Unit 41: Liquid Metal Casting Processes

Unit code: R/600/0307

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners an understanding of liquid metal processing for the production of castings.

Unit introduction

Casting is a process used throughout the engineering and manufacturing industries to produce a wide variety of products, for example vehicle engine blocks and cylinders and aerospace engine turbine blades. The process involves introducing liquid metal into a mould where it then solidifies into the required shape. It is then removed to produce the fabricated object or component.

In order for castings to be produced correctly, metals technicians need to have an understanding of the different casting processes that can be used and the way that metals and alloys are prepared for casting.

It introduces learners to a range of casting processes and provides them with a deeper understanding of the more common ones. The unit covers the main systems that are used to produce sand moulds and cores and the equipment used in die casting. The main types of equipment used to melt metal for casting are introduced, and some of the metallurgical treatments and controls that are required for different ferrous and non-ferrous alloys are also covered.

Due to the potentially hazardous nature of melting and casting metals the unit also covers the health and safety aspects and environmental considerations of working in the casting industry.

Learning outcomes

On completion of this unit a learner should:

1 Know the principles of casting processes and the selection of suitable processes for given applications

2 Know the main furnace types and melt procedures used in the preparation and treatment of common casting alloys

3 Know about defects in castings and their possible causes

4 Know the health, safety and environmental issues that relate to casting processes.

Unit content

1 Know the principles of casting processes and the selection of suitable processes for given applications

Casting processes: non-permanent moulds eg greensand, chemically bonded sand systems; permanent moulds/dies eg die casting – gravity, low and high pressure; other processes eg ingot, continuous, investment (lost wax), lost foam, shell, centrifugal, squeeze casting; use of terminology eg casting simulation, cope, drag, pattern, mould cavity, runner system, sprue, feeder, core, dies

Specified alloys: eg cast steels, grey and ductile cast iron, aluminium casting alloys, copper-based alloys, nickel casting alloys, magnesium casting alloys, zinc casting alloys

Typical components or applications: automotive eg alloy wheels, engine blocks, cylinder heads, ignition cases, locks; aerospace eg turbine blades, wheels, engine cases; medical eg orthopaedic implants; street furniture eg bollards, manhole covers, garden furniture; telecommunications eg mobile phone cases, automated teller machines (ATMs); other general engineering applications eg machine tool beds, pumps, valves

Post-casting operations: non-permanent moulds eg knockout, shot blasting, de-gating, fettling; permanent moulds/dies eg degating, fettling

2 Know the main furnace types and melt procedures used in the preparation and treatment of common casting alloys

Metal melting furnaces: eg cupola, electric induction, channel induction, electric arc, crucible, gas fired, rotary

Metal preparations and melt treatments: ferrous and non-ferrous metals eg steel, grey and ductile/spheroidal graphite (SG) cast irons, aluminium, copper; preparation eg charge calculation, alloy additions, deoxidation, desulphurisation, degassing; treatment eg inoculation, nodularisation, grain refinement, modification, addition rates

3 Know about defects in castings and their possible causes

Monitoring molten metal quality: melt monitoring and control tests eg test bars, temperature measurement, chemical composition, gas content

Defects in castings: cavities eg blowholes, sinks, internal shrinkage (macro/micro), pinholes; projections and incomplete castings eg misrun, flash, scab, cold lap; metallic and non-metallic inclusions eg shot, oxide skin, sand inclusion, dross

4 Know the health, safety and environmental issues that relate to casting processes

Hazards: process related hazards eg due to mould and core making, casting, fettling and mechanical handling; personal safety and the safety of others eg personal protective equipment (overalls, gloves, boots, gaiters, face and eye protection, ear protectors); environmental impact of casting processes eg use of energy and raw materials, beneficial re-use of waste, air pollution and toxic waste

UK and EU health, safety and environmental legislation and regulations: legislation eg Health and Safety at Work Act 1974, Fire Precautions Act 1971; regulations eg Management of Health and Safety at Work Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER) 1998, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Personal Protective Equipment at Work Regulations 1992, Control of Noise at Work Regulations 2005, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Health and Safety (First Aid) Regulations 1981; integrated pollution prevention and control (IPPC) eg control of air, water and land pollution, noise and energy efficiency

