

# Unit 39: Metallurgical Techniques

<b>Unit code:</b>	<b>F/600/0304</b>
<b>QCF Level 3:</b>	<b>BTEC Nationals</b>
<b>Credit value:</b>	<b>10</b>
<b>Guided learning hours:</b>	<b>60</b>

## ● Aim and purpose

This unit aims to develop learners' understanding of the range of techniques used for testing and examining metals.

## ● Unit introduction

For every metal product or application, the choice of metal or alloy used and the means by which it is processed depends on its properties. In order to make the correct choice, technicians need to be able to examine and test metals and alloys to find out their characteristics. These include the mechanical properties (such as strength and hardness) and the microscopic and macroscopic mechanisms that cause a metal or alloy to behave in the way that it does (ie the changes that occur on an atomic level that affect the metal's properties).

This unit aims to develop learners' understanding of the range of techniques used for testing and examining metals. Learners will gain the knowledge and skills needed to measure the properties of alloys using mechanical testing techniques. They will be introduced to the macro analysis of metals and will learn how to prepare samples and use a metallographic microscope to assess a metal's structure.

The unit covers chemical analysis and learners will gain knowledge of the principles and procedures involved and the limitations of spectroscopic methods. Finally, learners will develop a knowledge of the defects found in metals and the means of detecting them using non-destructive testing techniques.

## ● Learning outcomes

**On completion of this unit a learner should:**

- 1 Be able to use mechanical testing methods to measure the properties of an industrial alloy
- 2 Be able to prepare samples for macro and micro-examination and carry out a metallographic examination
- 3 Know the principles and procedures used in the chemical analysis of metallic materials
- 4 Know about non-destructive testing techniques that can be used to reveal defects in metallic component.

## Unit content

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### 1 Be able to use mechanical testing methods to measure the properties of an industrial alloy

*Measurement of mechanical properties:* tensile, hardness, impact tests; application and use of national and international standards eg BS, EN, ISO

*Special purposes:* other mechanical tests eg creep, fatigue, Erichsen cupping test, compression tests, torsion tests

### 2 Be able to prepare samples for macro and micro-examination and carry out a metallographic examination

*Macroscopic examination:* sample selection and preparation; procedures and etching reagents for macro-etching; principles and procedures for sulphur printing

*Microscopic examination:* sample selection and preparation; construction and operation of metallurgical microscope; identification of defects; determination of cleanliness; typical etchants for common industrial alloys; identification of grain structures and phases; measurement of grain size and phase proportions

### 3 Know the principles and procedures used in the chemical analysis of metallic materials

*Chemical analysis:* principles, applications, and limitations of spectroscopic methods eg spark emission, inductively coupled plasma, glow discharge, atomic absorption, atomic fluorescence, x-ray fluorescence

### 4 Know about non-destructive testing techniques that can be used to reveal defects in metallic components

*Manufacturing process defects:* nature, origin and influence on properties and performance of metallic components; types of defects and their causes eg porosity, shrinkage, segregation, inclusions, lamination, cracking

*Non-destructive techniques:* principles and applications of non-destructive testing (NDT) methods eg visual, dye penetrant, magnetic particle, eddy current, ultrasonic and radiographic inspection

## 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:
<b>P1</b> use suitable methods to measure the mechanical properties of an industrial alloy	<b>M1</b> explain the procedures that ensure a specified mechanical test is performed accurately and reproducibly	<b>D1</b> analyse the uncertainty in the measurement of a selected mechanical property
<b>P2</b> describe a method to measure the suitability of an industrial alloy for a given special purpose	<b>M2</b> compare methods used for the chemical analysis of industrial alloys	<b>D2</b> evaluate the processing history of an industrial alloy from an analysis of its structure
<b>P3</b> describe and carry out a procedure for the macroscopic examination of an industrial alloy	<b>M3</b> explain the origin and effect of a defect observed in a metallic component	<b>D3</b> justify a suitable NDT technique to evaluate the quality of a metallic component.
<b>P4</b> measure, record and identify the features observed in the microstructure of an industrial alloy [IE I]	<b>M4</b> compare the advantages and limitations of two alternative NDT techniques in assessing the quality of a metallic component.	
<b>P5</b> describe a method used for the chemical analysis of a given industrial alloy		
<b>P6</b> describe manufacturing process defects in a given metallic component		
<b>P7</b> describe a suitable NDT technique that could be used to assess the quality of a given metallic component.		

