WASC 2195

ERDE

Accident
Prevention Guide

1965

Mr. A.R. Treadgold

MINISTRY OF AVIATION

ACCIDENT PREVENTION GUIDE

EXPLOSIVES RESEARCH
AND
DEVELOPMENT ESTABLISHMENT
WALTHAM ABBEY
ESSEX

1965

EMERGENCY CALLS FOR

FIRE)
AMBULANCE) DIAL 222
POLICE)

ACTION TO BE TAKEN

FIRE

Keep doors and windows closed.
Call for assistance and Fire Brigade.
Endeavour to extinguish fire with equipment available.
Do not apply water to electric equipment.
If explosives are involved warn people in the area to take cover.
Cut off gas and electric supplies at isolator.

INJURY

Call for First Aid Attendant for building or area.
Remove injured person only if danger exists from fumes, fire or other cause.
See first aid is given and arrange for person to go to Surgery.
If ambulance is called arrange for it to be directed to a convenient place.

E.R.D.E. ACCIDENT PREVENTION GUIDE

CONTENTS

CHAPTER 10

CHAPTER 11

CHAPTER 12

CHAPTER 13

PART IV

ACCIDENT PREVENTION APPLIED TO LARGER-SCALE EXPERIMENTS

CHAPTER 14

CHAPTER 15

PART I ACCIDENT PREVENTION AS A SUBJECT

CHAPTER 1

HOW AND WHY OF ACCIDENT PREVENTION

About this Book

Purpose

1.1 Many severe accidents could result from operations performed by careless or uninformed persons with the substances used in E.R.D.E. Nevertheless, our accident record is good in comparison with that of industry generally, a situation which has been brought about by careful planning and execution of accident prevention measures based upon knowledge and experience gained over many years. The prevention of all preventable accidents and the removal of "un-" from unpreventable accidents are the necessary steps to ensure that this record is not only maintained but improved, for it is a melancholy fact that the large majority of accidents can be traced (whenever this has been possible) to human failings of one sort or another.

This Guide is addressed to all scientific staff engaged in research and development at E.R.D.E; supporting staff also need to be familiar with its contents. Its purpose is to inform and instruct newcomers to E.R.D.E. and those who are starting unfamiliar work, and to aid the memory of the more experienced.

Arrangement and Treatment of Contents

1.2 This book deals in the main with certain recurring patterns of circumstances which could or do result in accidents; it cannot be fully comprehensive. Therefore the examples given are to be considered in two ways: firstly as specific points to be noted; and secondly as illustrating the kinds of feature which should be looked for in all relevant circumstances.

Part I is concerned with the approach of the individual to safety and accident prevention, and with points of general organisation having a direct bearing on these matters; it concerns everyone, whatever his field of work in the Establishment.

The remaining parts of the Guide cover the main fields of work in E.R.D.E., but it must be emphasised that the parts are complementary in various respects and cross-reference may often be necessary. Some of the principal cross-references have been noted in the text; individuals will note many others in applying the guide to accident prevention in their own work.

This Guide must be read in conjunction with the Rules of E.R.D.E. and with the E.R.D.E. Standing Instructions on Safety; here again, leading cross-references are given, but these are not necessarily complete.

The Guide must, of course, be read in conjunction with any local safety rules or operating instructions which apply to the reader's activities.

Necessity for Accident Prevention

1.3 It is immaterial whether the matters under consideration are called 'safety' or 'accident prevention', but since, in order to achieve safety, positive steps must be taken to prevent accidents there is some justification for preferring the term Accident Prevention.

Experience shows that Accident Prevention is best treated as a distinct subject if its objectives are to be attained, thus giving recognition to its special importance.

1.4 The measures required for prevention of accidents are never to be regarded as irksome distractions, diverting effort from the main undertaking; such an attitude can prejudice the successful application of preventive measures and so cause accidents. The extra effort required to minimize the chance of accidents should be regarded as a necessary part of the work in hand.

Preventing Accidents

1.5 A hazard must be recognised if it is to be avoided; it may be recognised out of one's own experience, or by comparison with the experience of others or by intelligent anticipation. When the hazard has been recognised, preventive measures can be planned and executed; others should be told about it.

This basic situation in accident prevention is amplified in the remainder of the chapter, which presents a framework of general advice to guide the steps required to find and eliminate potential causes of accidents.

The other chapters in the book deal with accident prevention in specific fields and cases.

Information on Hazards

1.6 Information on properties of substances and hazards may be obtained from the following sources:

1.6.1 The open scientific and technical literature (books, periodicals, abstracts,Association of British Chemical Manufacturers Safety Bulletins).

1.6.2 The Safety Officer, who has special responsibility for and experience of questions of accident prevention, and who can call upon the services and staff of the Ministry Chief Safety Officer.

1.6.3 Other members of the staff who have experience of the topic in question.

1.6.4 E.R.D.E. Library Services. The Library staff can advise on searching the security classified literature and on the use of abstract and reference books.

1.6.5 In particular, reference should be made to E.R.D.E. Standing Instructions on Safety, No. 4, 'Safety Searches'.

1.6.6 Members of other departments or organisations, e.g. Royal Ordnance Factories or I.C.I. Ltd. (Ardeer); these contacts may lead to access to unpublished information.

1.6.7 Account must be taken of all relevant Statutory Instruments, M.O.A. Regulations and Establishment Instructions, which not only lay down approved procedures, but contain information on hazards and means to deal with them.

Examples of these documents are:

The Factories Act, 1937 et seq.
Comprehensive Classified List of Government Explosives, 1958.
Ministry of Aviation Explosives Regulations, 1960.
Ionizing of Radiations Code of Practice: M.O.A. 1962.
Rules of E.R.D.E. 1962.
Standing Instructions on Safety, E.R.D.E.
Procedure in Event of Accident or Fire, E.R.D.E.

Note

It must be borne in mind continually in all work with explosives that these substances may explode if treated incorrectly; even small quantities of explosive can cause serious damage or injury in unfavourable circumstances.

If there is any doubt whatsoever about the explosive nature of a particular substance or mixture, no work with it should proceed until the Safety Officer has been consulted in accordance with the procedures described above and in Chapter 10.

Anticipation of Hazards

1.7 Making use of all available information an attempt must be made to anticipate whether any hitherto unforeseen accident could occur. It is important not to overlook possible circumstances or combinations of circumstances which might arise, such as mechanical failures or the sudden cutting off of electricity or other services. Serious hazards may arise from the proximity of operations which on their own would not be regarded as unduly dangerous.

The ability to recognise potential causes of accidents develops with experience and this skill should be consciously cultivated and constantly used.

Plan of Action

1.8 Information on known and anticipated hazards provides a basis for the satisfactory planning of the experimental work intended. Often only minor modifications of a projected method or procedure will be called for, but sometimes radical changes are required; therefore accident prevention must be considered at the very beginning of a project.

It has been estimated that five out of six laboratory accidents are attributable to human shortcomings, and therefore when designing accident prevention measures, it is necessary as far as practicable to regulate or eliminate the human element.

Safety Rules

1.9 Details of the required action are often most appropriately communicated to those who must carry it out by making rules. Rules are essential for the protection of less-skilled staff who may not be able to recognise the danger in a situation; rules are also a convenient means of ensuring that conduct in groups of staff does not fall below the minimum acceptable level.

Rules should be concise and unambiguous; they should be reduced to the smallest number compatible with achieving the desired ends; they should be duly authorised by a section leader or more senior officer acting in conjunction with the Establishment Safety Officer; they should be adequately displayed and communicated; obedience by all must be insisted upon lest they fall into disrepute; they must be kept up-to-date, and read regularly. (E.R.D.E. rule book, p.4.)

Habits

1.10 It would be impracticable to devise or operate rules for accident prevention in all conceivable situations. Therefore, the cultivation of SAFE HABITS is to be regarded as an objective to be pursued by every employee in in E.R.D.E. This calls for continual alertness, self-criticism and self-discipline. Circumstances tending to blunt these qualities lead to unsafe working and to accidents.

Recording of Experience

1.11 It is important that all relevant information learned about accident prevention should be recorded in such a way that it can be passed on to others. Therefore, members of staff who acquire such information in the course of their investigations should send a statement or a reference and abstract to the Establishment Safety Officer and to E.R.D.E. Library Services. Full details should be given whenever possible, and the communication should be endorsed for filing under 'Accident Prevention'. See also E.R.D.E. Standing Instructions on Safety No. 6, Reporting of Accidents and unusual occurrences.

1.12 Accident prevention information and rules need to be frequently reviewed especially in changing circumstances. Everyone has some responsibility to see that this is not neglected.

1.13 This Guide will be revised periodically. All members of the staff are invited to contribute by offering new information or views which they consider to be relevant; any changes in practice or interpretation would be particularly important. These contributions should be sent to the Establishment Safety Officer for consideration, and endorsed "Proposal for revision of Accident Prevention Guide".

The Object of the Exercise

1.14 The final objective is efficient working with freedom from accidents; this requires a balanced attitude, one which is neither unduly cautious nor at all careless, but always alert.

CHAPTER 2

RESPONSIBILITY FOR ACCIDENT PREVENTION

Supervisors

2.1 Supervisors have responsibilities for the prevention of accidents to staff and equipment under their control. The extent of the responsibilities of anyone with supervisory duties depends upon his circumstances, but anyone in this position should ensure that he adequately discharges his duties under the following headings:

2.1.1 Staff should be fitted by temperament and ability for the duties to which they are assigned. When authority is delegated, each should know clearly what is required of him, and gaps should not be left between areas of responsibility.

2.1.2 Planning and execution of work must make adequate provision for accident prevention.

2.1.3 Suitable facilities and equipment must be provided for carrying out the work which is to be done. It is important not to sacrifice safety to enable makeshift equipment to be used. "Pressing-on", e.g. working against time or with inadequate improvisation, should be discouraged.

2.1.4 Provision must be made for training newcomers and retraining staff moved to other work, reminding staff of hazards, protection and precautions, and the issue of rules and instructions. If there is any reason to anticipate hazards in the work, it should be confirmed that instructions have not only been received, but also understood. See also E.R.D.E. Standing Instructions on Safety No. 2 on Safety Meetings and No. 3 on Instruction and Training of Personnel.

2.1.5 Health supervision must be arranged when toxic or radiation hazards are involved.

Employees

2.2 All employees have responsibilities for accident prevention, both towards themselves and towards other.

2.2.1 Each must ensure that his conduct and actions do not result in danger to himself or to others; each must observe the spirit and the letter of instructions and rules, know the reasons for them and know the actions to be taken in emergency.

2.2.2 Each should make himself familiar with the services and facilities provided by the management for his protection and in turn ensure that he gives his fullest co-operation at all times.

2.2.3 The majority of accidents arise from human shortcomings such as failure to take sufficient care, failure to observe instructions, failure to give attention when it is obviously required. Elimination of failures of this kind depends finally upon the individual, who must recognise his special responsibilities for the cultivation of SAFE HABITS (see para. 1.10).

2.2.4 Occasionally, individuals who are in responsible positions and have reasonable regard for the safety of co-workers may show themselves willing to take chances with their own safety. This attitude is often the result of a false logic; the individual knows the necessary protection standard and agrees with it but argues that to put it into practice would impede his work; these individuals are often most conscientious workers who deem it necessary to take "calculated" risks. It is necessary to emphasise to such people that it is foolhardy to take avoidable risks; they should also be reminded of their responsibilities in providing an example for others.

2.2.5 Each should feel himself responsible for inexperienced staff who are unfamiliar with accident prevention matters and should give any necessary assistance to such people.

2.2.6 All have a duty to report to their superiors any matters coming to their notice involving breaches of accident prevention rules and procedures, or cases where new or modified accident prevention action is required.

The Safety Officer

2.3 The special importance attached to the maintenance of safety is recognised by the appointment of a Safety Officer and the presence of a Safety Section.

2.4 The Safety Officer is responsible for advice on all matters relating to accident prevention and safe working and should always be consulted when matters such as those listed below are under consideration:

2.4.1 Safety aspects of the design, installation, operation, alteration or destruction of:

- 2.4.1.1 Buildings.
- 2.4.1.2 Plant.
- 2.4.1.3 Machinery and equipment.
- 2.4.2 Safety of processes.
- 2.4.3 Safety of experiments and work in progress during closed periods.
- 2.4.4 Decontamination of buildings and equipment.
- 2.4.5 Destruction of explosives, chemicals and contaminated plant.
- 2.4.6 Issue of clearance certificates authorizing work in explosives buildings and dangerous places, and work on decontaminated equipment.
- 2.4. Issue of Safety Certificates for explosives (see paras. 8-1 et seq).
- 2.4.8 Hazards associated with chemicals.
- 2.4.9 Hazards associated with explosives.
- 2.4.10 Provision and use of radioactive materials.
- 2.4.11 Provision and use of X-ray equipment.
- 2.4.12 Provision and use of protective devices and equipment.
- 2.4.13 Fire precautions.
- 2.4.14 Training in Safety and Accident Prevention.
- 2.4.15 Training in first aid.
- 2.4.16 Training in use of breathing apparatus.
- 2.4.17 Storage and transport of chemicals.
- 2.4.18 Storage and transport of explosives.
- 2.4.19 Issue of Fire passes authorizing use of naked flames in the Establishment area.
- 2.4.20 Advice on Rules and Instructions.

2.5 In addition to the Safety Officer and the Assistant Safety Officer, the Safety Section has a staff of three Safety Assistants.
(See also E.R.D.E. Standing Instructions on Safety No. 1, Duties of Establishment Safety Officer.)

CHAPTER 3

MANAGEMENT OF LABORATORIES AND WORKROOMS

3.1 A good standard of General management is an important factor in securing the safety of workers and equipment in laboratories and workrooms. A number of items which fall under this heading and are of general interest are dealt with in this Chapter; attention is confined mainly to items connected with safety.

General Supervision

3.2 The responsibilities of supervisors for safety have been mentioned previously (para. 2.1). Parts of these responsibilities are usually delegated, by Superintendents to section leaders, and by section leaders to scientists-in-charge. Adequate supervision must be maintained, usually by a section leader or a designated deputy, who must know of all the work in a section and must ensure by regular inspection that it is being done safely.

Written instructions (paras. 1-9 & 3.11) may be provided to enable foremen or senior experimental workers to supervise the work of industrial workers, provided that likely hazards have been thoroughly reviewed and preventive measures have been taken; this will facilitate day-to-day supervision, but overall supervision is still a responsibility of more senior staff.

Unauthorised Work

3.3 No unauthorized work may be done. (For action in case of fire or an emergency, see para. 3.23 and inside of cover).

Opening and Closing Laboratories and Workrooms

3.4 If buildings are unlocked at the start of work before the arrival of scientific staff, supervision must be arranged and clear instructions must be given for work which is to be carried out; these should cover cleaning, starting equipment, and any other operations to be performed. (See also Rules of E.R.D.E.,Nos. 11 and 12).

Buildings and equipment must be made safe before being closed at the end of work. Everyone must inspect his apparatus and equipment to ensure that it is safe to be left and that services are safely turned off. Explosives, dangerous chemicals and inflammable solvents must be put away in the proper labelled places and any exceptional hazards for cleaners or others should be removed. Finally, a systematic check should be made by one individual, to ensure that everything is safe to be left and that windows and doors are properly closed. Usually, many of these routine tasks of opening and closing can be delegated to an industrial worker, but such an arrangement does not affect the responsibility of others for making their equipment safe to be left.

Supervision during Meal Breaks and Closed Periods

3.5 If it is decided by the scientist-in-charge that experiments or equipment must be left running during these periods, the necessary supervision must be arranged well in advance; it is unsafe practice to make hasty last-minute arrangements. If supervision is left to industrial staff, it is important to consider in detail what may possibly go wrong, and whether such eventualities can safely be accepted; explicit instructions should be given, saying what action is to be taken in the various foreseen eventualities; clear notices should be placed on the equipment concerned, to assist such action.

During closed periods supervision may be carried out by the Temperature Recorders; (See E.R.D.E. Standing Instructions on Safety No. 8, Procedure covering work in closed hours). It may be necessary to consult the Safety Officer before experiments are left under these arrangements.

Working Alone or Working out of Hours

3.6 Working alone is allowed only on authorized routine work where no undue hazard exists; otherwise, prior consent must be given by the Head of Section, who will generally arrange for someone to make occasional visits.

When it is necessary to work outside normal hours, special arrangements must be made. Prior consent of the Superintendent is necessary and the A.D. Police must be informed. If an appreciable hazard is involved, a second person must be reasonably close at hand and must know what is being done; in such cases it may be necessary to make special arrangements with the Surgery and perhaps also with the Temperature Recorders; the Safety Officer should be consulted.

Cleaning and Tidiness

3.7 Accidents are more likely to occur or spread when work is done in crowded, untidy or dirty surroundings. It is therefore important that rooms and equipment should be regularly cleaned, that unused apparatus, equipment and materials should not be allowed to accumulate in working spaces and that floor -space should be kept clear. Dangerous materials of any kind should not be left lying about, but should be stored in appointed safe places. (See Chapter 7 for storage of dangerous chemicals and Chapter 12 for storage of explosives). Cupboards and stores should be regularly cleaned; unserviceable or surplus equipment and dangerous materials should be disposed of in a safe manner and not left to become a danger to others.

Hazard Surveys

3.8 Staff should make regular surveys of workrooms, laboratories and other areas in which they work or for which they are responsible; the object should be to anticipate, detect and remove unsafe conditions. These surveys are conveniently held at fixed times, e.g. before Bank Holidays. They can with advantage be combined with periodical clearance of cupboards and stores, inspection of electrical, gas and water connections, inspection of tools, checking magazine records against contents, disposal of surplus explosives, chemicals and equipment, inspection of labels, and checking adequacy of storage arrangements. On these occasions staff should be reminded to re-read the rules concerned with safety.

Training

3.9 New staff are generally ignorant of the properties of explosives and the proper way to handle them, and often have imperfect understanding of the other kinds of hazard encountered in the Establishment. Some basic training is given to most new entrants, but in all cases senior staff must ensure that anyone working under them receives adequate instruction in all aspects of his work, including accident prevention; the necessity for such training must not be overlooked in the case of staff transferred to new work.

See also E.R.D.E. Standing Instructions on Safety; No.2 Safety Meetings and No.3, Instruction and Training of Personnel.

Conduct of Work

Planning

3.10 The planning of accident prevention was mentioned in paras 1.5 to 1.14; technical planning and accident prevention planning generally proceed in parallel since they are interdependent. Therefore, sound planning for accident prevention depends upon the existence of a technical plan, and any changes in the technical plan are likely to entail changes in measures taken to ensure safety.

