Manufacturing Technology
LEVEL 3

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Preface

This book has been written specifically for the Level III Manufacturing Technology (U80/737) unit of the BTEC programme for mechanical and production engineering. In following on from the previous volume, *Manufacturing Technology Level 2*, the style and structure used in that book have been retained as it was felt that this formula best suited the needs of the student. Consequently, both this and the previous volume should prove to be a basis for learning and not just a source of reference.

When the previous volume was being written, open learning was still in its infancy and traditional day-release and block-release courses were predominant. At the present time of writing, however, a number of open tech. schemes have already been launched and these herald the rapidly changing styles of learning. Many more colleges will soon adopt some form of student-centred learning to replace the more rigid, previously established systems. It was these new open learning systems that were kept in mind during the writing of this book.

The adoption of a student-centred learning system should enable lecturers to overcome many of the problems that have plagued the teaching of BTEC units, such as mixed abilities and varying paces of study, insufficient time after teaching the material to complete the practical work or to obtain adequate feedback on the effectiveness of teaching and the depth of learning. It is with the hope of alleviating some of these problems that this book has been written.

Acknowledgements

I would like to express my sincere thanks to Mrs Sylvia M. Harding, who so ably translated my writing and typed the manuscript for this and the companion volume.

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Figure 4.1 is reproduced by kind permission of British Aerospace.

Introduction

To the student

This book has been planned to enable you to obtain the maximum benefit in studying, learning and understanding the topic areas of Level III Manufacturing Technology. The contents of the chapters have been arranged and structured to help you digest the information easily and effectively.

Each chapter is preceded by a list of objectives which have been adapted from those contained in the BTEC unit for Level III Manufacturing Technology. These are the learning objectives for the unit and inform you of the aims of that particular chapter. You therefore know in advance what you should learn while reading the chapter.

Each chapter contains a consolidation section. This summarises the main points of the foregoing material. It is intended as a brief revisionary exercise, firming in your mind as you read it the basic facts of the material to which it relates.

Finally, each chapter is followed by five sections of questions which range in difficulty from the simple to those which require a profound understanding of the facts to be able to answer them. Do not expect, therefore, to answer all of these questions correctly, if at all. The structure of the questions is explained in detail on the following pages, together with the means by which you can gauge your performance.

If you are a student following a pattern of day-release or block-release study at a college, then it is hoped that this book will help you in every aspect of your studies under the guidance of your lecturer. If you are a student following one of the many systems of open learning, then it is hoped that this book will form an adequate basis for your studies under the direction of your tutor. The needs of either group are not far removed and the book should therefore serve you both. Certainly your objectives and goals are the same.

To the lecturer

If you wish to use this book as a supplement to your teaching notes then please do so. It is certainly hoped that you will make full use of the many questions that are contained within its pages, either as they stand or modified to suit your particular taste and needs. However, the book would fulfil a far more useful role in replacing rather than supplementing the lecture notes you give to your students. By using the book as a ready-made set of student's notes, ample time is released for you to carry out assessments, and enable your students to perform practical work. You will reap the benefit of obtaining adequate feedback and your students will be given the opportunity of a greater depth of understanding of the subject.

Using a textbook in this way does not in any way undermine your lecturing role. In fact it should enhance its effectiveness, for no textbook can say in a few hundred pages what you can say as a lecturer. Nor can it express an idea in the alternative ways that a classroom situation quite often demands. These aspects of your role are still needed, as are your tutorial help and direction in guiding and channelling the efforts of your students to use the book effectively.

However, it is not the intention of this introduction to dictate how the book should be used. Only you can appreciate your particular students' needs and abilities and only you, therefore, can judge which teaching method is the best one for your students.

Self-assessment questions

These are intended for use either as the text is being studied or immediately following the completion of the chapter. The questions are arranged chronologically with the text and are designed to enable the student to assess whether a particular point or objective has been fully understood.

The questions have been chosen arbitrarily and the number used is far from exhaustive. It would certainly prove beneficial if the lecturer or tutor could structure further questions in a similar vein to test those objectives which, due to the need to adopt some degree of limitation, have been omitted.

