Components (PLC): control unit, programming device, input/output modules, memory, system clock, use block diagrams to aid description

Ladder Logic programming: basic instructions, examine if open/closed, output, latched output, bit / flag instructions, timers, counters

Components (PIC): Central Processing Unit (CPU), analogue to digital converter (ADC), input / output ports, communication port, timers, memory, system clock, block diagrams to aid description

Programme Languages: *low level assembly language* - RISC (Reduced Instruction Set Computing) high *level language* - requiring a compiler (i.e., Basic) e.g simple robot arm movements

Embedded control systems: dedicated controllers, slave controllers

Logic gates: And, Or, ExOr, Not, Nand, Nor

Unit 332 Mechatronics systems principles and fault finding

Outcome 5 Be able to carry out fault finding on pneumatic, hydraulic, mechanical and electrical actuation systems

Assessment Criteria

The learner can:

1. diagnose simple faults on **control and actuation systems**
2. explain **methods** of fault location
3. explain the operation and applications of **test instruments**
4. explain safe isolation procedures for **systems**
5. evaluate the effects of faulty or inefficient **pneumatic systems** and **hydraulic systems**.

Range

Control and actuation systems: pneumatic, hydraulic, electrical

Methods: half split method, input to output/output to input, component/ unit substitution, component/unit response, visual inspection, consideration of symptoms, pressure monitoring

Test instruments: signal injector, logic probe, multimeter, signal sources (i.e., 4 mA – 20 mA), data logger

Systems: electrical power, electrical control, pneumatic radial, pneumatic ring, hydraulic

Pneumatic systems: cost of producing, lost air, environmental effects

Hydraulic systems: dangers of pressurised liquids, environmental effects

Unit 333 Computer automated and robotic systems principles and control

Level: 3
Credit value: 9
UAN: R/503/0431

Unit aim

This unit is concerned with automated and robotic systems.

It covers the operation of various types of control systems, open and closed loop control, robotic drive systems, effective robot tooling design, basic robotic control and programming tasks, PLC applications in integrated control environments and analysis techniques for various modes of control for automation systems.

Learning outcomes

There are **ten** learning outcomes to this unit. The learner will:

1. Understand the architecture and uses of computer automated and robotic systems
2. Understand the operation of various types of control systems
3. Be able to apply open and closed loop control
4. Be able to use transducers in control and robotic systems
5. Be able to use robotic drive systems
6. Be able to apply effective robot tooling design
7. Be able to apply basic robotic control and programming tasks
8. Be able to perform PLC applications in integrated control environments
9. Be able to use analysis techniques for various modes of control for automation systems
10. Be able to integrate computer based operator interfaces

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

NVQ 1686 Level 3 – Engineering Technical Support; Unit 29: Providing operational support for computer control programs

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 333 Computer automated and robotic systems principles and control

Outcome 1 Understand the architecture and uses of computer automated and robotic systems

Assessment Criteria

The learner can:

1. explain the **architecture** of computer based automation systems
2. explain **variable names** used in computer based automation systems
3. explain the significance and use of mathematical modelling of system components and the concept of transfer functions
4. explain the basic **physical construction** of a robotic system
5. explain **movements** and **joints** in robotic systems
6. classify **robotic arms**
7. explain **wrist design** features
8. explain the factors which determine the **choice of end effectors**
9. classify **types of robot** for different applications
10. obtain **characteristic responses** for simple control and robotic systems
11. describe the **benefits** and possible **implications** of using an automated control system
12. explain the **design considerations** in relation to implementation of a robotic system
13. explain the **physical layouts** for robotic systems
14. explain robot/automation **safety aspects** relating to both machines and personnel.

Range

Architecture: process, inputs, outputs, energy source, measurement system, controller, feedback loops

Variable names: controlled variable, manipulated variable, measurement variable, disturbance variable, error, set-point controller output

Physical construction: jointed manipulator, end effector, controller, programming unit

Movements: arm sweep, shoulder swivel, elbow extension, X plane (width movement), Y plane (height movement), Z plane (depth movement), roll, pitch, yaw, prismatic, revolute, symbols for prismatic and revolute joints, six degrees of freedom

Joints: prismatic, revolute, symbols for prismatic and revolute joints

Robotic arms: Cartesian, cylindrical, polar, jointed arm, SCARA (Selective Compliance Assembly Robot Arm), partial spherical (pendulum), multiple joint (spline)

Wrist design: three revolute degrees of freedom, accuracy of end effecter manipulation

Choice of end effectors: vacuum, stepper motor driven, specialist design

Types of robot: programmable manipulator, pick and place, loading and unloading, production

Characteristic responses: input/output, effect of variables

Benefits: increased productivity, improved quality, increased efficiency, improved safety, convenience, power assistance, repeatability, accuracy, speed, use in hazardous areas

Implications: effect on jobs, capital costs, variable costs, available space, maintenance costs, loss of production due to failures, upgrade costs, safety

Design considerations:

Planning – personnel involved, application, feasibility review

Development – task, part presentation, handling equipment, process machines, quality control process

Mock-up & testing – commissioning, de-bugging, trial runs, quality control checks

Installation – pilot production runs, parallel running with manual cells, final implementation

Physical layouts: radial layout, in-line track mounted, in-line fixed

Safety aspects: category B, category 1, category 2, category 3, category 4, operator competence, operator training, emergencies

Unit 333 Computer automated and robotic systems principles and control

Outcome 2 Understand the operation of various types of control systems

Assessment Criteria

The learner can:

1. describe the difference between **control system types**
2. explain **classifications** of control systems
3. explain the operation of **digital and analogue motion control systems**
4. evaluate the relationship between **functions** in a motion control system.

Range

Control system types: regulatory/following, numerical/ servo/sequential

Classifications:

Set-point changes – infrequent change – regulatory system, frequently changed – following system

Industry found in – processing – process control, continuous system, batch system

Part manufacturing – machine control – numerical control systems, robotic control systems

Category of controller or control – Programmable Logic Controller, event sequenced control, time sequenced control, industrial, controller

Digital motion control system: set-point, gain, output signal, feedback devices, actuator types, error codes

Analogue motion control system: rectification, d.c. bus, chopping circuit, output section

Functions: frequency/speed, speed/torque, switching frequency/noise

Unit 333 Computer automated and robotic systems principles and control

Outcome 3 Be able to apply open and closed loop control

Assessment Criteria

The learner can:

1. explain the **requirements** and **true value inputs** of a measurement system
2. classify **signal conditioning** in measurement systems
3. explain **input transducer** circuit arrangements and operations
4. explain the principles of **damping** in open and closed loop systems
5. explain the **actions** and meaning of **terms and expressions** of open and closed loop systems
6. apply **formulae** to derive controller output
7. describe the difference between **integral and derivative control**
8. explain the basic principles of **output analysis**
9. **build and analyse circuits** on open and closed loop control systems.

Range

Requirements: reliability, repeatability, range (reproducibility), sensitivity, stability, response time, rise time, settling time, steady state, desired value, loading effects/errors

True value inputs: measurement system, measured value of variable output

Signal conditioning: voltage to voltage, voltage to current, frequency to voltage, resistance to voltage

Input transducer: transducer action, analogue input interfaces, digital input interfaces, signal conditioning circuits, calibration procedures

Damping: under-damped, over-damped, critical damping

Actions: system block diagrams, reliability, repeatability, range (reproducibility), sensitivity, stability, response time, rise time, settling time, steady state, desired value, loading effects / errors

Terms and expressions: two step control, continuous control, proportional band, dead band, off-set, hysteresis, Proportional gain (Kp), Derivative gain (Kd), Integral gain (Ki)

Formulae: controller output = Kp(error + Ki x integral of error + Kd x derivative of error), output = $kp(e+ki\int e + kd\ de/dt)$

Integral and derivative control (statements): integral control is a controller output that is proportional to the integral to the error with respect to time, derivative control is a controller output that is proportional to the rate of change of the error with respect to time

Output analysis: *input signals* – stepped, ramped, sinusoidal *measuring equipment* – PC-based data logger, storage scope

Build and analyse circuits: configure inputs, analyse outputs, simulated analysis, system tuning using tables / charts

Unit 333 Computer automated and robotic systems principles and control

Outcome 4 Be able to use transducers in control and robotic systems

Assessment Criteria

The learner can:

1. explain typical **applications** for sensors employed in control and robotic systems
2. interpret and use technical information contained in manufacturers data sheets relating to **thermocouples, pt100 devices**, **proximity sensors, tacho generators and differential pressure devices**
3. classify digital, analogue, safety and internal and external sensors
4. explain actions and calibration of **actuators**
5. explain common **connection types** used with transducers
6. explain the **connection of proximity switches** in parallel and series to achieve Boolean Logic external to a controller
7. explain technologies required for circuits that operate in areas of high radio frequency interference, and electromagnetic interference (**RFI/EMI**)
8. explain the **connection of devices** to proximity sensors
9. explain **sensor power supply** considerations
10. set up sensors
11. set up actuators
12. select an appropriate sensor for a given application
13. wire a selection of transducers with different connection types into a control system
14. wire proximity switches to obtain AND and OR functions
15. wire proximity switches in sink and source mode

Range

Applications: measuring machine parameters for robot control loops, determining the position of objects in 3-D space, adjusting the robot control for the environment, detecting and preventing failures, detecting and avoiding collisions, monitoring the interaction with the environment, monitoring the environmental changes / temperature, inspecting the final product

Thermocouple and pt100 devices: zero, range, span, junction compensation, type

pt100 devices: zero, range, span

Proximity sensors:

Types - inductive, capacitive, optical

Information – sensing range, material tuning, required output (sink source), switching capability, banking capability

Tacho generators:

