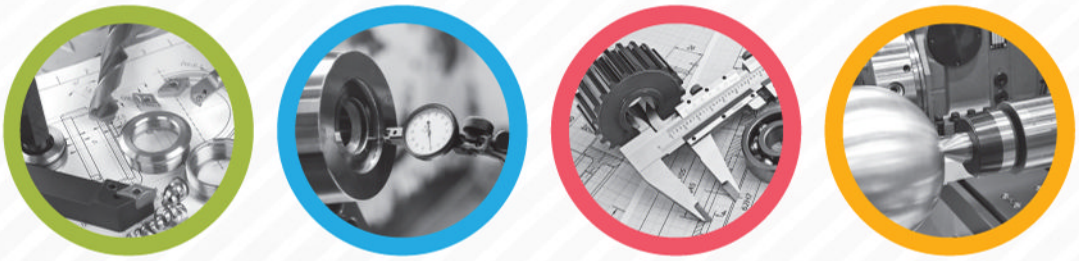
5TH EDITION

WORKSHOP PROCESSES, PRACTICES AND MATERIALS



BRUCE J. BLACK

ROUTLEDGE

Workshop Processes, Practices and Materials

An essential guide to the workshop for all mechanical and production engineering students

- Health and safety chapter covers current best practice and has been checked by a certified health and safety examiner.
- Addition of modern measuring techniques using laser scan micrometer, co-ordinate and visual measuring systems.
- Addition of an introduction to CNC milling and turning.

Workshop Processes, Practices and Materials is an ideal introduction for entry level engineers and workshop technicians, as well as university engineering students with little or no practical experience. With detailed illustrations throughout and simple, clear language, this is a practical introduction to what can be a very complex subject. It has been significantly updated and revised to include new material on current health and safety legislation, gauging and digital measuring instruments, as well as modern measuring techniques such as laser scan micrometer, co-ordinate and visual measuring systems. A new chapter on an introduction to CNC milling and turning has also been added.

This book covers all standard workshop topics, including safe practices, measuring equipment, hand and machine tools, metal and plastics materials, joining methods (including welding), presswork, primary forming, casting and moving loads, making it an indispensable handbook for use both in class and in the workshop. Its broad coverage makes it a useful reference book for many different courses worldwide.

Bruce J. Black has over 40 years' experience as a production engineer in machine tool and aircraft industries, as well as lecturing in production engineering, culminating as workshop director (wood, metal and plastics) at the then Gwent College of Higher Education in South Wales, UK. Now retired, he works as a freelance technical author.

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Fifth edition

Bruce J. Black

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Dedication

To my wife Gillian, children Susan and Andrew, and grandchildren, Alexander and Thomas Hattam, Darcey, Sophie and Bailey Black

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Contents

Preface to the first edition

I have written this book to cover the objectives of the Technician Education Council standard units Workshop processes and materials I (U76/055, which is based on and intended to replace U75/001), for students of mechanical/production engineering, industrial measurement and control, and polymer technology, and Materials and workshop processes I (U75/002), for students of electronic, telecommunication, and electrical engineering. These two units contain a great deal of common material, and by covering them both I hope that the book will be useful to a larger number of students and teaching staff.

From my own experience I have found the content of these units too great to be covered in the design length of 60 hours while still leaving time for adequate practical involvement by the student, which can best be carried out under the guidance of the lecturer. In writing this book, my aim has been to set out in detail the theoretical aspects of each topic, with appropriate line illustrations, in the hope that, by using the book as a course text and for assignments, more time can be spent by the student in practical work where machines and equipment can be demonstrated, handled, and used. Questions at the end of each chapter are directly related to the chapter content as a means of reinforcing the learning process.

An extensive coverage of health and safety has been included, as I feel very strongly that anyone involved in an industrial environment should develop a responsible awareness of the hazards which could affect not only his own health and safety but also that of his fellow workers.

Although specifically written for the TEC standard units, the content is also suitable for the syllabus requirements of the GCE ordinary-level examinations in Engineering workshop theory and practice (AEB) and Engineering workshop practice (WJEC), as well as a considerable amount of first-year work in the higher national diploma in mechanical engineering.