Assessment and grading criteria

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

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the principles of casting processes	**M1** explain the advantages and limitations of different casting processes	**D1** evaluate the factors that lead to the selection of a particular casting process route for a given component
P2 describe a casting process suitable for a specified alloy and a given component or application	**M2** justify the selection of a particular furnace for a given alloy	**D2** evaluate the quality implications that stem from a lack of process control
P3 describe post-casting operations	**M3** compare the metal preparation processes and melt treatments for two different alloys	**D3** evaluate the impact of a casting process on the environment and suggest ways that this impact could be reduced.
P4 select a particular metal melting furnace for a given alloy	**M4** carry out a risk assessment for a given casting process and identify the steps that could be taken to minimise risk.	
P5 describe the metal preparations and melt treatments required to prepare an alloy for casting		
P6 describe the control tests that are used to monitor molten metal quality		
P7 describe defects in given castings		
P8 identify the hazards associated with casting processes [IE4]		
P9 describe the aspects of UK and EU health, safety and environmental legislation and regulations that apply to casting processes.		

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

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

Essential guidance for tutors

Delivery

The teaching and learning strategies used to deliver this unit must enable learners to understand the principles and processes involved in making castings. Tutors will also need to make them aware of the applications and limitations of the different casting processes. Learners should also understand the procedures required to prepare metal for casting and the tests and procedures used to control the metal quality in order to produce quality castings.

A wide range of delivery methods and resources could be used including practical work and demonstrations, DVDs/videos, computer-based and text-based information and industrial visits. The use of case studies, based on processes that learners are familiar with from either their place of work or work placement, would be a valuable means of supporting the delivery of learning outcomes 1 and 2. These case studies could be used alongside visits to industrial sites where different alloys and casting processes are in use.

Whilst learners will benefit most from first-hand experience, health and safety issues and the limited availability of some specialist equipment used for mould making, melting metal and metal treatments may prevent this. However tutor-led demonstrations, CD-ROM and video materials can all be used, where appropriate. Examples, as well as photographs, of defective castings and pre-prepared sections of castings can be valuable in supporting the teaching and learning activities for learning outcome 3.

The importance of health, safety and environmental issues relating to liquid metals and casting processes should be highlighted throughout the unit. As such, the unit content relating to learning outcome 4 could be delivered in parallel to the relevant sections of content from the other three learning outcomes.

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

Outline learning plan

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

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

Topic and suggested assignments/activities and/assessment
Whole class teaching: • introduction to unit content, scheme of work and methods of assessment • explain the use of moulds and other processes for casting. Identify the terminology used • identify and explain the processes used for alloys and the typical components and applications • explain the use of post-casting operations. *Group activities:* • examine a range of cast components and discuss the casting processes that would have been used in their manufacture.
Prepare for and carry out **Assignment 1: Casting Processes** (P1, P2, P3, M1, D1)
Whole class teaching: • describe the main types of metal melting furnace, their operation and applications • describe the preparation processes and melt treatments used for ferrous and non-ferrous metals. *Industrial visit/workshop demonstration (depending on centre resources):* • view the use melt preparation preparations and a metal melting furnace.
Prepare for and carry out **Assignment 2: Furnaces and Melt Processes** (P4, P5, M2, M3)
Whole class teaching: • describe the melt monitoring and control tests used for maintaining molten metal quality • describe the common defects found in castings.
Prepare for and carry out **Assignment 3: Metal Quality** (P6, P7, D2)
Whole class teaching: • identify and describe the main hazards that relate to metal casting processes, including the correct use of PPE and the environmental effects of casting • identify and describe the main health, safety and environmental legislation that applies to metal casting processes.
Prepare for and carry out **Assignment 4: Health, Safety and Environmental Issues** (P8, P9, M4, D3)
Feedback, unit evaluation and close.