Devices – resolvers, encoders

Information – setting volts / rpm, setting of volts / mm, setting of data sequence

Differential pressure devices:

Devices – turbine, strain gauge, piezo electric, ultrasonic

Information – resistive bridge trimming, trimming of volts / seconds, trimming of power level

Digital sensors: limit switch, proximity switch, photo electric switch, Hall effect switch, float switch, ultrasonic switch

Analogue sensors: temperature sensor, flow switch, load cell, laser, pressure transducer, vision system

Safety sensors: gate plug, light curtain, safety mat

Internal and external sensors:

Internal – potentiometer, LVDT's, synchros, resolvers, optical encoders, load cells, photoelectric

External – proximity, limit switch, optical systems, Hall effect switch, ultrasonic switch

Actuators:

Proportional valves – trimming of input signals, span, zero

Servo motors – setting of absolute datum optical sensor / drive to stall, deriving maximum holding torque

Connection types:

2 wire d.c. & a.c. – normally open (NO) contact, normally closed (NC) contact, **grounding connections, residual load current**

3 wire d.c. – transistor switched outputs (NPN & PNP types), normally open, normally closed

4 wire d.c. – transistor switched outputs (NPN & PNP types), normally open/closed

Connection of proximity switches: parallel and series connection (benefits and limitations), parallel connection using 2 wire technology, parallel connection using 3 wire technology, series connection using 2 wire technology, series connection using 3 wire technology

RFI/EMI: need for screening, need for short cable lengths, segregation of data and power conductors, power supply filtering, limit error signals at source

Connection of devices: controllers, relays, display elements, current consumption considerations, load resistance considerations, sensor current considerations, transient protection

Sensor power supply: switch-on spikes, supply voltage ripple, stabilisation

Unit 333 Computer automated and robotic systems principles and control

Outcome 5 Be able to use robotic drive systems

Assessment Criteria

The learner can:

1. explain common methods used to **power** robotic systems
2. explain the configuration and operation of typical **robotic control** and **drive systems**
3. explain the operation of, and give applications for, **transmission systems**
4. use suitable robotic **actuators** in a robotic control system

Range

Power: fluid, pneumatic, electrical, production of compressed air (pneumatic power), production of compressed fluid (hydraulic power)

Robotic control systems: control element, actuator, transmission element, load, sensor, feedback, comparator

Robotic drive systems: pneumatic cylinder single acting, pneumatic cylinder double acting, hydraulic cylinder double acting, pneumatic rotary actuator, hydraulic rotary actuator, electro-mechanical solenoid, spool valve, stepper motor

Transmission systems: spur gears, helical gears, straight bevel gears, spiral bevel gears, worm gears, rack and pinion, ball and roller screws, pulley drives and tendons, linkages, bearings

Atuators: pneumatic, hydraulic, electric, reasons for choice.

Unit 333 Computer automated and robotic systems principles and control

Outcome 6 Be able to apply effective robot tooling design

Assessment Criteria

The learner can:

1. explain **component design considerations** with regard to component automation
2. explain the **application**, **operation** and **limitations** of end effectors
3. apply suitable end effectors

Range

Component design considerations: symmetry, datum's, tangling, feeding, insertion, alignment

Application: welding, grinding, painting, gripper and effector, vacuum, clamp, intelligent hand

Operation: vacuum cup, pneumatic gripper, servo controlled gripper, intelligent hand

Limitations: rated payload and gripper mass, force required to accelerate and decelerate payload (F = ma), force required to change payload direction, clamping force, co-efficient of friction between gripper and part

Unit 333 Computer automated and robotic systems principles and control

Outcome 7 Be able to apply basic robotic control and programming tasks

Assessment Criteria

The learner can:

1. use **programming tools** employed in robotic systems
2. explain **online and offline programming** considerations
3. produce robot program designs utilising **flow charts** and **block diagrams**
4. explain the use of kinematic and isometric diagrams to relay information relating to a robot system
5. explain the relationship and interaction between **control systems**
6. explain **performance specifications** for robots
7. explain **safety implications** of combined discipline systems.

Range

Programming tools: control pendants, software, simulation

On-line programming: axis limit control, point to point, contouring, line tracking

Off-line programming: safety, 3D visualisation of a robot arm, need for computing ability, specialist programming language, absolute and incremental co-ordinates, trouble shooting, planning, communication between CAD and CAM systems (Computer Aided Drawing/Computer Aided Manufacture)

Flow charts: symbols, labelling, inputs

Block diagrams: layout, process, sequence

Control systems: robot, motion

Performance specifications: payload, normal and maximum, static and rated, static and dynamic, repeatability, speed, limit on certain motion, weight restrictions

Safety implications: verification of inputs, collision detection, working envelope

Unit 333 Computer automated and robotic systems principles and control

Outcome 8 Be able to perform PLC applications in integrated control environments

Assessment Criteria

The learner can:

1. explain the function of the **component parts** of PLC architecture
2. explain **programming languages** used to program PLCs
3. explain programming device **communications configuration** methods
4. explain the characteristics and methods of configuring different types of **interface module**
5. perform **simple operations** on a PLC controlled system

Range

Component parts: control unit, programming device, input / output modules, memory

Programming languages: industrial standard languages, IEC 61131-3, statement list, structured text, function block, sequential function chart, basic instructions in Ladder Logic, examine in open / closed, output, latched output, bit / flag instructions, timers, counters, move and logic, arithmetic and compare

Communications configuration: upload programmes from a PLC, modify programmes both online and offline, test programmes and re-evaluate operation, use software and hardware to troubleshoot problems in a PLC based control system, document and save programmes

Interface module: digital I/O, analogue, remote I/O, RFID (Radio Frequency Identification) scanning systems, bar code readers, camera vision systems

Simple operations: programming using Ladder Logic, communications configuration, PLC programme download/upload tests, PLC programme modification, interface module configuration, e.g programme a robot arm to carry out a simple task

Unit 333 Computer automated and robotic systems principles and control

Outcome 9 Be able to use analysis techniques for various modes of control for automation systems

Assessment Criteria

The learner can:

1. describe methods used to describe **sequential processes**
2. explain the principles of **control modes** used in automation systems
3. explain the characteristics of automation systems employing combinations of **control modes**
4. explain **methods** used to optimise/tune the response of a control system for various types of control mode
5. explain methods used to **analyse the response** of a control system to determine the levels of stability in a system
6. carry out simple **analysis operations** on a PLC controlled system

Range

Sequential processes:

Time driven – statement algorithm, timing diagrams

Event driven – ladder diagrams, Boolean expressions, sequential function charts, state diagrams, process timing diagrams

Control modes: proportional (P), integral (I), derivative (D), combinations (PI and PID)

Methods: process reaction curve, ultimate cycling method,, self tuning adaptive controllers

Analyse the response: Bode diagrams for phase and gain, phase and gain margins

Analysis operations: program simple time/event driven processes using a PLC as the controller, tune simple control systems, frequency response check for various modes of control wire proximity switches in sink and source mode e.g , a frequency response check for various modes of control

Unit 333 Computer automated and robotic systems principles and control

Outcome 10 Be able to integrate computer based operator interfaces

Assessment Criteria

The learner can:

1. explain the main **elements, features and functions** of PC based (SCADA) systems
2. explain software **data linking standards** used to exchange data between software applications
3. explain methods used to link real I/O to PC based applications via **database objects**
4. explain the use of **functions and features** available with HMI systems
5. explain the main features and functions of **system interfaces**
6. configure **control interfaces** on PLC based control systems.

Range

Elements, features and functions: linked animated graphics, PC control of system functions, display and logging of system errors, need for archiving of process errors, alarm functions of variable priority, display of process trends in various graphical formats

Data linking standards: dynamic data exchange (DDE), object linking and embedding (OLE)

Database objects: I/O PLC based, HMI (human machine interface) based

Functions and features: function key control, touch screen controls, communication links available with typical systems, creation of graphical objects and configuring links to PLC and SCADA based systems

System interfaces: PC based operator, HMI based

Control interfaces: SCADA or HMI, graphical interface to include control / animation / alarming / archiving / trends, data exchange link between software applications

Unit 334 Power supply, and analogue and digital circuit principles and fault finding

Level: 3
Credit value: 9
UAN: Y/503/0432

Unit aim
This unit is concerned with d.c. power supplies, analogue circuits including amplifiers and oscillators, and digital circuits including logic families, sequential logic, and digital transmission systems.

The topics covered will enable the leaner to interpret circuit diagrams, explain the operation of circuits, produce waveform diagrams for given points in a circuit, and be able to identify and test electronic components.

The leaner will also be able to perform circuit and diagnostic checks on prepared boards, and make deductions from the results of these checks which lead to a correct fault diagnosis.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Understand power supply circuits to component level
2. Understand the function of components in analogue circuits
3. Understand digital electronics and data transmission systems
4. Be able to find faults on digital circuits and data transmission systems

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
NVQ 1788 Level 3 – Engineering Maintenance: Unit 316: Carrying Out Fault Diagnosis on Electronic Equipment and Circuits

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 334 Power supply, and analogue and digital circuit principles and fault finding

Outcome 1 Understand power supply circuits to component level

Assessment Criteria

The learner can:

1. explain the operation of low voltage d.c. **power regulator circuits**
2. explain the **key components,** and the **operation** of, a switch mode power supply (SMPS)
3. evaluate the **advantages and disadvantages** of SMPS compared with series and shunt regulator circuits
4. explain principles of **fault location** in power supply circuits.