Finally, I would like to thank my wife for her patience and understanding throughout the period of writing the book, my colleagues for their assistance, and Mrs Brigid Williams for her speedy and skilful typing of the manuscript.

Preface to the second edition

Preparing the second edition has enabled me to update a number of areas and to increase the scope of the book by including additional material. It has also afforded the opportunity of resetting to current popular book size and format.

In this second edition I have increased the content to cover a wider range of topics in order to make the book even more comprehensive by providing additional chapters on processes to include sand casting, rolling, extrusion, drawing, forging, presswork, investment casting, shell moulding and die casting.

I have updated the Safe Practices chapter to include current Health and Safety Regulations and the chapter on Measuring Equipment to include electronic instruments. A section on bonded abrasive grinding wheels has been added to the chapter on Surface Grinding and moulding processes has been included in the chapter on plastics.

Preface to the third edition

The third edition has enabled me to increase the scope of the book by including additional material to cover much of the units in the Performing Engineering Operations syllabus.

Where required, chapters have been updated in line with current developments, e.g. lost foam casting and metal injection moulding.

New chapters have been added to cover Standards, measurement and gauging as well as Moving loads and Drawing specifications and data.

I have also taken the opportunity to include review questions at the end of each chapter.

Preface to the fourth edition

In this fourth edition I have included, by request, additional material including gas welding and the dividing head. I have updated to the current health and safety legislation in Chapter 1 and in relation to abrasive wheels, power presses and manual handling and pictures of machine guards have been added. The section on adhesives has been enhanced and the section on protective coatings has been enlarged to include plasma electrolytic oxidation, electrocoating, powder coating and coil coating. Chapter 14 has additions to include the high-performance polymers such as polyimides and PEEK as well as the recycling of plastic materials.

Preface to the fifth edition

This fifth edition has enabled me to further increase the scope of the book. I have updated to current health and safety legislation. Chapter 5 has been extended by adding the use of length bars and angle gauge blocks as well as updating some of the text. Some alterations have been made to Chapter 6 and I have included the latest digital instruments used in measurement and added a section on modern measuring techniques using the laser scan micrometer, co-ordinate and visual measuring machines. Cutting tool materials has been re-written in line with current practice and the use of high-pressure coolant has been included. A description of hand tapping on the lathe and knurling has been included by request. In the materials section I have been requested to include a description of non-destructive testing. Chapter 16 has been enhanced by the addition of the vacuum casting technique. Finally I have added a completely new chapter (Chapter 12) as an introduction to the computer numerical control of machine tools.

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Table 1.2 and Figs. 1.12–1.16 (BS ISO 3864); Tables 5.4 and 5.5 (BS 1134–2010); Table 5.3 (BS EN ISO 286–1:2010).

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CHAPTER 1

Safe practices

Almost everyone working in a factory has at some stage in his or her career suffered an injury requiring some kind of treatment or first aid. It may have been a cut finger or something more serious. The cause may have been carelessness by the victim or a colleague, defective safety equipment, not using the safety equipment provided or inadequate protective clothing. Whatever the explanation given for the accident, the true cause was most likely a failure to think ahead. You must learn to work safely. Your workplace will have its own safety rules so obey them at all times. Ask if you don't understand any instruction and do report anything which seems dangerous, damaged or faulty.

1.1 Health and Safety at Work Act 1974 (HSWA) (as amended)

This Act of Parliament came into force in April 1975 and covers all people at work except domestic servants in a private household. It is aimed at people and their activities, rather than at factories and the processes carried out within them.

The purpose of the Act is to provide a legal framework to encourage high standards of health and safety at work.

Its aims are:

- to secure the health, safety and welfare of people at work;
- to protect other people against risks to health or safety arising from the activity of people at work;
- to control the keeping and use of dangerous substances and prevent people from unlawfully having or using them;
- to control the emission into the atmosphere of noxious or offensive substances from premises.

What the law requires is what good management and common sense would lead employers to do anyway, i.e. to look at what the risks are and take sensible measures to tackle them.