Although the answers to these questions can be found in the text, they have also been given at the end of the chapter. This was considered desirable for two reasons. The printing of the answers in a slightly different format helps to consolidate the material for the student. The main reason, however, is that the process of moving the centre of learning from the text to the student has been initiated.

Data-response questions

These questions supply the student with a limited amount of information and require a good deal of application in order to reach an answer. Hence this situation ensures the student applies the knowledge gained from the text as part of the thought process, rather than merely regurgitating the information as so many facts. Once again, because the answers to these questions help to consolidate the knowledge gained, they are printed at the end of the chapter. These questions have also been chosen to extend the student's knowledge of the subject beyond that required by the unit objectives. This level of learning, although not essential, is desirable as it ensures the student has reached the required level. However, average students will find that they can answer only about half of these questions.

Worked examples

Having established a student-centred learning situation, these questions now continue with the consolidation process by assessing the student's knowledge of the material in the text. The structure of these questions is of a more conventional nature and adheres fairly rigidly to the specific objectives of the unit. They do not, therefore, go beyond the depth of treatment required by the unit. If the student has worked methodically through the self-assessment questions and the data-response questions, no serious difficulties should be encountered in answering at least half of these questions. Consequently they have been divided into two groups, and the answers to the first group are printed at the end of the chapter for guidance. Both groups of questions have been carefully graded so that they range from the relatively easy to the fairly difficult. If the student finds no real difficulties in answering

most of these questions, then the objectives required by the unit have been comfortably exceeded.

BTEC assessment questions

These are sample questions typical of those that may be used for assessment purposes in phase tests. They have been derived directly from the unit-specific objectives and the standard therefore reflects that envisaged by BTEC. The nature of all the questions may not be to every lecturer's taste, but a selection of both short- and long-answer questions have been chosen in an attempt to reach some degree of acceptability.

The student should find these useful in deciding if a frame of mind, and the necessary standard, have been attained to attempt a particular phase test successfully. However, it is advised that the student should concur with the subject lecturer or tutor on this particular point, in view of the remarks in the previous paragraph.

Assignments

These have been included mainly in the hope that they will be of value to the lecturer in adopting a programme of practical work, complementary to the text. Every one of the assignments can be written up as a formal report or 'labwork', which will give the student practice in written communication. The assignments generally are suitable for students of all ages and abilities, as they tend to be open-ended to some extent, with regard to the depth of treatment which can be applied to them.

The assignments can also be used to continue with the established situation of student-centred learning. Alternatively they can be closely supervised by the lecturer or tutor to ensure the younger or less experienced student derives the maximum benefit from them.

Contents

1
Safety

AFTER completing this chapter the student should be able to:

1. Identify from the processes and equipment described in this book those which represent a hazard.
2. Describe the nature of the hazard and the safety precautions necessary.
3. Explain the implications of the appropriate sections of the Health and Safety at Work Act 1974 for the processes in this book.

1.1 Introduction

The student will be well aware of the kinds of processes and equipment that represent a hazard from the knowledge gained from studying manufacturing technology at level II. Perusal of the contents section of this book would reveal the following areas as those which fall into this category:

(a) welding processes;
(b) casting processes;
(c) single-point cutting;
(d) multi-point cutting.

Many of the hazards and relevant safety precautions will have been identified when studying the level II unit, but covering this ground again is all the better. The legislation contained in the Health and Safety at Work Act constitutes a very lengthy document, and an attempt has been made in this chapter to condense this as much as possible. It is all of great importance to everyone, no matter what type of industry in which they are employed or the actual job they may do. Some time should be devoted to studying this material and answering the questions posed at the end of this chapter.

1.2 Safety in welding

A great deal of thought has already been given to safety when designing oxy-acetylene and arc-welding equipment—the colour coding of gas cylinders and ancillary equipment, for example, and the use of opposite-handed threads for oxygen and acetylene. However, the onus still rests firmly on the person using the equipment with regard to its safe handling and correct utilisation.