Range

Power regulator circuits: series regulator, shunt regulator, voltage doubler, dc-dc converter, inverters, feedback control for voltage/current regulation, over-current protection circuits, safety critical components

Key components: d.c. input, power switching, chopper control, start-up, feedback, d.c. output generation, safety critical components, rf suppression components, transient suppression components

Operation: power switching, chopper control, start-up, feedback, over-voltage protection, over-current protection, stand-by mode, d.c. output generation, expected waveforms and voltages

Advantages and disadvantages: efficiency, circuit complexity, physical size, heat output, current output capabilities, factors determining choice of PS

Fault location: recognise symptoms, relate symptoms to fault conditions, expected changes in waveforms and voltages for given fault conditions, use of dummy loads, typical adjustment methods

Unit 334 Power supply, and analogue and digital circuit principles and fault finding

Outcome 2 Understand the function of components in analogue circuits

Assessment Criteria

The learner can:

1. explain the operation of single and multi-stage **bipolar transistor voltage amplifiers**
2. explain the different **classes and modes of operation** of bipolar transistor circuits
3. explain how to obtain **response plots** for amplifier circuits
4. explain the operation of **MOSFET amplifier, transistorised power amplifier** and operational amplifier circuits
5. explain the meaning of **common terms** relating to **operational amplifiers**
6. state the conditions for oscillation in **amplifier circuits**
7. explain the operation of **common oscillator circuits** and **555 timer circuits**
8. apply **fault location to component level** using appropriate test instruments.

Range

Bipolar transistor voltage amplifiers: common circuit arrangements, inter-stage coupling, typical component values, effects of collector load resistor value on voltage gain, effects of negative feedback (both a.c. and d.c.), expected waveforms and voltages, causes and effects of distortion

Classes and modes of operation: A, AB, B, C, common emitter, common base, common collector (emitter follower)

Response plots: frequency response, bandwidth measurement (@ -3dB), voltage gain

MOSFET amplifier: common circuit arrangements, typical component values, expected waveforms and voltages

Transistorised power amplifier: Class A bipolar, Class B transformerless push-pull, MOSFET designs, need for a.c. and d.c. feedback, integrated circuit types

Operational amplifier circuits: common circuit arrangements, feedback circuits, 'virtual earth', inverting input, non-inverting input, integrator differentiator, differential amplifier, comparator, Schmitt trigger, high / low pass filters

Common terms: drift, offset, slew

Conditions for oscillation: effects of positive feedback, feedback factor

Common oscillator circuits: crystal, ceramic resonator, RC phase shift, Wien bridge, LC, VCO (voltage controlled oscillator) using PLL (phase locked loop), expected waveforms and voltages

555 timer circuits: astable, monostable, deriving a sawtooth output

Fault location to component level: identification of fault area from fault symptoms, visual inspection, half split method, input to output/output to input, component substitution, choice of suitable test instrument(s) for a given fault condition, tests are appropriate to the fault condition, correct setup of test instruments, correct interpretation of results, recording results of applied tests, correct diagnosis of defective component(s)

Unit 334 Power supply, and analogue and digital circuit principles and fault finding

Outcome 3 Understand digital electronics and data transmission systems

Assessment Criteria

The learner can:

1. classify common **logic device encapsulations**
2. explain **common terms** used with digital electronics
3. classify and compare devices in **logic families**
4. explain the operation of **logic devices** using waveform diagrams
5. connect bistable logic devices to produce **counting and dividing circuits**
6. explain the operation of synchronous and asynchronous **integrated counters**
7. explain the effects of mechanical switch/relay **contact bounce** on logic circuits
8. explain the principles of **Time Division Multiplexing (TDM)**
9. critically compare digital **encoding methods** employed in data transmission systems
10. critically compare **transmission medium** for data transmission employing TDM
11. explain **error detection and correction** techniques employed in digital systems.

Range

Logic device encapsulations: device numbering, type of packaging, pinout numbering

Common terms: supply voltages, supply current, high level input voltage, low level input voltage, noise margin, input and output currents, rise and fall times, propagation delay, power dissipation, absolute maximum ratings, fan in/fan out

Logic families: 4000 Series, 74LS Series, 74HC Series, 74HCT Series, 74AHC Series

Logic devices: JK bistable, D-Type bistable, Master–Slave JK bistable

Counting and dividing circuits: modulo-n dividers, up/down counters, associated timing diagrams and waveforms

Integrated counters: decade counters, modulo-n counters, modulo-n dividers, ring counters, twisted ring, shift registers, associated timing diagrams and waveforms

Contact bounce: causes, effects on circuit operation, methods for suppression (de-bounce circuits)

Time Division Multiplexing (TDM): sampling, sampling rate, multiplexing, demultiplexing

Encoding methods: RZ (Return to Zero) encoding, NRZ (Non Return to Zero) encoding, Manchester code, Gray code, BCD (Binary Coded Decimal)

Transmission medium: copper cable, fibre-optic cable

Error detection and correction: parity check, CRC (Cyclic Redundancy Check)

Unit 334 Power supply, and analogue and digital circuit principles and fault finding

Outcome 4 Be able to find faults on digital circuits and data transmission systems

Assessment Criteria

The learner can:

1. **assemble, test an**d **find** faults on digital circuits.
2. explain common causes of **failure of integrated circuits (IC's)** during use and servicing
3. explain **methods for preventing IC damage** by electrostatic discharge during assembly/servicing
4. explain the uses and limitations of **test equipment** in relation to logic circuits
5. explain **fault finding techniques**

Range

Assemble, test and find faults : effects of floating inputs, output loading effects, input drive options, connect circuits via a fibre-optic link, use of TDM to transmit multiple signals across a single transmission path, use of logic tutors to investigate circuit operation and verify Data Sheet information, circuits using JK and D-type bistable ICs, integrated shift registers employing ICs such as 74XX194, integrated synchronous and asynchronous modulo-n counters employing ICs such as 74XX74 / 74XX112 / 74XX193 / 74XX380, switch bounce, locate faults in digital equipment such as combinational logic circuits/synchronous and asynchronous counters, shift registers, bistables/remote controls/D-A and A-D converters/7 segment displays

Failure of ICs during use: incorrect supply voltages, electrostatic discharge (ESD), lightning strike, excessive heat, mechanical vibration

Failure of ICs during servicing: incorrect orientation when fitting / replacing, poor soldering techniques, insertion/removal whilst power is applied, shorting of pins during measurements, electrostatic discharge (ESD)

Methods for preventing IC damage: storage/transportation of ICs, non-static floor coverings / work surfaces, non-static clothing, wrist/heel straps, conductive matting

Test equipment: multimeter, logic probe and clip, logic pulser, logic analyser, current tracer, signature tracer, oscilloscope

Fault finding techniques: visual inspection, consideration of symptoms, half split method, input to output / output to input, component substitution, recording results of applied tests

Unit 335 Electronic power control principles and practice

Level: 3
Credit value: 9
UAN: H/503/0434

Unit aim

This unit is concerned with the basic principles of three phase mains power, power electronic components, the electronics employed in process control and automation systems, and basic customer care.

The topics covered will enable the leaner to interpret circuit diagrams, explain the operation of circuits, and perform tests on circuits. The leaner will also be able to carry out simple PLC programming, and describe methods of customer care.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Understand power electronics principles and circuits
2. Be able to process control and transducers
3. Be able to apply motor drive systems
4. Be able to program industrial automation systems employing PLCs

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

NVQ 1788 Level 3 – Engineering Maintenance: Unit 317: Testing Electronic Equipment and Circuits

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 335 Electronic power control principles and practice

Outcome 1 Understand power electronics principles and circuits

Assessment Criteria

The learner can:

1. explain the principles of a **3-phase mains electricity** supply
2. explain typical **functions** for low voltage 3-phase power supplies
3. explain the wiring configurations for typical 3-phase **power connectors**
4. explain the operation of **3-phase rectification** circuits
5. explain the operation of, and applications for, **heavy current components**
6. use methods for testing **heavy current components**
7. describe applications for low voltage/heavy current **switched mode power supplies**
8. explain controlled **a.c. power transmission systems** employed in localised power networks
9. explain the operation of **Uninterruptible Power Supplies (UPS)**

Range

3-phase mains electricity: 3-phase 4 wire output from a substation, line to line and phase voltages, graphical representation of 3-phase waveforms, star and delta connections, typical applications for 3-phase supplies

Functions: reduced PSU output ripple, increased efficiency

Power connectors: IEC60309 connector, 3-phase + earth, 3-phase + neutral + earth

3-phase rectification: half wave, full wave, input/output waveform relationships for rectifier circuits, output ripple, ripple frequency

Heavy current components: capsule thyristors, thyristor/diode modules, triacs, capsule rectifier diodes, stud mount rectifier diodes, fast diode modules, power insulated gate FETs (IGFETs), insulated gate bipolar transistors (IGBTs), insulated gate commutated thyristors (IGCTs)

Switched mode power supplies: single phase, three phase

a.c. power transmission systems: Flexible a.c. Transmission Systems (FACTS), Uninterruptible Power Supplies (UPS)

Uninterruptible Power Supplies (**UPS):** on-line UPS, off-line UPS

Unit 335 Electronic power control principles and practice

Outcome 2 Be able to process control and transducers

Assessment Criteria

The learner can:

1. describe common **control methods**
2. describe **common terms** used in control systems
3. describe the operation of **block diagrams** for systems used in process control
4. explain the operation of **transducers and sensors** employed in control systems
5. explain the operation of **feedback** as employed in control systems
6. locate faults in systems listed in block diagrams.