1.2 Health and safety organisation (Fig. 1.1)

The HSWA established two bodies, the Health and Safety Commission and the Health and Safety Executive (HSE). These were merged in 2008 to form a single body, the HSE. The HSE is a statutory body established by the HSWA (as amended) which consists of a chairperson and between 7 and 12 executive directors.

The HSE Board is responsible to appropriate ministers for the administration of the 1974 Act.

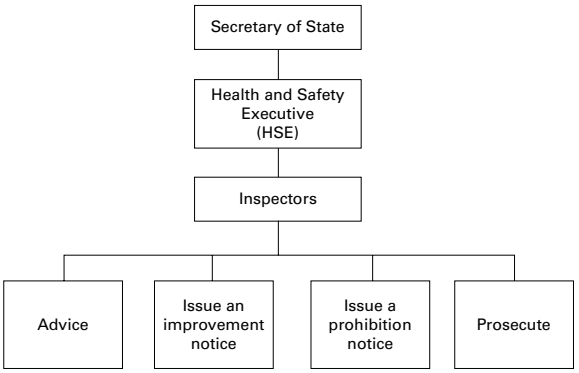


Figure 1.1 Health and safety organisation

The HSE's mission is: 'the prevention of death, injury and ill health to those at work and those affected by work activities'.

HSE's aims are to protect the health, safety and welfare of people at work, and to safeguard others, mainly members of the public, who may be exposed to risks from the way work is carried out.

HSE's statutory functions include:

- proposing new and updated laws and standards;
- conducting research;
- providing information and advice;
- making adequate arrangements for the enforcement of health and safety laws.

In recent years much of Britain's health and safety law has originated in Europe. Proposals from the European Commission may be agreed by member states who are then responsible for making them part of their domestic law. Where HSE consider action is necessary to supplement existing arrangements, their three main options are to provide:

1. guidance;
2. approved codes of practice (ACOPs);
3. regulations.

Guidance – can be specific to health and safety problems of an industry or of a particular process used in a number of industries.

The main purposes of guidance are to:

- help people understand what the law says;
- help people comply with the law;
- give technical advice.

Following guidance is not compulsory, but if followed, will normally be enough to comply with the law.

Approved codes of practice – offer practical examples of good practice. They give advice on how to comply with the law by, for example, providing a guide to what is 'reasonably practicable'.

Approved codes of practice have a special legal status. If employers are prosecuted for a breach of health and safety law, and it is proved that they have not followed the relevant provisions of the approved code of practice, a court can find them at fault unless they can show that they have complied with the law in some other way.

Regulations – are law, approved by Parliament. These are usually made under HSWA following proposals from HSE. This applies to regulations based on EC directives as well as 'home-grown' ones.

Health and safety law is enforced by inspectors from HSE.

Local authorities also enforce health and safety law in the workplace allocated to them – including offices, shops, retail and wholesale distribution centres, leisure, hotel and catering premises.

Inspectors may visit a workplace without notice at any reasonable time. They may want to investigate an accident or complaint or examine the safety, health and welfare aspects of the business. They can talk to employees and safety representatives and take photographs and samples.

Inspectors may take enforcement action in several ways to deal with a breach in the health and safety laws.

In most cases these are:

- *Informal*: where the breach of the law is relatively minor – give advice both face to face and in writing.
- *Improvement notice*: where the breach of the law is more serious – requires remedial action within a time period.
- *Prohibition notice*: where the activity involves risk of serious personal injury – prohibit the activity immediately until remedial action is taken.

- *Prosecution*: where individuals or corporate bodies fail to comply with the regulations – can lead to a substantial fine or imprisonment or both.

The Health and Safety (Fees) Regulations 2012 puts a duty on the HSE to recover costs from companies who are found to be in breach of health and safety law, referred to as Fee for Intervention (FFI) cost recovery scheme. The fee is based on the amount of time an inspector has had to spend in identifying the breach, helping to put it right, investigating and taking enforcement action. Companies who comply with the law will not pay a fee for any work that the HSE does with them.

