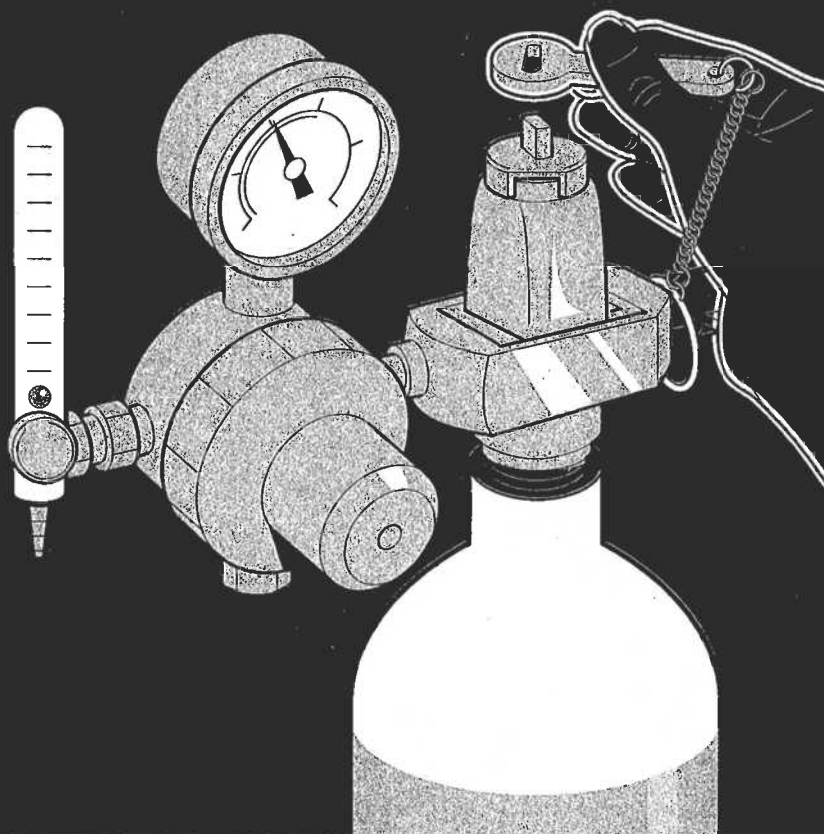




VSO Books

# Care and Safe Use of Hospital Equipment

Muriel Skeet and David Fear



VSO 01



**CARE AND SAFE USE**  
**OF**  
**HOSPITAL EQUIPMENT**

Muriel Skeet and David Fear



VSO Books



Voluntary Service Overseas  
317 Putney Bridge Road  
London  
SW15 2PN  
UK

© VSO Books 1995

First published in 1995  
Reprinted in 1998

Designed and typeset in Great Britain by Technical and Pictorial  
Illustrations  
Printed by The Chameleon Press

Every reasonable effort has been made to ensure the accuracy of the contents of this publication and that the publication does not suggest practices which might be dangerous. However VSO can accept no liability for any injury or damage to persons or property arising from the use to which any information in the text is put.

British Library Cataloguing in Publication Data  
A catalogue record for this book is available from the British Library.

ISBN 0 9509050 5 4

# CONTENTS

---

|  |     |
|--|-----|
| INDEX OF FIGURES   | iii |
| ACKNOWLEDGEMENTS   | v   |
| FOREWORD by Dr Andrei Issakov of the World Health Organisation | vii |
| INTRODUCTION   | 1   |
| EVALUATION OF THIS BOOK  | 5   |

## **PART I PREPARING SYSTEMS FOR THE CARE AND SAFE USE OF HOSPITAL EQUIPMENT**

|           |   |    |
|-----------|---|----|
| <b>1.</b> | The Management of Maintenance   | 9  |
|           | a. Setting up routines and fault reporting systems                                      |    |
|           | b. Identifying individuals to take responsibility for the maintenance and repair system |    |
|           | c. Setting up an inventory  |    |
|           | d. Training personnel   |    |
|           | e. Safety aspects: Ethical and legal responsibilities                                   |    |
| <b>2.</b> | New Equipment   | 27 |
|           | a. Purchase of new equipment  |    |
|           | b. Checking new equipment   |    |
| <b>3.</b> | Basic Tool Kit for First Line Maintenance   | 31 |

## **PART II GUIDELINES FOR THE CARE AND SAFE USE OF HOSPITAL EQUIPMENT**

|           |  |     |
|-----------|--|-----|
| <b>4.</b> | General Principles of Maintaining Electrical Equipment           | 35  |
| <b>5.</b> | Checking Power Supplies, Sockets, Plugs and Spares               | 41  |
| <b>6.</b> | Battery Maintenance  | 45  |
| <b>7.</b> | Bottled Medical Oxygen and Oxygen Concentrators                  | 53  |
|           | a. Bottled medical oxygen  |     |
|           | b. Oxygen concentrators  |     |
| <b>8.</b> | Disinfection and Sterilisation of Medical Supplies and Equipment | 73  |
|           | a. Introduction  |     |
|           | b. Boiling water disinfectors                                    |     |
|           | c. Autoclaves  |     |
| <b>9.</b> | Theatre Equipment  | 105 |
|           | a. Operating tables  |     |
|           | b. Electrical suction apparatus                                  |     |
|           | c. Manual suction apparatus                                      |     |
|           | d. Shadowless theatre lamps                                      |     |

|            |                          |     |
|------------|--------------------------|-----|
| <b>10.</b> | Vacuum Extractors        | 127 |
| <b>11.</b> | Incubators for Babies    | 133 |
| <b>12.</b> | Refrigerators            | 149 |
| <b>13.</b> | Blood Pressure Apparatus | 163 |
|            | SELECTED BIBLIOGRAPHY    | 175 |
|            | USEFUL ADDRESSES         | 179 |
|            | EVALUATION QUESTIONNAIRE | 184 |

