Unit 45: Monitoring and Fault Diagnosis of Engineering Systems

Unit code: F/600/0321

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit gives learners the opportunity to apply a range of techniques relating to the reliability, monitoring and fault diagnosis of engineering systems, including the use of test equipment and the relevant health and safety considerations.

Unit introduction

Condition monitoring and quality control techniques are used to detect potential failure symptoms in engineering systems. The methods used by engineering technicians range from fully automated monitoring down to the use of the human senses. This unit provides learners with an understanding of the fundamentals of engineering system monitoring and fault diagnosis and explains the basic concepts of condition monitoring. The unit examines the development of engineering system monitoring and fault diagnosis and how modern technology, quality control and environmental issues have affected current thinking.

The unit will give learners an understanding of the precautions required to protect themselves and others in the workplace and focuses on the safety measures needed when carrying out monitoring activities, especially those for isolating equipment.

Learners will understand how to use a range of condition monitoring equipment and will develop the skills and knowledge required for the location and identification of faults in engineering systems. Learners will be required to select the appropriate monitoring technique and equipment based on the type of plant or equipment being monitored and the conditions checked.

The unit will enable learners to check and set up monitoring equipment before using it to carry out diagnostic condition monitoring on engineering systems, in accordance with approved procedures. Learners will be expected to use a variety of fault diagnosis methods and techniques, and utilise a number of diagnostic aids and equipment. From the evidence gained they will then identify the fault and its probable cause.

Learning outcomes

On completion of this unit a learner should:

1 Know the health and safety requirements relevant to monitoring and fault diagnosis of engineering systems

2 Know about system monitoring and reliability

3 Be able to use monitoring and test equipment

4 Be able to carry out fault diagnosis on engineering systems.

Unit content

1 Know the health and safety requirements relevant to monitoring and fault diagnosis of engineering systems

Legislation: appropriate statutory acts and regulations eg Health and Safety at Work Act 1974, Management of Health and Safety Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER) 1998, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)1995, Lifting Operations and Lifting Equipment Regulations 1998, Manual Handling Operations Regulations 1992, Personal Protective Equipment at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Control of Noise at Work Regulations 2005, Health and Safety (First Aid) Regulations 1981; specific safety requirements eg company rules, permit to work procedures, risk assessment, environmental issues; health and safety procedures eg response to alarms, use of safety equipment, reporting of accidents, reporting of hazardous items of plant or equipment; personal safety eg appropriate dress, protective clothing, appropriate or protective headgear, protective gloves and footwear, eye protection, face masks and respirators, appropriate use of barrier creams, personal cleanliness, prompt attention to injuries

Hazards and practices: workplace hazards eg compressed air, hydraulic fluid, gases, hot surfaces, electrical equipment, unfenced machinery, toxic substances and fumes, falling objects, liquid spillage, untidy work area, badly maintained tools and test equipment; safe working practices eg isolation procedures, methods of immobilising equipment, precautions to be observed when operating or working on live equipment, permit to work, use of danger tags, warning notices, safety barriers, cones and tapes

Engineering systems: process monitoring and control; fault diagnosis; systems eg mechanical, fluid power, electrical, process control, environmental systems (such as fume extraction or air conditioning), medical (such as cardiovascular, anaesthetic and ventilation, medical imaging)

2 Know about system monitoring and reliability

Monitoring terminology: condition monitoring methods eg offline portable monitoring, sampled monitoring, continuous monitoring, protection monitoring, human sensory monitoring; monitoring techniques eg vibration analysis, temperature analysis, flow analysis, particle analysis, crack detection, leak detection, pressure analysis, voltage/current analysis, thickness analysis, oil analysis, corrosion detection, environmental pollutant analysis

Failure and reliability: calculations concerning failure eg degrees and causes of failure, failure rate, failure modes, functional failure, primary and secondary functions, mean time between failures (MTBF), reliability; factors affecting reliability eg design, operation, environment and manufacture, reduction in system/device failure eg routine servicing, adjustments; data eg defects examination, statistical process control (SPC), quality

3 Be able to use monitoring and test equipment

Monitoring and test equipment: use of fixed and portable monitoring equipment for on and offline monitoring including continuous and semi-continuous data recording eg vibration monitoring of bearings, self-diagnostics (such as PLCs/smart sensors, computerised data acquisition, data logging, electrical data, gas analysis); use of handheld instruments eg meters, thermal imaging; test equipment for taking measurements of parameters eg temperature, pressure, viscosity, speed, flow, voltage, current, resistance, sound, vibration