Instructions

3.11 Instructions must be clear and unambiguous. Those who issue instructions should consider carefully whether instructions can be dispensed with, and if in doubt, written ones should be issued. Factors which point away from the necessity are small risk, well-qualified staff, good degree of senior supervision and single operations; factors of the opposite kind indicate that written instructions are necessary. Instructions for routine work and for industrial staff should generally be in written form.

The writer of instructions should put himself in the position of the recipients, taking account of their knowledge and background; instructions for similar work elsewhere can often be used as a guide. Instructions should be reviewed periodically. See also sub-para. 2.1.4.

Sources of inconvenience should be removed from places of work, so that operators can give their full attention to executing their instructions.

Operating Instructions for cases in which explosives are involved are dealt with in Rules of E.R.D.E., page 15.

Local Safety Rules

3.12 Those responsible for local groups of workers must consider what minimum actions and standards of conduct are required for safety in the group, and must make appropriate local safety rules. These local rules often contain the most important safety precautions in operating instructions; they often repeat Establishment rules but with amplification to take specific account of local conditions. Local safety rules are always necessary in group operating processes involving special hazards (e.g. explosives); these are incorporated in Special Rules which are dealt with in Rules of E.R.D.E., page 15. (See also para 1.9).

When an emergency drill is considered to be necessary it should be incorporated into written rules or instructions and it should be practised.

People not directly concerned but working near enough to be involved should not only know the nature of the work others are doing but should also be familiar with the emergency drill. Regular short rule-reading sessions should be arranged for industrial staff, scientists taking turns with the reading.(E.R.D.E. rules P.4).

Examination of Equipment before Use

3.13 Equipment and apparatus should be carefully examined before use or re-use. Equipment which has not been used before should be checked and tested for correct assembly and functioning; if the necessity for safeguards is revealed, these should be incorporated before the equipment is used.

Equipment which has been used before should be examined for evidence of weakness likely to lead to danger or bad functioning, e.g. flawed glassware, frayed electric cables, bad electrical contacts, overheating, defective taps and valves, defective safeguards, and all such defects should be corrected. The settings of controls should be checked to ensure that they have not been interfered with.

Routine Maintenance

3.14 Plant and equipment must receive regular inspection and maintenance. The hazard surveys (para 3.8) may serve this purpose for little-used equipment but plant in constant use should receive attention more frequently, e.g. regularly every Monday morning. Details of routine maintenance should be included in operating instructions, and should include systematic.regular cleaning of equipment used for explosives, lubrication, checking of clearances, functioning of safeguards and drenchers etc. Any source of danger discovered in use, e.g. sharp edges, must be removed by qualified staff before use. Some aspects of routine inspection and maintenance are best delegated to specialist branches or sections; this would be the case, e.g. for example with the periodical inspection and maintenance of engineering and electrical equipment; it is obligatory to do so in the case of portable electrical equipment (Rules of E.R.D.E., rule 107) and ladders and lifting tackle (ibid., rule 103), and pressure equipment (Standing Instructions on Safety: No 17)

It is often best to keep systematic records in a book of the inspections carried out under this paragraph and para. 3.13. Such records serve a twofold purpose; they often provide useful technical information and they help to ensure that no details are overlooked.

Protective Devices (considered in more detail in paras 5.74-5.83).

3.15 Whenever the work to be done involves hazards to people or equipment, suitable protective devices must be employed. A range of standard equipment is available, suitable for protection against explosion, fire, corrosive irritant or toxic substances and also against flying grit; details of the equipment are given in paras. 5.74-5.83 and advice on its employment may be obtained from the Safety Officer. When the character or scale of the hazard is such that standard equipment is inadequate, special arrangements must be made; such cases are further considered in Part IV.

Protective equipment should be kept easily available for use; it should be regularly inspected for evidence of deterioration and repaired or replaced when necessary; equipment, such as goggles or gloves, which may be issued on a personal basis must be inspected in this way.

Fume Cupboards

3.16 Fume cupboards must be used whenever the escape of noxious fumes, gases and dusts cannot be prevented; they must also be used in all cases where toxic substances are being handled and might escape in the event of fracture or other accident.

Radiation Monitoring (considered in more detail in paras. 5.84-5.86).

3.17 When emitters of radiation are employed (e.g. radioisotopes, X-ray equipment, high voltage devices including diode rectifiers etc.), it is important to check regularly the efficiency of the local protective measures.

It should be noted that protection against radiation is now governed by regulations made under the Factories Act. (Statutory Instrument 1470, 1961).

3.17.1 **Equipment and Surroundings** must be regularly surveyed with a suitable radiation monitoring instrument, to ensure that the intensity of escaping radiation does not exceed permitted limits; if any significent changes are made in the disposition of equipment shielding, a re-survey is necessary.

3.17.2 **Personnel** must undergo regular medical examination (see paras. 5.84); they must also be provided with a personal monitoring device suitable for the conditions of work; this is usually some form of film badge, which is evaluated by a specialist health physics laboratory, but other devices may be necessary in some circumstances. The Safety Officer should be consulted for further particulars.

Medical Inspection of Staff

3.18 Members of the staff whose work involves hazards to health, e.g. from toxic, dermatitic and corrosive substances, radioactive materials and X-rays, must undergo medical examination at regular intervals, and should be examined before starting such work; the purpose of these examinations is to exclude those who may be unsuitable (e.g. owing to sensitiveness to some chemicals). and to check the effectiveness of local protective measures.

For further details of dangerous chemicals see Chapter 6; for precautions to be taken with radiation, see paras 5.84 et seq.

Special Medical Precautions

3.19 It is sometimes necessary to arrange remedies at the place of work, so that immediate action can be taken to limit injury in case of accident. Some examples follow:

3.19.1 Eye wash bottles filled with water must be provided when corrosive materials are being handled. For particulars see para. 6.7.4. see also Rules of E.R.D.E., Rule 115.

3.19.2 A readily accessible means of drenching with water should be provided where there is much work with corrosive or dangerous chemicals (e.g. acids, hydrogen peroxide); this may be a sink, a bath filled with water, a water shower or a hose. For particulars see para. 6.7.5.

3.19.3 When cyanides or cyanogen halides are in use, special arrangements should be made through the Safety Officer with the Surgery for provision of a "Cyanide Emergency Kit" and other special facilities.

3.19.4 Special first-aid charts are available which describe the immediate action to be taken in certain specific cases, e.g. electric shock and some chemical hazards; advice should be obtained from the Safety Officer.

Medical Services

3.20 Surgeries on the North and South Sites cover the needs of all employees. The main Surgery is on the South Site and the Establishment Medical Officer attends daily; he or a partner is always on call in case of emergency. Trained nursing staff are on duty at both surgeries between 8.00 a.m. and 5.00 p.m. Monday to Friday, and on Saturday between 8.00 a.m. and 12.00 mid-day on the South Site only. (For arrangements for work outside normal hours, see para. 3.6).

An ambulance is always on emergency call, and carries a nursing sister with extensive first-aid kit.

First Aid to the injured

3.21 First aid equipment under the charge of a trained first aider is available for every building. Cards are exhibited in each building giving the names of first aid attendants.

See also inside cover of this book, para. 3.23 below and E.R.D.E. Rules 17 and 116 .

Fire Fighting

3.22 See Rules of E.R.D.E. (Rules 16 & 58) and Standing Instructions on Safety: No 5, Fire Procedure and Equipment, and on the inside of the cover of this book

Action in Emergency

3.23 IN CASE OF SERIOUS ACCIDENT OR FIRE, DIAL 222, REQUESTING AMBULANCE AND/OR FIRE BRIGADE, AND ARRANGE FOR FIRST AID TO BE RENDERED OR SEEK HELP TO CONTROL THE FIRE. (Rules of E.R.D.E.).

A separate manual, entitled "Procedure in the Event of an Accident or Fire" was issued in September 1961, reference WAC/15/012. Copies are held by Superintendents and certain others.

PART II ACCIDENT PREVENTION IN CHEMICAL AND PHYSICAL LABORATORIES OF AN EXPLOSIVES ESTABLISHMENT.

CHAPTER 4

LABORATORY POWER SUPPLIES AND SERVICES

4.1 Power supplies and services are engineered for convenience and simplicity in operation and are generally reliable and trouble-free. They may, however, become sources of danger if certain simple precautions are not observed.

Temporary connections (e.g. flexible wire or rubber tubing) are a source of weakness. Permanent connections, installed by a qualified tradesman, should be used whenever possible; such connections are much less susceptible to deterioration and accidental damage. When temporary connections are employed, the likely effects of deterioration (e.g. perishing of rubber)and accidental damage (e.g. passing knocks) or malfunction (e.g. trapping or kinking of hose) should be considered and suitable precautions taken; temporary connections should be frequently inspected.

Some precautions must be observed in the use of power supplies and services for experimental purposes; these are generally of a commonsense kind, but this must not be allowed to obscure their importance.

Electricity

4.2 Fire and electric shock are the principal hazards to be avoided in the use of electrical equipment.

Electric Supply Mains

4.3 Connections to the electric supply mains to meet a permanent experimental requirement should normally be made by a qualified electrician

The service up to and including the socket is the responsibility of the appointed engineering staff and must not be altered or interfered with by others. Scientific staff are permitted to make temporary connections to the supply mains but ONLY through the three pin plugs and sockets provided. The safety and efficiency of these temporary connections can be achieved if attention is paid to the following points:

4.3.1 One of the conductors of the mains supply has an appreciable potential difference from earth. This conductor is called the LIVE side of the mains, and the corresponding pin of the 3-pin plug is marked L; any additional single pole switch to be included in the circuit must be wired in the lead connected to this pin; if this precaution is neglected a severe shock can be experienced, even with the single pole switch in the OFF - position, from exposed portions of the circuit by contact with surrounding earthed objects.

The live lead is recognised by the fact that nearly full mains voltage is obtained by connecting it through a voltmeter to a temporary earth connection, e.g. a water pipe. (The supply SOCKETS may only be tested by the appointed engineering staff.)

The other conductor of the mains supply, called the NEUTRAL side is at, or near earth potential. This main is already connected to earth at the generating station and no connection with an additional local earth should be permitted; the corresponding pin of the three-pin plugs is marked N.

The third conductor in a three pin socket is connected to a local earthed point during installation. The corresponding EARTH pin of the three-pin plug is marked E and should be connected to the metallic non-current carrying frame of the electric apparatus, so as to give protection in the event of an insulation breakdown; such a properly installed supply from the electric mains includes an earth connection and NO other additional DIRECT EARTH connection should be permitted UNDER ANY CIRCUMSTANCES.

In three-core flexible cable used for connections with three-pin plugs, the insulating covers of the conductors are distinctively coloured; in this country these colours are allotted as follows by convention:

RED	LIVE wire	Connect to plug pin marked L
BLACK (sometimes BLUE)	NEUTRAL wire	" " " N
GREEN	EARTH wire	" " " E

The conducting wires should not be subjected to mechanical stress during use; this can be prevented by securely clamping the outer cover of the cable to the plug, using the device provided; when a clamping device is not already provided (e.g. cables joined to connector blocks, etc.), one must be incorporated.

WARNING: The indentification colours of the various leads in foreign made electrical apparatus may be different from those used in this country and dangerous mistakes can easily be made. In German equipment for instance, the identification colour for the earth lead is red, and green is used for the live side.

4.3.2 If, exceptionally, an earth connection to a piece of experimental equipment is required, the lead should be firmly attached to an earthing rod or earthed pipe, either by soldering, or by the use of a properly designed earthing clip. The apparatus should not be earthed at more than one point. Temporary earth connections MUST NOT be made to the gas mains.

4.3.3 Care should be taken to ensure that the current-carrying capacity of the mains wiring and of the wiring of the temporary circuit is appropriate to the conditions of the experiment.

Lamp sockets should not normally be used to supply current for experimental apparatus and in any case the load from each socket must not exceed 250 watts (corresponding to a current of about 1 ampere at 240 volts). See also sub-para. 4.3.6.

Extension cables (i.e. cables with connectors at both ends) from a mains socket to a distribution panel of an apparatus or to a coupling MUST always terminate in another socket.

4.3.4 The number and length of exposed conductors should be reduced as far as possible and they should be adequately guarded. Any worn or frayed cables should be replaced.

Electric cable must be guarded against contact with chemicals, steam, or hot objects, e.g. soldering irons.

Temporary leads between sections of equipment should be suspended at high level. Trailing of cables across gangways and along the floor is objectionable and should be avoided.

4.3.5 Leads to portable equipment, such as inspection lamps, hand drilling machines, ovens, etc., should be inspected at regular intervals, by a competent electrical engineer, for continuity in all leads to the apparatus and for satisfactory insulation. (Rules of E.R.D.E. Rule 107).

4.3.6 A fuse is introduced into each supply circuit to limit the current to a suitable maximum value. If for any reason this value has been exceeded and the fuse has blown, the circuit should be examined for faults before fresh fuses are inserted. Fuse ratings should not be greater than necessary, and must never exceed the designed ratings of the switches or wiring. Before making repairs or alterations to electrical equipment the current should always be switched off and fuzes drawn.

4.3.7 Special care is needed for circuits intended to be operated continuously for long periods with the minimum of attention. All components in such circuits should be used well within their rated values and with adequate ventilation. For example, tubular laboratory rheostats operate at a lower, and therefore safer, temperature in the vertical position with free convection cooling, than when operated horizontally. It should also be noted that the values of permissible current quoted by the makers are sometimes unduly large, and should not, in any case, be exceeded for continuous operation.

Rheostats or furnaces that are required to run for long periods without attention, e.g. overnight, should not rest in contact with the wooden top of a laboratory bench, but should be supported on a metal sheet raised on bricks so that free air circulation can occur. A metal sheet is preferable to one of heat-resisting material (asbestos cement) as the formation of local hot spots is prevented by conduction through the sheet.

4.3.8 Special plugs and sockets may be obtained to meet different conditions of service, e.g. waterproof, dust-tight and three-phase.

High Voltages

4.4 No attempt should be made to operate any electrical circuit involving voltages in excess of 400 volts without advice from the service engineer who will ensure that the circuit is correctly designed and assembled, and fitted with the necessary safeguards. These safeguards should, wherever practicable, include the provision of an easily accessible and plainly marked switch, or other means of bringing all parts to a safe potential in an emergency. A warning notice must be clearly displayed on the apparatus.

High Frequency Apparatus

4.5 Exposed H.F. conductors should whenever possible be guarded by a suitable earthed barrier of H.F. conducting material to prevent accidental contact. If neon lamps are used as warning devices, they should be fitted in duplicate to reduce chance of error due to lamp failure. A warning must be displayed on the apparatus.

Contact with an H.F. conductor may result in deep-seated burns although no shock is felt and the effect on the skin may only be very slight. All cases of high frequency contact must be reported to the Medical Officer without delay.

Town Gas

4.6 Town gas is poisonous and forms explosives mixtures with air. Leaks must therefore be repaired immediately.

If the characteristic smell of gas is detected in a room, regard the atmosphere as an explosive gas mixture. Do not switch on electric lights or any other electric equipment, nor use any kind of open flame. Turn off the stop cock of the laboratory gas mains and provide ample ventilation by opening doors and windows. Test for leaks with soap solution, never use an open flame for this purpose. Report leaks to the Engineering Branch (Services).

Before lighting gas from a main into which air may have diffused, sufficient time must be allowed for the displacement of the air-gas mixture. Apparatus having a large volume, e.g. additional gas meters, must be flushed with nitrogen immediately before use.

Gas burners, particularly when used in small rooms, must be well adjusted and cool objects should not be immersed in the inner part of the flame. Neglect of these precautions may result in incomplete combustion and release into the atmosphere of the odourless, very toxic, carbon monoxide. Lighted burners should not be placed near the edges of benches and should be extinguished when not required; unattended burners are a source of danger, particularly when inflammable solvents are in use in the laboratory.

For the more permanent installations, the burner should be connected by steel or brass tubes. Rubber connecting tubes should be frequently inspected and replaced before deterioration has given rise to danger; they should be protected from thermal radiation. Connecting pieces for lengths of rubber tubes should be made of metal, or plastic; glass should not be used. In some parts of the Establishment, gas is supplied from cylinders of compressed gas, instead of from the town supply. Attention is drawn to para. 5.42 et seq., and particularly to para. 5.59; special burners are required for cylinder gas. When gas from the mains is used in conjunction with compressed or mains air or oxygen, an approved non-return valve must be fitted to the gas supply. If these valves are omitted, there is a risk of explosive mixtures of gases being blown back into the mains.

Mains Compressed Air

4.7 Some laboratories are provided with compressed air mains. Although air is regarded generally as safe to work with, there are some subtle dangers attached to its use in the laboratory.

Never direct a compressed air jet towards any part of the human body. When a so-called air-gun is used for drying and cleaning solid surfaces care must be taken that particles removed by the deflected jet cannot injure the operator or any other persons nearby. Goggles should be worn by the operator.

The operation of compressors near to sources of inflammable gases or fine sprays of inflammable liquids, has resulted in the formation of explosive mixtures. Such mixtures can be ignited and explode as a result of the development of heat by adiabatic compression, or shock pressure. Even thin films of oil in an apparatus, particularly when this has been exposed for some time to sunlight can cause explosion on admittance of compressed air. See paras. 5.11 and 5.12 and 5.13 for precautions to be observed in using apparatus which is subjected to pressure. See para. 4.6 and 5.49 for necessity for non-return valves.

Vacuum

4.8 Mains vacuum lines must not be contaminated, and must not be connected to containers of volatile liquids, dangerous chemicals or corrosive gases. Particular care must be taken to see that explosive materials are not drawn into these lines; if this does occur, the vacuum must be turned off and the system decontaminated. Contamination of vacuum lines may be prevented by insertion between the apparatus and the line of a suitable trap or filter, and a device of this kind should always be used if there is a risk of contamination.

Drains

4.9 Contamination of drains by waste explosives, volatile inflammable liquids or toxic materials must be prevented. All exits from laboratory sinks should be provided with catchpots to collect dangerous materials, and steps must be taken to ensure that these are kept clear. The terms of the Trade Waste Agreement controlling discharge of chemicals into drains must be obeyed; the Safety Officer should be consulted in cases of doubt.

Steam

See para. 5.13.