## INDEX OF FIGURES

|            |   |    |
|------------|---|----|
| Figure 1:  | Fault reporting documentation   | 14 |
| Figure 2:  | Repair documentation  | 15 |
| Figure 3:  | Maintenance documentation   | 17 |
| Figure 4:  | Examples of plugs and associated cable colour codes   | 36 |
| Figure 5:  | Checking mains lead for conductor break   | 38 |
| Figure 6:  | How to wire a plug  | 44 |
| Figure 7:  | Care of battery terminals   | 45 |
| Figure 8:  | Battery safety  | 46 |
| Figure 9:  | Topping up acid (electrolyte)   | 47 |
| Figure 10: | How to prepare distilled water  | 48 |
| Figure 11: | Checking the battery  | 50 |
| Figure 12: | Valve types used for medical oxygen and cylinder colour code to British Standards   | 54 |
| Figure 13: | Use of correct spanner/key on cylinder valves   | 55 |
| Figure 14: | Use of clear warning signs  | 56 |
| Figure 15: | Safe storage of cylinders   | 57 |
| Figure 16: | Protective caps and seals   | 58 |
| Figure 17: | Pin index and bullnose regulators, 'O' ring and Bodok washer locations  | 60 |
| Figure 18: | Typical air intake filter, also known as the coarse filter  | 66 |
| Figure 19: | Typical appearance and layout of secondary filters  | 67 |
| Figure 20: | Oxygen concentrator in operation  | 69 |
| Figure 21: | Materials which can be sterilised by autoclaving  | 73 |
| Figure 22: | Thermal death curve for steam   | 75 |
| Figure 23: | Combinations of temperature and time required for sterilisation by steam  | 76 |
| Figure 24: | Altitude considerations for disinfection and sterilisation  | 77 |
| Figure 25: | Boiling water disinfectors in cross-section:<br>a: with an immersion-type heating element<br>b: with a panel-type heating element | 81 |
| Figure 26: | Typical heating elements and simmerstat switch  | 82 |
| Figure 27: | Cross-section of a boiling water disinfecter equipped with a simmerstat switch  | 83 |
| Figure 28: | Autoclaves are available in a wide range of sizes and for various applications  | 89 |
| Figure 29: | Vertical build, single-chamber, non-vacuum type autoclave; electrically heated  | 90 |
| Figure 30: | The temperature/time and pressure/time diagram of a typical sterilisation cycle of a non-vacuum autoclave                         | 91 |
| Figure 31: | Methods for testing the performance of autoclaves   | 93 |
| Figure 32: | Fuel-heated, pressure cooker-type autoclave as used in the WHO Expanded Programme on Immunisation                                 | 96 |
| Figure 33: | Vertical, single-chamber, non-vacuum type autoclave for large volumes; electrically heated  | 98 |

|            |   |     |
|------------|---|-----|
| Figure 34: | Process for sterilisation of porous loads in a non-vacuum autoclave | 100 |
| Figure 35: | Hydraulic operating table   | 107 |
| Figure 36: | Typical suction circuit   | 111 |
| Figure 37: | Typical reservoir jar (plastic or glass)                            | 113 |
| Figure 38: | Fixed theatre lamp  | 118 |
| Figure 39: | Mobile theatre lamp   | 119 |
| Figure 40: | Bulb replacement  | 122 |
| Figure 41: | Vacuum extractor  | 128 |
| Figure 42: | Vacuum pump parts   | 129 |
| Figure 43: | Basic incubator layout and air flow                                 | 134 |
| Figure 44: | Typical alarm panel and canopy                                      | 135 |
| Figure 45: | Removing the fan impeller and testing the fan fail alarm            | 139 |
| Figure 46: | Door seal check   | 151 |
| Figure 47: | Kerosene refrigerator - cleaning flue and burner                    | 152 |
| Figure 48: | Defrosting using bowls of hot water                                 | 154 |
| Figure 49: | Tape over switch socket   | 154 |
| Figure 50: | Stocking the refrigerator   | 156 |
| Figure 51: | The mercury blood pressure apparatus                                | 163 |
| Figure 52: | Testing/calibrating manometer arrangements                          | 165 |
| Figure 53: | Water tray and mercury storage bottle                               | 167 |
| Figure 54: | Disassembly of blood pressure apparatus                             | 169 |
| Figure 55: | Cleaning mercury  | 171 |



## ACKNOWLEDGEMENTS

---

VSO would like to thank Dr David Peel for writing the section on **Safety aspects - ethical and legal responsibilities**, and Helena Twist LL.M. for her contribution and advice on this section. Thanks are also due to Jan Huys of Heart Consultancy, who wrote the section on **Disinfection and sterilisation of medical supplies and equipment**.