Procedures: practical methods eg crack detection, leak detection, corrosion detection, flow analysis, vibration analysis, pressure analysis

4 Be able to carry out fault diagnosis on engineering systems

Diagnostic terminology and techniques: terminology (definitions and explanations of symptoms, faults, fault location, fault diagnosis and cause); techniques eg six point, half-split, input–output, emergent problem sequence, functional testing, injection and sampling, unit substitution

Diagnostic aids: test and measuring equipment; other aids eg plant personnel, manufacturers' manuals, system block diagrams, circuit and schematic diagrams, data sheets, flow charts, maintenance records/ logs, self-diagnostics, software-based test and measurement, trouble shooting guides

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 list the aspects of health and safety legislation that apply to monitoring and fault diagnosis of an engineering system	**M1** identify and describe four factors which influence either failure or reliability in a given engineering system	**D1** analyse the environmental effects on reliability of temperature, humidity, vibration and pressure for a given engineering system
P2 describe the workplace hazards and safe working practices relevant to specific monitoring and fault diagnosis situations	**M2** identify and describe the environmental conditions which affect the reliability of the components in given items of congruent equipment.	**D2** analyse monitoring/quality control data and information to predict/detect potential failures in given engineering systems.
P3 describe a condition monitoring method and technique related to a given engineering system	**M3** evaluate the quality of measurements made and the limitations of given items of condition monitoring equipment	
P4 use given data to calculate failure rates for a range of components and equipment	**M4** demonstrate a logical approach to finding faults by identifying and distinguishing between symptoms, faults and causes.	
P5 describe the factors affecting reliability for a given engineering system		
P6 describe the monitoring and test equipment used for measuring given system condition parameters		
P7 use procedures to carry out system monitoring on two separate engineering systems		
P8 describe the terms and two different techniques related to fault diagnosis		

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:**
P9 use diagnostic techniques, test and measuring equipment and aids to locate faults on two separate engineering systems where two malfunction symptoms are evident on each system. [IE4]		

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

Since most learners are unlikely to have had prior experience in this area of work, it is essential that some formal introduction to the unit content is given. Learners should then be given the opportunity to examine a range of complex engineering systems and tutors should encourage an investigatory approach throughout.

The unit can be delivered in an electronic, electrical, mechanical or instrumentation context. However, it would be advantageous to choose a system which involves combined areas of engineering, since this is more likely to be encountered by learners at work.

The engineering system used for practical work should be complex enough to allow for a logical approach and have all relevant supporting monitoring and fault finding aids. The use of rigs would allow learners to carry out practical investigation. The following are examples of such systems:

- fluid power system
- a machine tool
- electrical system
- an audio/video product
- a position/speed/process control system
- a small PLC network
- an environmental control system
- a material transfer system.

Learners will require instruction in the use of simple condition monitoring tools and test equipment, eg equipment for monitoring temperature, physical and electrical effects. It should be possible to place data obtained from the system in a software context and undertake analysis. Visits are encouraged to industrial sites where sophisticated condition monitoring is used.

The delivery approach used will be best determined through an analysis of learners' needs and in particular through consideration of the range of industries that the centres are working with or preparing their learners for. Whichever approach is taken should provide learners with an understanding of engineering system monitoring and fault diagnosis in most industrial settings.

The learning outcomes are logically ordered and it would be a reasonable approach to develop them sequentially. In this way, learners will be able to understand system monitoring, fault diagnosis methods and procedures and be able to carry out monitoring and fault diagnosis safely.

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 and methods of working • explain relevant health and safety legislation, safety at work and risk assessment. *Individual learner study:* • investigate a range of safety legislation and regulations. *Tutor-led practical activities:* • investigating a range of different hazards and safety practices in the workplace. *Whole-class teaching:* • introduction to reliability, monitoring and fault diagnosis of engineering systems.
Preparation for and carry out **Assignment 1: Health and Safety in System Monitoring and Fault-finding** (P1 and P2)
Whole-class teaching: • introduce monitoring terminology • purpose and different types of system monitoring methods and techniques • different failure types, reliability, performing pertinent calculations, means of managing reliability and product quality.
Preparation for and carry out **Assignment 2: System Condition Monitoring and Reliability** (P3, P4, P5, M1, M2, and D1)
Whole-class teaching: • explain and demonstrate types and uses of test equipment. *Small group activities:* • case study work on investigations into typical practical monitoring methods and procedures for a range of quantities and parameters.
Preparation for and carry out **Assignment 3: Performing System Monitoring and Measurements** (P6, P7 and M3)
Whole-class teaching: • explain and demonstrate diagnostic terminology and techniques. *Small group activities:* • activities on the practical use of diagnostic equipment and fault-finding.
Preparation for and carry out **Assignment 4: System Fault-finding Techniques** (P8, P9, M4 and D2)
Feedback and unit evaluation.