CHAPTER 5

LABORATORY APPARATUS AND OPERATIONS

Apparatus

Glass

5.1 Glassware is a source of danger and all laboratory staff should learn how to avoid accidents with glass. It is good practice for people working in laboratories where bursts of glass apparatus may possibly occur to wear safety spectacles at all times and other special eye protection when necessary. See for example para. 5.67. The following simple precautions are also important.

5.1.1 When carrying a glass vessel through a doorway, beware of another person bumping against you. Never carry glassware by bicycle unless it is fully contained in a suitable basket or box firmly attached to the bicycle.

5.1.2 Examine all glassware prior to use. Glass apparatus which is damaged or cracked should never be used.

Fused joints should be carefully annealed to dissipate strain. Critical joints should be tested for strain, employing polarized light.

5.1.3 Whenever possible use a duster or other suitable protection for the hands in all operations with glass, particularly when applying force or handling heated, stressed or broken glass apparatus.

5.1.4 Fuse the cut edges of all glass tubes and rods used in the laboratory.

When pushing a tube into a stopper always use a lubricant and employ a twist motion. Hold the tube close to the stopper, never more than one inch away.

To remove a glass tube which is stuck in a rubber bung, use a cork borer which will fit over the tube; hold the bung and introduce the borer with a twisting motion between the tube and the bung so enlarging the hole and allowing the tube to be withdrawn easily. The method may also be used in reverse, as a safe way of inserting tubes into bungs.

5.1.5 Scrap broken glassware immediately or make it safe. Never put it into a drawer or cupboard. Never accumulate bent glass tubing in a drawer. Never put broken-ended tubing back into stock; cut the ends clean. Glass must be stored carefully to avoid accidental damage; tubing should not project in a manner likely to cause injury.

5.1.6 Support all large glass flasks adequately. It is bad practice to clamp any glass vessel of more than 500 ml capacity solely by the neck. Winchesters should never be carried by the neck alone. Avoid handling large pieces of glass (or other) equipment with wet hands. Use cork rings of the correct size to support round-bottomed flasks on the bench.

5.1.7 Pyrex glass is generally used in E.R.D.E. for apparatus, and will withstand most thermal shock conditions likely to be imposed. However, articles made of soda-lime glass, e.g. bottles and measuring cylinders, will only stand about 50 deg. C. thermal shock; great care must, therefore, be taken in melting the solidified contents or bottles. Glass apparatus intended for use above 50°C. should be made of toughened soda-lime glass, or borosilicate (e.g. Pyrex) glass. Advice on the design, strength and suitability of glassware for its purpose may be obtained from the Glass Engineer.

Centrifuges and Power Operated Equipment

5.2 Power-operated centrifuges should be examined by the Safety Officer on installation and before use; this procedure should also be followed for other power-operated equipment in laboratories if there is any doubt regarding its safety.

5.3 Care should be taken with clothing in laboratories in which there is power-operated machinery, since unbuttoned laboratory coats, ties, and long hair can easily become entangled in moving machinery and pull the operator on to the machine.

5.4 Never start an electric motor (fan, stirrer, etc.) without first making sure that no one will be endangered. Always treat moving machinery with the greatest respect: a moment's carelessness can maim you for life. NEVER REMOVE THE GUARDS OR NULLIFY THE SAFETY DEVICES ON A MACHINE WHEN IT IS RUNNING.

5.5 Fixed and portable power tools, such as saws, guillotines, electric drills, and lathes, may only be operated by authorized staff who are experienced in their use; persons who are inexperienced in their use should receive supervision and instruction until they have acquired a satisfactory degree of competence. When drilling, the work should be securely clamped in a vice or with hold-down bolts, to prevent the workpiece spinning or flying off. Grinding wheels should not be used without a guard, and the operator MUST wear safety goggles.

5.6 Physical and mechanical testing equipment should never be stressed beyond its maximum permitted load, which should be half the safety-test load.

It is possible to overload even robust equipment, with consequent danger due to falling weights, and particularly due to the whip of a snapped steel cable. See also E.R.D.E. Standing Instructions on Safety No. 13, Machinery in Laboratories.

Vacuum Equipment

5.7 Metal vacuum systems are generally preferred for safety reasons, but often are excluded by the nature of the application. Glass apparatus for use under vacuum must be able to withstand the applied stresses with a factor of safety; round-bottomed flasks are acceptable but flat-bottomed and conical ones are not, **unless** they have been specially designed for the purpose.

Filter Flasks

5.8 These flasks are thicker than ordinary ones in order to withstand evacuation. The specification is under review as some of the previously permitted base thicknesses were found to be inadequate.

In future, the flat-based pattern will only be made in sizes up to 2 litres, and will be suitable for filtering liquids at 100°C. The stores stock has been examined for suitability by the Glass Engineer. The 3, 4 and 5 litre sizes are only available from the Glass Engineer. The 5 and 10 litre sizes will only be made with convex bases and must be used with a suitable stand; they are suitable for use with hot liquids, but must not be used for heating purposes.

If there is uncertainty about the suitability of existing laboratory stocks of filter flasks, they should be sent to the Glass Engineer for inspection for conformity with Safety requirements.

Glass Vacuum Desiccators

5.9 In E.R.D.E. the Jencon-Phoenix series has been adopted as standard. Davey and Moore desiccators also are suitable. **No other desiccators** should be used under vacuum.

It is good practice to shield vacuum desiccators, particularly the larger ones, with heavy wire gauze or a suitable box.

Vacuum Apparatus

5.10 So-called vacuum apparatus is used for investigation of systems in the absence of air. A vacuum apparatus must be built on a rigid frame and protected against accidental knocks. Glass taps must be supported (on both sides) by clamps as near to the tap as possible; glass joints should be supported similarly. It is good practice to cover the weaker larger glass bulbs with adhesive tape in order to reduce danger from splinters. Vacuum Dewar flasks must also be protected in the same way: when in use they should be supported on cork rings inside protective wooden boxes.

5.10.1 In some systems the admission of air can cause an explosion. It is dangerous to test vacuum apparatus for leaks with a Tesla coil if liquid nitrogen baths are in use; oxygen can be condensed under these circumstances and may form explosive mixtures. See also para. 5.70. For cooling baths see para. 5.72.

Glass Pressure Equipment

5.11 Glassware for use under pressures above atmospheric should be confirmed as suitable by the Glass Engineer, and if necessary hydraulically tested to a test-pressure at least 50 per cent above the expected working pressure. Water or similar non-compressible liquid should be employed for test, NEVER compressed air or gas. Such vessels in use must always be adequately protected, e.g. by a surrounding metal vessel or safety screen.

5.12 Comparatively low gas pressure applied to a glass vessel (e.g. through rubber tubing) can cause it to burst. Always use an approved reducing valve on a compressed gas cylinder, and connect the apparatus to it via a surge tank or trap provided with a safety-valve or blow-off device; needle valves must not be used since a blockage in the outlet will cause the apparatus to be subjected to the full pressure in the cylinder. (See also para. 5.42 et seq. Compressed Gases).

Metal Pressure Equipment and Steam-heated Equipment

5.13 There are serious risks associated with the installation and operation of pressure equipment; examples of such risks include wounding by high pressure jets of gas, by propulsion of insecure parts of the apparatus, and by whipping of loose connecting tubes. Pressure equipment may not be installed in E.R.D.E. unless the design and proposed method of operation have been approved in detail by the Safety Officer. Special regulations under the Factories Acts govern the testing and inspection of pressure apparatus. See E.R.D.E. Standing Instructions on Safety, No. 17.

A metal air receiver or pressure vessel must be of approved construction, and be clearly marked with its safe working pressure; it must be fitted with a safety valve set to blow off as soon as the safe working pressure is exceeded and it must be fitted with a correct pressure gauge which must be frequently tested; if connected to a compressing plant or steam generator, it must either have a safe working pressure above that of the maximum the compressor or generator will achieve, or an approved reducing valve,must be inserted in the connecting pipe, to regulate the working pressure to a safe value. There must be a suitable appliance for draining and a manhole for cleaning.

Compressors should not be operated near sources of inflammable gas or vapour (see para. 4.7).

Operations

Vacuum Distillation

5.14 All distillations under reduced pressure should be carried out behind adequate screens. Always use a suitable trap between the source of vacuum and the apparatus. This is especially important when using a water pump with apparatus at a high temperature, or when using a mechanical pump in the presence of reactive substances.

5.15 The use of flames for direct heating should be avoided as far as possible. It is always preferable to use oil baths with electric immersion heaters or electric heating mantles. Gas-heated air baths may be used for higher temperatures.

5.16 Evacuate the apparatus and check for leaks before commencing heating. The apparatus should never be subjected to rapid changes of pressure and it should be allowed to cool at the end of distillation before SLOWLY letting air or nitrogen into the apparatus.

5.17 Nitrogen is preferable to air on all capillary bleeds, since all organic substances tend to oxidise at elevated temperatures.

5.18 Rubber stoppers should not be used for distillation equipment since they tend to soften with heat and may be pulled into the distillation flask.

5.19 Do not use a water-cooled condenser if the distillate is entering the condenser above 120°C.

Solvent Extraction and Distillation of Flammable Solvents

5.20 Flammable volatile solvents should only be handled well away from open flames, electric heating mantles, electric hot plates, resistances, switches, etc. Flammable vapours are generally much denser than air, and they can flow a considerable distance along a bench top or floor before becoming sufficiently diluted to be non-inflammable. Solvents can easily be ignited by electrical equipment still at black heat; carbon disulphide is particularly dangerous and fires have occurred from ignition of vapour by a steam radiator. Wherever possible, flammable liquids should be heated by steam; where this is impracticable an approved form of electrically heated mantle should be used and the absence of solvent vapour must be ensured by use of a condenser or vapour trap. Energy regulators are not flameproof, and should be used with care. Heating by an open flame or on a sand or oil bath should be avoided if possible, but if used, proper precautions must be taken.

5.21 The distillation, boiling or refluxing of flammable liquids in glass apparatus presents grave fire risks. Every precaution should be taken to prevent the spread of fire in the event of breakage of the solvent container or receiver. Catch trays can be used to localise possible solvent fires. Allow adequate space between experiments, and make sure that sufficient fire extinguishers are available.

5.22 Particular care should be taken when using large quantities of flammable solvents; it is advisable to isolate the work in a well ventilated room from which all sources of ignition are excluded. A suitable alternative is to carry out such operations in a well ventilated fume cupboard, provided that the electrical equipment is all flameproof.

5.23 Get to know the position of the laboratory main controls for gas, electricity and water; they must be easily accessible in case of emergency, and must not be obstructed by equipment.

5.24 Dialkyl ethers, tetrahydrofuran, and dioxan form peroxides in contact with air and on exposure to sunlight. They should be stored in dark bottles with the air space above the liquid kept to a minimum. Any ether which has been stored in a partly filled bottle for several months is a possible source of hazard. Do not attempt to distill the low-boiling aliphatic ethers nearly to dryness, because this concentrates the peroxides, and can cause serious explosions. Peroxides can easily be destroyed: ask the scientist in charge of the laboratory for instructions. (See also Chapter 13).

5.25 When running a Soxhlet extraction, the type of condenser being used must be adequate to cope with the solvent in use, especially if inflammable.

5.26 When solvent extraction is being carried out by shaking in a separating funnel, release the pressure frequently; point the funnel away from the eyes, and away from other workers in the laboratory.

Opening Sealed Glass Ampoules

5.27 Sealed glass ampoules should always be opened with care. Such ampoules usually contain materials which either are toxic or have a high vapour pressure. They are usually made of soda-lime glass, with very variable wall thicknesses, and are liable to shatter if cooled too quickly. Before opening, an ampoule should be cooled slowly, and wrapped in a cloth; then the neck is scratched with a glass-knife, and the top cracked off with a hot glass rod. There is a risk of ignition if the cooling is inadequate.

Cleaning Glassware

5.28 The scientist conducting an experiment is responsible for making sure that apparatus handed to junior staff for dismantling or cleaning is safe. If dangerous residues, e.g. corrosive acids, sodium, hydrogen peroxide or organic matter are likely to be present, the scientist should remove them before the apparatus is handed over. Sodium may be removed by treatment with methylated spirit.

5.29 Junior staff should be instructed in the correct methods of cleaning apparatus, particularly when dangerous cleaning agents such as nitric acid, or mixtures of sulphuric acid and potassium dichromate, etc., are used. These acids are capable of inflicting severe burns if they are spilt or splashed on the exposed skin. Such work should be carried out whenever possible in a large sink with an adequate water supply, and protective clothing, gloves, goggles, etc., should be worn as appropriate. Cleaning reagents may develop violent reactions with residues in the apparatus and with rinse-drying agents such as alcohol and ether. An explosion has occurred through the use of sulphuric acid/chromate mixture to clean a flask containing traces of concentrated hydrogen peroxide. Carbon disulphide should not be used by laboratory attendants as a cleaning agent.

5.30 Occasionally it is necessary to discard dirty glassware or other apparatus instead of cleaning it; in such cases precautions must be taken. Under no circumstances should apparatus, containers or scrap material containing chemicals, even if quite harmless, be placed in waste bins until they have been freed from contamination; if they cannot be cleaned, the Safety Officer should be consulted regarding disposal.

Pipetting

5.31 Preferably, pipettes should not be filled by mouth suction. Mouth suction must not be used to transfer toxic, corrosive or radioactive solutions; instead, pipettes must be filled using a "Pumpette", a rubber bulb, a piston safety pipette, or other means.

Organic Preparative Reactions

5.32 A preparative experiment should not be left unattended if it is being carried out for the first time. Never increase the size of a preparation, or alter the conditions or reactants, without first consulting the scientist in charge.

5.33 A stirrer which efficiently agitates a 500 ml flask may be completely useless on the 2-litre scale. The stopping of a stirrer can lead to overheating and possible explosion. Make sure that the stirrer gear is in good order before starting an experiment. Do not restart a stirrer if it has been stopped for any length of time in a heated reaction flask - first allow the flask to cool to prevent possible boiling over.

5.34 Choose the size of the reaction flask carefully: make sure its capacity is adequate to allow for possible frothing. The condenser should be of suitable type, and its capacity should always be in excess of requirements.

5.35 Always make provision for rapid removal of the heating source. Make certain before starting an experiment that there is free access to gas taps and electric switches.

5.36 Isolate all potentially dangerous experiments and conduct preparations involving toxic reactants, by-products, etc., in a fume cupboard. Never look into a flask which is being agitated.

Limit the size of:

(a) "First time" experiments.
(b) Experiments involving the alkali metals, lithium hydride, etc.
(c) Halogenations, particularly brominations.
(d) Reactions involving fluorine, hydrofluoric acid, boron trifluoride etc.
(e) Reactions involving alkylene oxides.
(f) Polymerisation reactions which are liable to become uncontrollable.
(g) Nitric acid oxidations; adequate gas outlet needed.
(h) Reactions involving the use of hydrogen peroxide of 50% strength or above.

5.37 It is generally bad practice to add active catalysts at elevated temperatures - never do it unless previous small-scale trials have shown that it is safe to do so.

5.38 Add boiling aids to a liquid well below its boiling point, and limit the amount. Comparatively small pieces of pot can knock out the bottom of a distilling flask so that this material should be powdered; in some cases it is better to use a small strip of wood. The addition of finely divided materials, such as activated charcoal, to a nearly boiling liquid can cause frothing over.

5.39 The bench in the vicinity of an experiment involving alkali metals should be wiped dry. Ensure that it is impossible for pieces of the metal to fall into water and oil baths during addition.

Wash bottles

5.40 Wash bottles containing liquids other than water should carry labels stating the contents.

Fires have been started through the focussing of sunlight by glass apparatus, e.g. wash-bottles. The risk is particularly great when explosives are present, but should be guarded against generally.

Mercury

5.41 It is widely recognised that mercury compounds are very toxic, but the danger from mercury metal is not so generally known; the concentration of mercury vapour in equilibrium with the metal is 15 to 20 times the maximum permissible, and therefore suitable precautions should be taken in handling the metal. Spilled mercury must be collected immediately and that which cannot be collected should be treated with sulphur; suitable traps and trays should be used for apparatus containing mercury; the escape of mercury vapour may be minimised by covering the metal with water or the vapour can be absorbed in suitable traps, e.g. active carbon treated with bromine or iodine.

Not more than four pounds (ca. 130 ml.) of mercury should be handled in a glass beaker. Advice on glassware for use with mercury may be obtained from the Glass Engineer. Never put mercury into contact with aluminium vessels since aluminium corrodes rapidly in the presence of mercury.

Compressed Gases

5.42 When experiments with gases under pressure are first planned the authority of a senior scientist must be obtained before work is started and the Establishment Safety Officer should be notified.

5.43 No one should attempt work with compressed gases unless he has been thoroughly trained in the subject. Receivers, pressure vessels, etc. are subject to stringent controls under the Factories Acts and the safe designs of unions, pipes, valves, etc. have only been achieved as the result of long experience. To cite one example of the outcome of the omission of well-known precautions, there have been fatal accidents as a result of failure to provide against adiabatic heating of explosive gaseous mixtures in pipelines.

5.44 No member of the staff should be permitted to use either trade or experimental compressed gas cylinders unless he has been trained in their safe use. When compressed gas cylinders are used for the first time the operator must read the British Oxygen Company's booklet on safe handling of compressed gas cylinders; this can be obtained from the Safety Officer.

5.45 There are dangers attendant on the use of compressed gases in trade cylinders; these cylinders are in common use and familiarity must not be allowed to lead to dangerous practices.

Types of Compressed Gas Cylinders

5.46 Compressed gases supplied commercially in cylinders are of three types:

(a) "Permanent" gases (e.g. oxygen, nitrogen, carbon monoxide, coal gas, methane) at a pressure of up to 1,980 pounds per square inch in round-ended cylinders which can be stored or used in either the vertical or horizontal position. The cylinders for inflammable or toxic gases are provided with a screwed collar to take a valve cap, but caps are not usually provided.

(b) "Liquefiable" gases (e.g. ammonia, carbon dioxide, sulphur dioxide, chlorine, hydrocyanic acid, phosgene, ethylene, nitrous oxide, methyl chloride) in round or flat-based cylinders which must be stored upright and used upright (unless it is intended that they should deliver the contained chemical in liquid form). The cylinders usually have valve caps.

(c) Dissolved gases, of which the only example is acetylene dissolved in acetone under a pressure of 225 pounds per square inch. The cylinders are flat-based and must be stored and used upright. A valve cap ring is provided; caps are not usally provided.