Extra care is needed when transporting the gas cylinders and this should always be done with the aid of a purpose-built trolley. The cylinders, particularly the oxygen pressurised to 170 atmospheres, are potential bombs and can certainly create as much damage if suddenly fractured. The main valves should never be opened unless all the hoses and torch are properly connected and all valves turned off. Always ensure that the acetylene is ignited immediately it is turned on. The minimum explosive atmosphere of 2 per cent does not take long to build up, particularly in confined or poorly ventilated areas. Oxygen should not be allowed to escape excessively into the atmosphere, for

although it does not itself burn, it supports combustion. Any inflammable material will burn much more fiercely in an oxygen-enriched atmosphere. Never allow grease or oil to come into contact with the oxygen fittings and regulators as an explosive substance may be formed. When not in use the cylinders should be stored in a well-ventilated room and acetylene cylinders should be stood upright at all times.

Due to the relatively low operating voltages of arc-welding equipment, less attention is paid to the danger of electric shock than the situation warrants. Although the voltage across the arc may be as low as 20 to 40 V, the circuit voltage has to be higher in order to overcome the resistance of the circuit. With high-power arc equipment the circuit voltage may be above 100 V, and this is well above the level capable of stopping the heart. The greatest danger exists when the power has been turned on but the arc has not been struck, as operators may inadvertently complete the circuit with their body. The dangers are increased when working in damp and restricted spaces, but are obviated by the wearing of the right kind of protective clothing. Full protective clothing should always be worn when working with both oxy-acetylene and arc-welding equipment. This should consist of long-sleeved, high-necked overalls of the heavy-duty type, reinforced safety boots and heavy gauntlets. Apart from the obvious danger from sparks and hot metal inherent in both processes, the electric arc emits ultra-violet radiation and this can cause severe 'sunburn' to any exposed part of the body. It is for this reason that a full face shield must be worn when using arc-welding equipment, fitted with the correct radiation filter lens as prescribed in BS 679. These lenses should not be confused with the tinted goggles worn to reduce the glare from an oxy-acetylene flame. These do not contain an ultra-violet filter, and, if they are worn for arc-welding operations permanent blindness will almost certainly result.

The danger from the radiation emitted by the electric arc cannot be overemphasised, and even a short flash from the arc can cause a condition known as 'arc eye' or 'eyeflash'. This will cause symptoms ranging from watering of the eyes or a feeling of sand in the eyes, to temporary blindness in more severe cases. Screens need to be erected around the welding area in order to protect people passing by.

Adequate ventilation should be provided in the welding area to prevent the build up of fumes and gases which are given off by electrode coatings, fluxes, hot metal, oxy-acetylene flames and electric arcs. The problem is particularly acute when working in enclosed or confined spaces. An awareness is needed of combustible materials which may be present in the general confines of the welding area.

One final danger exists for metal arc welders during slag-removal operations. In order to chip away the slag, the face shield has to be removed or raised in order to see the work clearly. The slag is a hard, cindery material that could easily fly into the eyes, causing serious damage. A pair of clear goggles should be kept on hand, or worn under the face shield to provide the necessary protection.

1.3 Safety in casting processes

The casting processes all involve hazardous operations, as the metal processed is molten. The correct clothing is absolutely essential and for operators of these processes heavy-duty safety boots, leather aprons over full-cover overalls, gauntlets and protective headgear with full-face visors are all necessary. For people having access to the working area, protective headgear, safety footwear, overalls and protective glasses must be worn.

The casting processes cannot be guarded due to the method of working and an even greater awareness of safety is needed than for some workshop processes. Even the best

protective clothing will not resist molten metal for very long. When pouring molten metal into moulds, entrapped gases and steam can cause a blow back of the metal, showering the area in molten droplets. Nor is it unusual for the pressure of the molten metal to lift the cope off the drag and escape from between them.

Similar accidents can happen with die-casting equipment if the closing pressure for the dies is exceeded by the pressure exerted by the molten metal. In such situations the metal ejected can travel over fairly long distances and due to its density, can possess considerable energy. Even though the dies may be heavily guarded during the injection cycle, it is unwise to stand in the immediate area.

Red-hot or molten metal coming into contact with water and other liquids can generate steam and gas at an explosive rate. Even when gases and fumes are given off normally, they create a dangerous atmosphere unless adequate ventilation has been allowed. Foundry atmospheres are also contaminated with dust and aerosols that can present a health hazard.