**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

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## Delivery

The teaching and learning strategies used to deliver this unit must enable learners to understand the scientific principles involved in testing and examining metals. Learners will need to be aware of the applications and limitations of the test methods, be able to undertake basic mechanical testing and metallographic examination of metals, and be aware of standard test procedures for the testing and examination of metals.

Practical work and demonstrations will therefore form an essential part of the teaching and learning process. These may be undertaken in small groups or individually, since both team working and individual accountability are professional requirements of an engineering technician in this field.

Learners will benefit enormously from hands-on experience of carrying out destructive and non-destructive testing of industrial alloys, although the limited availability of specialist equipment (such as that used for chemical analysis) may mean that demonstrations are sometimes necessary.

Direct practical experience is essential to complete learning outcomes 1 and 2. In completing learning outcomes 3 and 4, use may be made of demonstrations. Where a centre does not have 'in-house' access to the techniques listed in the unit content, the centre should consider arranging visits to industrial laboratories so that learners can see the techniques first hand.

It is also important that techniques are practised on common industrial alloys rather than simple or ideal metallic systems. The type and range of alloys is not specified in the unit; they should be chosen to reflect the needs of local industry. In learning outcome 4, use should be made of industrial metallic components containing representative defects.

Learners should experience the full range of metallurgical techniques although achievement of the assessment and grading criteria may allow learners to focus on a selected few in their assessed work.

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
<p><i>Whole class teaching:</i></p> <ul style="list-style-type: none"><li>• introduction to unit content, scheme of work and method of assessment</li><li>• explain and demonstrate the use of tensile, hardness and impact tests</li><li>• explain the use of national and international standards</li><li>• explain and demonstrate the use of other mechanical tests.</li></ul> <p><i>Practical workshop exercise:</i></p> <ul style="list-style-type: none"><li>• learners carry out and practise mechanical testing on industrial alloys.</li></ul> <p><i>Individual learner research:</i></p> <ul style="list-style-type: none"><li>• investigation of mechanical testing techniques.</li></ul>
Preparation and carrying out for <b>Assignment 1: Mechanical Testing Methods</b> (P1, P2, M1 and D1)
<p><i>Whole class teaching:</i></p> <ul style="list-style-type: none"><li>• explain and demonstrate principles and procedures for macroscopic examination</li><li>• explain and demonstrate principles and procedures for microscopic examination.</li></ul> <p><i>Practical workshop exercise:</i></p> <ul style="list-style-type: none"><li>• learners carry out and practise macroscopic and microscopic examinations on a selection of different metal materials.</li></ul> <p><i>Individual learner research:</i></p> <ul style="list-style-type: none"><li>• investigation of macro and micro examination.</li></ul>
Preparation and carrying out for <b>Assignment 2: Macro- and Micro-Examination</b> (P3 and P4)
<p><i>Whole class teaching:</i></p> <ul style="list-style-type: none"><li>• describe the principles and applications of spectroscopic methods for chemical analysis of metals.</li></ul> <p><i>Individual learner research:</i></p> <ul style="list-style-type: none"><li>• investigation of spectroscopic examination.</li></ul>
Preparation and carrying out for <b>Assignment 3: Chemical Analysis of Metallic Materials</b> (P5, M2 and D2)
<p><i>Whole class teaching:</i></p> <ul style="list-style-type: none"><li>• explain the different types of defects that can occur in the manufacture of metallic components</li><li>• describe the affect of defects on the properties and performance of metal components</li><li>• explain and demonstrate the use of non-destructive testing methods.</li></ul> <p><i>Individual learner research:</i></p> <ul style="list-style-type: none"><li>• investigation of macro and micro examination.</li></ul>
Preparation and carrying out for <b>Assignment 4: No-destructive Testing</b> (P6, P7, M3 and D3)
Unit evaluation, feedback and close.