Precautions Applicable to all Types of Compressed Gas Cylinders

5.47 As an aid in identification, a colour code for gas cylinders has been introduced by the British Standards Institution. (See Rules of E.R.D.E., p. 33). This code is not in full use and reference should always be made to stamped markings or attached labels to be sure of the identification of the cylinder contents.

5.48 To prevent the interchange of fittings between cylinders of combustible, and non-combustible gases, the valve outlets are screwed left and right hand respectively. This difference in threads is maintained on all accessories such as pressure regulators, adaptors, hose connectors, etc. which are supplied for use with cylinders, but does not apply to the valve spindle on the cylinder valve which is always closed by turning clockwise.

5.49 Non-return valves must be fitted to the main supply of gas or air if used in conjunction with cylinders. If these valves are not used there is a risk of explosive mixtures of gases being blown back into the mains.

5.50 When in use, cylinders must be held in the approved type of stand or firmly clamped in position and must be placed well away from sources of heat. Out of doors they must not be left exposed to the sun or weather.

5.51 Cylinders should be transported only on the special trucks supplied for the purpose by the Stores Officer and always handled with care. Instances have occurred when the dropping of a cylinder has caused it to explode. Careless handling of a cylinder may result in the valve head being broken off and the escaping gas can cause the violent projection of the cylinder. If the cylinder has a valve cap it should always be put on during handling and transport. To prevent accident due to building up of pressures in the valve cap in the event of the cylinder valve leaking, valve caps are provided with a vent and before fitting a valve cap it should be confirmed that the vent is not blocked.

5.52 When gas is not being taken from the cylinder the cylinder valve must be closed. It is unsafe to leave the cylinder valve open when the valve on the reducing valve or other attached system is closed.

5.53 No undue force should be used in opening or closing cylinder valves. If the valve does not turn with moderate force the gland nut should be slackened slightly and if this does not ease the spindle, the gland should be re-tightened and the cylinder returned to the suppliers. No attempt should be made to correct a leaky valve by forcing the valve spindle on to the seating; the valve should be opened slightly to allow it to clear any minor obstruction and then closed firmly but using no more force than can be applied by one hand on the key. If repetition of this treatment fails to remedy the leak, the cylinder should be taken into the open and discharged under suitable precautions. A leak at the valve packing will only be evident when the valve is open and can usually be remedied by tightening the gland nut. A cylinder valve is fully open after two complete turns of the spindle; further opening is unnecessary, and may result in serious accident due to ejection of the spindle by high-pressure gas.

5.54 Run down cylinders should always be left with the valve closed to prevent air diffusing into them. No oil or grease should be used inside or outside any valve fitting or reducing valve.

5.55 Gas cylinders of all types are liable to explode when heated and constitute a serious addition to the fire risks of a building. This should be taken into account when deciding where to use them in a laboratory. Whenever it is practicable they should be removed to a fire-proof store or isolated building overnight. Always use the smallest size of cylinder adequate for the work.

5.56 Gas cylinders, even when empty, should not be used as mandrels to bend sheet metal, etc. or as rollers to move heavy equipment or indeed for any purpose other than the one for which they are designed. Cylinders should be returned to store immediately they become empty. They should be clearly labelled "Empty". A periodical tally should be taken of cylinders held on charge. Any that are found to be no longer required or which have been held for more than six months should be returned to store.

Special Precautions with Gas Cylinders of Different Types

Permanent Gases

5.57 Cylinders of permanent gases should be used only with a reducing valve and the reducing valve connections must be freed from dirt. The cylinder valve should always be opened gently; sudden release of the gas into the reducing valve may cause local heating by adiabatic compression or particles of grit propelled by the gas may become heated by friction and, with an inflammable gas, there is a risk of ignition. With oxygen, combustible material in the reducing valve and in some circumstances even metallic parts of the system may be ignited. For this reason, cylinder fittings should never be oiled and jointing materials such as red or white lead containing organic matter or components containing aluminium or magnesium, should be excluded from apparatus in which compressed oxygen is used. Oxygen cylinders should not be handled with greasy hands, gloves or rags, and oxygen must not be directed towards oily rags or oil-contaminated clothing. Oxygen should never be used in place of compressed air or nitrogen for pressure testing, flushing apparatus, etc.; SERIOUS EXPLOSIONS HAVE OCCURRED THROUGH NEGLECT OF THIS RULE.

Inflammable Gases

5.58 In the B.S. Colour Code, with one exception, cylinders of inflammable gas are coloured red or carry a band of red paint; the exception is acetylene, for which the cylinder colour is maroon.

5.59 Cylinders of inflammable gases should be used only in positions remote from flames, electric heaters, etc., and in well ventilated positions. Inflammable gases should never be released into the air in confined spaces (e.g. a room) or allowed to escape into a laboratory fume extraction system, as explosive gas - air mixtures may develop. The sudden discharge of a compressed inflammable gas into the air from a cylinder has on more than one occasion resulted in its catching fire.

Acetylene

5.60 Acetylene cylinders are liable to develop internal heating if roughly handled or improperly used. If a cylinder is found to have become hot the valve should be closed and the regulator detached. The cylinder should then be taken into the open and cooled by immersion in water or by means of a water hose. When cool the cylinder should be taken to a suitable place distant from buildings and flames and the gas allowed to escape by opening the valve. Cooling should be continued if practicable.

5.61 If gas is drawn too rapidly from an acetylene cylinder, there is a risk of its being diluted with acetone vapour. The hourly rate of withdrawal should not be greater than 20 per cent of the contents of the cylinder.

5.62 Copper reacts with acetylene to form an acetylide which is a very sensitive explosive. No pipe or fitting of copper or any alloy containing more that 70% of copper should be allowed to come in contact with acetylene.

Toxic Gases

5.63 In the B.S. Colour Code, cylinders of toxic gases have a yellow band.

5.64 Cylinders containing toxic gases must not be brought into a laboratory without permission from the Head of Section. Before work with a toxic gas is started the Establishment Safety Officer should be consulted. It should be confirmed that appropriate protection in the form of respirators, etc. is ready to hand. It should be noted, however, that respirators are only adequate to deal with moderate concentrations of gas, and that an emergency such as a cylinder freely discharging into the air calls for a self-contained breathing apparatus. When using a toxic gas, it is a good plan to fix the cylinder in the open air and lead the gas into the laboratory through a tube. Adequate protection of the cylinder from sun and rain must be provided.

Liquefied Gases

5.65 Metal containers for liquefied air and other gases depend for their efficiency on the maintenance of a high vacuum in the insulating chamber. If this chamber is damaged by rough handling the vessel will be ruined. Containers must, therefore, be handled carefully and not dropped or knocked. As liquid air, oxygen and nitrogen are continuously evaporating a vent must always be provided in any vessel in which they are stored or used. If the vent is closed the vessel will burst. The use of any type of plug, e.g. cotton or glass wool, is dangerous because it may become coated with ice owing to freezing of moisture from the atmosphere. For the same reason it is dangerous to leave a glass or metal funnel in the neck of the vessel.

5.66 Should the outlet of a liquid-gas container become obstructed by ice the blockage should be cleared by puncturing the ice with a clean piece of stiff wire; it may be necessary first to remove the vessel to an uncongested area. Do not attempt to use heat and be on the alert for the possibility of a burst. The face and hands should be protected by a mask and gloves but these must be of the type which can be quickly removed if liquid gas is accidentally entrapped.

5.67 Wide-mouthed Dewar jars are frequently used for transporting and storing liquefied gases. The clip-on lids must NOT be fastened, as the gas vent in the lid may become frozen up and cause the jar to explode.

Normal Dewar flasks should either be used in the metal container supplied or securely wrapped with adhesive tape, to prevent glass flying if the vacum vessel implodes due to thermal shock when being filled with liquefied gas. All filling of glass vacum vessels should be carried out behind a screen, or with the operator wearing safety goggles which are a close fit to the face.

5.68 When pouring liquefied gases, it is inadvisable to wear gloves since frost bite may result if contact with liquid is prolonged, e.g. by liquid entering a glove. Slight splashes on the skin are harmless; if protection for the hands is required a cloth may be used.

5.69 Liquid oxygen should only be used or stored under conditions which ensure adequate dilution of the escaping gas; otherwise the increased oxygen concentration near the apparatus or container will cause an increased fire or explosion risk. Liquid oxygen can cause spontaneous ignition if it comes into contact with oil, grease, clothing or other combustible material. Liquid oxygen should, therefore, not be used in place of liquid nitrogen for cooling purposes and NEVER for cooling combustible matter.

5.70 Explosive mixtures may be formed in systems cooled with liquid nitrogen or liquid hydrogen, owing to condensation of oxygen from the atmosphere; This may often be prevented by purging the system with an inert gas before reducing the temperature. See also 5.10.1

5.71 There are special regulations for transport of liquid gases – application should be made to the Establishment Safety Officer.

Gas Syphons

5.72 The precautions detailed in the paragraph above are in part applicable to the use of glass syphons containing sulphur dioxide, phosgene, etc. Care should be taken not to place them where they can be accidentally heated, or broken by falling objects.

Solid Carbon Dioxide ("Drikold" or "Cardice") Baths

5.73 Cooling baths of solid carbon dioxide and acetone may present a fire risk, particularly when the bath warms to room temperature: this can be avoided by using a non-flammable substitute for acetone, e.g. trichlorethylene or ethyl bromide. When preparing these baths, the liquid should be added to the solid carbon dioxide.

Ice may form around the top edge of a bath and may obstruct movement; care is needed to ensure that movement of the bath does not cause breakage of the apparatus.

Protective Appliances

5.74 An extensive range of protective equipment is maintained in the Establishment to assist the safe working of staff. This equipment has been designed or obtained to deal with those hazards frequently encountered, but should only be used within its tested limits; if staff are not certain of its correct use or require protection against other hazards, the Safety Section should be consulted.

Armoured Cupboards

5.75.1 Armoured cupboards are marked by the Safety Section to show the approved limits and must not be used for greater amounts of explosives or equivalent reactive materials; even when the limits are not exceeded, explosions in such cupboards may cause shock and possibly damage to ears. The method of fixing and other details of the installation are taken into account in approving the limit for a cupboard; the Safety Officer should be consulted for further particulars.

Test data on Armoured Cupboards

Sliding-door type

5.75.2 With four-section front and no lid (Drawing No. D.4467, 2 sheets), tested to 50 grammes of H.E.

Hinged-door type

(a) S.E.I. type
4 or 5 door and no lid, (Drawing No.M.O.W.8871/213 and 214), tested to 30 grammes of H.E.

(b) Free-standing type, 4 door with metal back and no lid (Drawing No. D.6269), tested to 30 grammes of H.E.

(c) As (b), with addition of steel centre and top-brace and fitted with 1/8th inch hardboard lid (drawing No. D.6269), tested to 30 grammes of H.E.
The door bolts, also serving as hinge-pins, must extend ½ inch beyond the bolt holes. Unless one set of bolts is locked, there is a danger that the door may fall out when opened; a modification to reduce this danger is shown on the latest drawings (D.6269).

5.75.3 Cupboards must conform to the approved drawings listed above and must not be altered in any way without consulting the Safety Section. It has been found in trials that even minor alterations can reduce the protection afforded.

5.75.4 The amount of explosive at risk must be kept as small as possible.

5.75.5 Operators MUST wear goggles as protection against glass splinters. (See Section 10.5).

5.75.6 No holes or slots should be left open in the sides or backs of cupboards.

5.75.7 A lid can greatly reduce the safe working limit of a cupboard and the Safety Section must be consulted before any lid is fitted.

Safety Screen

5.76 Several types of screen are available and are designed for non-explosive use. The standard large "picture frame" screen (30 x 24 inches) (Drawing No. 4483, 1950) fitted with 3 mm thick cellulose acetate has been tested and withstands glass fragments from an oxygen/acetylene explosion in a 1-litre flask at a distance of 12 inches. The expanded aluminium mesh screen (12½ x 13 inches) (Drawing No. 5602, 1960) fitted with 3 mm cellulose acetate has been tested satisfactorily against 5 grammes of tetryl in a glass beaker at 15 inches.

The screens available of 3 mm or more cellulose acetate and those of ½ inch laminated glass are suitable for chemical work, but they should not be used for explosives work owing to their light weight.

5.76.1 Fixed metal screens are provided for other operations, e.g. vacuum stability testing, but must only be used for their designed purpose and limits.

Information on suitable screens should be obtained from the Safety Officer, since various factors, e.g. method of fixing, venting, etc. affect the protection afforded. For example, in high pressure work, whilst adequate venting can greatly reduce pressure effects following a burst, the high velocity of fragments will demand heavy protection.

Face Visors, Goggles, Spectacles

5.77 Devices for eye protection should be selected with regard to the work in hand since use of the wrong type may not only afford inadequate protection but may increase danger of injury. See also E.R.D.E. Standing Instructions on Safety No. 11, Protection of eyes.

Face visors and spectacles will not give more than 75-90% eye protection against liquid splashes or sprays; rubber or P.V.C. - framed goggles with double plastic lenses will afford 100% protection against splashes if they are fitted and worn correctly, but they will not give the same degree of protection against fragments as visors or spectacles. The following test data indicate the degree of protection to be expected (all tests at 15 inches from lens or face):

5.77.1 Face Visor (Non-Flammable Material)

The thick (1/8 inch) cellulose acetate visor withstood the explosion of 5 grammes of tetryl in a glass beaker; it provides satisfactory protection against flame and fragments.

The thin (0.04 inch) cellulose acetate visor failed against a bare charge of 2½ grammes of tetryl and was badly damaged by 2 grammes of tetryl in a glass beaker; it is satisfactory against flame, but is only suitable for use against low-velocity fragments.

5.77.2 Spectacles (0.05 inch plastic lenses or toughened laminated glass lenses) and spectacle protectors.

Undamaged by blast from 5 grammes of tetryl and severely damaged by 2 grammes of tetryl in a glass beaker; suitable only against low-velocity fragments.

5.77.3 **Goggles**

Detonator type has either double plastic or double laminated glass lenses; the inner lenses were undamaged by 2½ grammes of tetryl in a glass beaker. The thin plastic sheet type fitted with two shields give good protection against liquids, but are only satisfactory against low-velocity fragments, e.g. hand chipping.

5.77.4 To summarise, the best protection against high-velocity fragments and flame is given by the thick visor, which also gives 75-90% protection against liquids.

Staff working in laboratories are advised always to wear protective spectacles of plastic or glass; light-weight types of these will afford reasonable protection against accidents arising in the laboratory, and are available in the Establishment. When hazardous work is being done, the spectacles should be changed for one of the more protective types.

5.77.5 Spectacles are also available for ultraviolet and infra-red work.

Several grades of filters are available for protection against glare, furnace or welding flash and the Safety Section will advise on the choice of filters.

5.78 **Gloves**

5.78.1 The following types are stocked:

Material	**Sizes**	**Weight**	**Type**
Rubber	All	Surgical,medium,heavy	Wrist and Gauntlet
P.V.C.	-do-	-do-	-do-
Neoprene	Men	Medium	Wrist
Butyl rubber	-do-	-do-	-do-
Asbestos	-do-	Medium and Heavy	Wrist and Gauntlet
Leather	-do-	Heavy	Wrist
Cotton	-do-	Medium	Wrist

Gloves must be selected according to the intended use.

5.78.2 Gloves must be kept in good condition, and where possible washed after use; they are issued to individuals, who are responsible for their care.

Incorrectly worn, punctured or torn gloves do not afford adequate protection.

Protective Clothing

5.79 Cotton twill coats are available for issue to all staff needing them; where additional protection is required this can be obtained through the Safety Section.

Surgical-type overall coats and aprons in rubber or P.V.C. are obtainable if considered necessary by the Head of Section.

Breathing Apparatus, Respirators and Dust Masks

5.80 Where toxic or offensive fumes or dust arise, the first line of defence is isolation by use of a fume cupboard or extraction system, or the provision of a fresh air supply to the operators. See also E.R.D.E. Standing Instructions on Safety, No. 12.

5.81 Temporary protective measures may be necessary for certain non-repetitive work or emergency conditions. The following types of apparatus are provided:

5.81.1 Self-contained air breathing apparatus; this gives complete protection in any atmosphere and contains sufficient air supply for 20-25 minutes of normal exertion. Users of this apparatus must be trained; this can be arranged by the Fire Brigade Officer.

5.81.2 Respirators fitted with filter canisters are provided for use only against light concentration of gas (1% by volume); most canisters have a specific application and some, e.g. those for nitrous fumes, give only 20 minutes protection. Composite canisters are provided which protect against most well-known gases but there are exceptions, some of the most important being carbon monoxide and hydrogen cyanide. Before commencing work where fumes may arise either in normal or abnormal conditions, it is necessary to CHECK with the Safety Section or Fire Brigade that the canister supplied offers protection.

The composite canister filter will retain droplets and solid particles.

5.82 **Fresh air apparatus** is provided for use where toxic dust or fumes cannot be satisfactorily dealt with by an extraction system. The following types are available:

5.82.1 Antipoys or Bloman apparatus consist of a face piece or hood fitted with a long tube of up to 30 feet, the end of which is placed in a fresh air supply. For greater distances up to 100 feet, the air is supplied by a bellows pump.

5.82.2 Air pressure hoods consist of a plastic hood fastening around the waist, with a heavy plastic window. Air is supplied by a special compressor which draws air from a fresh air source; one compressor will accommodate two operators. Other compressors must not be used since the air from these may contain carbon monoxide; fatalities from this cause have been reported.

5.83 **Dust masks** are only intended for occasional use; where dusts are highly toxic or met with in quantity, as on process operations, the air pressure hood should be used. Two types of dust mask are stocked, viz:

5.83.1 For non-toxic but offensive dusts, the Martindale Dust-Respirator, consisting of a flexible aluminium holder for a cloth filter.

5.83.2 For toxic dusts, dust respirators Mk. IV and Mk. VIII, and Siebe-Gorman Microfilter Dust-Respirator, all approved by the Inspector of Factories.

Ionizing Radiations

5.84 Ionizing radiations emitted by radioactive materials or electrical apparatus may be classified into three main types; Alpha-particles are doubly positively charged helium nuclei; beta-particles are fast-moving electrons (4ve or-ve charged); gamma- and x rays are electromagnetic radiations, with gamma-rays much the more energetic. Exposure of the body to these radiations is a serious risk to health, and must be avoided.

For a given energy, the penetrating power of these rays varies greatly. All alpha-particles, regardless of energy, may be stopped by a single sheet of paper; beta-particles with a maximum energy of 1 MeV will be absorbed by 4 mm of Perspex or 2 mm. of glass; but 2.8 inches of lead or 18 inches of concrete must be used to reduce the intensity of gamma-radiation by one hundredfold.