Range

Control methods: On/Off, proportional derivative (PD), proportional integral derivative (PID)

Common terms: critical damping, stability, proportional band, dead band, transport lag

Block diagrams: micro-controller based linear control system, temperature control systems, speed control systems, position control systems, fluid control systems, gas flow control systems

Transducers and sensors: analogue output, digital output, digitally encoded output, signal conditioners, temperature, motion sensors, rotary encoders, optical transducers, displacement transducers, image sensors, proximity sensors, fluid/gas flow transducers

Feedback: positive, negative, voltage derived series applied, voltage derived shunt applied, current derived series applied, current derived shunt applied

Unit 335 Electronic power control principles and practice

Outcome 3 Be able to apply motor drive systems

Assessment Criteria

The learner can:

1. explain typical applications for d.c. motors employing different **methods of excitation**
2. explain typical applications for different types of **a.c. motor**
3. select suitable motors for tasks where particular **characteristics** are required
4. explain and illustrate the operation of motor **speed control systems**
5. explain the operation of **stepper motors** and their drive systems
6. measure values to determine **characteristics** of motor drive systems.

Range

Methods of excitation: series, shunt, split field, permanent magnet

a.c. motor: capacitor start induction run single phase, three phase induction with d.o.l. starting, synchronous three-phase

Characteristics: constant torque, high speed, low speed, low maintenance, precise positional control

Speed control systems: a.c. motor, d.c. motor

Stepper motors: permanent magnet, variable reluctance, hybrid

Characteristics: feedback signals, start/running currents, torque/speed characteristics

Unit 335 Electronic power control principles and practice

Outcome 4 Be able to program industrial automation systems employing PLCs

Assessment Criteria

The learner can:

1. explain the operation of **Programmable Logic Controllers (PLCs)**
2. classify **PLC inputs and outputs**
3. explain briefly the operation of **field device networking protocols**
4. write **programs for PLCs** using ladder diagrams
5. program a PLC to perform an operation in response to a sensor input.

Range

Programmable logic controllers (PLCs): PLC as a system, PLC as a part of an automated production system

PLC inputs:
Instruction inputs – keypads, selector switches
Sensor inputs – limit switches, proximity switches, photosensors

PLC outputs:
Low current – small solenoid valves, motors, electromagnetic clutches
High current – large solenoid valves, three-phase motors
Indicators – pilot lamps, digital display

Field device networking protocols: Actuator Sensor Interface (AS-Interface, or ASi), Profibus

Programs for PLCs: standard ladder diagram symbols, logic functions, latching, timers, markers, counters, shift registers

Unit 336 MIG welding of aluminium

Level: 3
Credit value: 9
UAN: H/503/0353

Unit aim

This unit sets out the requirements for metal inert gas (MIG) welding of aluminium and aluminium alloys in a modern engineering environment, in terms of what needs to be achieved by the leaner, ie: welding a series of challenging joint configurations across in a wide range of positions that are compliant to welding procedure specifications.

The unit is concerned with the technology and practices involved in the application of MIG welding of aluminium and aluminium alloys. The unit is demanding in terms of technological content and the complexity of the welding that leaners are expected to achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (i.e. electrodes) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Be able to apply safe working practices to MIG welding
2. Be able to prepare equipment for performing MIG welding of aluminium and aluminium alloys
3. Be able to perform MIG welding operations to meet welding procedure specification requirements
4. Be able to evaluate welded joints for welding procedure specification conformance

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 5: Welding Materials by Manual MIG/MAG and other Continuous Wire Processes

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 336 MIG welding of aluminium

Outcome 1 Be able to apply safe working practices to MIG welding

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** in a welding environment and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: fume, fire, electricity, arc radiation, hot metal,, hazards associated with the storage, handling and use of pressurised gas cylinders

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance cylinders (safe storage conditions, safe handling/moving, safe use)

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to welding process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment at Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection [PPE, screening, warnings {verbal, notices}]), hot metal (methods of avoiding), hazards associated with the storage, handling and use of pressurised gas cylinders

Unit 336 MIG welding of aluminium

Outcome 2 Be able to prepare equipment for performing MIG welding of aluminium and aluminium alloys

Assessment Criteria

The learner can:

1. list the range of **welding equipment** available
2. describe the functions of welding equipment
3. prepare the **welding equipment** for a range of given applications
4. prepare the welding **shielding gases** for a range of given applications

Range

Welding equipment: power sources, inverter , generator, rated output, measurement of electrical output and continuity, relationship between wire feed speed control and welding current, power source characteristics, function of induction, return, earth, construction, rated output, welding guns, contact tip, return clamps, wire feed control, ancillary equipment

Shielding gases: cylinders, manifold systems, regulators (fixed, single-stage, two-stage), gas flow meters, gas tubes and connectors, use of solenoid valves, heaters for CO_2

Additional Guidance

Welding equipment: power sources (output direct current [d.c.], transformer/rectifier [function, operation, construction {diodes, thyristors} function of smoothing capacitors], inverter [function, operation, construction], generator [fuel driven, function, operation, construction], rated output [duty cycle]), measurement of electrical output and continuity (voltage – use of voltmeter/multi-meter, current – use of ammeter/shunts/coils, continuity – use of continuity tester/ohmmeter), relationship between wire feed speed control and welding current, power source characteristics (volt/ampere graph, flat characteristic, constant voltage output), function of induction (principle, effect, fixed, stepped, variable control, leads used (welding [water cooled, air cooled, harness construction], return, earth, construction, rated output [duty cycle]), welding guns/torches (water cooled, air cooled, construction, types [push, pull, reel-on-gun] swan neck design, pistol design, nozzles [dip, spray], contact tip [functions, material, sizes, clearing a burn-back), return clamps (types, clamping mechanisms), wire feed control (variable speed motor, direct control of wire feed rate, indirect control of welding current, solenoid valves [shielding gas, water], relay for electrical power, jog-feed control, gas purge control) ancillary equipment (angle grinders, wire brushes, linishers, hammer and chisel)

Unit 336 MIG welding of aluminium

Outcome 3 Be able to perform MIG welding operations to meet welding procedure specification requirements

Assessment Criteria

The learner can:

1. critically compare **welding consumables** for a range of given applications
2. describe the difference between **welding consumables** by their classification
3. produce complex welded aluminium and aluminium alloy joints in a range of positions in accordance with welding procedure specification (WPS) parameters
4. **restore work areas** to a clean and safe condition on completion of welding operation.

Range

Welding consumables:

Electrode wires:

BS EN ISO 18273:– Welding consumables. Wire electrodes, wires and rods for welding of aluminium and aluminium alloys, classification: (sizes [diameters, lengths], strength and elongation of the weld metal, chemical composition of the weld metal, storage, identification, segregation (classification, size), application to aluminium alloy groups (1000 – 7000 series)

Shielding gases:

BS EN 439: Welding consumables. Shielding gases for arc welding and cutting, effects of shielding gases/gas mixtures (weld pool/arc area protection, heat input, weld geometry, penetration profile, travel speed, mode of metal transfer), applications for shielding gases/gas mixtures (argon, helium, argon/helium mixtues, helium/argon mixtures), benefits and limitations, gas pressure requirements, flow rates for applications

WPS: welding process, parent metal, consumables, pre welding activities (cleaning [including scraping, filing, abrasives, stainless steel wire brushing, degreasing, chemical etching and associated care in use], edge preparation, assembly, pre-heat – relation to thickness, effect upon fusion, material composition]), welding), welding parameters, welding positions (EN ISO 6947 – PA, PB, PC, PD, PE, PF, PG), number and arrangement of runs to fully fill/weld joints, electrode sizes for joint thicknesses, mode of metal transfer (spray, pulse, synergic pulse), electrical conditions required (type of current, direct [d.c.], electrode polarity (positive), wire feed speed ranges, voltage (open circuit, arc), control of heat input input (preheat temperatures and methods of application), shielding gas (type, flow rate) interpass/run cleaning/back gouging methods, post welding activities (spatter removal, wiring brushing, removal of excess weld metal where required), post-weld heat treatment (normalising, stress relief)

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 336 MIG welding of aluminium

Outcome 4 Be able to evaluate welded joints for welding procedure specification conformance

Assessment Criteria

The learner can:

1. explain the implications of quality specifications used to determine the **integrity of welded joints**
2. **visually evaluate** welded joints for conformance
3. prepare and **destructively test** joints to evaluate sub-surface for conformance

Range

Integrity of welded joints: classification of defects, quality specification (BS EN ISO 10042 – Welding, arc-welded joints in aluminium and its alloys, quality levels for imperfections), methods of avoiding, rectification methods

Visually evaluate: use of visual techniques, lighting, low powered magnification, fillet weld gauges, dye penetrant testing, preparation for inspection, qualitative (defect levels, appearance), quantitative (extent, size, dimensional accuracy)

Destructively test: nick-break (fracture), macroscopic examination (x5) bend tests (butt welds, side, face, root), methods of preparation for testing

Unit 337 TIG welding of aluminium

Level: 3
Credit value: 9
UAN: Y/503/0351

Unit aim

This unit sets out the requirements for tungsten inert gas (TIG) welding of aluminium and aluminium alloys in a modern engineering environment, in terms of what needs to be achieved by the leaner, ie: welding a series of challenging joint configurations across in a wide range of positions that are compliant to welding procedure specifications.