1.3 Employer's responsibilities (Fig. 1.2)

Employers have a general duty under the HSWA 'to ensure, so far as is reasonably practicable, the health, safety and welfare at work of their employees'. The principle of 'so far as is reasonably practicable' applies to all the following areas and means that an employer does not have to take measures to avoid or reduce the risk if they are technically impossible or if the time, trouble or cost of the measures would be grossly disproportionate to the risk. The HSWA specifies five areas which in particular are covered by the employer's general duty.

1. Provide and maintain machinery, equipment and other plant, and systems of work that are safe and without risk to health. ('Systems of work' means the way in which the work is organised and includes layout of the workplace, the order in which jobs are carried out or special precautions to be taken before carrying out certain hazardous tasks.)
2. Ensure ways in which particular articles and substances (e.g. machinery and chemicals) are used, handled, stored and transported are safe and without risk to health.
3. Provide information, instruction, training and supervision necessary to ensure health and safety at work. *Information* means the background knowledge needed to put the instruction and training into context. *Instruction* is when someone shows others how to do something by practical demonstration. *Training* means having employees practise a task to improve their performance. *Supervision* is needed to oversee and guide in all matters related to the task.
4. Ensure any place under their control and where their employees work is kept in a safe condition and does not pose a risk to health. This includes ways into and out of the workplace.
5. Ensure the health and safety of their employees' working environment (e.g. heating, lighting, ventilation, etc.). They must also provide adequate arrangements for the welfare at work of their employees (the term 'welfare at work' covers facilities such as seating, washing, toilets, etc.).

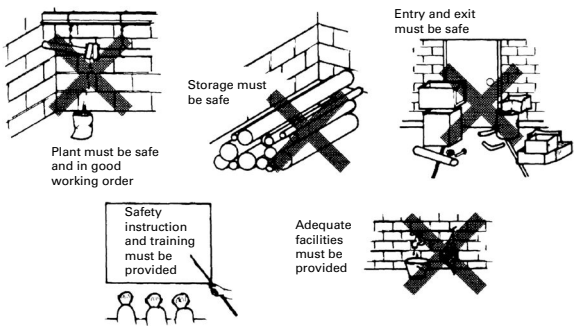


Figure 1.2 Duties of employers

1.4 Safety policy

The HSWA requires every employer employing five or more people to prepare a written statement of their safety policy. The written policy statement must set out the employer's aims and objectives for improving health and safety at work.

The purpose of a safety policy is to ensure that employers think carefully about hazards at the workplace and about what should be done to reduce those hazards to make the workplace safe and healthy for their employees.

Another purpose is to make employees aware of what policies and arrangements are being made for their safety. For this reason you must be given a copy which you must read, understand and follow.

The written policy statement needs to be reviewed and revised jointly by employer and employees' representatives as appropriate working conditions change or new hazards arise.

1.5 Safety Representatives and Safety Committees Regulations 1977 (as amended)

1.5.1 Safety representatives

The Regulations came into force on 1 October 1978 and provide recognised trade unions with the right to appoint safety representatives to represent the employees in consultation with their employers about health and safety matters of the organisation.

Employers have a duty to consult on the following matters:

- the introduction of any measure at the workplace which may substantially affect the health and safety of employees;
- arrangements for getting competent people to help them comply with health and safety laws;
- the information they must give their employees on the risks and dangers arising from their work, measures to reduce or eliminate these risks and what the employees should do if exposed to a risk;
- the planning and organisation of health and safety training;
- the health and safety consequences of introducing new technology.

An employer must give safety representatives the necessary time off, with pay, to carry out their functions and receive appropriate training.

The functions of an appointed safety representative include:

- investigating potential hazards and dangerous occurrences in the workplace;
- investigating complaints relating to an employee's health, safety or welfare at work;
- making representations to the employer on matters affecting the health, safety or welfare of employees at the workplace;
- carrying out inspections of the workplace where there has been a change in conditions of work, or there has been a notifiable accident or dangerous occurrence in a workplace or a notifiable disease has been contracted there;
- representing the employees he or she was appointed to represent in consultation with inspectors or any enforcing authority;
- attending meetings of safety committees.