1.4 Safety in machine tools

Extreme care is needed when operating any machine tool and the observation of safe working practices, at all times, cannot be emphasised too strongly. Accidents involving machinery are invariably disfiguring and incapacitating, and all too often fatal. Correct clothing is essential and protective gear should be worn at all times. Overalls should not be worn loosely when operating a machine; the cuffs especially are prone to becoming caught in revolving parts. Ties present a particular hazard and it is better to remove them than risk strangulation. The hair is often the cause of a very painful and disfiguring accident when it becomes entangled in revolving machinery, but this can easily be avoided by wearing a safety cap.

Safety shoes incorporating a protective steel toecap are the best form of footwear generally for the workshop, but especially when operating machine tools. The work may be in the form of heavy steel billets or castings; or heavy ancillary equipment, such as chucks and machine vices, may have to be mounted and dismounted. Safety glasses should be immediately available so they may be worn during the actual machining operation, and it is good practice to keep these on the person at other times.

Each machine tool presents its own particular dangers, and many accidents would be avoided if everyone made themselves familiar with these before attempting even the simplest operation.

Lathes should be operated without getting too close to the revolving chuck. The majority of major accidents occurring on the lathe arise from the fingers, arms and hair coming into contact with either the chuck or the workpiece.

Swarf accounts for most of the less serious accidents on lathes and no attempt should be made to handle this with the bare hands, even after all cutting actions have ceased. The tools mounted in the tool post may project at dangerous angles and if all four positions on the tool post are occupied then a similar situation also exists here. An awareness should be developed of these dangers, which are characteristic of lathes.

The revolving multi-toothed cutters of milling machines are extremely dangerous and this situation is not encountered to the same extent with other machine tools. On no account should the hands be placed anywhere near the cutters when these are moving. Grinding wheels present a similar hazard and, because of the precision and speed of their rotation, the fact that they are moving at all can easily be overlooked. A mishap which can result is the remarkably rapid removal of the fingertips. The swarf produced by grinding is so fine that it combusts instantly unless a copious flow of coolant is used. Although this is of little

danger to the skin, it can damage the eyes, as can the minute particles of grit with which it is mixed.

The dangers associated with drilling machines depend mainly upon the size of machine. With the sensitive drilling machine there is a tendency to restrain the component by hand rather than use a vice or clamps. If the drill jams, it can snatch the component from the hand, causing severe lacerations in the process. With larger drilling machines the swarf is often much thicker and rigid, and with the operator usually working in close proximity, it is particularly hazardous. Although all drilling machines claim their quota of scalps, the larger machines with their slower rotating drills do not suggest the same element of danger as do the higher speeds of the smaller machines, yet they are much more lethal.

Shaping machines are probably the least hazardous of all the machine tools, but the commonsense rules of safety still need to be observed. The main source of danger lies with the hot, thick chips produced by the cutting tool, which have an alarming tendency to fly haphazardly off the tool point at the finish of the cutting stroke.

All machine tools can be fitted with suitable guards, and these are usually designed so that the operator is completely protected from the inherent dangers of the machine. The fact that accidents are all too common usually stems from the guards not being fitted in the first place, not being replaced after carrying out maintenance work, or not being positioned by the operator before machining is commenced.

1.5 Abrasive wheel regulations

These were introduced in April 1970 to govern the use of power-driven abrasive wheels for any cutting or grinding operation in premises covered by the Factories Act 1961. The main provisions of the regulations are as follows:

1. *Wheel speed.* Wheels shall not be operated above the maximum speed indicated apart from any proportionate allowance for a reduction of diameter.
2. *Spindle speed.* Spindles shall be marked with their maximum speed and have some means of ensuring that this speed is not exceeded.
3. *Mounting.* Every abrasive wheel shall be properly mounted.
4. *Training.* No person shall be permitted to mount an abrasive wheel unless competently trained to do so, and the names of such persons shall be registered together with the category of wheel for which they are appointed.
5. *Guards.* Guards shall be provided and used on all abrasive wheels unless their use is totally impracticable. Guards must be so constructed and maintained that they enclose the wheel and contain it in the event of it bursting.
6. *Flanges.* Where the exposed portion of the wheel exceeds 180° then it must be tapered from the centre to the periphery and a suitable flange used.
7. *Selection.* Wheels must be correctly selected to do the job for which they are required and to constitute the minimum danger to the operator.
8. *Controls.* Controls for starting and stopping the machine shall be efficient and conveniently placed for the operator.
9. *Rests.* Work rests must be securely fixed and as close as practicable to the wheel. They must be substantially constructed and properly maintained.