Assessment

Evidence of achievement of the learning outcomes and grading criteria may be obtained from well-planned investigative assignments or reports of workshop activities. Alternatively, it may be accumulated by learners building a portfolio from investigations and monitoring and fault diagnosis operations in the workplace or through realistic exercises and tests. In either case the opportunity should exist for merit and distinction grades to be achieved with relevant and sufficient evidence to justify the grade awarded.

Assuming that the unit is delivered in the same order as the learning outcomes, a first assignment could cover the criteria for learning outcome 1 (P1 and P2). This assignment could be a written or practical task requiring learners to identify appropriate health and safety procedures and personal safety requirements for an engineering system. Such a system might be mechanical, fluid power, electrical, process control or an environmental system (such as fume extraction or air conditioning).

Learning outcome 2 could be assessed through a written or time-constrained assignment requiring learners to calculate, from given data, failure rates for a range of components and equipment. These could be pumps, actuators, compressors, air receivers, accumulators, valves, generators, motors, transformers, switch gear, machine tools, engines or gearboxes (P4). The assignment could contain a task requiring learners to describe factors affecting reliability (P5) and monitoring methods and techniques (P3). A third task could be added to cover M1, requiring learners to identify and describe four factors that influence either failure or reliability in a given engineering system. A further task requiring learners to identify and describe environmental conditions affecting the reliability of components in items of equipment and analyse the effects of the environment on component/asset reliability could enable achievement of M2 and D1. The range of components and equipment should be sufficient to allow these higher grading criteria to be achieved. However, the range required for pass criterion P4 would need to be at least one mechanical type, one electrical type and one fluid type system. Therefore a range of data for each is required to be given to learners.

Assessment of learning outcome 3 could be by a well-planned practical investigative assignment covering criteria P6, P7 and M3. This would require learners to carry out monitoring activities on two separate engineering systems, such as bearing vibration analysis, temperature, flow, particle, oil, pressure, voltage/current corrosion, environmental pollutant, crack and leak detection. Such systems may be mechanical, fluid power, electrical, process control or environmental systems. This could be supported by written evidence that shows the learner is able to describe the use of monitoring and test equipment and evaluate the quality of measurements and the limitations of given items of monitoring equipment. Witness statements and annotated photographs would be suitable evidence to support the use of procedures to carry out system monitoring.

Learning outcome 4 is best suited to practical investigation. For P8, learners need to explain the terms and two different techniques from those in the unit content, such as six-point, half-split, input-output, emergent problem sequence, functional testing, injection and sampling and unit substitution. For P9, they need to use diagnostic techniques, test and measuring equipment (such as dial test indicators, torque instruments, logic probes, multimeters etc) and aids to locate faults on two separate engineering systems where two malfunction symptoms are evident on each system. The assignment to cover this could have a task requiring learners to carry out fault diagnosis on a given engineered system. This could be either in a simulated situation or in the workplace using evidence gathered in a logbook containing items such as equipment used, tests carried out and measurements taken. This could be supported by the inclusion of witness statements.

Learners must describe typical fault conditions and find faults independently on equipment, which exhibits symptoms of more than one function failure. For example, a pump can have two functions, one to pump water at a given rate, the other to be free of water leaks whilst pumping. To achieve M4 learners must demonstrate a logical approach to fault finding and be able to distinguish between symptoms, faults and causes. A second task supported by written evidence would enable learners to demonstrate that they are able to analyse data and use this information to predict/detect potential failures in given engineering systems for D2.