1.6 Health and Safety (Consultation with Employees) Regulations 1996 (as amended)

The law is different if there are employees within the organisation who are not represented under the Safety Representatives and Safety Committees Regulations 1977.

For example:

- The employer does not recognise trade unions.
- There are employees who do not belong to a trade union and recognised trade unions have not agreed to represent them.

Where employees are not represented under the Safety Representatives and Safety Committee Regulations 1977, the Health and Safety (Consultation with Employees) Regulations 1996 will apply.

If the employer decides to consult the employees through an elected representative, the employees have to elect one or more within their group to represent them. These elected health and safety representatives are known as 'representatives of employee safety' in the Regulations. The range of functions of union-appointed representatives and elected representatives within each Regulation is similar and it is good practice for employers to give equivalent functions, where they agree to them.

1.6.1 Safety committees

If two or more union-appointed health and safety representatives request, in writing, that the employer set up a health and safety committee, then it must be done within 3 months of the request.

Although there is no such requirement if the employer consults health and safety representatives elected by the workforce, it is good practice to do so.

The main objective of such a committee is to promote co-operation between employers and employees in setting up, developing and carrying out measures to ensure the health and safety at work of the employees.

The committee can consider items such as:

- statistics on accident records, ill health and sickness absence;
- accident investigation and subsequent action;
- inspection of the workplace by enforcing authorities, management or employee health and safety representatives;
- risk assessments;
- health and safety training;
- emergency procedures;
- changes in the workplace affecting the health, safety and welfare of employees.

If the health and safety committee is discussing accidents, the aim is to stop them happening again, not to give blame. Committees should:

- look at the facts in an impartial way;
- consider what precautions might be taken;
- recommend appropriate action;
- monitor progress of any action taken.

Consulting employees about health and safety can result in:

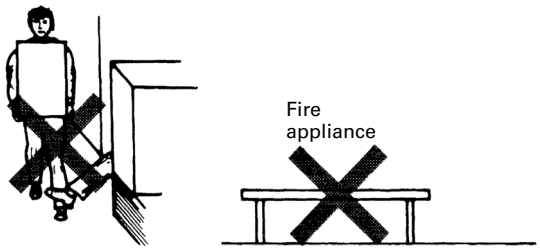
- a healthier and safer workplace – employees can help identify hazards, assess risks and develop ways to control or remove risks;
- better decisions about health and safety – based on the input and experience of a range of people including employees who have extensive knowledge of their own job;
- a stronger commitment to implementing decisions or actions – since employees have been actively involved in reaching these decisions;
- greater co-operation and trust – employers and employees who talk and listen to each other gain a better understanding of each other's views;
- joint problem solving.

These can then result in real benefits for the business, including:

- increased productivity;
- improvements in overall efficiency and quality;
- higher levels of workforce motivation.

1.7 Employees' responsibilities (Fig. 1.3)

Under the HSWA it is the duty of every employee while at work:



Every employee must take reasonable care of the safety of himself and others

Never interfere with anything provided in the interests of safety

Figure 1.3 Duties of employees

- To take reasonable care for their own health and safety and that of others who may be affected by what they do or don't do.

This duty implies not only avoiding silly or reckless behaviour but also understanding hazards and complying with safety rules and procedures. This means that you correctly use all work items provided by your employer in accordance with the training and instruction you received to enable you to use them safely.

- To co-operate with their employer on health and safety.

This duty means that you should inform, without delay, of any work situation which might be dangerous and notify any shortcomings in health and safety arrangements so that remedial action may be taken.

The HSWA also imposes a duty on all people, both people at work and members of the public, including children, to not intentionally interfere with or misuse anything that has been provided in the interests of health, safety and welfare.

The type of things covered include fire escapes and fire extinguishers, perimeter fencing, warning notices, protective clothing, guards on machinery and special containers for dangerous substances.