The unit is concerned with the technology and practices involved in the application of TIG welding of aluminium and aluminium alloys. The unit is demanding in terms of technological content and the complexity of the welding aluminium and aluminium alloys that leaners are expected to achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Learning outcomes

There are **four** learning outcomes to this unit. The learner will:

1. Be able to apply safe working practices to TIG welding
2. Be able to prepare equipment for performing TIG welding of aluminium and aluminium alloys
3. Be able to perform TIG welding operations to meet welding procedure specification requirements
4. Be able to evaluate welded joints for welding procedure specification conformance

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the NVQ 1681 Level 3 – Fabrication and Welding Engineering; Unit 6: Welding Materials by Manual TIG and Plasma-arc Processes

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 337 TIG welding of aluminium

Outcome 1 Be able to apply safe working practices to TIG welding

Assessment Criteria

The learner can:

1. apply the health and safety **regulation**s relevant to welding
2. assess **hazards and risks** in a welding environment and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, Management of Health and Safety at Work Regulations, Personal Protective Equipment at Work Regulations, Noise at Work Regulations

Hazards and risks: fume, fire, electricity, arc radiation, hot metal, hazards associated with the storage, handling and use of pressurised gas cylinders

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance cylinders (safe storage conditions, safe handling/moving, safe use)

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to welding process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection [PPE, screening, warnings {verbal, notices}]), hot metal (methods of avoiding), hazards associated with the storage, handling and use of pressurised gas cylinders

Unit 337 TIG welding of aluminium

Outcome 2 Be able to prepare equipment for performing TIG welding of aluminium and aluminium alloys

Assessment Criteria

The learner can:

1. list the range of **welding equipment** available
2. describe the function of **welding equipment**
3. prepare the **welding equipment** for a range of given applications
4. prepare the welding **shielding gases** for a range of given applications

Range

Welding equipment: power sources, direct current [d.c.], transformer, transformer/rectifier, inverter, generator, measurement of electrical output and continuity, methods of current regulation, power source characteristics, torches, collet, collet holder, gas lens, electrodes, return clamps, ancillary equipment

Shielding gases: cylinders, manifold systems, regulators (fixed, single-stage, two-stage), gas flow meters, gas tubes and connectors, use of solenoid valves

Additional Guidance

Welding equipment: power sources (output [alternating current [a.c.], direct current [d.c.], transformer [function, winding ratio, input/output ratio, construction], transformer/rectifier [function, operation, construction {diodes, thyristors} function of smoothing capacitors], inverter [function, operation, construction], generator [fuel driven, motor driven, function, operation, construction], rated output [duty cycle]), measurement of electrical output and continuity (voltage – use of voltmeter/multi-meter, current – use of ammeter/shunts/coils, continuity – use of continuity tester/ohmmeter), methods of current regulation (tapped reactor, moving core, moving coil, moving shunt, saturable reactor, variable resistance), power source characteristics (volt/ampere graph, drooping characteristic, constant current output), leads used (welding [water cooled, air cooled, harness] return, earth, construction, rated output [duty cycle]), torches (types, water cooled air cooled, pencil, construction, connections, contactor/switch, foot pedal/amptrol, back caps [long. medium, short, applications], nozzles [long. medium, short, applications], collet, collet holder, gas lens [construction, effects, benefits, limitations, applications), electrodes (thoriated, zironiated, ceriated, lananathed, compositions, sizes, identification, applications, preparation [grinding: techniques, equipment, health and safety implications {dust, particulates, extraction, radioactivity for thoriated}), return clamps (types, clamping mechanisms), ancillary equipment (angle grinders, linishers, wire brushes, oxide removal, degreasers)

Unit 337 TIG welding of aluminium

Outcome 3 Be able to perform TIG welding operations to meet welding procedure specification requirements

Assessment Criteria

The learner can:

1. critically compare **welding consumables** for a range of given applications
2. differentiate between **welding consumables** by their classification
3. produce complex welded aluminium alloy joints in a range of positions in accordance with welding procedure specifications (WPS) parameters
4. explain the effects of the **electrical characteristics** of the TIG welding arc
5. **restore work areas** to a clean and safe condition on completion of welding operation.

Range

Welding consumables:

Electrode wires:

BS EN ISO 18273:– Welding consumables: wire electrodes, wires and rods for welding of aluminium and aluminium alloys, classification (sizes [diameters, lengths], strength and elongation of the weld metal, chemical composition of the weld metal, storage, identification, segregation (classification, size), application to aluminium alloy groups (1000 – 7000 series)

Shielding gases:

BS EN 439: Welding consumables: shielding gases for arc welding and cutting, effects of shielding gases/gas mixtures (weld pool/arc area protection, heat input, weld geometry, penetration profile, travel speed), applications for shielding gases/gas mixtures (argon, helium, argon/helium mixtures, helium/argon mixtures), benefits and limitations, gas pressure requirements, flow rates for applications

WPS: welding process, parent metal, consumables, pre welding activities (cleaning [including scraping, filing, abrasives, stainless steel wire brushing, degreasing, chemical etching and associated care in use], edge preparation, assembly, pre-heat – relation to thickness, effect upon fusion, material composition]), welding), welding parameters, welding positions (EN ISO 6947 – PA, PB, PC, PD, PE, PF, PG), number and arrangement of runs to fully fill/weld joints, electrode sizes for joint thicknesses, electrode, filler wire, electrical conditions required (type of current, alternating [a.c.] direct [d.c.], electrode polarity (positive), welding current ranges, methods of arc ignition (scratch, high frequency, lift start), shielding gas (type, flow rate, pre-weld gas flow, post-weld gas flow), techniques, control of heat input (preheat temperatures and methods of application), interpass/run cleaning/back gouging methods, post welding activities (wiring brushing, removal of excess weld metal where required), post-weld heat treatment (normalising, stress relief)

Electrical characteristics: effects of types of current (a.c./d.c.) and electrode polarity (d.c.: positive, negative) upon: heat input/distribution, electrode, weld bead profile, penetration; methods of a.c. arc stabilisation and maintenance (including: square wave); welding current features (pulse current, slope in, slope out) voltage (open circuit, arc)

Additional Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions

that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 337 TIG welding of aluminium

Outcome 4 Be able to evaluate welded joints for welding procedure specification conformance

Assessment Criteria

The learner can:

1. explain the implications of quality specifications used to determine the **integrity of welded joints**
2. **visually evaluate** welded joints for conformance
3. prepare and **destructively test** joints to evaluate sub-surface for conformance

Range

Integrity of welded joints: classification of defects, quality specification (BS EN ISO 10042 – welding, arc-welded joints in aluminium and its alloys, quality levels for imperfections), methods of avoiding, rectification methods

Visually evaluate: use of visual techniques, lighting, low powered magnification, fillet weld gauges, dye penetrant testing, preparation for inspection, qualitive (defect levels, appearance), quantitive (extent, size, dimensional accuracy)

Destructively test: nick-break (fracture), macroscopic examination (x5) bend tests (butt welds, side, face, root), methods of preparation for testing

Unit 338 Flux-cored arc welding of materials

Level: 3
Credit value: 9
UAN: K/503/0354

Unit aim
This unit sets out the requirements for flux-cored arc welding in a modern engineering environment, in terms of what needs to be achieved by the leaner, ie: welding a series of challenging joint configurations across in a wide range of positions that are compliant to welding procedure specifications.

The unit is concerned with the technology and practices involved in the application of flux-cored arc welding. The unit is demanding in terms of technological content and the complexity of the welding that leaners are expected to achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (i.e. electrodes) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Learning outcomes
There are **four** learning outcomes to this unit. The learner will:
1. Be able to apply safe working practices to flux-cored arc welding
2. Be able to prepare equipment for performing flux-cored arc welding
3. Be able to perform flux-cored arc welding operations to meet welding procedure specification requirements
4. Be able to evaluate welded joints for welding procedure specification conformance

Guided learning hours
It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards
NVQ 1788 Level 3 – Engineering Maintenance: Unit 317: Testing Electronic Equipment and Circuits

Assessment
This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.

Unit 338 Flux-cored arc welding of materials

Outcome 1 Be able to apply safe working practices to flux-cored arc welding

Assessment Criteria

The learner can:

1. apply the health and safety **regulations** relevant to welding
2. assess **hazards and risks** in a welding environment and recommend safety precautions, procedures and Personal Protective Equipment (PPE) to overcome hazards
3. follow safe working practices

Range

Regulations: Health and Safety at Work etc. Act, COSHH, PUWER (scope within the welding environment), RIDDOR, Management of Health and Safety at Work Regulations, Personal Protective Equipment At Work Regulations, Noise at Work Regulations

Hazards and risks: fume, fire, electricity, arc radiation, hot metal/slag

Safe working practices: safe start-up and shutdown procedures, safe use of equipment, equipment checks by operator, routine maintenance cylinders (safe storage conditions, safe handling/moving, safe use

Additional Guidance

Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within the welding environment), RIDDOR (application to welding process, major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment at Work Regulations (application to welding process, employers' duties, employees' duties, protection against hazards [fumes, airborne particles, arc radiation, hot metal, sparks, falling objects, factors render Personal Protective Equipment (PPE) provided as protection ineffective or unsafe]), Noise at Work Regulations (action levels)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection [PPE, screening, warnings {verbal, notices}]), hot metal/slag (methods of avoiding), hazards associated with the storage, handling and use of pressurised gas cylinders

Unit 338 Flux-cored arc welding of materials

Outcome 2 Be able to prepare equipment for performing flux-cored arc welding

Assessment Criteria

The learner can:

1. critically compare **welding equipment** for a range of given applications
2. describe the functions of **welding equipment**
3. prepare the **welding equipment** for a range of given applications
4. prepare the welding **shielding gases** for a range of given applications

Range

Welding equipment: power sources, transformer/rectifier, inverter, generator, measurement of electrical output and continuity, methods of current regulation, power source characteristics, leads, electrode holders, return clamps, ancillary equipment

Shielding gases: cylinders, manifold systems, regulators (fixed, single-stage, two-stage), gas flow meters, gas tubes and connectors, use of solenoid valves, heaters for CO2

Additional Guidance

Welding equipment: power sources (output direct current [d.c.], transformer/rectifier [function, operation, construction {diodes, thyristors} function of smoothing capacitors], inverter [function, operation, construction], generator [fuel driven, function, operation, construction], rated output [duty cycle]), measurement of electrical output and continuity (voltage – use of voltmeter/multi-meter, current – use of ammeter/shunts/coils, continuity – use of continuity tester/ohmmeter), relationship between wire feed speed control and welding current, power source characteristics (volt/ampere graph, flat characteristic, constant voltage output), function of induction (principle, effect, fixed, stepped, variable control, leads used (welding [water cooled, air cooled, harness construction], return, earth, construction, rated output [duty cycle]), welding guns/torches (water cooled, air cooled, construction, types [push, pull, reel-on-gun] swan neck design, pistol design, nozzles [dip, spray], contact tip [functions, material, sizes, clearing a burn-back), return clamps (types, clamping mechanisms), wire feed control (variable speed motor, direct control of wire feed rate, indirect control of welding current, solenoid valves [shielding gas, water], relay for electrical power, jog-feed control, gas purge control) ancillary equipment (angle grinders, wire brushes, linishers, hammer and chisel)

Unit 338 Flux-cored arc welding of materials

Outcome 3 Be able to perform flux-cored arc welding operations to meet welding procedure specification requirements

Assessment Criteria

The learner can:

1. critically compare **welding consumables** for a range of given applications
2. differentiate between **welding consumables** by their classification
3. produce complex welded joints in a range of positions in accordance with welding procedure specifications **(WPS)** parameters
4. **restore work areas** to a clean and safe condition on completion of welding operation.