VSO and the authors would like to thank volunteers and their national colleagues in VSO health programmes throughout the world who contributed to the planning stages of this book by completing extensive questionnaires. Thanks also go to volunteers and their colleagues in health programmes in Namibia, Nepal, Uganda, Tanzania, Sierra Leone and Malawi for trialling and commenting on early drafts of this book. Without their willingness to share their first-hand experience this book would not have been written.

Particular thanks go to Peter Lee, who for four years was Head of the Technical Department at ECHO (Equipment to Charity Hospitals Overseas), for his help to the authors and for his corrections of drafts, extensive comments and advice, and to Dr Hendrik Chapel for his advisory role in the writing of the text and for his ideas and contributions to the section on **Setting up routines and fault reporting systems**.

Finally, thanks are also due to the many referees who generously gave their time to comment on drafts of the book, in particular: Dr Andrei Issakov, Dr Cattaneo and Mr John Lloyd at WHO in Geneva; Dr CA Pearson in Bury St Edmunds; Kathy Attawell of AHRTAG in London; Rob Waite, Malcolm Bowering and Ron Ford of the Electro-medical Engineering Department at Southmead Hospital in Bristol, and Rebecca McNair (affiliations are listed for identification only.)

### **Thanks for permission to reproduce illustrations are due to:**

The British Safety Council for Figure 6

WHO/UNICEF for Figure 20

Prestige Medical for Figure 32

AHRTAG for Figure 47



Many developing countries have attempted to establish a comprehensive health care technical service. In most cases this is still at a very early stage of development, and district health facilities which are remote from engineering expertise and technical back-up frequently find their medical and hospital equipment not functioning or unsafe. Inability of health services to make full use of available equipment results in decreased quality of care and high wastage of scarce resources, ultimately hampering progress towards a country's health goals.

However, most technical problems can be avoided by proper management of equipment, planned preventative maintenance and service by locally available technical staff, and correct use by medical personnel. The issues involved in good equipment maintenance and user practice are still not appreciated enough in many places and the major reason for this is lack of information, particularly of clear guidelines and training materials appropriate for developing countries' circumstances.

This volume provides district health facility staff with the required information in a simple, user-friendly manual, based on the extensive experience of many people working in the field.

The point of departure from other available material is that this book addresses primarily non-specialists in clinical/hospital engineering, such as health facility managers, equipment users and multi-skilled craftsmen. The manual has a considerable focus on maintenance management and approaches to user training, and provides practical guidelines on planned preventative maintenance. It will help managers at district level to review and improve their equipment maintenance systems, medical staff to use equipment with care and respect, and craftsmen to implement first-line maintenance and repair procedures and refer more complex problems to a qualified technician/engineer.

The authors, the publishers, and all those who contributed to this publication should be congratulated on this endeavour. It is an important contribution to the international drive towards improving equipment management, and ultimately towards improving safety, quality and cost-effectiveness of health care in developing countries.

**Dr Andrei Issakov**

Programme on Health Physical Resources Management

National Health Systems and Policies Unit

Division of Strengthening of Health Services

World Health Organisation, Geneva



## INTRODUCTION

---

Many of us working in hospitals or health centres have been frustrated at some time or other because a piece of equipment is not in good working order when we most need it. Even worse, our patients may suffer or be put at risk if, for example, oxygen is not available when urgently required or a steriliser is not up to standard when we come to do the ward dressings. Often, at district level, spares are not readily available and engineers, even where they exist, are not present around the clock.

In the majority of hospitals, maintenance services are not seen as being of vital importance to good patient care and good management. There may be a local handyman with a small work place and a few tools to carry out repairs but rarely does he have the encouragement and incentives which will motivate him to do a good and speedy job. Many health care professionals do not see the care and safety of equipment as a priority. In the past it has been easy to ask for a new piece of machinery but donors are in shorter supply today. The world-wide recession has meant that industrialised countries are cutting many programmes including those overseas.

In the meanwhile, health problems have increased alarmingly. Every country is affected by the AIDS pandemic. Malaria has resurged and in 1993 the World Health Organization (WHO) declared the incidence of tuberculosis as a global crisis. Cardiovascular diseases and cancer rates are now reaching similar levels in developed and developing countries while population changes, geographic as well as demographic, have brought new health problems of displaced persons and very old people in almost all countries.

As we approach the turn of the century the world faces the increasing pressures of war, pestilence, famine and death. Although the majority of nations made a positive start in their quest for Health-for-All after the Alma-Ata Conference of 1978, formidable political, economic and social circumstances have meant that in many instances the gap between policy-making and policy implementation remains very wide indeed. Resources are in even shorter supply than they were ten years ago. Health problems have increased while funds to solve them have diminished.

Each of us must be concerned with conserving costs and the care and maintenance of the equipment we use daily must become 'a concept which is part and parcel of our decentralised (district) health care system'<sup>1</sup>.