Because of this, gamma-radiation and X-rays present a serious RADIATION hazard, whereas hazards due to INGESTON of radioactive materials are greater for beta- and greatest for alpha- emitters. We therefore distinguish two kinds of risk, those of 'sealed' and those of 'open' sources.

Radiation Protection with Sealed Sources

5.85 The term sealed source refers to radioactive substances when they are not handled directly but are encased in an inactive covering, and to apparatus which is capable of emitting X- or gamma-radiation.

The effect of ionizing radiations on living cells is destructive by direct ionization or by indirect action via free radicals. The radiation energy absorbed (the dose) must therefore be restricted; it is measured in rads which is now the accepted international unit of radiation dose and is defined as 100 ergs per gram of irradiated material. For most practical purposes the older units of the rontgen or the rep. are identical with the rad. The basic safeguard against ionizing radiations is shielding by heavy materials such as lead or concrete, particularly in the case of X-rays, gamma-rays and high energy beta-rays, and all sources must be suitably confined to provide adequate protection.

Statutory Instrument 1961, No.1470 issued by the Ministry of Labour under the Factories Act, specifies the maximum permissible dose of ionizing radiation. E.R.D.E. conforms to the rather more stringent control recommended by the Chief Safety Officer of the Ministry of Aviation.

Permitted Radiation Doses (Ministry of Aviation)

	Doses in Rems (see Note)	
	Calendar Quarter	Calendar Year
Controlled Persons(i.e. those approved for radiation work).		
(a) whole body	3.0	5.0
(b) eyes	3.0	5.0
(c) hands,forearms,feet and ankles	20.0	75.0
Uncontrolled Persons above 18 years of age		
(a) whole body	0.5	1.5
(b) eyes	0.5	1.5
(c) hands,forearms,feet and ankles	2.0	7.5
Uncontrolled Persons below 18 years of age		
Whole body	0.5	0.5

Note:

The dose in rems is equivalent to the dose received in rads, multiplied by the relative biological effectiveness which is:-

For X, gamma and beta radiations 1
For alpha particles 10

The control measures to ensure that these limits are not exceeded include:

(a) the periodic medical examination of classified workers including blood counts

(b) the wearing of film badges for the purpose of radiation dose records and

(c) regular monitoring

Monitoring will be carried out for record purposes under the supervision of the Safety Officer, but more frequently for the purpose of routine checks under the supervision of the Head of the Section concerned; this enables a dangerous situation to be spotted before any harm is done. Everybody concerned has a duty to ensure that simultaneous monitoring should accompany an operation involving any risk so that, if necessary, it can be interrupted without delay. These are the standard safeguards with sealed sources; in the case of open gamma-ray sources, however, the use of pocket ionization chambers is recommeded as an added safeguard. It should be noted that damage to the container of a "sealed" source may result in the source being an "open" one (see below). Detailed advice can be obtained from the Safety Officer.

Radiation Protection with Open Sources

5.86 The term open source refers to radioactive materials which have to be handled and used in the course of chemical operations.

Radiochemical tracer experiments must be carried out in the Radiochemical Laboratory, L.128, unless special permission has been obtained from the Director or his nominee. All personnel engaged in these experiments must be authorised after having undergone a full medical examination, and must be familiar with the Radiochemical Laboratory Handbook (a copy is kept in building L.128).

Hazards involved in the use of radiochemical materials may be divided broadly into two categories, external radiation and ingestion (including inhalation). External radiation has been discussed in para. 5.84; this paragraph is concerned with those precautions necessary to prevent ingestion of, and contamination by, radioactive materials.

The seriousness of the ingestion hazard depends mainly on the uptake and localisation in the body of the element in question, and on the method and rate of elimination. These factors, together with the half-life and radiation characteristics of the nuclide, were taken into account in the production of tables listing the degree of toxicity of the isotopes and the maximum level of activity of each nuclide permissible in various types of radiochemical laboratory. These tables are given in the detailed safety instructions located at the Radiochemical Laboratory, L.128.

Generally, the techniques used to minimise ingestion hazards are similar to those recommended for toxic substances. To reduce the danger of entrainment, operations which involve heating radioactive solutions should always be carried out in a fume cupboard, and wherever applicable in a distillation or reflux system. Experiments should be designed so that the radioactive material is kept in solution when handled. Solid radioactive substances, especially in powder form, present a greater hazard, and if their use is unavoidable all operations must be carried out in a glove box. In some cases it may be permissible to use a fume cupboard, and if this is so it may also be necessary to wear a suitable mask for the duration of the experiments; advice should be sought from the Responsible Officer (see Radiochemical Laboratory Handbook).

In order to minimise both the radiation and ingestion hazards, experiments must be carefully planned in advance. It is essential that trial runs be carried out with inactive materials first. In this way, all the apparatus and materials necessary for the performance of the experiment will be accumulated in readiness for the work using radioactive material, and there is less chance of oversight.

Fire Fighting Equipment

5.87 Emphasis is placed on first aid fire fighting, and equipment for this purpose is placed in all laboratories and explosives work rooms. The equipment may consist of water hose reel, CO_2, CTC, foam or water extinguishers, and buckets containing sand or water. Special extinguishing media are provided when the above-mentioned equipment is not suitable.

The Fire Brigade Officer must be informed whenever fire-fighting equipment has been used. See also, E.R.D.E, Rules 16 and 58.

CHAPTER 6

Dangerous Chemicals

6.1 Most people know that chemicals are dangerous. Yet instances are still found where adequate precautions are applied only to those substances which are known to be exceptionally dangerous; this attitude neglects the facts that many chemicals have insidious or long term effects, and that certain dangerous properties of others may be unknown. ALL chemicals should be treated as dangerous, and contact with the body should be avoided; in handling materials known or suspected to present particular hazards, appropriate EXTRA precautions should be taken.

In all cases prevention is better than cure and work should always be designed to avoid contact of the person with solid, liquid or gaseous chemicals. The present chapter summarises in broad outline the dangers to be guarded against and makes brief reference to some of the types of compound which have been found to be dangerous.

Toxic Chemicals

6.2 Toxic chemicals may be absorbed into the body by ingestion, or through the lungs or the skin, and some may enter by more than one of these routes. The precautions to be adopted will depend upon the mode of entry favoured by the nature of the substance and of the operations. (See sub.-para. 3.19.4.).

Substances Absorbed by Ingestion (Swallowing)

6.3 Manipulation of chemicals can always be designed to avoid the possibility of ingestion, but careful attention to detail is necessary ; this mode of entry is possible during pipetting, from dusts, from splashes and from failing to wash the hands and mouth after handling poisonous materials.

Substances Absorbed through the Lungs

6.4 Maximum allowable concentrations (M.A.C. values) in air of toxic substances are given in various publications (e.g. Bibliography, refs. 2, 3); these values refer to conditions of continuous exposure during the working day.

The following table, (reproduced with permission of the publishers, Reinhold Publishing Corporation, from "Dangerous Properties of Industrial Material" by N.I. Sax, 1957). is of assistance in interpreting these values:–

	M.A.C. Values	
Toxicity	Dust, Fumes, Mists mg/m^3	Vapours, Gases p.p.m.
High	0 – 0.25	0 – 25
Moderate	0.25 – 2.5	25 – 250
Slight	2.5 – 25	250 – 2500
None	25	2500

A few illustrative M.A.C. values for some commonly encountered materials are given below.

Maximum Allowable Concentrations

Substance	M.A.C.	
	mg/m^3	p.p.m.
Aniline		5
Benzene		25
Carbon disulphide		20
Carbon tetrachloride		25
Chloroform		100
Dimethyl sulphate		1
Dioxan		100
Hydrazine		1
Hydrocyanic acid		10
Nitroglycerine		0.5
n-Pentane		1000
Picric acid	0.1	
Tetryl	1.5	
Toluene		200
TNT	0.5	

Vapours

6.4.1 These are the major toxic hazards in most chemical processes. The vapours of many common solvents (e.g. benzene, trichlorethylene, carbon disulphide, carbon tetrachloride) are toxic, even in low concentrations and the volatile nature of many of these make it readily possible for dangerous concentrations to arise. Vapours often give rise also to danger of fire and explosion (see para. 6.8).

Toxic risks are combatted by preventing the escape of vapours (e.g. use of traps, condensers, etc.), by the use of efficient fume cupboards or extraction systems, and when necessary by the use of respirators or breathing apparatus (see para 5.80).

Attention must be given to disposal of substances which give dangerous vapours; small quantities of water-soluble materials may be washed down the drain, but others should be sent to the burning ground. The formation of dangerously incompatible mixtures in waste solvent containers must be avoided.

Gases

6.4.2 Some toxic gases are easily detected by smell or sight, e.g. chlorine and its oxides, sulphur dioxide, nitrogen dioxide, hydrogen halides, coal gas, hydrogen sulphide, phosphines, arsine, boranes and many others. Others are not easily detected in this way and are therefore more insidious; these include phosgene, carbon monoxide, hydrogen cyanide (for some observers), fluorohydrocarbons, perchloryl fluoride and others.

Ammonia, chlorine and some other gases may cause asphyxiation by halting the breathing mechanism (gasping, choking).

The precautions to be observed in dealing with toxic gases are generally similar to those used against vapours.

Some gases, e.g. nitrous fumes and some boranes, produce delayed effects. It is advisable always to report and seek medical advice even for slight exposure to noxious gases.

Dusts, Smokes and Mists

6.4.3 These particulate airborne materials have the toxic hazards of the substance in bulk, with the added danger caused by high mobility and often by the high rate of reaction with moisture on the skin, eyes, lungs, etc. Many compounds in this form attack the eyes (acids, acid chlorides, aluminium and ferric chlorides), sometimes causing permanent damage.

The precautions necessary in dealing with smokes, etc., are again generally similar to those used against vapours; however, the use of traps is complicated by the difficulty of removing these fine particles from the gas in which they are suspended. The Safety Officer should be consulted about the selection of filters or scrubbers, etc., for this purpose; respirators and dust masks must be of the correct approved type. (See Section 5.82).

Substances Absorbed through the Skin

6.5 Many toxic chemicals are able to enter the body by absorption through the skin. Benzene and aniline are common examples of such substances. In other cases, contact of the skin with chemicals can result in dermatitis; tetryl, TNT, hexanitrodiphenylamine (hexanite) and many other explosives are well-known agents; hexamine and chlorinated biphenyls and naphthalenes also possess this property. These effects vary from one person to another, but an apparent immunity must not induce carelessness, as sensitization may occur after a period of continuous or sporadic exposure. Both solvents and detergents can damage the skin, making it vulnerable to infection or giving rise to skin rashes.

Measures against these agents include the use of protective clothing, gloves, and barrier creams applied to the skin.

Poisonous Chemicals

6-6 It is not possible here to list even a fraction of the compounds known to exert detrimental effects; the references given at the end of this chapter may be consulted for information in specific cases. A few common examples are quoted here to emphasise the widespread occurrence of toxic properties and the consequent need for caution in handling chemicals.

A number of compounds are subjects of legislation (radioactive materials, lead, silicones, dust, phosphorus, nitrocompounds, etc.). Inorganic poisons include beryllium and its compounds (also carcinogenic); mercury and lead (cumulative poisons); fluorides and thallium salts; arsenic, barium, boron and chromium compounds; hydrogen sulphide, selenide and telluride.

Monofluoracetic acid is the most powerful poison known among simple chemicals; many quaternary ammonium compounds exhibit curare-like action; a compound obtained when sulphamic acid is added to a preparation of hexamine is five times more poisonous than atropine; amines are apt to show carcinogenic properties, e.g. benzidine and alpha-naphthylamine; certain polycyclic hydrocarbons are well-known to give rise to cancer of the skin. Many halogen-containing materials have narcotic and toxic action (e.g. chloroform, trichloro-ethylene) and, in addition, may contain phosgene produced by photochemical oxidation; others are irritants (bromoacetone) or vesicants (bromacetic acid) or may cause dermatitis (chlorinated naphthalenes and biphenyls). Volatile fluorine compounds are dangerous; precautions are necessary in machining Teflon, Kel-F, etc.

Corrosive Chemicals

6.7 Before corrosive chemicals are used in any operation, careful consideration should be given to the possibilities of accidents (spillage, etc.), and appropriate precautions should be taken. Protective clothing and gloves should be used if necessary; rubber gloves are available with roughened surfaces which are less slippery when wet; the eyes should ALWAYS be protected by safety spectacles, goggles or a face visor. In addition, appropriate remedies should be at hand for the immediate first-aid treatment of casualties. (See para. 3.21).

6.7.1 These precautions are necessary with a wide variety of chemicals, including strong mineral acids (sulphuric, nitric, perchloric, phosphoric) and anhydrides (sulphur trioxide, phosphorus pentoxide), many organic acids and anhydrides (formic acid, acetic acid and anhydride), acyl halides and many others. When diluting concentrated sulphuric acid, it should always be poured into water, never the reverse; this operation should be carried out under the supervision of an experienced person until the correct technique is learnt. The best first-aid treatment, following contact with such acidic substances is to wash with a large excess of cold water. Extreme cases of skin attack arise with hydrofluoric acid which should never be manipulated without the use of gloves and eye protection; after first-aid treatment casualties should always receive immediate medical attention.

6.7.2 Solid caustic alkalis, e.g. sodium and potassium hydroxides and their solutions, and quicklime, are dangerous and should be removed from the body with copious amounts of cold water, followed by treatment with boric acid solution.

6.7.3 Many other corrosive chemicals may be encountered, e.g. bromine, hydrogen peroxide, phenol, but it is not possible to give details of first-aid treatment for all of these; reference should be made to the bibliography and First Aid Charts exhibited in all laboratories. Advice should be obtained before such materials are used.

6.7.4 Any chemical in the eye is to be taken seriously. Buffered isotonic eye lotions are standard in the establishment, and may be used freely in case of splashes; in the absence of eye lotion, tap water should be applied freely. All eye injuries are matters for treatment by the surgery, and must be conveyed there by ambulance with the patient in a prone condition.

The lotion may be made up as follows:

Potassium dihydrogen phosphate KH_2PO_4	70	g.
Disodium hydrogen phosphate decahydrate	180	g.
Distilled water	850	g.

It should be contained in a bottle which a person can apply himself, either of squeeze type, gravity flow type, or operated by blowing with the mouth.

6.7.5. Some rooms are fitted with shower baths, for use when corrosive material has been spilt on the person; in other places baths are maintained at a suitable temperature in which a person may be immersed. All personnel should be acquainted with the location and operation of these facilities.

6.7.6. Some of the chemicals referred to above (e.g. bromine, concentrated nitric acid) produce extremely irritating fumes, and should generally be handled in a fume cupboard or in the open from the windward side.

Flammable Chemicals

6.8. Fire is the major laboratory hazard. The precautions to be taken in handling flammable solvents have been mentioned in para 5.20; these are based on the principle of preventing access of flammable or explosive mixtures with air to means of ignition (gas burners, heating mantles, sparking electrical contacts, and hot surfaces).

6.8.1 The flash-point of a substance is the temperature at which a flammable mixture of vapour with air can be formed; it is measured in a special apparatus. Substances having a low flash-point should always be treated with extra care.

Some vapour/air mixtures explode when ignited; information on the concentrations of vapours in air which produce explosive mixtures may be found in the bibliography, ref.1.

6.8.2. The ignition temperature of a vapour mixture is often quite low; e.g. for example carbon disulphide vapour has been reported to ignite against a radiator and particular care is necessary with this substance, also with ether and other low-boiling liquids. Care must be taken that heavy vapours do not run along benches or floors and ignite at a source some distance away.

A few substances ignite spontaneously upon exposure to air, e.g. some metal alkyls and hydrides, some phosphines and boranes; there are also pyrophoric solids, e.g. Raney nickel and some other metallic powders. Some substances may inflame on grinding, e.g. lithium aluminium hydride or on contact with water or other reagents, e.g. alkali metals.

The danger of ignition of flammable or explosive materials by electrostatic discharges must be remembered (see para 8.8, 10.12).

6.8.3 Materials dispersed as dusts, mists and smokes may be more dangerous than the material in bulk; fuels (i.e. substances able to combine with oxygen) such as metal dusts, organic solids and solvent sprays may be flammable or explosive when dispersed in this way.

Explosive Chemicals

6.9 Recognised explosives and their handling are dealt with in Part 111. The present remarks are intended to assist recognition of the possibility of explosive properties in compounds and mixtures. Compounds or mixtures which it is suspected may possess explosive properties must be treated as explosives, and the precautions outlined in Part 111 must be applied.

6.9.1. Any mixture or compound capable of exothermic decomposition is to be treated with caution. Oxidising groups including nitro, nitroso, peroxy, ozonide and nitric esters; compounds such as perchlorates, nitrates, and many other oxy-acids, peroxides, and the oxides of easily reduced metals can all react with fuel in the same or different molecules to give rise to dangerously rapid heat evolution. Strong hydrogen peroxide, nitric acid and chromic acid are very common causes both of fire and explosions.

6.9.2. Cyano-groups, double and triple bonds, and hydroxy, amino and aldehyde groups, having endothermic and reducing properties, increase the reactivity of molecules in which they occur.

6.9.3 Halogens, free or sometimes bound, can serve as oxidant; among less obvious cases are the action of carbon tetrachloride with sodium and aluminium, and the explosion of lead tetramethyl with bromine.

6.9.4 Strong acids, bases and desiccants often promote explosion of mixtures, e.g. sulphuric acid on sugar/perchlorate mixtures; caustic soda on some explosives; phosphorus pentoxide in many instances, and magnesium perchlorate.

6.9.5 Highly dangerous materials can arise in the course of analysis and other chemical processes. Silver acetylide and copper acetylide are examples. Solutions used for silvering mirrors can reach a state where a touch will cause explosion; they should never be kept after use.

6.9.6 Acetylene in any form is subject to special regulations, which should be known before using it. Hydrazoic acid, which can arise by the action of acid on azides, is poisonous; even in aqueous solution it is dangerously explosive and the gas can easily produce highly dangerous metallic azides by attack on copper or other metals.

6.9.7 Peroxide formation in solvents- ethers, ketones, alcohols and others - gives rise to danger, especially in evaporation and distillation. Normally, acidified potassium iodide solution with starch and a trace of ammonium molybdate will turn blue in the presence of peroxide, but a blank experiment with a drop of hydrogen peroxide in the otherwise identical mixture is necessary to show whether interfering compounds are present.