Range

Welding consumables:

Electrode wires:

BS EN 756: Welding consumables, solid wires, solid wire-flux and tubular cored electrode-flux combinations for submerged arc welding of non-alloy and fine grain steels, classification: (sizes [diameters, reel sizes available], strength and elongation of the weld metal, impact properties of the weld metal, chemical composition and types of flux core (rutile, basic, metal-cored, self-shielded, gas-shielded)

Shielding gases:

BS EN 439: Welding consumables: shielding gases for arc welding and cutting, effects of shielding gases/gas mixtures (weld pool/arc area protection, heat input, weld geometry, penetration profile, travel speed, mode of metal transfer), applications for shielding gases/gas mixtures (carbon dioxide, argon/carbon dioxide mixtures, argon/oxygen/carbon dioxide mixtures), gas pressure requirements, flow rates for applications

WPS: welding process, parent metal, consumables, pre welding activities (cleaning, edge preparation, assembly, pre-heat), welding parameters, welding positions (EN ISO 6947 – PA, PB, PC, PD, PE, PF, PG), number and arrangement of runs to fully fill/weld joints, electrode sizes for joint thicknesses, mode of metal transfer (dip [short-circuiting, globular, spray, pulse), electrical conditions required (type of current, direct [d.c.], electrode polarity (positive or negative depending upon the wire), wire feed speed ranges, voltage (open circuit, arc), control of heat input, shielding gas (type, flow rate) interpass/run cleaning/back gouging methods, post welding activities (spatter removal, wiring brushing, removal of excess weld metal where required), post-weld heat treatment (normalising, stress relief)

Addition Guidance

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Unit 338 Flux-cored arc welding of materials

Outcome 4 Be able to evaluate welded joints for welding procedure specification conformance

Assessment Criteria

The learner can:

1. explain the implications of quality specifications used to determine the **integrity of welded joints**
2. visually evaluate welded joints for conformance
3. prepare and **destructively test** joints to evaluate sub-surface for conformance

Range

Integrity of welded joints: classification of defects, quality specification (BS EN 25817 – arc welded joints in steel – guidance on quality levels for imperfections), methods of avoiding, rectification methods

Visually evaluate: use of visual techniques, lighting, low powered magnification, fillet weld gauges, dye penetrant testing, preparation for inspection, qualitive (defect levels, appearance), quantitive (extent, size, dimensional accuracy)

Destructively test: nick-break (fracture), macroscopic examination (x5) bend tests (butt welds, side, face, root), methods of preparation for testing

Unit 339 Principles of composite materials

Level: 3
Credit value: 9
UAN: L/505/2427

Unit aim

This unit enables learners to understand the underlying principles that apply to composite materials. Learners will understand the principles and components of composite materials including the chemical composition of thermoplastics and thermosets, and the overall advantages of using composite materials as an alternative to other materials. Learners will also be able to demonstrate their understanding of different materials and techniques used in dry fibre moulding and the preparation and use of adhesive and bonding materials for composite structures.

Learning outcomes

There are **five** learning outcomes to this unit. The learner will:

1. Understand the principles and components of composite materials
2. Understand composites matrix chemistry
3. Understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-forms) materials
4. Understand the materials and techniques used in dry fibre moulding
5. Understand preparation and use of adhesive and bonding materials for composite structures including potential defects

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the Composite Engineering Suite 2 National Occupational Standards.

Assessment

This unit will be assessed by a short answer question paper.

Unit 339 Principles of composite materials

Outcome 1 Understand the principles and components of composite materials

Assessment Criteria

The learner can:

1. Describe different **types** and **applications** of composite materials
2. Describe the concept and **types of reinforcement** embedded within a **matrix** and the properties of the combined material
3. Outline reinforcement **styles** and their selection for use
4. Describe the concept of **core structures** and their selection for use
5. Describe the **mechanical properties** of composite materials
6. Describe the principle of ply direction and the importance of consolidation
7. Explain the **advantages** of composites
8. Outline specific health and safety and environmental **requirements** for handling and using composite materials

Range

Types: PMC, MMC, CMC

Applications: eg, sector-specific (aircraft, automotive, marine, power generation, construction, civil engineering, rail)

Types of reinforcement: glass, carbon, aramids, thermoplastic fibres, metal, aligned continuous, random discontinuous, ceramic, metal, natural fibres

Matrix: chemical and adhesive properties

Styles: uni-directional, bonded eg CSM, stitched, braids, roving, weave styles

Core structures: honeycombs, woods, foams

Mechanical properties: stiffness, strength, toughness, thermal stability, light weight, chemical resistance, anisotropic

Advantages: material performance, weight, cost, lifespan, degradation, repair, assembly, bespoke properties

Requirements: bulk storage, ventilation and temperature control of work areas, protection of respiratory system, skin, fire protection, long and short term exposure to fibres, solvents and matrix materials, safe disposal of waste, COSHH

Unit 339 Principles of composite materials

Outcome 2 Understand composites matrix chemistry

Assessment Criteria

The learner can:

1. Describe the **principles** of polymer chemistry
2. Describe the **properties** of thermoplastics and thermosets
3. Explain the use of **additional materials** in resin systems
4. Describe how resin systems are recycled and/or disposed of safely

Range

Principles: polymerisation, reaction, curing

Properties: physical, chemical

Additional materials: additives, fillers, pigments, fire retardants

Unit 339 Principles of composite materials

Outcome 3 Understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-forms) materials

Assessment Criteria

The learner can:

1. Explain the **differences** between pre-preg and pre-form materials
2. Describe laminate **preparation** including consolidation
3. Describe the **techniques** used for manufacturing components from pre-preg materials
4. Explain **advantages and disadvantages** of using pre-preg and pre-form materials

Range

Differences: material consistency, application, usage, storage requirements

Preparation: template, nesting, cutting, kitting, bagging materials, release films, safe disposal of waste

Techniques: manual (use of heat and pressure, autoclave, out of autoclave, vacuum bag)

automated systems

Advantages/disadvantage: price, set-up cost, component parts, productivity rate, labour, cost of machinery, quality control

Unit 339 Principles of composite materials

Outcome 4 Understand the materials and techniques used in dry fibre moulding

Assessment Criteria

The learner can:

1. Identify **materials** used in dry fibre moulding
2. Explain the principles of manufacturing **techniques** used in dry fibre moulding
3. Explain **advantages and disadvantages** of using dry fibre moulding techniques
4. Explain the effects of consolidation

Range

Material categories including: cores, resins, fibres

Techniques: manual, resin infusion, resin transfer, filament winding, pultrusion, fibre placement

Advantages/disadvantages: price, set-up cost, component parts, productivity rate, labour, cost of machinery, quality control

Unit 339 Principles of composite materials

Outcome 5 Understand preparation and use of adhesive and bonding materials for composite structures including potential defects

Assessment Criteria

The learner can:

1. Explain the use of **adhesive and bonding agents** in composite structures
2. Describe the importance of correct **surface preparation**, sealing and c**uring**
3. Describe **typical defects** and methods used for **detection**

Range

Adhesive and bonding agents: jigs, fixtures, chemical products

Surface preparation: mechanical, abrasion, solvent

Curing: temperature, pressure, environmental conditions

Detection: eg tap testing, thermography, x-ray, shearography, ultrasonic

Typical defects: eg voids, disbonds, porosity

Unit 340 Principles of composites manufacture

Level: 3
Credit value: 9
UAN: D/505/2433

Unit aim

This unit enables learners to understand the underlying principles that apply to composites manufacture. Learners will understand the different manufacturing processes used for thermoplastics and thermosets, types and sources of defects, different applications of NDT methods and the process and quality systems required for composite component and structure manufacture. On completion of this unit, learners will be able to plan, make and test a manually fabricated component to given specifications.

Learning outcomes

There are **five** learning outcomes to this unit. The learner will:

1. Understand the manufacturing processes used for composite components and structures
2. Understand types and sources of manufacture defects of composite components and structures
3. Know different methods of Non-Destructive Testing (NDT) available
4. Understand process and quality systems required for composite component and structure manufacture
5. Be able to plan, make and test manually fabricated components to given specifications

Guided learning hours

It is recommended that **80** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Details of the relationship between the unit and relevant national standards

This unit is linked to the Composite Engineering Suite 2 National Occupational Standards.

Assessment

This unit will be assessed by a short answer question paper and a short practical task.