We are all aware of the need for safety at work – not only in relation to ourselves but also regarding those in our care. Machinery and equipment must be safe to use at all times. That is one of our greatest responsibilities and one which those in charge of a hospital or health centre must take very seriously indeed. Of course the best solution for the problem would be to introduce a national maintenance and equipment management scheme as described in the report of a WHO Round Table discussion<sup>2</sup>. Although this idea must remain the ultimate goal, most developing countries cannot afford the rapid implementation of such a programme for their public health service<sup>3</sup>.

Most problems with health-care equipment can be traced back to fairly simple causes. According to a Swiss study<sup>4</sup>, 60% of accidents with medical equipment are caused by the users. A similar percentage of user-caused defects or malfunctions requiring repair and calibration to rectify them has also been recorded. In developing countries the number of user-caused defects appears to be significantly higher. In general, users in developing countries have not been trained to handle their equipment properly. The problem is often aggravated by low motivation due mainly to lack of management and few, if any, incentives. It was found that equipment belonging to non-government health services was often in better working condition because of clearer definitions and control of responsibilities and thus better motivation for staff. The authors concluded that adequate user training would drastically reduce the incidence of equipment failure. Their cautious estimate was a decrease of 30 to 40%. In summary, good management, clear responsibility for maintenance and effective guidelines are three key issues in the maintenance of hospital equipment.

### **The aims and audience of this book**

This book has been commissioned by VSO to help hospital staff overcome problems in equipment maintenance where there is no hospital engineer at hand. VSO health workers and their local colleagues in health programmes throughout the developing world identified the need for the guidance and information offered in this book. They participated in trials of the guidelines presented in Part II, along with a range of other health professionals worldwide.

This book is addressed to three groups of people – all without relevant technical expertise. First, it is written to help managers of hospitals and health centres who, ultimately, are responsible for the care and safe use of equipment in their hospitals. It is intended to help them review their existing maintenance system and see whether it can be improved. This book will help management to select and train at least one member of staff as a Maintenance Staff Member. It also aims to help management to set up an inventory, to choose new equipment which is appropriate for local circumstances and to withstand offers of machinery which is not. We hope that all members of the hospital management team will have access to a copy of this publication so that they are able to work together to establish safe and reliable routine practices throughout their institution.

The second group for whom this book has been written is the Maintenance Staff Members designated by their management teams to provide a maintenance service in hospitals and health centres where there is no engineer. The vast majority of the text is compiled to provide step-by-step guidelines on how to carry out first-line maintenance in carefully prescribed circumstances and on when to send for a qualified technician. It also includes suggestions on how to teach staff to use equipment with care and respect.

The third group the authors had in mind is those daily users of equipment – doctors, nurses and therapists. Short summaries of good practice – the User Checklists in Part II - are set out for them which, it is envisaged, will be copied onto a poster, translated into a local language and displayed in a prominent position either on or near each piece of equipment.

This book may be used as a teaching aid and the text has been deliberately written in the second person to facilitate its use as a manual for staff training. In other circumstances it may be used as a resource for problem-solving when a fault or breakdown occurs.

The book is divided into two parts. The first part describes the management of maintenance and suggests ways in which preparation for change in maintenance practice may be planned and implemented including the appropriate training of all hospital staff. It includes information on the basic tool kit which should be assembled and gives examples of how to set up a routine system for care and fault identification. It goes into safety aspects, including the ethical and legal responsibilities of hospital managers and it deals with the purchasing and checking of new equipment.

The second part of the book is more specific. It consists of guidelines for the care and maintenance of individual pieces of equipment. These are presented in a logical sequence for training purposes. It is under the last heading of each set of these guidelines that the important check lists for users of the equipment can be found.

Because of the variation in hospital equipment throughout the world, we have concentrated on the most common types in use and the book is well illustrated so that these may be identified and the text adapted as necessary. Some of the simple line drawings may be reproduced either on a chalk board or a flip chart.

It is recognised that there are many other pieces of equipment which could be included in Part II. As the aim was to produce useful material for those situations where there is no engineer, the focus is on items of equipment which most commonly break down, which are most important for patient care or which can be mended relatively simply. The items of equipment were identified through VSO health programmes where VSO volunteers worked with local colleagues in rural situations throughout the developing world. A future publication is planned which deals with electric generators, water supplies and the physical fabric of hospitals.

Much lip service is paid today to self-help as a key factor in human development. But in order to be self-reliant, new knowledge has to be acquired, new skills must be learned and attitudes – even towards the use of machinery and equipment – may have to undergo change. Hospital and health centre managers today find themselves with a major responsibility to inform, explain, guide and advise their staff. It is hoped that this publication will help them in this important task in relation to the care and safe use of hospital equipment.

Muriel Skeet

## References

1. Halbwachs, H., *Maintenance and the district health system - Approach and perspectives*, unpublished report on a seminar in Senegal, GTZ, Eschborn, 1993.
2. Bloom, G. et al, 'The right equipment in good working order', round table discussion, *WHO Forum*, Vol.10, 1989.
3. Halbwachs, H. and Werlein, R., *Training health personnel to operate health care equipment - How to plan, prepare and conduct user training*, GTZ, Eschborn, 1993.
4. Von der Mosel, H., 'Der Klinisch-biologische Ingenieur', *Schweizerische Ärztezeitung*, No 51, December 1971.