You can see that it is essential for you to adopt a positive attitude and approach to health and safety in order to avoid, prevent and reduce risks

at work. Your training is an important way of achieving this and contributes not only to your own but also to the whole organisation's health and safety culture.

1.8 New regulations for health and safety at work

Six new sets of health and safety at work regulations came into force on 1 January 1993. The new regulations implement European Community (EC) directives on health and safety at work in the move towards a single European Union. At the same time they are part of a continuing modernisation of existing UK law.

Most of the duties in the new regulations are not completely new but clarify and make more explicit what is in current health and safety law. A lot of out-of-date law will be repealed by the new regulations, e.g. many parts of the Factories Act 1961. Some of these have been updated since 1993.

The six regulations are:

- Management of Health and Safety at Work Regulations 1999;
- Provision and Use of Work Equipment Regulations 1998;
- Workplace (Health, Safety and Welfare) Regulations 1992;
- Personal Protective Equipment at Work Regulations 1992;
- Health and Safety (Display Screen Equipment) Regulations 1992;
- Manual Handling Operations Regulations 1992.

1.9 Management of Health and Safety at Work (Amendment) Regulations 2006

These Regulations set out broad general duties which operate with the more specific ones in other health and safety regulations. They are aimed mainly at improving health and safety management. Under these Regulations employers are required to assess the risks posed to workers and any others who may be affected by the work or business.

They focus on risk assessments and how to use them affectively to identify potential hazards and risks, preventive measures that can be applied and the management and surveillance of health and safety procedures that should be followed in the event of serious or imminent danger.

The Regulations require employers to:

- assess the risk to health and safety of employees and anyone else who may be affected so that the necessary preventive and protective measures can be identified and record the significant findings of the risk assessment – trivial risks do not need to be recorded;
- introduce preventive and protective measures to control the risks identified by the risk assessment;
- set up an effective health and safety management system to implement their health and safety policy to include organising, planning, monitoring, auditing and review, and keeping records;
- provide appropriate health surveillance of employees required by specific health and safety regulations, e.g. COSHH;
- appoint competent people to help devise and apply measures needed to comply with health and safety legislation;
- establish emergency procedures to be followed in the event of serious and imminent danger to persons at work;
- arrange necessary contacts with external services, e.g. first aid, emergency medical care and rescue work;
- give employees information about health and safety matters;
- work together with other employers who share the same workplace;
- give other employees and self-employed people working in that business information about health and safety matters;
- make sure that employees have adequate health and safety instruction and training and are capable enough at the job to avoid the risk;
- provide health and safety information to temporary workers to meet their special needs;
- ensure that young persons employed by him are protected at work from risks to their health and safety which are a consequence of their

lack of experience, absence of awareness and immaturity.

The Regulations also:

- place a duty on the employees to follow health and safety instructions and training in the use of equipment.

1.10 Provision and Use of Work Equipment Regulations 1998 (PUWER)

The Regulations require risks to people's health and safety from equipment they use at work to be prevented or controlled. Although power presses are included as work equipment, part IV of PUWER contains specific requirements for power presses and is dealt with in Chapter 17. In addition to the requirements of PUWER, lifting equipment is also subject to the requirements of the Lifting Operations and Lifting Equipment Regulations 1998 and is dealt with in Chapter 20.

Work equipment has wide meaning and, generally, any equipment which is used by an employee at work is covered:

- machines such as circular saws, drilling machines, photocopiers, mowing machines, tractors, dumper trucks and power presses;
- hand tools such as screwdrivers, hammers and hand saws;
- lifting equipment such as lift trucks, elevating work platforms, vehicle hoists and lifting slings;
- other equipment such as ladders and water pressure cleaners;
- an installation such as a series of machines connected together, an enclosure to provide sound insulation or scaffolding.

Similarly if you allow employees to provide their own equipment, it too will be covered and the employer will need to make sure it complies.

Examples of use of equipment covered by the Regulations include starting and stopping the equipment, programming, setting, repairing, modifying, maintaining, servicing, cleaning and transporting.

PUWER cannot be considered in isolation from other health and safety legislation but needs to be considered alongside other health and safety laws, e.g. HSWA and the Workplace (Health, Safety and Welfare) Regulations 1992.