Unit 340 Principles of composites manufacture

Outcome 1 Understand the manufacturing processes used for composite components and structures

Assessment Criteria

The learner can:

1. Explain the **processes** used in the manufacture of thermoset composite materials
2. Explain the **processes** used in the manufacture of thermoplastic composite materials
3. Explain **advantages and disadvantages** of thermoset and thermoplastic processes

Range

Processes (thermosets): hand layup, resin infusion systems, resin transfer, filament winding, pultrusion, automated tape and fibre placement, hot press

Processes (thermoplastics): hot press, extrusion, compression moulding

Advantages/disadvantage: price, set-up cost, component parts, productivity rate, labour, cost of machinery, quality control

Unit 340 Principles of composites manufacture

Outcome 2 Understand types and sources of manufacture defects of composite components and structures

Assessment Criteria

The learner can:

1. Describe different **types** of manufacturing defects
2. Describe **sources** of manufacture defects
3. Explain the **effects** of different types of manufacturing defects on component and structures fitness for purpose

Range

Types: eg cavities, wrinkling, porosity, de-lamination, bridging, disbonds, pre-release

Sources: eg contamination and cleanliness, incorrect process control, environmental, equipment failure, manufacturing damage

Effects: eg unsatisfactory properties, cost, rework, delivery, service life, premature failure

Unit 340 Principles of composites manufacture

Outcome 3 Know different methods of Non-Destructive Testing (NDT) available

Assessment Criteria

The learner can:

1. Outline the principles of **NDT methods**
2. Describe **types** of NDT systems
3. Describe the function and **limitations** of NDT systems

Range

NDT methods: visual, physical, penetrative

Types: tap test, visual surface, thermography, x-ray, ultrasonic

Limitations: eg costs, accuracy, repeatability, skill level available, effectiveness

Unit 340 Principles of composites manufacture

Outcome 4 Understand process and quality systems required for composite component and structure manufacture

Assessment Criteria

The learner can:

1. Explain the need for materials life control and correct storage of raw materials and finished product
2. Explain the need for environmental controls in composite manufacture and storage
3. Describe the process of defect management and concessions (allowable defects) for composite materials

Unit 340 Principles of composites manufacture

Outcome 5 Be able to plan, make and test manually fabricated components to given specifications

Assessment Criteria

The learner can:

1. Select material, consumables and tooling from the specification
2. Develop plan of work
3. Produce fabricated component
4. Test fabricated component

Unit 341 Pipe and tube fabrication

Level: **3**
Credit value: **9**
UAN: **T/505/2728**

Unit aim

Learners will develop a broad range of skills and understanding related to the fabrication of pipe and tube. The skills and techniques that are used extensively within the sector include preparing, cutting, bending and assembling pipe and tube fabrications in a safe manner. This knowledge will allow learners to select the most suitable methods and techniques to address practical situations in the workplace.

Learning outcomes

There are **five** learning outcomes to this unit. The learner will be able to:

1. Understand how to apply health and safety in a pipe and tube fabrication environment
2. Be able to prepare and plan for the production of pipe and tube fabrication
3. Be able to prepare and use equipment to cut pipe and tube
4. Be able to prepare and use equipment to bend pipe or tube
5. Understand assembly, joining and inspection methods to pipe and tube fabrications

Guided learning hours

It is recommended that **68** hours should be allocated for this unit, although patterns of delivery are likely to vary.

Assessment

This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds

Unit 341 Pipe and tube fabrication

Outcome 1 Understand how to apply health and safety in a pipe and tube fabrication environment

Assessment Criteria

The learner can:

1. describe the **health and safety regulations** applicable to pipe and tube fabrication
2. assess **hazards** and risks in a pipe and tube fabrication environment
3. follow safe **working practices and procedures** in a pipe and tube fabrication environment

Range

Health and safety regulations: Health & safety at work act (1974) (HASAWA); Control of substances hazardous to health (COSHH), Provision and use of work equipment (PUWER), Reporting injuries, diseases and dangerous occurrences regulations (RIDDOR)

Management of health and safety at work regulations, Personal protective equipment at work regulations, Noise at work regulations;

Lifting operations, lifting equipment regulations

Hazards: fume, fire, electricity, arc radiation, hot metal, hazards associated with the storage, handling and use of pressurised gas cylinders

Working practices and procedures: use appropriate PPE, safe shutdown procedures, permissions to work, clearance certificates, arrangements for stand-by operations, isolating valves, controlled pressure release, cooling down allowance, pressure checking, blanking off, hydrostatic pressure testing, cutting materials

Unit 341 Pipe and tube fabrication

Outcome 2 Be able to prepare and plan for the production of pipe and tube fabrication

Assessment Criteria

The learner can:

1. interpret instructions and working drawings to identify **production requirements**
2. calculate **data** for pipe and tube fabrication using standard formula
3. extract information from working drawings to produce:

- material cutting lists
- parts and fittings list
- pipe layouts
- templates
- flow charts

4. **mark out** pipe/tube in readiness for cutting and bending

Range

Production requirements: materials, cutting methods and equipment, pipe protection methods, pipe fittings

Data: calculation of cutting, joining and bending allowances, angles of cut, neutral line concept

Mark out: pipe lengths, bend lines, angular measurement and bend position, set out perpendicular and inclined branches

Unit 341 Pipe and tube fabrication

Outcome 3 Be able to prepare and use equipment to cut pipe and tube

Assessment Criteria

The learner can:

1. describe the types of **cutting equipment** used for pipe and tube fabrication
2. set up and use **cutting equipment** for pipe and tube fabrication
3. produce pipe and tube to the required **shape** and size for a **range of configurations**

Range

Cutting equipment: saws, grinding machines, thermal cutting, cutting guidance systems

Shape: hole profile, branch profile, end preparations

Range of configurations: bends in same plane, bends in two or more different planes, offsets in same plane and offsets in two or more different planes (rolled offsets)

Unit 341 Pipe and tube fabrication

Outcome 4 Be able to prepare and use equipment to bend pipe or tube

Assessment Criteria

The learner can:

1. describe **forming methods** for pipe or tube-bending applications
2. select and set up appropriate **bending and forming equipment** to undertake bending
3. bend pipe or tube in a **range of configurations**

Range

Forming methods: bending principles, bend factors, hot and cold techniques, safety considerations, heat lengths, localised cooling, free bending

Bending and forming equipment: machine types (compression, draw, ram press and roll (coil)

Range of configurations: bends in same plane, bends in two or more different planes, offsets in same plane and offsets in two or more different planes (rolled offsets)

Unit 341 Pipe and tube fabrication

Outcome 5 Understand assembly, joining and inspection methods to pipe and tube fabrications

Assessment Criteria

The learner can:

1. select joining **methods** for the assembly of pipe and tube fabrications
2. justify the selected joining **methods** for the assembly of pipe and tube fabrications
3. describe **installation requirements** for pipe and tube fabrications
4. perform joining operations for pipe and tube fabrications using a range of **methods**
5. describe and use a **range of inspection techniques** to check pipe and tube fabrications against specification.
6. explain the implications of **defects** identified during inspection and the methods of avoidance
7. restore work areas to a clean and safe condition on completion

Range

Methods: threaded, welded, adhesive bonded, hot air welded, soldered, brazed, compression

Installation requirements: pipe supports, lagging, surface protection, in-service conditions

Range of inspection techniques: visual inspection, hydrostatic testing, thread insertion check, dimensional checks

Defects: crushed bore, puckering, split tube, misalignment, wall thinning, weld defects

Unit 341 Pipe and tube fabrication
Guidance

Outcome 1:
Regulations: Health and Safety at Work etc. Act, COSHH (risk assessment, consumable data sheets, training and awareness, safe working procedures, hierarchy of control), PUWER (scope within pipe and tube fabrication) , RIDDOR (major injuries, over three day injuries, diseases, dangerous occurrences) Management of Health and Safety at Work Regulations (risk assessment, five steps to risk assessment, control measures, training and awareness, safe working procedures), Personal Protective Equipment At Work Regulations (applicable to thermal joining process, use of machines, hot bending of pipe and tube, employers' duties, employees' duties, protection against hazards [fumes, noise, airborne particles, arc radiation, hot metal, sparks, lifting/handling material, falling objects], factors rendering PPE provided as protection ineffective or unsafe), Noise at Work Regulations (action levels), vibration, Lifting operations, Lifting Equipment Regulations, LOLER, (condition, suitability, inspection and identification of lifting chains, ropes and equipment, conditions relating to SWL of lifting equipment, faults that render wire ropes unserviceable)

Hazards and risks: fume (composition, visible particulate, invisible gaseous, risks to health, control measures to reduce exposure, extraction [background, local, natural ventilation, e.g. on-site, air-fed headshields, respirator, breathing apparatus, monitoring the effectiveness of control measures), fire (sources of combustion, identification of hazards, methods of reducing risks, identification of extinguishers), electricity (shock, fire, burns, methods of avoiding shock hazards, emergency procedures in the event of an electric shock, function of protection devices, earthing, workpiece, plant), arc radiation (visible light, infra-red, ultra-violet, effects, protection [PPE, screening, warnings {verbal, notices}), hot metal (methods of avoiding), grinding, thermal cutting, arc cutting, welding, hot bending.

Safe working practices and procedures: protect yourself and other people, know emergency procedures, report all hazards, thermal cutting and welding safe start-up and shut down processes, safety requirements and procedures when shutting down an in service pipe line, permission to work, certification of clearance for work on hazardous pipe lines (chemical and flammable liquids), arrangements for stand-by operation during shut down, safety precautions to be taken when dismantling a pipe line which has been isolated but is still under pressure, safe shut-off isolating valves, controlled release of pressure, cooling down allowance, pressure checking prior to dismantling, blanking off as appropriate, precautions for carrying out hydrostatic pressure tests

Outcome 2:
Pipe materials: metals: cast iron, low-carbon steel, low alloys steel, stainless steel, copper and its alloys, nickel and its alloys, aluminium and its alloys. **non-metals:** PVC, polythene, polypropylene, rubber.