6.9.8 Explosive gas mixtures may be produced when certain reactions are carried out (e.g. dissolution of alkali metals) or accidentally by the action of the atmosphere on reagents (e.g. lithium aluminium hydride); this can usually be avoided by displacing the air from an apparatus by an inert gas.

Bibliography

1. Dangerous Properties of Industrial Materials. N.I. Sax, 1957. Reinhold, New York Chapman & Hall Ltd.

2. Laboratory Handbook of Toxic Agents. Edited C.H. Gray. Royal Institute of Chemistry.

3. Threshold limit values (Annual List). American Conference of Governmental Industrial Hygienists. 1014 Broadway, Cincinnati 2, Ohio.

4. The Toxicity of Explosives and Materials used in their Manufacture. War Office, Chemical Inspectorate.

5. The Merck Index of Chemicals and Drugs. Merck and Co., Inc., Rahway, N.J., U.S.A.

6. The British Pharmacopoeia. 1958. Pharmaceutical Press.

CHAPTER 7

HANDLING, STORAGE AND TRANSPORT OF CHEMICALS

7.1 In handling chemicals, as with explosives, it is necessary to build up and maintain a discipline, and to avoid any possibility of a casual or thoughtless attitude being adopted.

Issue and Receipt of Chemicals

7.2 From the time chemicals are issued from Central Stores they become the responsibility of the requisitioning officer. It is necessary therefore for him to arrange that the stores are collected in a proper carrier, and that the attendant is aware of any hazard involved (e.g. risk of fire, toxic fumes, etc.) Care must be taken to avoid spillage and contamination; potential incompatibilities need special attention (see below, storage).

Proper transport or apparatus should be used for the carriage of large containers.

On receipt of the chemicals the officer should verify that the materials are correctly and adequately labelled, and then arrange for storage in a safe place. Empty bottles and containers must be in a safe condition before being returned to stores. (See para. 5.28).

Handling Chemicals

7.3. It is a rule of the Establishment that senior scientific staff in arranging experimental work advise their staff of the hazards involved and the precautions to be taken. This should cover possible use of fume or armoured cupboards, wearing of visors, goggles, gloves, protective clothing and breathing apparatus. If highly toxic materials are being used the Safety Section should be advised, so that the Medical Section may be informed.

Certain work may require isolation facilities, and the Safety Section can advise on the availability of such services.

Laboratory and Section Stores

7.4 The Head of the Section should appoint an experienced officer to be in charge of the chemical store to ensure that materials are correctly stored and maintained; this officer should not necessarily be responsible for withdrawals but should ensure that containers are properly labelled and stored in accordance with his instructions, and he should make daily inspection for leakages, fuming, cleanliness, heat, etc.

Materials should be segregated into groups, with the object of limiting or avoiding dangerous accidents in the event of leakage of containers, e.g. strong acids should be stored separately from other chemicals, and solvents should form another separate group.

The storage in laboratories and workrooms of dangerous chemicals in excessive quantities or under unsuitable conditions may involve hazards comparable with those arising from incorrect storage of explosives.

Heavy containers should be stored on the floor. Inflammable solvents and acids should be kept in the appropriate store or bins in the open. There should be a regular check of stocks, and materials not required should be returned to the main stores. Fire fighting appliances appropriate to the chemical stores should be available.

Trays should be provided for corrosive and other materials where there is a danger or reaction in the event of spillage or leakage.

Labels on containers of corrosive chemicals may easily become illegible; this may be avoided by stamping the name on a strip of lead or suitable plastic material attached to the container, or by sealing a label into a glass tube and placing this in the container.

Containers of chemicals may become dangerous on storage, e.g. pressure may be developed; aluminium chloride is a source of danger from this cause and should be stored in small bottles which should be opened with proper precautions. See also E.R.D.E. Standing Instructions on Safety No. 19, Surveillance of Explosives and Chemicals in Store.

Main Acid and Solvent Stores

7.5 These stores should be used for bulk storage in order that as small a quantity as possible is at risk in the laboratories. Materials no longer required should be removed from laboratories and transferred to the main stores. Main stores must be supervised in the same way as section stores. (Para. 7.4 above).

Acid Stores

7.5.1 Heavy containers should stand on the floor and corrosive materials should stand in trays of sufficient size to accommodate the contents of the containers in the event of spillage. Staff must be trained in the precautions necessary for dispensing the material. In the event of spillage or leakage, the scientist in charge must be advised before any action is taken to remove the material, except by routine prescribed methods. Suitable precautions must be observed, e.g. gloves, goggles and breathing apparatus must be used if necessary. A water supply must be available for washing down or diluting spillage and for drenching in the event of clothing becoming contaminated.

Carboys should not be piled one above another; a syphon or a tilting carrier should be used for withdrawing supplies. The protecting baskets must be in good condition.

Solvent Stores

7.5.2 Similar regulations apply to the storage of solvents and in addition special regard must be paid to the avoidance of means of ignition, e.g. sparks or naked flame.

These stores must be well ventilated and containers must be kept sealed. If a vapour concentration does arise, the doors should be left open, and entry forbidden until the concentration has dispersed.

If flammable solvents are stored in metal drums, non-sparking tools must be used for opening and earthing clips must be attached.

Transport of Chemicals

7.6 The transport of dangerous goods is covered by E.R.D.E. Standing Instructions on Safety, No. 15, which applies also to radio-active substances.

Internal Transport

7.6.1 Small amounts of chemicals may be collected from Chemical Stores and the person collecting them is responsible for their safety; he must therefore be provided with proper carriers, gloves, goggles, etc. Bicycles must not be ridden whilst chemicals are being carried unless proper carrying facilities are provided.

Stores Section are responsible for the delivery of larger quantities of materials and will be responsible for adopting proper safety precautions.

External Transport

7.6.2 This is covered by statutory regulations and the Safety Section will advise Stores Section on the requirements to be met.

Special arrangements may be made for the transport of small samples and the Safety Section should be consulted.

PART III PREVENTION OF ACCIDENTS WITH EXPLOSIVES AND PYROTECHNICS

CHAPTER 8

PROPERTIES OF EXPLOSIVES

Characteristics and the Safety Certificate

8.1 It is convenient to divide explosive substances into classes, e.g. "high explosives", "propellants" and so on; but from the accident prevention aspect they all share one common property: given the appropriate conditions they will all explode or burn disastrously. Safety results from the planned avoidance of these conditions, and to draw up a successful plan reference must be made to the characteristics of the particular explosive handled.

The "Safety Certificate" is a document which relates in each case to a particular composition; it does not imply that the explosive is safe, since no explosive is intrinsically safe, but certifies that a number of prescribed trials have been carried out, and sets out information on the characteristics of the composition together with some general advice on handling and storage. It will be appreciated that, in an experimental establishment concerned with new explosives and ingredients, it is often necessary to handle such materials before the full information required for the Safety Certificate has been assembled. The characteristics dealt with are:

(a) Physical state, i.e. solid, liquid or gaseous and in the case of a solid the state of division.
(b) Sensitiveness to impact, friction, and electric discharge.
(c) Temperature of ignition.
(d) Ease of ignition.
(e) Behaviour on inflammation.
(f) Inherent chemical stability.
(g) The effect on chemical stability, or sensitiveness, of contact or admixture with another material.
(h) Volatility.
(i) Toxicity.
(j) Tendency to develop static electrification.

When a material is accepted for Service the Safety Certificate is issued in its "Permanent" form by the Chief Safety Officer (Aviation or Army Dept. as the case may be). When information is needed on materials already so adopted, application should be made to the E.R.D.E. Safety Section for this document, together with their general advice. At an earlier stage a "Provisional" Safety Certificate is issued by the Senior Safety Officer of the originating establishment for the benefit of others working on new compositions, e.g. R.O.Fs. and Weapon Establishments, and these may also be obtained through the Safety Section. With entirely new materials the information will have to be built up by the Sensitiveness and Compatibility Sections. Toxicity is dealt with by the Chief Medical Officer but it is convenient to pass all enquiries through the E.R.D.E. Safety Section.

From the safety point of view, the most important properties of explosives are: (a) sensitiveness to friction, impact and electrostatic discharge, and (b) stability, so that these properties are generally the first to be studied with new materials. The production of a sufficient quantity of material to meet the demands of the tests may in itself be dangerous; therefore, the programme of testing should be planned in co-operation with both the Safety and the Sensitiveness Sections, so that tests covering the more dangerous aspects are carried out first on the minimum size of sample. In case of sensitiveness, impact tests are usually done first, followed by friction tests, but in some cases (e.g. initiators) it is more profitable to examine the electrostatic hazard first.

The Interpretation of Sensitiveness tests

8.2 The interpretation of test data is always a specialist function and information should be sought in relation to proposed usage rather than as a numerical value. Reference should also be made to the Manual of Safety Certificate Sensitiveness Tests, E.R.D.E., 1963.

When considering sensitiveness test data two cardinal points should be borne in mind. First, explosions are statistical phenomena. This means that for any given kind of stimulus (say impact) there is a probability than an explosion will occur with any impact, the probability being small for feeble blows and increasing with the force of the blow; it is not implied that there is a minimum level below which the explosive never responds. Second, an explosive does not have an intrinsic probability of explosion but only one which is related to a given environment. Thus, two different probabilities of explosion will be obtained for the same impact energy applied by different devices. It is therefore, neither possible to predict the chance of an explosion in a plant operation, nor even necessarily to compare the data from tests in two establishments (e.g. unless there has been careful standardisation), but only to draw up tables of sensitiveness wherein a new explosive is compared with those for which a fund of experience exists.

Impact and Friction

8.3 Impact and friction tests are designed to yield information on the chance of initiation when materials are "nipped" between two relatively hard surfaces. The general interpretation is "very sensitive", "sensitive" or "comparatively insensitive". Materials in the "very sensitive" class must be handled with extreme care, e.g. the avoidance of all impact, even of cardboard surfaces. If a material is "sensitive" the precautions need not be so stringent, but friction and impact between materials harder than soft wood (including all metals) must be avoided. If the material is "comparatively insensitive" it is wise to treat it as a dangerous explosive and to exclude blows between hard surfaces; however, simple transfer between metal containers, or through pipes, valves, etc., is permissible.

The impact and friction tests were originally developed for use with crystalline high explosives so that "new" materials could be compared with those already established (for example, tetryl was compared with picric acid). When assessing data obtained with other kinds of material it must be appreciated that these tests relate to the chance of initiation of thin layers of material, and that in making comparisons like can only be compared with like. Thus cordites in thin layers nipped between metals do have a high probability of ignition, and in the same kind of test bubble-free layers of many liquid explosives are relatively inert.

If the numerical data for all materials are considered uncritically it can be said that there are a number of anomalous classes: most colloidal propellants would be classified "very sensitive", and many liquids appear by these tests to be far safer than experience has shown to be the case.

Another class of materials for which the standard sensitiveness test data need to be interpreted with care are compositions containing strong oxidants. These materials react with material abraded from the surface of some of the materials used in the tests, for example the wooden mallet used in the friction test, or an aluminium surface if this is used. Often, the correct interpretation of such a result is not that the composition is intrinsically sensitive but that a hazard will arise if it is handled with implements made of the offending material.

Ease of Ignition and Behaviour on Inflammation

8.4 These tests are intended to demonstrate the consequences of applying flames to small quantities of explosive.

The "ease of ignition" (Bickford fuze) test subjects three grammes of material to a flame of standard size and duration. The "behaviour on inflammation" test (train test) consists of igniting, by means of a gas flame, about 30 grammes of material contained in a narrow iron trough.

If a material ignites in the Bickford fuze test it must be handled on the assumption that any incendive spark will ignite it. There is a large class of compositions which are not likely to be ignited by a single spark but are nonetheless flammable, and these will respond to the train test but will fail to ignite in the Bickford fuze test. Only if a material is truly non-flammable will it fail to ignite in the train test.

The violence of the combustion subsequent to ignition in both tests is a measure of the consequence of any ignition, and the information can be made the basis of the design of safety screens. The tests are limited in the quantity of explosive used and in the degree of confinement; in most cases they must be followed up in a more elaborate way if the conclusions are to apply to more than a few grammes of material.

Stability

8.5 Many explosives are intrinsically unstable, that is to say they are always decomposing even at room temperature. The rate of decomposition is determined by the chemical nature of the material and will increase with temperature; it is also affected by the physical state and the purity of the sample.

The common tests for stability, e.g. the heat test, depend on the regular increase in rate of decomposition with temperature; they consist of trials in which the rate of decomposition is measured at elevated temperatures, by which means some judgement can be made of the safe life at normal temperatures.

In practice, the standard "stability" tests are acceptability tests. An acceptable level of stability is laid down after a considerable degree of experimentation with the explosive concerned, and subsequent samples tested to see if they conform. Thus both tetryl and RDX are said to have "satisfactory" stability although the rate of decomposition of pure tetryl is much greater than that permitted for RDX.

Some compositions tend to show a progressive loss of stability when stored and the rate of decomposition may eventually rise catastrophically. It is therefore essential to monitor the deterioration of new compositions by frequent stability tests, usually by some form of heat test. Only when sufficient experience has been gathered can the necessary routine stability testing programme (surveillance testing) be decided upon. Even those compositions which owe their acceptable stability to the presence of chemical stabilizers must be tested periodically, since the stabilizer will eventually be used up. See also E.R.D.E. Standing Instruction on Safety No. 19.

The simplest stability test is the safety certificate "temperature of ignition" test. In this test the temperature of a small sample of explosive is slowly raised until it ignites; this is the temperature at which there is for this sample, a runaway decomposition. Materials of low stability will have correspondingly low temperatures of ignition. The test only gives the temperature at which the material will ignite in the conditions of the test and the temperature of ignition of a charge different in any way from that used in the safety certificate experiment will certainly differ from the figure recorded by that method.

Compatibility

8.6 A substance is said to be incompatible with an explosive if contact with the explosive under realistic conditions of time, temperature, etc., is detrimental to its safety of effectiveness. This, of course, embraces formation of dangerous conditions by action of the explosive on the other material (e.g. picric acid on lead paint).

No generalisations are possible and each case must be considered on its merits; a natural impurity may exhibit incompatibility, for example, the presence of acid will greatly increase the rate of decomposition of nitrocellulose. On the other hand, acid RDX is more stable than alkaline RDX. Copper is incompatible with lead azide because, in hot damp conditions, hydrazoic acid is liberated and then the extremely sensitive copper azide is formed.

Grit is an obvious example of extraneous material which can sensitize almost any explosive, but it is less known that with the hard crystalline high explosives such as RDX and HMX small proportions of many organic materials can also act as sensitizers.

For Service applications the compatibility requirements are exacting and a list of forbidden materials is given on the safety certificate. For short term experimental work these requirements may be relaxed somewhat but the concession necessary must always be discussed with the appropriate expert.

Volatility

8.7 There are several hazards associated with volatility. The explosive itself may be volatile and, by a distillation process, reach positions where it is subjected to forces capable of causing initiation, e.g. in a screw thread. The vapour of the explosive itself, or of a solvent used in its manufacture and retained in the finished product, may give rise to an inflammable or even explosive atmosphere. In general, gases are much more easily ignited than solids or liquids. Explosives are sometimes desensitized by the addition of solvents, e.g. nitroglycerine by methyl alcohol, and the differential volatility can cause an undesirable change in composition.

Static Electrification and Electric Spark Ignition

8.8 Besides the hazards enumerated above, there is another and less obvious one. This is the ignition of explosives and solvent/air vapours by electrical discharges resulting from static electrification. Electrostatic charges are produced whenever two surfaces are separated e.g. when powders are sieved, mixed and poured, when driving belts pass over their pulleys, and when a person walks across a floor. If the charge so produced can collect, e.g. on an insulated item which can act as a capacitor, then sufficient energy may be stored to provide a spark capable of igniting initiatory explosives and solvent/air mixtures, and possibly other explosives.

Insulated items can easily be avoided by permanently earthing all fixed pieces of plant and equipment, and by having a flexible earthing connection for moveable apparatus. Driving and conveyor belts can be made of conducting material. These "First Degree" precautions are the minimum permissible and should always be carried out. However, this does not cover the electrification of the operative or of highly insulating powders. In this country it is possible for a person to attain a potential of 10,000 volts. Assuming his capacitance is 500 micromicrofarads, this means the stored energy is 0.025 joule. This figure provides a convenient criterion for the necessary precaution. If the explosive in question requires a spark of energy greater than 0.025 joule for ignition, the minimum or First Degree precautions are sufficient. If the explosive can be ignited by a spark of energy less than 0.025 joule, then higher or "Second Degree" precautions are needed. In addition to those already mentioned, these comprise (a) earthing of all operatives, by the use of conducting shoes and conducting floor, and all small objects, e.g. by the use of conducting containers and conducting benches, (b) the provision of a humid atmosphere, i.e. between 65 and 75 per cent relative humidity, and (c) the wearing of suitable clothes to minimise the risk of frictional electrification, removing rings from fingers (important with primary explosives), and avoiding the use of metal tools. It is essential, also, that operatives check, on entering the workroom, that their resistance to earth via their footwear is sufficiently low; this is carried out with the Personnel Test Meter.

The spark sensitiveness of an explosive is assessed by subjecting it to the discharge obtained from a capacitor of 0.1 microfarad, 0.01 microfarad or 0.001 microfarad charged to 9,500 volts, i.e. energies of 4.5, 0.45 and 0.045 joule. If the material is not ignited in 50 consecutive trials with the 0.045 joule spark, then First Degree precautions are sufficient. If the material is ignited by the 0.045 joule spark, a more extensive series of tests with smaller energies is carried out to assess the hazard in handling it under Second Degree precautions.

Electrostatic hazards often arise in large-scale operations, very large charges can accumulate, so that the hazard increases as scale of operations increases.

Classification for Storage and Transport

8.9 Different explosives need different types of storage for maximum safety; and even if two different materials are properly kept in the same type of storage (e.g. high explosives and detonators) the hazard may be seriously increased by placing both in the same building.

The "Comprehensive Classified List of Government Explosives" classifies all government explosives in no less than 15 different ways. This complex system is designed to nominate exactly how any explosive may be stored or transported, and while it is both necessary and complete, it is too detailed for explanation here. See Chapter 12 for further details on storage and transport of explosives.

Explosive Chemicals

8.10 Some chemicals, and more often mixtures of chemicals, can acquire explosive properties. These materials must be treated with as much care as the recognised explosives. See para. 6.9.