1.6 Health and Safety at Work Act 1974

Part 1 of the Act comprises four sections which make provision for health, safety and welfare in relation to work. These are:

(a) to secure the health, safety and welfare of people at work;
(b) to protect people, other than those at work, from risks to health and safety

in connection with the activities of people at work;

(c) to ensure the safe keeping and control the use of explosive, flammable or other dangerous substances;

(d) to control the emission of noxious or offensive substances.

For the purposes of the foregoing processes and equipment, we are concerned mainly with the first section relating to the health, safety and welfare of persons at work. This lays down fairly rigid guidelines for both employees and employers in relation to their general and specific duties under the Act, and these are summarised below. It is implied that, where applicable, the words 'so far as is reasonably practicable' qualify all the specific duties.

General duties of employers

(a) To appoint a safety representative, who is also an employee, and to establish such safety committees as requested.

(b) To consult employees' representatives and committees to promote and develop health and safety measures, and to monitor and review their effectiveness.

(c) To give information on hazards to contractors and the public; to control premises where such people may have access by ensuring they are without health risk and have adequate means of access and egress.

(d) To ensure that manufactured articles are designed and constructed to be safe and without risk to health; to test, examine and supply adequate information so they may be put to their designed use safely and without health risk; to undertake or arrange for any research to eliminate or minimise any risks.

(e) To ensure that any erected or installed article for use at work is not unsafe and is without risk to health.

Duties of employers to employees

(a) To provide and maintain plant and systems of work that are safe and without risk to health.

(b) To ensure that the use, handling, storage and transport of articles and substances are carried out safely and without risk to health.

(c) To ensure any place of work under their control is safe and without risk to health; to provide and maintain safe means of access and egress which are without risks to health.

(d) To provide and maintain a safe working environment without risks to health, having adequate facilities and arrangements for welfare.

(e) To prepare and revise written statements of general policy with regard to health and safety at work; to organise and arrange for the carrying out of the policy, and to bring such to the notice of all employees.

Duties of employees

(a) To take reasonable care for the health and safety of themselves and other people who may be affected by their acts or omissions.

(b) To co-operate with their employers, so enabling them to carry out their duties and requirements under any relevant statutory provision.

(c) Not to intentionally or recklessly interfere with or misuse anything provided in the interest of health, safety or welfare.

Enforcement

The Act provides for the appointment by local authorities of inspectors who enforce the Act for the Health and Safety Executive. The inspectors have the necessary power to enter premises of work at any time to make relevant examinations or inspections. As a

result they may remove samples or articles, or prevent any apparatus, equipment or process from being used. Alternatively they may require that any device or method which contravenes any statutory regulations be remedied within a specified period of time.

Questions

Self-assessment questions

1.1 List the safety features incorporated into oxy-acetylene welding equipment.
1.2 State the correct method of storing oxy-acetylene cylinders.
1.3 What is the minimum acetylene content at which an explosive atmosphere will form?
1.4 Explain the difference in the function of the lenses in oxy-acetylene welding goggles and the lens in an arc welding face shield.
1.5 State the three most serious accidents to which the operator of electric arc welding equipment is prone.
1.6 Identify the two main hazards of which the sand casting operative must be aware during the pouring process.
1.7 What are the health hazards that are endemic in foundry atmospheres?
1.8 List the hazards that are inherent about the person when operating machinery.
1.9 Identify the dangers associated with the lathe.
1.10 Identify the malpractice that probably accounts for the greatest number of accidents associated with the sensitive drilling machine.
1.11 Name another major source of danger when using the sensitive drilling machine.
1.12 Identify the three situations that defeat the safety function played by machine guards.
1.13 State the four general provisions of Part 1 of the Health and Safety at Work Act.
1.14 Identify the people or groups to whom Part 1 of the Act refers.
1.15 State the three main areas relating to the general duties of employers.
1.16 State the three main areas relating to the duties of employers to employees.
1.17 State the duties of employees.
1.18 How is the Act enforced?
1.19 Who is responsible for enforcement of the Act?
1.20 What powers are available for enforcement of the Act?