## **EVALUATION OF THIS BOOK**

---

In order to ensure that this publication achieves its objectives it will be necessary to update it from time to time. The publishers and authors would welcome comments from both trainers and users, particularly in regard to how useful the book has been; where it has failed; what difficulties have been experienced in using it; what corrections or amendments are required and additional comments on illustrations, drawings, presentation, distribution and so on. It is hoped that it may be assessed for effectiveness very easily. Observations could be made during and after its use and comments collected from persons who have participated in the teaching/learning sessions.

For a more detailed evaluation, a simple questionnaire is supplied at the back of the book. Collated and analysed, it is hoped that these comments and suggestions will result in the improvement of a future edition.



**PART I**

**PREPARING SYSTEMS FOR THE  
CARE AND SAFE USE  
OF  
HOSPITAL EQUIPMENT**



# 1. THE MANAGEMENT OF MAINTENANCE

## a. SETTING UP ROUTINES AND FAULT REPORTING SYSTEMS

**Is maintenance and repair of hospital equipment a problem at your hospital?**

The breakdown of a piece of equipment is inconvenient to us and can put our patients' lives at risk. The result is frustration and stress.

Sometimes a breakdown is inevitable or a repair is delayed because a spare part is not available or an expert is required to identify and repair the fault.

### **Is maintenance of equipment a problem at your hospital?**

- is care of patients affected?
- does it cause frustration to staff?
- does it endanger patients?
- how long does it take to get equipment repaired?

**If maintenance is a problem, what is the cause?**

Every hospital has some kind of system by which broken or faulty equipment is repaired. But it is not always efficient.

**There may be several reasons for this. It may be that:**

- the hospital has outgrown the system
- the policy has been changed
- newly appointed staff have not been adequately briefed
- simple repair jobs are sent away unnecessarily
- repaired items are not collected promptly
- a fault is not reported even when identified

### **What is the maintenance problem?**

- do you have a maintenance system?
- do all staff members know to whom to report equipment faults?
- is there a staff member trained in maintenance and repair of equipment?
- who decides when an item needs to be sent away for repair?
- are there spares available?
- if so, does everyone know where spares are kept?

## **Should something be done about the problem?**

The problem may have one or more causes but is it a priority?

All hospital services, especially those which affect treatment and welfare of patients, should be reviewed on a regular basis. Where a problem is identified, it should have priority.

### **Does your hospital need to change its system of equipment maintenance?**

- is the problem a serious one?
- how does the problem compare with others?
- is there an easy solution to it?

If maintenance of equipment is a problem, two routine procedures can reduce the number of times equipment breaks down and the length of time it takes to get it into service again. They are:

- correct and careful operation of equipment by all users
- an efficient fault-reporting and simple repair service within the hospital itself

### **How can the use, maintenance and repair of hospital equipment be improved?**

Whether or not you think the use, maintenance and repair of hospital equipment is a problem in your hospital or health centre, the topic should be discussed at regular intervals with all those involved. In this way, any problem which does arise can be dealt with at an early stage.

When a problem is identified, it should be discussed and a plan for change agreed upon. The solution should include targets to be reached by certain dates (e.g. equipment will be repaired within a specific number of days from the time of fault reporting), making individuals responsible for action.

Every action taken should be *recorded* and each step of the system monitored. Performance can then be reviewed regularly and new standards set if necessary.

### **How to improve the use, maintenance and repair of equipment:**

- put the subject on the management agenda
- identify the problem(s)
- plan change to solve the problem
- set targets and dates
- implement change
- supervise and monitor the changed system
- report back and review
- re-set targets if necessary

### **Why keep records?**

When a record is kept of each stage of this procedure and its outcome, it enables:

- ward/department staff to follow up the process of repair of their equipment
- an identified staff member responsible for maintenance to monitor the repair process and account for the piece of equipment at any stage
- management to set and monitor the attainment of targets
- management to produce monthly and quarterly reports on the efficiency of the system
- management to review the maintenance and repair system at regular intervals and to identify any problems with it

### **Communication**

Good communication is an essential element of good management and is of great importance in the management of change. First, the management team must be involved and then all members of the hospital staff.

*The following steps should be taken:*

1. Clarify the problem: Identify with the management team just what the problem is. Consult with them. Get colleagues to state how they see the present system; what difficulties they have with getting equipment repaired; the life-span of a piece of equipment. Are items frequently out of service and, if so, why? What are their solutions to the problem?
2. Gain the co-operation of all those affected: All staff members are affected by change. Persuade people to speak freely, listen to them and give credit to the ideas expressed. Lead meetings effectively.
3. Transmit the decision to bring about change: The more staff you involve in making change, the fewer problems you will have in implementing it. Plan how to communicate the proposed new system and gain the co-operation which you require from all your staff to make it a success.
4. Motivate people to carry out the change: Tell staff members what you expect of them. Show them how their personal objectives (good care and safe, effective treatment of their patients) are related to the proposed change.

5. Evaluate the impact of your communication: Assess the effectiveness of meetings. Are people discussing among themselves? Do all staff members understand their own contributions to making the new system work? Do they understand and have they accepted the responsibilities of the newly authorised maintenance staff member as suggested below? Has the care and safety of equipment taken on a new importance throughout your hospital?