CHAPTER 9

EXPLOSIVES WORKROOMS

9.1 Work on explosives must only be carried out in rooms approved for the purpose. (Rules of E.R.D.E., p. 14). Wherever possible, the work should be done in rooms designed specially for explosives work, and containing (apart from permanent fixtures) only the apparatus and tools necessary for the intended operations. Where this is not practicable, and explosives have to be handled in a laboratory used for other work, an adequate area of bench should be cleared of all apparatus and tools not required for work on the explosives.

9.2 Approval for use must be obtained from the Safety Officer who will allot an explosives limit. This must be displayed outside the building, with the appropriate fire classification sign. The quantity of explosives in the workroom must not exceed the limit laid down, and should moreover be kept to the minimum required for the work in hand. The amount of explosive material in use must be recorded on a notice board fixed on the outside of the room.

9.3 All personnel must be trained in the operations to be carried out. Written instructions must be issued for industrial staff, and to cover temporary operations the instructions should be written in a log book and signed by all the operators concerned, to indicate their understanding. The instructions should state the tools permitted and specify precautions necessary, the protective equipment to be used (e.g. goggles, shields, etc.) and the amount of material to be handled. The safety cabinets must be marked to show their approved limits, which must never be exceeded.

9.4 Clearance certificates and fire permits must be obtained for repair work; procedure for emergency or minor repairs is given in Rules of E.R.D.E. Nos. 76-79. Normal clearance procedure covering buildings and plant is given under Rules 66-75.

9.5 Working procedures and selection of plant and tools must take account of the explosive hazards involved in the operations. (Information on handling and safety precautions can be obtained from the Safety Section and from Safety Certificates). The fact that the work is varied and may cover different explosives does not permit the relaxation of precautions applying to the particular explosive in use, e.g. if Second Degree precautions are required for electrostatic hazards, these must be provided. Controls should be sited in relation to the escape door to provide an unimpeded escape route.

9.6 No alteration to electrical installations or replacement of fuses is to be made except by the Electricians. Connections from plug sockets are best avoided but may be made by the scientist (using sound flexible leads); care must be exercised to ensure that the plugs are correctly and soundly wired and they should be inspected frequently (See also para. 4.2). The cables must not be laid on the floor, and should, together with any control apparatus, be kept away from the explosives. All items of electrical apparatus should be approved by the Safety Officer.

9.7 Any mechanical equipment must be approved by the Safety Officer as safe to use and adequately guarded, and must be properly maintained.

9.8 The Safety Section must be informed before any new work is commenced, i.e. work which involves an alteration in the amount of explosives to be processed, changes in composition or techniques, or the use of new plant.

9.9 Procedure for disposal of waste explosive and solvents will be as defined in Rules of E.R.D.E. (p. 23, Section 12).

9.10 Establishment Notice 6/63 deals with the care of floors, including those of explosives workrooms.

CHAPTER 10

EXPERIMENTAL WORK WITH EXPLOSIVES AND PYROTECHNIES

General Precautions

10.1 Before any work is started on the preparation or the handling of an explosive the proposed procedure must be critically examined. Full information must be obtained on the properties of the reactants and the explosive concerned. This will include sensitiveness and any special properties or features and means of making safe during and after the operation. If a new compound or composition is involved such information may be incomplete and precautions must be taken to provide for the unexpected degree of sensitiveness or violence. The senior member of the staff directly in charge of the work is responsible for assessing the available information. The Establishment Safety Officer is available for advice on any matter regarding possible dangerous materials or operations and the precautions to be adopted. Attention is again drawn to para. 1.5 et seq, "Preventing Accidents", and to E.R.D.E. Standing Instructions on Safety No. 4, Safety Searches.

10.2 It is necessary to survey all the safety features of the proposed operation. Are the protective screens, goggles, etc., adequate? Can the quantities be reduced without detriment to the value of the results? It is especially useful to go through all the motions of the operation in the absence of explosive material. Such dummy runs will often disclose unforeseen difficulties, for example, a sticking tap, variation in temperature control, or the need for adjustment of remote operating gear.

10.3 In any operation involving explosives the amount of explosive in one place (screen, bench, room or building) must be the minimum necessary for the work in hand. This is often inconvenient and time-consuming, but must be provided for in a timetable demanding unhurried yet efficient attention to all details. Explosives must not be put away in drawers and cupboards and all must be accounted for at the end of the operation. Residues must be labelled, and, if not required, must be safely disposed of before any further work is started.

10.4 Cleanliness is essential in all explosives work. Benches, receptacles and equipment must be maintained free from contamination, especially hard or gritty material or traces of reactive chemicals. Glass equipment which is chipped or shows signs of irregularities which could lead to cracking or fragmentation should never be used. Avoid glass and other brittle materials if possible.

Dangerous Operations

10.5 All operations involving explosives are potentially dangerous and measures must be taken to safeguard personnel. The operation must be planned to take into full account the sensitiveness and quantity of explosive concerned for adequate protection. The need for protecting the eyes of the operator by screens or goggles is stressed; such protection must be type tested as suitable. Even if the quantity of explosive or dangerous material is very small, eye protection must not be neglected.

10.6 The number of persons concerned in a dangerous operation must be kept to the minimum and disposed to take full advantage of protective measures. When two or more persons are working as a team their respective duties should be clearly defined, one acting as the responsible leader in order that rapid decisions can be made. For many operations only one person is required, but it is important for someone else to be close at hand who will know the work that is being undertaken and be able to help if needed.

10.7 When considering the explosive hazards of an operation due regard must be given to providing against any associated difficulties which could arise, such as mechanical failure of equipment, risk of fire, spillage of corrosive reagents, toxic effects, and so on.

Use of Tools

10.8 Explosives can be ignited by mechanical impact or friction and this hazard is always present, especially when using tools of any kind. Every tool used should afford the greatest margin of safety when handling. Thus spatulas made of paper are appropriate for manipulating small quantities of the highly sensitive explosives. Even with less sensitive explosives, tools made of iron or steel or other hard substances must be avoided. There is also the added danger of ignition by spark, and tools which are liable to produce sparks must not be used. The possibility of ignitions arising from accidentally dropped tools or parts of equipment must be remembered.

10.9 When using the softer materials and metals, cleanliness is especially important as they can take up particles of grit and offer an abrasive surface to the explosive. Chemical incompatibility can result in an increase in sensitiveness. Thus bronze or copper must not be employed for explosives containing nitrates, or aluminium for mixtures containing solid peroxides, perchlorates or chlorates.

Containers for Explosives

10.10 The use of glass bottles as containers for explosives should be avoided whenever there is a satisfactory alternative available, approved by the Safety Officer.

Glass stoppers must never be used for bottles containing explosives. Cork or rubber stoppers should be used for high explosives or fine grain propellants. Plastic screw-on caps may be used for propellants, other than fine grain, but not for other types of explosive. Metal screw-on caps must not be used.

For explosives in the Very Sensitive class (see para. 8.3) containers designed to eliminate friction must be used, e.g. papier-mache boxes with lids lined with felt or chamois leather, or special rubber or soft metal containers with with loose fitting rubber lids. For other explosives, papier-mache boxes with ordinary lids are suitable.

For transport of Very Sensitive explosives by vehicle, specially designed boxes are available (see para. 12.7).

Toxicity of Explosives

10.11 Information on toxicity is given in Chapter 6.

Static Electrification

10.12 If the explosive is suspected to be sensitive to electrostatic sparks, or the particular operation is likely to produce an appreciable charge, precautions of a local nature should be employed, e.g. a conducting mat or grid, connected to earth, can be placed at the particular spot where the explosive is being handled, so that the person wearing appropriate shoes is effectively earthed. All equipment should be earthed. If electrical equipment is being used in such a way that a conducting mat would create danger for the operator then the mat should be of antistatic grade material complying with British Standard 2050:1961. The humidity should be increased to 65 - 75 per cent relative humidity if the material electrifies to any extent on sieving and has a high spark sensitiveness.

The group of explosives most susceptible to the electrostatic hazard is the one comprising initiating compositions, the worst member being lead styphnate. Dry guncotton is also fairly sensitive. It has already been mentioned that solvent/air mixtures can be ignited quite readily, and precautions need to be taken during the processing of solvent-type propellants, e.g. neonite and ballistite.

Further information on static electrification is given in para. 8.8.

Spilt Explosives

10.13 If explosives are spilt during weighing or other operation it is important not to make hasty and ill-considered attempts to salvage the material. All spilt explosive must be regarded as contaminated and assigned for destruction, using a safe procedure. Even in 'clean' buildings it is to be assumed that explosive spilt on to the floor will be sensitised by the presence of grit. It is essential for the bulk explosive to be removed before cleaning up operations are started. Initiators present special problems, and it may be necessary to apply small wet swabs of cottonwool to remove unwanted explosive.

10.14 A special problem can arise in connection with slurries and residues from preparation of explosives. These may be insensitive when wet but dangerous if allowed to dry out in inaccessible places in the equipment, such as in vacuum traps, pipe lines and drains. Appropriate flushing and cleaning procedures must be devised and carried out in such cases.

Heating

10.15 All explosives must be regarded as sensitive to the application of heat and all the circumstances must be considered critically before any explosive is heated.

10.16 The equipment must be of an approved type and situated in a safe location. TheEstablishment Safety Officer will advise. The conditions of heating must be appropriate to the type of explosive with safeguards against excessive temperature or time of heating. The quantity must be within the prescribed limits for the equipment and building.

10.17 Some explosives, such as mercury fulminate, will ignite on prolonged heating at a temperature well below the ignition temperature stated in the safety certificate or recorded literature. Chemical deterioration, dehydration and contamination can also lead to an increase in sensitiveness to heat, and some explosives are more sensitive to friction after heating.

Drying

10.18 For the reasons stated in the previous paragraphs the drying of explosives without the application of heat is preferred. The use of drying agents and/or vacuum processes to hasten drying must be selected with care. Thus concentrated sulphuric acid is dangerous to use in a desiccator and silica gel or anhydrous calcium sulphate are preferred; if a more powerful desiccant is required phosphorus pentoxide may be used, but this (or any other reactive chemical) must not be allowed to come into contact with an explosive.

10.19 The use of drying under reduced pressure, if adopted at all, must guard against the danger of implosion and of contamination of the vacuum line. As an obvious example, glass vacuum desiccators must not be used for very sensitive explosives. Fully effective traps must be used to prevent contamination of vacuum lines. Re-admission of air to the desiccator must be done very slowly, in order to prevent dispersal of the explosive.

Cutting and Machining of Explosives

10.20 The major hazards associated with the cutting or machining of explosives are (a) the frictional contact of the cutting tool with the explosive, (b) the accidental contact of the cutting tool with the jig or fixture, or with an occluded foreign body, and (c) the accumulation of dry explosive swarf.

There is a considerable body of experience available on bandsawing, milling (both surface and slit saw), facing, turning and drilling certain types of explosive. Drilling is by far the most hazardous operation, as there is extensive frictional contact under confinement on the sides of the drill. Explosive swarf must never be allowed to accumulate on the machine.

Where machining operations seem necessary, the Safety Officer must be consulted, so that the proper procedure for the work can be laid down with help from experienced staff; approval must be obtained for the adaption of the machines, e.g. precautions must be taken to prevent ingress of explosive to the machine, motors must be of an approved type and proper arrangements must be made for the collection of swarf.

Grinding and Sieving

10.21 Any operation which includes the application of mechanical energy to an explosive must be regarded at all times as presenting hazards. It is permissible for very small quantities, not exceeding about 0.05 gramme to be ground in an agate pestle and mortar. Where a master/slave manipulator or other remote control equipment is available this should be used. If such equipment is not available the Establishment Safety Officer will advise on protection and the details to be observed. Grinding of quantities exceeding 0.05 gramme and any operations such as pressing into pellets or extrusion must be remotely controlled.

10.22 The sieving of powdered explosives must be carried out with proper regard to the sensitiveness and amount of explosive concerned in order that the operator and the equipment can be protected. The equipment should be designed to eliminate the trapping of explosive dust between hard surfaces; all parts must be electrically earthed and special precautions observed in the case of explosives which are known to be very sensitive to ignition by electrostatic sparks. Thus humidification of the sieving area, the observance of minimum waiting periods and the wearing of conducting footwear on conducting floors may be required. Sieving processes tend to be dusty and there is special need for cleanliness of equipment and buildings and the avoidance of conditions which could lead to propagation of fire or explosion. See also para. 8.8, Static Electrification.

Operations on Live Ammunition and Filled Containers

10.23 Assembly or breaking down of explosives in live ammunition or containers presents special hazards. The Safety Officer must be consulted and advise on operations. Precautions must be obtained from staff or organisations with specialist knowledge of live ammunition stores.

10.24 Packages and assemblies containing initiating explosives in any form (including fuzes, igniters and detonators) must be handled only by staff who are thoroughly trained in these stores and who know the precautions to be adopted. It is especially important for quantities to be kept to the minimum required for the work in hand.

CHAPTER 11

SPECIFIC EXPLOSIVE RISKS

11.1 In this chapter various compatibility problems are emphasised. Attention is drawn to some important properties of a number of explosives, and the extent to which their handling may be affected by contaminants. Some metallic corrosion products are particularly sensitive.

Effect of Various Chemicals on Explosives

Water

11.2 The addition of water to an explosive usually makes it less sensitive, but there are important exceptions to this rule, and with some explosives moisture is a dangerous contaminant. For example, although the sensitiveness of mercury fulminate and lead styphnate is appreciably diminished when these explosives are thoroughly wetted, that of lead azide is not affected. Moreover, wet lead styphnate can pick up the detonation wave from initiated dry lead styphnate. A further complication with lead azide is that, with moisture, reaction takes place with the evolution of hydrazoic acid vapour which can form highly sensitive azides on certain metal surfaces, e.g. on the outside of a copper detonator sheath.

Compositions containing metallic powders can be dangerously reactive if they become moist. Pyrotechnic compositions containing magnesium powder and a nitrate, and smoke compositions containing zinc dust, if moistened, may heat-up to the ignition temperature. Aluminised high explosive compositions tend to gas, and the rate is increased by moisture. Residues of any of these compositions, if they cannot be kept free of moisture, should not be left in a slightly moistened or damp condition, but should be completely immersed in water (with thorough stirring in the case of smoke or pyrotechnic composition) and the containing vessel kept in the open.

Alkalies and Acids

11.3 The presence of alkali (including ammonia) in TNT, may increase its ease of inflammation. TNT on exposure to gaseous ammonia forms compounds with ignition temperatures considerably below 100^{o}C. Nitrammes, e.g. R.D.X., may be ignited by strong alkali.

The stability of nitric esters, e.g. nitroglycerine and nitrocellulose, is seriously affected by the presence of acids, leading sometimes to inflammation. Strong alkalis have similar effects.

Coloured smoke compositions, which usually consist of a mixture of a sugar and potassium chlorate, heavily diluted with a dye, are liable to become dangerously unstable if contaminated with a trace of acid, e.g. in the dye.

Chlorides

11.4 Smoke compositions are seriously affected by contamination with soluble chlorides, e.g. sea water or zinc chloride soldering flux. Spontaneous fires have been attributed to both of these contaminants.

Reactions of Metals

11.5 Since the majority of explosives are filled into some form of metal container for Service use, their compatibility with metals is a very important consideration. In general, the following metals and their alloys are the most reactive - copper, lead, aluminium, magnesium and zinc.

Copper or brass, especially if tinned, will react with ammonium nitrate producing sensitive salts. Basic stannous nitrate is especially sensitive.

As already mentioned copper and brass cannot be used with lead azide, especially under moist conditions.

Lead is incompatible with ammonium nitrate, and nitrophenolic compounds. Picric acid and picrates, for example, form the much more sensitive lead picrate.

Aluminium and aluminium alloys are rapidly attacked by mercury fulminate, and these cannot be used for containers for fulminate compositions. Similarly, they cannot be used with chlorates.

Magnesium is unsatisfactory in contact with PETN, nitrophenolic compounds and chlorates.

Zinc cannot be used with nitroglycerine, double-base propellants or ammonium nitrate.

Sensitiveness of Mixtures Containing Oxidising Agents

11.6 Reference has already been made (paras. 6.9 and 8.10) to the explosive nature of mixtures of oxidising agents with organic chemicals. Mixtures containing a chlorate must be handled with the greatest care, as in general they are extremely sensitive to friction. Mixtures containing bromates tend to be even more sensitive, and those containing perchlorate are somewhat less sensitive, than the corresponding chlorate mixtures.

Chlorates should not be allowed to come into contact with ammonium salts, or strong acids.

Sensitising Action of Grit

11.7 Nearly all explosives are more easily initiated if they are contaminated with hard gritty material. This is one of the reasons for working in "clean areas". The possibility of contamination by airborne grit must not be overlooked. But sometimes gritty material is deliberately added to a composition e.g. certain cap compositions contain calcium silicide or silicon carbide to increase their sensitiveness to an acceptable level for functioning and certain pyrotechnic compositions contain powdered metals. In both of these cases the compositions can be very friction-sensitive and especial care is needed, particularly if the mixing, sieving and filling equipment is used subsequently for another type of composition.

Plastics, Synthetic Resin Adhesives, Cements, and Rubber

11.8 Plastics and rubber, like all other substances, may be unsuitable for use with explosives, and must be tested for compatibility. Service specifications exist for those materials which have been found to be compatible, and these should be used if possible.

In general, phenol/formaldehyde (suitably cured), polyethylene, polystyrene, nylon, terylene and polyurethane are compatible with explosives. Polymethyl methacrylate is chemically compatible with explosives, but is softened by NG and double base propellants. Polyvinyl chloride is also chemically compatible provided (a) the stabiliser is not a lead compound, and (b) the explosive in question is not a nitrophenolic substance; if plasticised it is softened by double-base propellants. Cellulose acetate is satisfactory provided a suitable plasticiser is used. Polyvinylidene chloride is marginally satisfactory with double-base propellants.

As regards the resin mouldings and cements, the epoxy types, hardened with amines are usually incompatible with explosives; in particular, the hardeners used in the cold setting types - aliphatic and cyclic amines - are very incompatible. Mixtures of single-base or double-base propellants with some amines have ignited. The types hardened with acid anhydrides, however, are compatible with most explosives, but some reaction is found with double-base propellants.

Liquid Explosives

11.9 Liquid explosives present special risks on account of their mobility and their range of sensitiveness. In handling them the use of glass, earthenware or metal stoppers and stopcocks must be avoided, and only suitable plastic types used. Special care must be taken to guard against dropping containers filled with them.