Assessment

Evidence could be generated through a variety of methods, such as tutor-led assignments, case studies, learner-led research and testing. For example, a suitable case study could require learners to select, specify and explain a casting process, furnace type and melt treatments and controls to produce a component in a particular alloy. Learners should be encouraged to cross-reference their evidence to the individual learning outcomes and grading criteria.

The pass criteria specify the minimum acceptable level required by learners. The assessments must cover all of the learning outcomes and assessment criteria. Achievement of a merit or distinction grade will require the learner to demonstrate a deeper understanding of the principles being described.

To achieve a pass learners should be able to describe casting processes involving non-permanent and permanent moulds and be able to give an outline description of other casting processes. They should know how to select a casting process for a particular alloy and component and be able to identify the process steps required in the production of a cast component, including post-casting operations. Learners will need to select a metal melting furnace and identify and describe the necessary metal preparation and melt treatments. They should know the main control tests used in the preparation of molten metal for casting and be able to recognise the most common defect types that occur in castings. They should be able to identify the major health and safety hazards and the legislation and regulations associated with the different stages in the casting process.

To achieve a merit learners should be able to explain the advantages and limitations of different casting processes and melting furnaces used for different alloys, types of component and applications. They should have a knowledge and understanding of the different metal preparations and treatments to molten metals prior to casting into the mould/die and why these are carried out and be able to calculate the charge, where appropriate, and any addition/treatment rates required. They should understand the main factors that can lead to the production of defective castings and be able to complete a health and safety risk assessment for a particular casting process understanding the measures that can be taken to minimise risk to themselves and others.

To achieve a distinction learners should have an understanding of the factors that influence the selection of a particular casting process for a component part. They should be able to evaluate the effects of process variables within a casting process on the characteristics of the casting and on the likely incidence of characteristic defects, and how process control can lead to the production of quality castings. They should be able to suggest ways in which the risk of defects occurring can be minimised. They should also be able to evaluate the environmental impacts of casting processes and how these may be minimised.

Programme of suggested assignments

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Casting Processes	Learners need to complete a poster about casting processes for new apprentices.	A written assignment based on a case study or industrial visit.
P4, P5, M2, M3	Furnaces and Melt Processes	Learners need to complete a poster about casting processes for new apprentices.	A written assignment based on a case study or industrial visit.
P6, P7, D2	Metal Quality	Learners need to complete a poster about casting processes for new apprentices.	A written assignment based on a case study or industrial visit.
P8, P9, M4, D3	Health, Safety and Environmental Issues	Learners need to complete a poster about casting processes for new apprentices.	A written assignment based on a case study or industrial visit.

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

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

Level 1	Level 2	Level 3
		Structure and Properties of Metals
		Industrial Alloys
		Metallurgical Techniques

Essential resources

Learners will benefit enormously from access to facilities and equipment for casting metal into moulds/dies. Examples of patterns, dies and industrial castings in a range of alloys and sizes – including examples containing a range of real defects that can be examined visually and metallographically (perhaps as ready prepared samples) – should be made available. Learners should also have access to relevant national and international standards (BS, EN, ISO and ASTM) for cast alloys and health and safety materials.

Employer engagement and vocational contexts

Further information on employer engagement is available from the organisations listed below:

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

Indicative reading for learners

Textbooks

Beeley P – *Foundry Technology, 2nd Edition* (Butterworth-Heinemann, 2001) ISBN 0750645679

Brown J – *Foseco foundryman's handbook* (Butterworth-Heinemann, 1999) ISBN 075064284X

Brown J – *Foseco non-ferrous casting handbook* (Butterworth-Heinemann, 1999) ISBN 0750642866

Campbell J – *Castings* (Butterworth-Heinemann, 2003) ISBN 0750647906

Delivery of personal, learning and thinking skills

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

Skill	When learners are ...
Independent enquirers	analysing and evaluating information relating to the hazards associated with metals casting, judging its relevance and value.

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

Skill	When learners are ...
Reflective learners	setting goals with success criteria for their development and work.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	describing casting processes and the related hazards and health, safety and environmental legislation
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	investigating and researching casting processes
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing casting processes and the related hazards and health, safety and environmental legislation.