### **A suggested model for an effective maintenance and repair system**

You may have a maintenance and repair system which is very simple. For example, from a field-test of the first chapters of this book, we learned of one hospital in which the ward or departmental staff reported the equipment breakdown or fault to the matron, who filled in a repair request and sent it to the storeman who assigned a hospital handyman to repair the fault immediately. In a small hospital with a limited amount of equipment, this simple practice can work well.

From other responses to the field-test, we learned that often there is no system and staff rely on a village handyman or have to send the faulty equipment hundreds of kilometres away for repair. Others reported long delays between fault-reporting and fault-repairing or confusion regarding the person who was responsible for maintenance and repair in their hospitals. If this is close to your own situation, then our suggested model for a maintenance and repair system may be used either to adapt or to replace your existing one.

The majority of hospitals have one person on the management team who is responsible for the maintenance of the hospital's equipment. In our suggested model he or she identifies someone on the hospital staff to be responsible for organising the maintenance of equipment – the title of the person identified will be Maintenance Officer. This will be someone who is literate – such as a nurse or a laboratory technician. This person reports to the management team.

A second staff member is appointed as Maintenance Staff Member. He or she is likely to be a driver, an electrician or a handyman and may be illiterate. He or she reports to the Maintenance Officer.

Both the Maintenance Officer and the Maintenance Staff Member are trained into the job gradually and their responsibilities are increased as their skills and knowledge grow. The Maintenance Officer trains the Maintenance Staff Member and the Maintenance Staff Member trains small user groups in the proper use of equipment. Care should be taken with respect to clinical and technical relationships in appointment and training of personnel.

### **When a piece of equipment breaks down or develops a fault, the following procedure is initiated:**

1. The ward or departmental staff member reports the need for a repair to be carried out using Form A (Figure 1) from the Fault Report Ledger. Part (a) is kept on the ward or department and Part (b) is sent to the Maintenance Officer.
2. The Maintenance Officer allocates the repair job an identification number and records this on Form B (Figure 2).



3. The Maintenance Officer sends the Maintenance Staff Member to view the equipment to assess whether it can be repaired by him in the hospital or it needs to be sent away for repair.
4. The Maintenance Staff Member reports back to the Maintenance Officer and deadlines may be set for the repair.
5. If it affects the treatment of patients, the Maintenance Officer informs the appropriate member of management (e.g. Matron or Chief Clinical Officer) that the equipment is out of service.
6. If the repair can be carried out in the hospital the Maintenance Officer organises the purchase of any spare parts required and supervises the work undertaken by the Maintenance Staff Member.
7. If the work cannot be done in-house, the Maintenance Officer arranges for the equipment to be sent away for expert repair.

**Form A Fault Record**  
**Sample page from Fault Report Ledger**

**Part (a)** To be kept on Ward or Department

|               |  |
|---------------|--|
| Date:         |  |
| Equipment:    |  |
| Problem:      |  |
| Action taken: |  |

**Part (b)** To be sent to Maintenance Officer  
 To be filled in by Ward/Departmental staff member

|                  |  |
|------------------|--|
| Date:            |  |
| Equipment:       |  |
| Problem:         |  |
| Department/Ward: |  |
| Signature:       |  |

**Part (c)** To be filled in by Maintenance Officer

|                      |  |
|----------------------|--|
| Date received:       |  |
| Identification No:   |  |
| Problem:             |  |
| Action taken:        |  |
| Follow-up:           |  |
| Date returned:       |  |
| Cost of repair:      |  |
| Maintenance Officer: |  |
| Signature:           |  |

**Figure 1:** Fault reporting documentation

**Form B Repair Record**  
 (Sample page from Repair Report Ledger or File)  
 To be kept by the Maintenance Officer

Sheet No: \_\_\_\_\_

| No:     | Date Received | Ward/<br>Department | Equipment | Problem | Action taken/<br>Date | Follow-up/Remarks<br>Cost of repair | Date<br>returned<br>to ward |
|---------|---------------|---------------------|-----------|---------|-----------------------|-------------------------------------|-----------------------------|
| .....1  |               |                     |           |         |                       |                                     |                             |
| .....2  |               |                     |           |         |                       |                                     |                             |
| .....3  |               |                     |           |         |                       |                                     |                             |
| .....4  |               |                     |           |         |                       |                                     |                             |
| .....5  |               |                     |           |         |                       |                                     |                             |
| .....6  |               |                     |           |         |                       |                                     |                             |
| .....7  |               |                     |           |         |                       |                                     |                             |
| .....8  |               |                     |           |         |                       |                                     |                             |
| .....9  |               |                     |           |         |                       |                                     |                             |
| .....10 |               |                     |           |         |                       |                                     |                             |

**Figure 2:** Repair documentation

### **Example of setting up a maintenance and repair system.**

- 1.** Identify a member of staff to be Maintenance Officer. He or she will be responsible for:
  - the maintenance of all hospital equipment
  - keeping records of all breakages and faults which occur
  - organising the repair (and, where necessary, the collection) of the broken or faulty equipment
  - reporting to the management team
  