In general terms the Regulations require that equipment provided for use at work is:

- suitable for use, and for the purpose and conditions in which it is used;
- safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case;
- used only by people who have received adequate information and training;
- accompanied by suitable safety measures, e.g. protective devices, markings and warnings.

The employer should also ensure that risks created by the use of equipment are eliminated where possible or controlled by:

- taking appropriate 'hardware measures', e.g. providing suitable guards, protection devices, markings and warning devices, system control devices (such as emergency stop buttons) and personal protective equipment;
- taking appropriate 'software measures' such as following safe systems of work (e.g. ensuring maintenance is only performed when equipment is shut down) and providing adequate information, instruction and training.

Working with machinery can be dangerous because moving machinery can cause injuries in many ways:

- workers can be hit and injured by moving parts of machinery or ejected material, and parts of the body can be drawn into or trapped between rollers, belts and pulley drives;
- sharp edges can cause cuts and severing injuries, sharp pointed parts can stab or puncture the skin and rough surfaces can cause friction or abrasion injuries;
- workers can be crushed both between parts moving together or towards a fixed part of the machine, wall or other object, and two parts moving past one another can cause shearing;
- parts of the machine, materials and emissions (such as steam or water) can be hot or cold enough to cause burns or scalds and electricity can cause electrical shock and burns;
- injuries can also occur due to machinery becoming unreliable and developing faults due to poor or lack of maintenance or when

machines are used improperly through inexperience or lack of training.

The specific requirements of PUWER include:

- *The suitability of work equipment* – equipment must be suitable by design and construction for the actual work it is provided to do and installed, located and used in such a way as to reduce the risk to users and other workers, e.g. ensure there is sufficient space between moving parts of work equipment and fixed and moving parts in its environment. Ensure that, where mobile work equipment with a combustion engine is in use, there is sufficient air of good quality.
- *Maintenance of work equipment in good repair* – from simple checks on hand tools such as loose hammer heads to specific checks on lifts and hoists. When maintenance work is carried out it should be done in safety and without risk to health.
- *Information and instruction on use of the work equipment* – including instruction sheets, manuals or warning labels from manufacturers or suppliers. Adequate training for the purposes of health and safety in the use of specific work equipment.
- *Dangerous parts of machinery* – guarding machinery to avoid the risks arising from mechanical hazards. The principal duty is to take effective measures to prevent contact with dangerous parts of machinery by providing:
  - fixed enclosing guards;
  - other guards (see Fig. 1.4) or protection devices;
  - protection appliances (jigs, holders);
  - information, instruction, training and supervision.
- *Protection against specified hazards*
  - material falling from equipment;
  - material ejected from a machine;
  - parts of the equipment breaking off, e.g. grinding wheel bursting;
  - parts of equipment collapsing, e.g. scaffolding;
  - overheating or fire, e.g. bearing running hot, ignition by welding torch;
  - explosion of equipment, e.g. failure of a pressure-relief device;
  - explosion of substance in the equipment, e.g. ignition of dust.
- *High and very low temperature* – prevent the risk of injury from contact with hot (blast furnace, steam pipes) or very cold work equipment (cold store).
- *Controls and control systems* – starting work equipment should only be possible by using a control and it should not be possible for it to be accidentally or inadvertently operated nor 'operate itself' (by vibration or failure of a spring mechanism).

  Stop controls should bring the equipment to a safe condition in a safe manner. Emergency stop controls are intended to effect a rapid response to potentially dangerous situations and should be easily reached and activated. Common types are mushroom-headed buttons (see Fig. 1.5), bars, levers, kick plates or pressure-sensitive cables.