Nitroglycerine should always be handled with the greatest care, and the risk of ignition is increased when it is in the frozen, or worse, semi-frozen condition. An additional hazard which arises with the lower members of the series, such as methyl nitrate, is their volatility; ignition of the vapour may spread to the liquid. Methyl nitrate and nitroglycerine are particularly sensitive to impact if trapped bubbles are compressed. The sensitiveness of methyl nitrate to friction between glass surfaces is very high, and under no circumstances must methyl nitrate be placed in a glass stoppered bottle.

Sensitiveness of Fine-grain Propellants

11.10 Cordites and other propellants, although not dangerous to handle when in stick or tubular form, are dangerously sensitive to impact or friction when in the form of fine flake or thin sheet and burn at enormously increased speed. For these reasons, ballistite and neonite, for instance, require special care in handling. Fine-grain single-base or double-base powders can burn to detonation under the degree of self-confinement imposed by packing in layers of depth more than 18 - 24 inches, more energetic compositions exhibit this behaviour in even thinner layers.

CHAPTER 12

STORAGE AND TRANSPORT OF EXPLOSIVES

Service Classification of Explosives

12.1 Service explosives, and stores containing them, are officially classified into numbered groups. The group number is shown by a label or stencil on each package as a guide to the precautions necessary in handling or storing the contents. Details of the group classification are given in the "Comprehensive Classified List of Government Explosives", which also specifies the type of storage, i.e. Magazine or Explosives Storehouse. Information concerning the classification and storage conditions for particular explosives should be obtained from the Safety Officer.

In this establishment the majority of buildings available for storage comply with the standards required for Magazines and can be used where explosives store-houses are specified. Buildings to be used for storage must first be approved by the Safety Officer who will fix an explosives limit having regard to the type and the amount of the proposed storage.

Experimental Explosives and Stores

12.2 The procedure for storage of experimental explosives is as follows:

12.2.1 Materials in frequent production in quantity should be given temporary classification and stored as Service explosives.

12.2.2 Materials in production where compositions have slight variations, should be temporarily classified as a group and stored as Service explosives.

Application for temporary classification must be made to the Safety Section.

Raw Materials (not Necessarily in themselves Explosives) for Use in Making Explosives

12.3 These materials, which include wet NC (over 30% moisture), ammonium perchlorate and ammonium nitrate are to be stored and transported so as to avoid contamination.

Locker Magazines

12.4 Locker magazines are provided for use by laboratory staff for the temporary storage of small quantities of explosives in use. Main storage facilities should be used for long-term storage.

The following limits are imposed in respect of each cabinet.

H.E.	8 lb.
or Propellents	8 lb.
or Fulminate class	1 lb.
or Gunpowder and Pyrotechnic compositions	2 lb.

See also Rules of E.R.D.E., p.35.

Conditions Governing Storage

12.5 No explosives or materials are to be placed in store unless:

(a) They are in approved containers as laid down by the Ministry Regulations or as approved by the Safety Officer.

(b) Each container or package is securely and clearly labelled with a description of its contents, date of first storage, date of last stability test or examination and the name of the scientist responsible. E.R.D.E. Standing Instruction on Safety No. 19 deals with stability tests to be carried out on stored explosives.

(c) The stability is satisfactory and the material is not unduly sensitive. Explosives or stores of doubtful stability should be referred to the Safety Officer who will arrange isolated storage.

No package or container is to be opened in the actual store room but is to be removed to a safe position at a safe distance.

No package or container is to be placed within two feet of any heating apparatus.

Rules and limits will be posted in each building giving instructions as to the handling of the materials stored.

General Rules

12.6 Records must be kept of the contents of any explosives store and should indicate batch or lot numbers for easy identification and the name of the scientist responsible for the item.

Stores not required should be disposed of, either by offering them to other establishments or by destruction by the Safety Section. It is the duty of all scientific staff to keep stocks as small as possible.

Records must also be maintained of the inspection (either chemical or visual) of the stores. Records should be checked every 3 months. Records should be maintained in such a manner that, in the absence of the scientist, responsibility can be taken over by his deputy without difficulty.

See also E.R.D.E. Standing Instructions on Safety, No. 19, Surveillance of Explosives and Chemicals in Store.

Transport of Explosives

12.7 The Transport (Internal and External) of Explosives, Dangerous Goods and Radio-active Substances is dealt with in E.R.D.E. Standing Instructions on Safety, No. 15.

CHAPTER 13

DISPOSAL OF WASTE EXPLOSIVES, AMMUNITION AND CHEMICALS AND DECONTAMINATION

13.1 The disposal of these materials or stores can be extremely dangerous and the following instructions should be rigidly observed. See also Rules of E.R.D.E., p. 23 and Standing Instructions on Safety No. 16, Disposal of Waste Explosives, Chemicals and Radio-active Waste.

Explosives which must be Destroyed under the Personal Supervision of the Scientist Concerned

13.2 The following material and stores are included in this class:-

13.2.1 Initiating explosives and compositions of all types, if not in filled stores.

Chemical methods should be used when practicable for destroying these materials, otherwise the Safety Officer should be consulted. Gunpowder may be destroyed by washing out the nitrate with water, and similar wet methods can be used for some other compositions.

13.2.2 Explosives or stores which are extremely sensitive by reason of their nature or design, of contamination or of having undergone trials affecting their safety.

The Safety Officer should be consulted in each case.

Explosives Other than Those in para. 13.2 Above

13.3 The scientist in charge of any experiment or process is responsible for ensuring that waste material is collected and passed to the burning ground for destruction.

13.3.1 Waste buckets are provided by the Safety Section, and can be installed at any building. The buckets should be kept in a safe place away from the building, loosely covered and out of direct sunlight. In laboratories the buckets should be labelled and waste separated according to type, e.g.

H.E.) Aluminised H.E.) Cordite) NC) Fine grained propellants) Composite propellants)	The contents of these containers must be well covered with water and stirred to prevent loose material floating on the surface
Liquid explosives absorbed in sawdust or kiesulguhr.	Water should not be added to this waste.

13.3.2 Contaminated waste e.g. paper, metal, rags, etc. should be placed in a separate container in water. Glassware should also be separated.

13.3.3 Dilute solutions of explosives in solvents (e.g. washings) should be kept in stoppered containers; glass stoppers should not be used.

13.3.4 The containers of waste should be removed daily to the waste collection centre, and will be collected at weekly intervals under arrangements made by the Safety Officer.

13.3.5 If the scientist considers that waste should not be kept, e.g. on grounds of instability or hazard, the Safety Officer will arrange special disposal.

A note should be sent with unusual or contaminated waste giving details of the material and the contamination.

Disposal of Rocket Motors and Ammunition

13.4 Filled or partly filled rocket motors should be sent to the burning ground in boxes, with information giving details of their filling.

Where ammunition is to be destroyed, application should be made to the Safety Officer who will arrange for its disposal; this also covers requests for sea dumping.

Disposal of Chemical Waste

13.5 Chemical waste (apart from radio-active material) may also be sent to the burning ground BUT MUST BE KEPT IN SEPARATE CONTAINERS AWAY FROM EXPLOSIVES, and accompanied by a description and such other information, e.g. toxic, flammable etc., as may be known. Sensitive or highly reactive materials and metal powders should be kept separate, and special arrangements should be made with the Safety Officer for collection and disposal.

Decontamination of Plant and Equipment Used in Connection with Explosives or Chemicals

13.6 Instructions are given in Rules of E.R.D.E., pages 16-20.

PART IV ACCIDENT PREVENTION APPLIED TO LARGER-SCALE EXPERIMENTS

CHAPTER 14

DESIGN AND DEVELOPMENT OF LARGER-SCALE EXPERIMENTS

Scale of Operation

14.1 In considering what precautions should be taken in carrying out any experiment, and especially large-scale experiments, there are two major features to be examined in the first instance, viz.

(a) THE SCALE OF OPERATION, i.e. weight of hazardous material involved.
(b) THE DEGREE OF VIOLENCE to be expected in the event of an accident i.e. detonation, explosion, fire.

The table below gives an approximate indication of the effect of three degrees of violence involving three different weights of material and serves as a guide to the weight levels at which serious consequences may occur.

Weights of Material	Effect of Detonation	Effect of Explosion	Effect of Fire
5 grammes	Localised. Is contained adequately by an armoured cupboard.	Localised. Safe behind suitable plastic shield.	Localised. Easily dealt with.
30-50 grammes	Is **just** contained under certain conditions by a special armoured cupboard (see para. 5.75). In open laboratory – serious.	Can be confined by screening in open laboratory.	Not serious. May be dealt with locally.
500 grammes	A serious hazard. Even in an armoured cupboard the blast will wreck a laboratory.	Missile danger arises and stout protection is required, e.g. steel plates rigidly fixed.	Fire arising from a litre flask of solvent needs urgent action.

It should be borne in mind that as the scale of operation increases, so does the potential danger from sources other than the process chemicals themselves. Steam, compressed air, hot oil and other hot materials must therefore be considered in assessing the hazards.

When the scale of operations is such that confinement of the results of an accident cannot be relied upon, the preliminary investigations to ensure the safety of the operations become vitally important.

Recognition of Hazard and Assessment of Risk

14.2 The most important step is the recognition of the hazards, as already pointed out in para. 1.5 et seq., and the procedure laid down in E.R.D.E. Standing Instructions on Safety No. 4, Safety Searches, must be followed. There are many factors arising in larger-scale work and it is essential for those concerned with design and operation to discuss with their Superintendent, the Safety Officer and the Chief Engineer, all aspects of the processes before deciding on the particular methods to be used.

Realistic assessment of risk and planning for accident prevention in larger-scale operations must be based on the assumption that no hazard is overlooked and it is therefore necessary for the proposed operations to be subjected to a systematic scrutiny. The following scheme, sub-divided into five stages for convenience, is suggested as a framework for this examination.

STAGE 1

(a) Investigate all hazards arising, including those leading to detonation, explosion, fire and toxic dangers.

This is the crucial stage and should be kept in mind whenever any alterations are made subsequently.

(b) Assess the hazards from all known sources including mal-operation.

(c) Whenever possible design out the hazards e.g., if a flammable solvent is being used, consider whether a non-flammable one may be substituted; air agitation might be less dangerous than mechanical agitation.

STAGE 2

Reassess the situation with respect to all hazards which cannot be removed. Obviously, as the scale of operation increases the effort to be devoted to this stage increases.

STAGE 3

Where experimental equipment involving quantities of the order of 5 kg or more is being considered the complexity of the problems increases and the method of approach to the work becomes important. More people are involved in the preparations, and the dissemination of information on the intended equipment is a major factor in avoiding accidents. It is recommended that chemical engineering flowsheets should be prepared to include process flow, material flow, heat flow and instrumentation and that these should be duplicated and sent to the appropriate officers at as early a stage as possible. Such information often serves a greater purpose than a lengthy meeting and enables others to comprehend what is proposed.

STAGE 4

Several important considerations need to be taken into account at this stage:

(a) The siting of the apparatus, particularly its proximity to other work,
(b) The preliminary selection of suitable types of equipment,
(c) The method of control, e.g. if remote control is envisaged this may have a considerable bearing on the design of the equipment,
(d) The type of operators to be employed on the work.

STAGE 5

Equipment Selection and Design

The selection and designing of equipment for processing has a twofold approach - the apparatus must be mechanically satisfactory and it must perform the processing functions required. In a guide of this kind it is not possible to deal with this subject; however, in Chapter 15 some notes are collected on the more common pitfalls encountered with equipment used for chemical engineering purposes.

14.3 It is good practice, when this stage of the project has been reached, to reassess the situation with respect to the hazards of the process. This will require that the flowsheets and drawings should be brought up to date. It is essential that a suitable numbering and dating system be applied and that master copies of the process flowsheets and major equipment drawings be kept on which modifications may be marked.

Whilst attention must naturally be given to explosion and fire risk as predominant dangers, it is essential not to overlook the physical dangers of electric shock, trapping of limbs, falling from heights and the fall of heavy or dangerous objects. A good design will eliminate such factors as far as possible.

14.4 In the course of development work, alterations may be made and the reasons for them may become obscure in the course of time, or again, staff may change. The maintenance of an INSTALLATION LOG BOOK, consisting of brief summaries of significant stages in the development, serves a useful purpose in recording this information. To be successful it must be succinctly written and neatly maintained in the manner of a laboratory notebook; it should contain dated records of the conclusions of meetings concerning the equipment, and should also give details of any alterations which are made to the equipment. This Installation Log Book of a project should not be confused with an Operating Log Book, which will contain experimental details.

It is desirable to keep records (drawings and specifications) of the plant or installation as originally built, and a system of keeping these records up to date by recording amendments and modifications (with dates) will ensure their continuing usefulness.

CHAPTER 15

SOURCES OF ACCIDENTS IN LARGER-SCALE EXPERIMENTS

The following list draws attention to some of the commoner points which must be borne in mind in the safe design and operation of larger-scale equipments; it is not in any sense a comprehensive glossary and attention is again directed to para. 14.2.

Constructional and Process Faults

15.1 These often arise through lack of appreciation of the hazards introduced.

Materials of construction are of primary importance. Compatibility, corrosion resistance and mechanical strength are obvious points to look for and specialist advice is often required. The sensitiveness of the material being processed may affect the choice of materials for plant. Thinning of materials by corrosion (especially at welds) sometimes leads to mechanical failure and a serious accident may result, e.g. stirrer blades becoming detached. The structural instability of many polymers (e.g. P.T.F.E.) is often overlooked and the "plastic memory" of such materials can lead to leaks.

Electrical equipment should be installed to meet the conditions required by flameproof, dust-tight, totally enclosed or normal installations, depending on circumstances; these terms are defined in M. of A. Explosives Regulations 1960. The normal working temperatures of electrical and other equipment must be considered in relation to the properties of the substances being processed, and steps must be taken to deal with consequent hazards.

Inflammable vapours usually show well-defined explosion limits which should be avoided, otherwise suitable blow out panels should be inserted in the pipes and ducts. It should be remembered that flash-back can occur over considerable distances.

Overheating may arise, amongst other ways, through failure of heat to be conducted away at the expected rate, by friction, by failure of a controller, and by the generation of unexpectedly high shear forces through failure of an overload switch. It will be remembered that 1 h.p. produces 176 calories/second when converted to heat energy.

Toxicity precautions are governed by statutory regulations which lay down the protection which must be given to operators handling toxic chemicals. Because of the insidious nature of poisoning, special attention must be given to handling new or unusual materials on which there is little information. Where known toxic materials are being handled, special attention must be given to the elimination of leakage and to venting arrangements. If material is ducted away from the immediate operating area it must not be released at a point where it could become a danger to others.

Larger items of equipment should be secured to the floor when rigid pipe connections are to be made, since vibration can produce considerable lateral movement.

The accidental introduction of impurity sometimes arises, for example there is often a danger of lubricating oil entering process vessels through inefficient glands. Another source of impurity is airborne grit, especially from forced circulation air systems.

If liquid explosives are being handled the possibility of condensation of films on cold metal surfaces should not be overlooked.

In explosives plant it is necessary to avoid blind holes and pockets which cannot be effectively freed from explosive; welds must be ground smooth wherever possible, and cavities avoided.

Flanged fittings are preferable to screwed fittings and are in some cases obligatory. On explosives operations the screwed joint is notorious for trapping material in the threads, making removal and decontamination matters of considerable difficulty.

Provision should always be made for the inspection and easy cleaning of the interior of vessels and pipes to be used for explosives.

Mixing Equipment

15.2 This falls into two main categories, high speed and low speed. In explosives handling the latter is usually preferred since the lower energy release, in the event of mechanical failure, is less likely to lead to a fire or detonation. In mixing equipment, clearances must be sufficient to avoid metallic contact if deflection occurs under load conditions. Bearings should be, if at all possible remote, from the material being mixed, and must be designed to prevent the ingress and nipping of explosives between moving metal surfaces. Electrostatic hazards may arise during the filling and emptying of mixing vessels.

Consideration should always be given to the means of cleaning; washing out may not always be effective and access for scrubbing may be required.

Valves

15.3 Of the four types, globe, gate, needle and diaphragm, the latter normally presents the most attractive method of control of flow in explosives plants. A common fault in the ordinary plug cock which is often overlooked is the trapping of a small quantity of liquid in the body of the cock when in the off position: this fault is even more serious in gate valves. The positioning of valves in a pipe line is of considerable importance; rapid closing of a valve at the end of a long line causes the development of abnormally high pressures, the so-called "water hammer" effect.

Reducing valves of the larger diaphragm type form a surprising hazard. Leakage of the main valve may in the absence of a suitably adjusted relief valve lead to mechanical failure and a dangerous explosion.

The access of explosive materials to the stems of valves must be avoided.

Pipelines

15.4 Couplings in pipelines are better flanged than screwed, but compression joints are unsatisfactory on explosives pipelines. Special attention should be given to the material and thickness of flange joint gaskets to avoid the risk of blowing out.

Pipelines should have adequate drainage slopes and accessible valves where remote control is not in use. Explosions may be transmitted by explosives enclosed in pipes, so that pipelines may form dangerous links between separated explosives workshops.

The use of inadequately secured flexible hoses presents a hazard where a compressible fluid is in use. They must be securely attached by suitable screw clips.

Reaction Vessels

15.5 Where these are not pressure vessels, care must be taken in assessing the nature of any untoward reactions which may take place. A rapid fume-off or evolution of gas may cause a large thin-walled vessel to burst. Effective drowning and drenching equipment should be fitted.

Where pressure vessels are used they should be designed to the appropriate A.S.M.E. or B.S. code, B.S. 1500 (1949). Weak points in a system, such as gauge glasses, should receive special attention. See also Standing Instructions on Safety No. 17, Procedure covering the examination or testing of pressure vessels.

Interlock and Central Systems

15.6 Use should be made, if practicable, of remote control and interlocking controls on any hazardous process.

Drowning and Drenching Devices

15.7 Consideration should always be given to the possibility of providing drowning tanks or drenching devices for charges which may become overheated or for reactions which get out of hand.

Such arrangements can also often be used for the washing out and drainage of the plant in normal working.

Run-offs to drowning tanks should be in the form of open troughs as the confinement caused by closed pipes may increase the risk of explosion.

Special automatic drencher units have been designed within the Establishment to cover heavy fire risks, e.g. cordite rolls, incorporators etc. Advice on this type of installation will be given by the Safety Section.

INDEX

51-1795 M.P. LTD