- 2.** Train a member of staff to be Maintenance Staff Member. He or she will be responsible for:
  - providing a maintenance service for all hospital equipment
  - assessing broken or faulty equipment
  - undertaking simple repairs within carefully prescribed circumstances
  - reporting back on assessments and repairs to the Maintenance Officer
  - training user groups in proper and safe use of equipment when possible
  
- 3.** Set up a reporting system by which:
  - all breakages and faults are reported to the Maintenance Officer
  - all breakages and faults are assessed by the Maintenance Staff Member
  - all breakages and faults are repaired or sent for repair
  
- 4.** Monitor the maintenance and repair system by:
  - agreeing targets and dates
  - checking records at regular intervals
  - reviewing targets if necessary
  - reporting back to the management team

In addition to trouble-shooting periodical maintenance is an essential component of the system. All hospital equipment requires regular inspection and maintenance. Faults and breakdowns occur from various causes. Some hospitals have hard water and mineral deposits (furring) which can result in damage or delay in the heating mechanism of equipment. In others, high temperatures may affect machinery and equipment. Depending upon the type of equipment and the suppliers' instructions, checks for faults and assessments of good working order should be undertaken either weekly or monthly or quarterly or yearly and recorded on Form C (Figure 3).

After the appropriate standards and intervals are agreed, the routine maintenance of all hospital equipment is carried out and recorded by the Maintenance Staff Member under the supervision of the Maintenance Officer. Records may be kept in a ledger or in a loose-leaf folder.

**Form C Maintenance Schedule**

**Weekly Maintenance**

| ITEM | Ward/Department | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 |
|------|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |
|      |                 |        |        |        |        |        |        |        |        |        |         |

**Monthly Maintenance**

| ITEM | Ward/Department | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 | Month 7 | Month 8 | Month 9 | Month 10 |
|------|-----------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |
|      |                 |         |         |         |         |         |         |         |         |         |          |

**Figure 3:** Maintenance documentation – date and signature to be entered in the relevant box each week/month

**b. IDENTIFYING INDIVIDUALS TO TAKE RESPONSIBILITY FOR THE MAINTENANCE AND REPAIR SYSTEM**

In hospitals throughout the developing world there are members of staff whose jobs do not reflect their level of education and who may be literate and possess the level of reliability, responsibility and technical aptitude suitable for the job of Maintenance Staff Member. Alternatively, potential candidates for maintenance posts may be illiterate, but still fulfil the other requirements for the job.

The kinds of existing posts where staff, men or women, do practical work with their hands and may already be informally involved in mending equipment and machinery include odd job personnel, drivers and electricians. These and other similar employees may be suitable candidates to assess for the role of Maintenance Staff Member.

To begin with, the amount of work may not require a full-time person and the employee may work part-time in both maintenance and his/her old job if time permits. Maintenance responsibility may be added over time as training progresses and higher levels of skill and knowledge are obtained.

In hospitals where there has been no formal maintenance and repair system, the proposed appointment of a Maintenance Officer and Maintenance Staff Member will need to be talked through with all members of staff, but most especially with those who have been doing their best to keep equipment in working order to date. They must be part of the new order and not displaced by it. It may require great diplomatic handling to persuade them that additional training will improve their knowledge and skills. If they have kept rigidly within their own trade boundary, it may be difficult for them to entertain the idea of becoming maintenance generalists. The notion of cross-over skills will need to be explained and discussed and the offer of appropriate incentives, including the increase in prestige, will be important considerations.

*The following steps should be taken:*

1. Discuss selection criteria (common sense, reliability, technical aptitude, interest, acceptance by colleagues) with other members of the management team.
2. Agree incentives to be offered.
3. Make sure that the proposed appointee is interested in the job, understands the responsibilities which go with it and is well motivated.
4. Inform all staff members of the appointment and of the responsibilities of the Maintenance Staff Member. Remind them of their own responsibilities in relation to the proper use and maintenance of equipment.
5. Outline the training programmes for the Maintenance Staff Member and the users. Answer questions and encourage discussion.
6. Give support, encouragement and be accessible for discussion with and feedback from all members of staff.

7. Discuss feedback with management team.
8. Revise, change or adapt system if necessary as agreed after appropriate consultation.

**c.      SETTING UP AN INVENTORY**

One of the first tasks when setting up a care and safety system is to make an inventory of all equipment in the hospital (and any other buildings for which the management team is responsible).

*The following steps should be taken:*

1. Repeat the main points of the system to all members of staff.
2. Answer any questions and allow time for discussion.
3. Explain the responsibility of each member of staff in relation to care of equipment and fault-reporting.
4. Request the head of each unit (ward, department, laboratory, classroom, store) to list and number all items of equipment and to group them by approximate age, type and functional status (whether usable or not usable).
5. Request the head of each unit to list the breakdown and maintenance problems for each item of equipment.
6. The Maintenance Officer will now have some valuable information to analyse from which he or she will be able to identify:
  - redundant or surplus items of equipment
  - the scope and extent of the job to be done
  - the training in use and maintenance which needs to be given to staff
  - the training the Maintenance Staff Member will need
  - the number of hours per week which the Maintenance Staff Member will need to work on maintenance

The result of each inventory, combined with the standardisation of equipment (when possible) should also form the basis for future purchasing and acceptance or rejection of gifts of equipment.