Pipe protection: externally: dipping, spraying, painting, bitumous coating, impregnated tapes, **internally:** rubber, cement, resin, synthetic linings, and metal linings.

Compare advantages and limitations of **pipe materials and pipe protection** for use on the following systems: air, steam, hydraulic fluids (water, mineral and synthetic oil), oil, refrigerants, and corrosive fluids.

Pipe fittings: reference to relevant national standards for malleable iron, flanges and cast iron valves; elbows, bends, reducers, flanges, couplings, unions, isolation and control valves.

Templates: function of templates, template materials, templates for branches, tees and mitred bends, template instructions

Flow charts: logical sequence of manufacture, economy of material and labour, simplicity of construction, quantity required, use of production aids, dimensional accuracy, standard of finish.

Layouts: function and use of datum surface and line, setting out points, trial and full size setting out, measuring and marking out equipment types and function, use of wires, bevel bars, checking fixtures, measurement of angular positions and bends relatives to datums, setting out for set on branches (perpendicular, inclined, equal and un-equal diameters)

Marking out methods: location of bend lines, allowance calculations (cutting, bending, joining), marking pipe lengths, marking out templates, cutting and forming instructions to avoid "wrong hand" errors, functions of setting out points (SOP)

Outcome 3:

Cutting machines: pipe and tube cutters, circular saws, band saws (vertical, horizontal), reciprocating hacksaws (mechanical and hand), abrasive saws, hand grinding machines, bevelling machines (reciprocating)

Thermal cutting: principle of oxy-fuel cutting; manual cutting, machine cutting, cutting head control methods, quality of cut, three point plate support, distortion control, accuracy. Principle and use of electric arc plasma cutting

Compare advantages and limitations of cutting processes in regard to cutting pipe and tube to length, end preparation for welding, pipe preparation for branches.

Outcome 4:

Principles:

- cold bending (machine types, machine set up, free bending, faults, low melting point alloys) faults, bend factors
- hot bending (sand loaded pipe, no internal support), hand bending equipment, use of winches, heat sources(torch, furnaces) aids(wire templates, localised cooling)heat lengths (position, bend configurations), faults, bend factors

Safety considerations: melting, filling and cooling of low melting point alloys, emptying allows after bending

Selection factors: pipe dimensions, pipe materials, mode of pipe manufacture, accuracy requirements, equipment availability.

Bending machine types: compression, draw, ram press, roll (coils)

Compare principles of operation, power sources, bending capacity, and applications of the machine types listed.

Bend configurations: bends in same plane, bends in two or more different planes, offsets in same plane and offsets in two or more different planes (rolled offsets).

Cold bending faults: flattening, ovality, wrinkling, changes in wall thickness.

Avoiding cold faults: use of mandrels, springs and low melting alloys.

Hot bending faults: flattening, burning, wrinkling or buckling, changes in wall thickness, scaling.

Avoiding hot faults: correct machine settings, correct packing, bend radius (3-5 diameters), heat applications control.

Bend factors: correct bend allowances, angle of bend, true length of bend, dimensions of pipe (diameter to wall thickness), spring back allowance, requirements for internal support, method of bending.

Outcome 5:

In-service conditions: physical and chemical properties of pipe content, thermal/pressure cycle, vibration.

Fittings: threaded to relevant standards, manipulative and non-manipulative fittings for compression joints, plain end fittings for fusion welding, plastic pipe fittings (adhesive, hot air gun, hot plate welding techniques), soldered fittings, malleable iron fittings.

Gasket & Joining compounds: in-service and environment conditions (physical and chemical properties of pipe content, thermal/pressure cycle, vibration), type of housing, flange face finish, range of gasket materials compatible with environmental conditions listed (rubber and rubber compounds, plastics, compressed asbestos free gaskets, metallic and semi-metallic, tapes and cords), range of jointing compounds compatible with environmental conditions listed.

Selection criteria: material, position, pipe and tube dimensions, in-service requirements, access.

Welding: processes (manual metal arc (MMA), manual active gas (MAG), tungsten inert gas (TIG), machine settings, consumables, tacking (procedures, settings and consumables for sound and effective tacks), joint configurations (open “square” corner, square butt, fillet, single v bevel, flanged), weld symbols.

Soldering: hard and soft soldering, spelters, fluxes

Production defects: pitting, laminations, split seams, ovality, variation to wall thickness and diameters.

Lagging: reasons for lagging (avoiding heat loss, prevent surface condensation, fire proofing, sound proofing), lagging considerations (operating temperature, pipe to pipe clearance, accommodating supports and brackets, walls and equipment clearances), lagging materials (rock wool, fibreglass, polystyrene , pre-formed section, aluminium), lagging forms of supply (pre-formed (rigid), paste, sheet, strip, mattress, loose fill), protection(environment, accidental damage, regular maintenance), hazards of removal.

Pipe support installation: considerations factors (permissible degree of movement, calculation of expansion movement), loading of pipework (gross weight of system, cycling, hydrostatic testing), ability of built structure to withstand applied load, position of supports relative to plant and equipment, vibration.

Methods to accommodate factors listed (natural changes of direction, expansion loops, expansion fittings (bellows and sliding type), constant load adjustable spring hangers, shock absorbers and shock absorbing materials.

Pipe support types: single and multi-pipe flat bar hangers, anchor brackets, pipe bridges, support trestles, cleats, clamping devices, support rods and locking devices, guides, flanges, location and fixing of wind bracing and space supports.

Restore work areas: leave the work area free of unused consumables, cleaning the work area, putting tools and equipment into safe storage, identify any materials used that are classified as hazardous and those that can be recycled, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed, informing all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area, work termination documents or reports that may be required are completed and passed on to an authorised person (eg terminating permits to work)

Appendix 1 Relationships to other qualifications

Links to other qualifications and frameworks

Centres are responsible for checking the different requirements of all qualifications they are delivering and ensuring that candidates meet requirements of all units/qualifications. For example, units within a qualification may be similar in content to units in the NQF qualification which the candidate may have already undertaken and this may present opportunities for RPL.

The qualification provides knowledge and practical skills related to the Level 3 NVQ Diploma in Engineering Maintenance, Level 3 NVQ Diploma in Mechanical Manufacturing Engineering, Level 3 NVQ Diploma in Fabrication & Welding and the Level 3 NVQ Diploma in Technical Support.

Literacy, language, numeracy and ICT skills development

These qualifications include opportunities to develop and practise many of the skills and techniques required for success in the following qualifications:

- Functional Skills (England) – see **www.cityandguilds.com/functionalskills**
- Essential Skills (Northern Ireland) – see **www.cityandguilds.com/essentialskillsni**
- Essential Skills (Wales) - see **www.cityandguilds.com**

There might also be opportunities to develop skills and/or portfolio evidence if candidates are completing any Key Skills alongside these qualifications.

Appendix 2 Sources of general information

The following documents contain essential information for centres delivering City & Guilds qualifications. They should be referred to in conjunction with this handbook. To download the documents and to find other useful documents, go to the **Centres and Training Providers homepage** on **www.cityandguilds.com**.

Centre Guide – Delivering International Qualifications contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification. Specifically, the document includes sections on:

- The centre and qualification approval process and forms
- Assessment, verification and examination roles at the centre
- Registration and certification of candidates
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Frequently asked questions.

Centre Manual - Supporting Customer Excellence contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification, as well as updates and good practice exemplars for City & Guilds assessment and policy issues. Specifically, the document includes sections on:

- The centre and qualification approval process
- Assessment, internal quality assurance and examination roles at the centre
- Registration and certification of candidates
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Management systems
- Maintaining records
- Assessment
- Internal quality assurance
- External quality assurance.

Access to Assessment & Qualifications provides full details of the arrangements that may be made to facilitate access to assessments and qualifications for candidates who are eligible for adjustments in assessment.

The **centre homepage** section of the City & Guilds website also contains useful information such on such things as:

- ***Walled Garden****:* how to register and certificate candidates on line
- ***Events***: dates and information on the latest Centre events
- ***Online assessment***: information on how to register for online assessments.

Useful contacts

UK learners General qualification information	T: +44 (0)844 543 0033 E: **learnersupport@cityandguilds.com**
International learners General qualification information	T: +44 (0)844 543 0033 F: +44 (0)20 7294 2413 E: **intcg@cityandguilds.com**
Centres Exam entries, Certificates, Registrations/enrolment, Invoices, Missing or late exam materials, Nominal roll reports, Results	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **centresupport@cityandguilds.com**
Single subject qualifications Exam entries, Results, Certification, Missing or late exam materials, Incorrect exam papers, Forms request (BB, results entry), Exam date and time change	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 F: +44 (0)20 7294 2404 (BB forms) E: **singlesubjects@cityandguilds.com**
International awards Results, Entries, Enrolments, Invoices, Missing or late exam materials, Nominal roll reports	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **intops@cityandguilds.com**
Walled Garden Re-issue of password or username, Technical problems, Entries, Results, GOLA, Navigation, User/menu option, Problems	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **walledgarden@cityandguilds.com**
Employer Employer solutions, Mapping, Accreditation, Development Skills, Consultancy	T: +44 (0)121 503 8993 E: **business@cityandguilds.com**
Publications Logbooks, Centre documents, Forms, Free literature	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413

If you have a complaint, or any suggestions for improvement about any of the services that we provide, email: **feedbackandcomplaints@cityandguilds.com**

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