Unit 45: Monitoring and Fault Diagnosis of Engineering Systems

NQF Level 3: **BTEC National**

Guided learning hours: 60

Unit abstract

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 provide learners with an understanding of the precautions required to protect themselves and others in the workplace and will focus 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

Upon completion of this unit a learner should:

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

2 Know about system monitoring and reliability

3 Be able to describe and use monitoring and test equipment

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

Unit content

1 **Know about 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 describe and 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 describe and 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

Grading grid

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

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

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:**
P7 use procedures to carry out system monitoring on two separate engineering systems P8 explain the terms and two different techniques related to fault diagnosis 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.		

Essential guidance for tutors

Delivery

This unit should be delivered using lectures, tutor-led demonstrations/tests and practical fault finding on a complex engineering system.

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. The unit can then be regarded as investigative in nature. Learners should 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.

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 provide an opportunity to achieve the criteria for learning outcome 1 (P1 and P2). This assignment could be a written or practical task requiring learners to identify health and safety legislation and carry out specific safety requirements, such as a risk assessment relevant to monitoring and fault diagnosis of an engineering system. In doing so they should identify appropriate health and safety procedures and personal safety requirements for that 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 discuss factors affecting reliability (P5), and to describe 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 D2.

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

This unit links to *Unit 44*: *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.

Indicative reading

Textbooks

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

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Staff should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• selecting, setting-up and using monitoring equipment for measuring condition parameters, eg vibration, temperature, pressure • computing failure rates and reliabilities etc for a range of components and equipment • presenting information.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use this information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.
Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• researching issues relating to manufacturers' manuals, specifications and statutory legislation • describing or explaining monitoring and fault finding terms and techniques.	C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.

Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• finding single component faults, by identifying and finding faults and symptoms evident on two engineering systems.	PS3.1 Explore a complex problem, come up with **three** options for solving it and justify the option selected for taking forward.