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	Health and Safety in System Monitoring and Fault-finding	An investigation of practical health and safety issues and legislation, relating to system monitoring and fault diagnosis.	A learner report and risk assessment, identifying and discussing relevant H&S issues, including the methods used to address these.
P3, P4, P5, M1, M2, D1	System Condition Monitoring and Reliability	Practical and theoretical investigations into the factors affecting component and system reliability, including: failure rate calculations; factors affecting reliability and system and component monitoring techniques, in general and as applicable to a specified engineering system.	A written and/or time-constrained assignment containing the learner's: calculations of failure rates for specified components and equipment; discussions on reliability; and on system monitoring methods. Supported by the learners engineering sketches and diagrams.
P6, P7, M3	Performing System Monitoring and Measurements	A practical investigation into the monitoring and evaluation of two different engineering systems.	A learner report or portfolio of evidence and data describing the monitoring techniques and equipment used, and interpreting the measurements made on the two systems. Supported by the learners engineering sketches and diagrams. Witness statements and annotated photographs.
P8, P9, M4, D2	System Fault-finding Techniques	A practical investigation into two different fault diagnosis techniques.	A learner report containing an explanation and evidence of the investigations and tests performed, and the conclusions drawn. Supported by the learners engineering sketches and diagrams. Witness statements and annotated photographs.

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
		Engineering Maintenance Procedures and Techniques

The unit has been mapped against the SEMTA National Occupational Standards and current NVQs at Level 3. Achievement of the learning outcomes of this unit will contribute skills, knowledge and understanding towards several units of the Level 3 NVQ in Engineering Maintenance, particularly:

- Unit 5: Carrying out Fault Diagnosis on Mechanical Equipment
- Unit 10: Carry Out Condition Monitoring on Plant and Equipment
- Unit 11: Carrying Out Fault Diagnosis on Electrical Equipment and Circuits
- Unit 16: Carrying Out Fault Diagnosis on Electronic Equipment and Circuits
- Unit 19: Carrying Out Fault Diagnosis on Fluid Power Equipment and Circuits
- Unit 23: Carrying Out Fault Diagnosis on Engineered Systems.

Essential resources

This unit is intended to provide learners with a practical introduction to monitoring and fault diagnosis methods and techniques. Therefore, it is essential that learners have access to:

- actual complex engineered systems or test rigs designed for monitoring/fault finding
- data books and manufacturers' specifications
- system manuals and functional flow charts and system diagrams
- computer software for data logging and self-diagnostics
- appropriate test equipment and tools
- maintenance records.

Employer engagement and vocational contexts

The use of relevant vocational contexts and real-world engineering information, documentation and materials should underpin the delivery and assessment of this unit. Much of the work could be set in the context of learners' work placements or be based on the relevant activities of local employers.

Company visits could provide opportunities to stress the relevance and application of health and safety legislation and the impact on equipment reliability of its environment. Production and manufacturing facilities can provide learners with a relevant and engaging context for the use of test equipment for performance monitoring and fault-finding activities.

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

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

Indicative reading for learners

Textbook

Yardley E – *Condition Monitoring – Engineering the Practice* (Professional Engineering Publishing, 2002) ISBN 9781860583612

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 and judging its relevance and value when using engineering diagnostic techniques
Creative thinkers	trying out alternatives and following ideas through when performing engineering fault-finding analysis.

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 ...
Independent enquirers	carrying out independent research for their learning and assignments
Creative thinkers	problem solving for their learning and assignments
Reflective learners	reviewing their own learning progress and acting on the outcomes
Team workers	collaborating with others when engaged in learning and assignment group work
Self-managers	working towards assignment and educational goals, showing initiative, commitment and perseverance
Effective participators	actively participating when engaged in learning and assignment group work.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	conducting research, completing and presenting the results of their engineering assignment tasks
Manage information storage to enable efficient retrieval	storing and managing data and reports relating to own work
Follow and understand the need for safety and security practices	storing and managing data and reports relating to own work
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	using non-computer based information sources to complete an electrical installation or other task
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	using computer based information sources to complete an electrical installation or other task
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	using appropriate ICT software packages and hardware to organise and edit information for engineering analytical and descriptive reports and visual presentations including written, graphical and technical data
Bring together information to suit content and purpose	use charts, spreadsheets, databases to represent engineering source and analytical data
Present information in ways that are fit for purpose and audience	produce and present clear and accurate engineering descriptions, reports and visual presentations
Evaluate the selection and use of ICT tools and facilities used to present information	selecting appropriate ICT software packages and hardware to organise and edit information for engineering reports and visual presentations including written, graphical and technical data
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	calculating cable sizes and other parameters for electrical installations
Use appropriate checking procedures and evaluate their effectiveness at each stage	calculating cable sizes and other parameters for electrical installations
Draw conclusions and provide mathematical justifications	calculating cable sizes and other parameters for electrical installations

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	speaking with and listening to peers and supervisors in an engineering context to communicate complex engineering concepts
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	selecting, reading and using appropriate information sources to solve an engineering task
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	taking notes and preparing documents to communicate engineering information effectively.