## Assessment

This unit can be assessed using a mixture of laboratory work and assignments/case studies. A suitable case study could involve learners in selecting, specifying and explaining suitable metallurgical techniques to evaluate a given metallic component.

To achieve a pass, learners should be able to describe and carry out routine mechanical testing (tensile, hardness and impact testing), working to relevant national and international standards. Learners will need to select and describe more specialised mechanical tests to measure such properties as formability, toughness and resistance to creep and fatigue loading. Additionally, learners should be able to carry out and describe the macroscopic and microscopic examination of an industrial alloy, including the selection and preparation of a sample. During these processes, learners should be able to record and describe the macroscopic and microscopic structures that are seen. Learners should also be able to describe a method used to determine the chemical analysis of a given industrial alloy. Finally, learners should be able to identify and describe manufacturing process defects in a given metallic component and describe a suitable non-destructive testing technique that could be used to assess the quality of such a component.

To achieve a merit learners must be able identify and explain how to measure mechanical properties accurately and reproducibly. They should also be able to explain both the benefits and limitations of macro-etching and sulphur printing and be able to evaluate methods used for the instrumental chemical analysis of metals. Finally, they should have an understanding of the cause and effect of metal defects and be able to evaluate the alternative non-destructive methods used for revealing surface and internal defects in metallic components, taking into account defect type, component design and the alloy used in its manufacture.

To achieve a distinction, learners must be able to estimate the size and cause of uncertainty in the measurement of mechanical properties. They will be able to evaluate the macrostructural and microstructural features seen in metal samples to determine the condition of the metal (as-cast/hot worked, cold worked, heat treated) and if the metal has been worked. Learners should also be able to select and justify a technique for the non-destructive examination of a metallic component, having regard for the type of defect likely to be found, its likely location, the alloy type and the shape and size of the component.

### 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, M1 and D1	Mechanical Testing Methods	Learners carry out testing methods used in an industrial laboratory.	Practical report.
P3 and P4	Macro- and Micro-Examination	Learners carry out testing methods used in an industrial laboratory.	Practical report.
P5, M2 and D2	Chemical Analysis of Metallic Materials	Investigation of chemical analysis carried out by a consultation laboratory.	Reports or case studies.
P6, P7, M3 and D3	No-destructive Testing	A laboratory needs to provide a report on non-destructive tests or is asked to comment on a case study.	Case study or individual investigation.

## 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
		Mechanical and Thermal Treatment of Metals
		Structure and Properties of Metals
		Industrial Alloys
		Extraction and Refining of Metals
		Liquid Metal Casting Processes

### Essential resources

Access to facilities and equipment for the metallurgical testing and examination of metals is essential for the delivery of this unit. Facilities are also required for the metallographic examination of industrial alloys using macro-etching and optical microscopy, including the ability to prepare the samples. Throughout, use should be made of samples of industrial alloy systems, including examples containing 'real' defects that can be examined visually, non-destructively and metallographically.

Learners should also have access to relevant national and international standards (BS, EN, ISO and ASTM) for the testing and inspection of metals.

### Employer engagement and vocational contexts

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

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

### Indicative reading for learners

#### Textbooks

Higgins R – *Materials for Engineers and Technicians* (Newnes, 2006) ISBN 0750668504

Ineson P – *Introduction to Practical Ore Microscopy* (Longman, 1989) ISBN 0582301408

Timings R L – *Engineering Materials, Volume 1* (Longman, 1998) ISBN 0582319285

## 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 ...
<b>Independent enquirers</b>	identifying questions to answer and problems to resolve when measuring and recording the features in the microstructure of an industrial alloy.

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 ...
<b>Creative thinkers</b>	asking questions about different metallurgical techniques to extend their thinking
<b>Self-managers</b>	organising time and resources, prioritising actions.

## ● Functional Skills – Level 2

Skill	When learners are ...
<b>English</b>	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	describing methods used to measure and test the properties of metallic components and alloys
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing methods used to measure and test the properties of metallic components and alloy.