  It should be possible to identify easily what each control does. Both the controls and

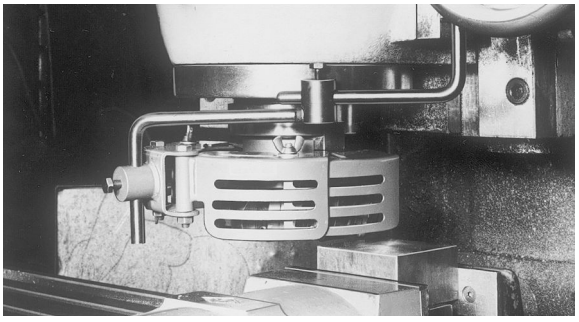


Figure 1.4 Guard fitted to vertical milling machine

Figure 1.5 Mushroom-headed stop button

their markings should be clearly visible and factors such as colour, shape and position are important.

- *Isolation from source of energy* – to allow equipment to be made safe under particular circumstances, e.g. when maintenance is to be carried out or when an unsafe condition develops. Isolation means establishing a break in the energy supply in a secure manner, i.e. by ensuring that inadvertent reconnection is not possible. Isolation may be achieved by simply removing a plug from an electrical socket or by operating an isolating switch or valve.

  Sources of energy may be electrical, pressure (hydraulic or pneumatic) or heat.
- *Stability* – there are many types of work equipment that might fall over, collapse or overturn unless they are fixed. Most machines used in a fixed position should be bolted down. Some types of work equipment such as mobile cranes may need counterbalance weights.

  Ladders should be at the correct angle (a slope of four units up to each one out from the base), correct height (at least 1 metre above the landing place) and tied at the top or secured at the foot.
- *Lighting* – if the lighting in the workplace is insufficient for detailed tasks then additional lighting will need to be provided, e.g. local lighting on a machine (Fig. 1.6).
- *Markings* – there are many instances where marking of equipment is appropriate for health and safety reasons, e.g. start/stop controls, safe working load on cranes, types of fire extinguishers and pipework colour coded to indicate contents. Markings may use words, letters, numbers or symbols and the use of colour and shape may be significant. Markings should conform to published standards (see 1.20 The Health and Safety (Safety Signs and Signals) Regulations 1996).
- *Warnings* – normally in the form of a permanent printed notice or similar, e.g. 'head protection must be worn' (see page 24). Portable warnings are also necessary during temporary operations such as maintenance.

  Warning devices can be used which may be audible, e.g. reversing alarms on heavy vehicles, or visible, e.g. lights on a control panel. They may indicate imminent danger, development of a fault or the continued presence of a potential hazard.
  They must all be easy to see and understand, and they must be unambiguous.

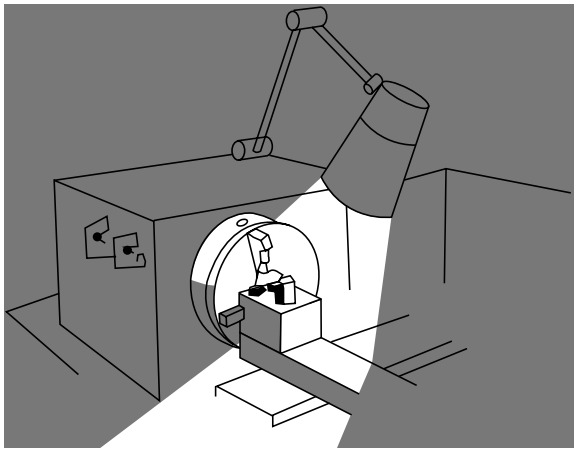


Figure 1.6 Local lighting on a centre lathe

1.11 Workplace (Health, Safety and Welfare) Regulations 1992 (as amended)

These Regulations cover a wide range of basic health, safety and welfare issues and apply to most workplaces. They aim to ensure that workplaces meet the health, safety and welfare needs of all members of the workforce, including people with disabilities. Where necessary, parts of the workplace, including in particular doors, passageways, stairs, showers, washbasins, lavatories and workstations, should be made accessible for disabled people.

A workplace in these Regulations applies to a very wide range of workplaces, not only factories, shops and offices, but also, for example, schools, hospitals, hotels and places of entertainment, and also includes private roads and paths on industrial estates and business parks.

The Regulations set general requirements in three broad areas, which are outlined here.

- Health
  - Ventilation: enclosed workspaces should be sufficiently well ventilated.