Answers

Answers to self-assessment questions

1.1 Colour coding, opposite-handed threads, blowback arresters.
1.2 In an upright position in a well-ventilated room.
1.3 When the atmosphere contains acetylene of 2 per cent by volume.
1.4 The lenses in oxy-acetylene welding goggles are only anti-glare, whereas the lens in an arc welding shield is an ultra-violet filter.
1.5 Electric shock, eye damage and severe burns.
1.6 Entrapped gases and steam causing a blowback of the molten metal and the pressure lifting the cope off the drag.
1.7 Dust, gases and aerosols.
1.8 Loose clothing, cuffs, ties, hair, fingers and arms.
1.9 The chuck, workpiece, tools and swarf.
1.10 Restraining the component by hand.
1.11 The hair becoming entangled in the chuck.

1.12 Not positioning the guard before using the machine, not re-fitting the guard after carrying out maintenance and not fitting a guard in the first place.

1.13 (a) to protect people at work;
(b) to protect people other than those at work;
(c) to control dangerous substances;
(d) to control offensive substances.

1.14 Employees, employers and members of the public.

1.15 (a) Appointment of, and consultation with, safety representatives.
(b) To inform non-employees of hazards.
(c) To ensure that equipment or products are safe.

1.16 (a) To provide safe plant and equipment.
(b) To maintain a safe environment.
(c) To provide policy statements relating to health and safety.

1.17 Not to endanger themselves or other employees. To co-operate with their employers in matters of health and safety. Not to interfere with health and safety provisions.

1.18 By inspectors appointed by the local authority.

1.19 The Health and Safety Executive.

1.20 The inspectors may enter premises, remove articles and prevent the use of equipment or processes.

2
Welding Processes

AFTER completing this chapter the reader should be able to:

1. State, with the aid of sketches, the principles of submerged arc welding, shielded arc welding, resistance welding and friction welding.
2. Compare the welding processes (including those in level II) with regard to speed, cost, quality, ease of operation, thickness and type of material.
3. State, with the aid of sketches, the effects of welding processes on the metal structure.
4. Select an appropriate welding process for a given application.

2.1 Introduction

There are about 35 different welding techniques currently used to join a wide range of engineering materials. The more commonly used ones are shown in Figure 2.1, but only those in general use will be covered in this chapter, and oxy-acetylene and manual metal-arc welding are dealt with in level II.

These welding techniques represent a relatively new process of joining engineering materials, the oldest having been used for only about 100 years. Before this the only metal welding operation was forge welding (practised since the iron age), in which lap joints were made in iron by hammering red-hot pieces together on an anvil.

Welding has replaced mechanical joining in a great many applications and assemblies. This has resulted in considerable savings in weight, time, material and cost, particularly where fabrication has replaced casting. Why then, is mechanical joining still used in preference to welding? The most versatile of the welding techniques, fusion welding, necessitates the input of heat at the joint interface to cause the metals to fuse together. This creates a number of problems depending upon the technique used, the type of joint, the type of metal and the metal thickness:

1. The molten metal in the weld area may react with gases in either the natural or weld atmosphere.
2. The heat-affected zone, around the fused zone, may affect the properties and microstructure of the metal.
3. Uneven thermal expansion may cause local distortion of the metal.
4. Contraction when cooling may cause distortion and set up residual stresses in the metal.
5. Solidification of the metal in the fused zone may result in an entirely different structure from that of the parent metal.

These disadvantages do not detract from the desirability of welding as a means of producing high-strength joints, which simplify the design and construction of many components. However, they do necessitate specialised non-destructive testing techniques where the weld is critical, and the