#### **d. TRAINING PERSONNEL**

In our example of an effective maintenance and repair system, we suggest that an untrained staff member is trained to be responsible for the maintenance and repair of equipment. Thus the Maintenance Officer, responsible for reporting to management after receiving appropriate training, trains the Maintenance Staff Member.

This training may be given in a number of ways, including on-the-job or in-service training, practical instruction in the form of demonstrations with reference to this book and other appropriate publications, and attendance at training courses or repair centres to observe skilled technicians at work. In time, it may be possible to send the Maintenance Staff Member to a short full-time course, either locally or in another country. Currently, relevant courses are being run in a number of countries, including Cyprus, El Salvador, France, Jordan, Kenya, Peru and Scotland. The prospect of such training could act as an incentive, a reward and recognition of achievement of higher levels of skills. A joint programme arranged with another hospital or 'twinning' are other possibilities.

Whatever the approach to training, it is vital to motivate both the Maintenance Staff Member and clinical staff whose co-operation is required in reporting faults and using equipment correctly.

#### **How to train the Maintenance Staff Member**

A common problem in rural and district hospitals is a lack of personnel with training skills. Even if the hospital has training personnel, they may confine their work to training clinicians and be unwilling to train maintenance staff.

We have identified the Maintenance Officer as the person responsible for training the Maintenance Staff Member, who may be illiterate. The Maintenance Officer will be literate and can refer to this book and other training manuals but he or she may not have training skills. If this is the case, the following guidelines on organising a training session or a practical demonstration may be useful as a starting point. For further guidance, refer to the training literature listed at the end of this book (Selected Bibliography).

It is important to remember that you are teaching an adult. Adults tend only to be interested in learning what they consider to be useful. Adults expect to be treated as equals. Once they have made the decision to learn, they can be strongly motivated. It is the responsibility of the trainer to encourage that motivation.

#### **Adults will tend to respond positively if:**

- they know the purpose of the training session
- they become involved in the learning process
- they are encouraged to give feedback

It is necessary to explain the objectives of each session (what they should be able to do at the end of a learning session that they could not do beforehand) and why it is important to them. Involve them in the learning process by encouraging them to ask questions and to relate the lesson or demonstration to their work.



## **Planning a training session**

The majority of training in relation to maintenance and repair of equipment is likely to take the form of a demonstration. Practical demonstrations are useful to show what needs to be done and the order in which to do it. Demonstrations are also useful when a task is complicated and difficult to describe.

*The following steps should be taken:*

### **1. Preparation:**

Establish the objective of the session: what the Maintenance Staff Member should be able to do at the end of the session that he or she could not do beforehand

Plan the demonstration to be simple and short

Collect all the equipment and materials you will need

Make brief notes if necessary

Have a trial run

### **2. Introduce the session to the Maintenance Staff Member by covering the following points:**

What he or she will be doing

Why he or she will be doing it (its relevance to the Maintenance Staff Member's work)

How he or she will be doing it

Safety aspects of the task

Ask the Maintenance Staff Member questions to check that you have been understood

Invite the Maintenance Staff Member to ask you questions

### **3. State the objective of the session:**

'By the end of the session you will be able to (e.g. wire a plug)'

### **4. Demonstration:**

Conduct the demonstration at normal speed with the Maintenance Staff Member watching

Conduct the demonstration slowly, this time explaining what is being done and identifying each part. The Maintenance Staff Member watches and listens

Conduct the demonstration at normal speed again with the Maintenance Staff Member watching

Allow the Maintenance Staff Member to repeat the task you have demonstrated while you watch

Ask the Maintenance Staff Member questions as he or she works (e.g. why is it necessary to do it this way?)

### **5. Evaluate the work of the Maintenance Staff Member:**

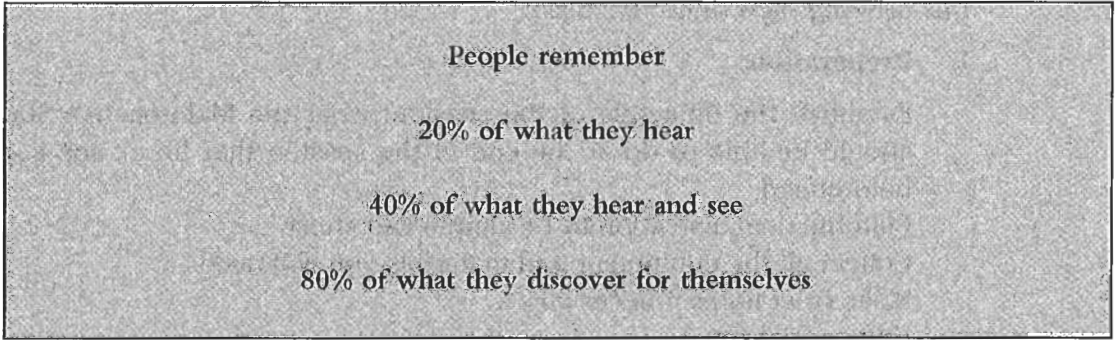
Did the Maintenance Staff Member repeat the task correctly?

Did the Maintenance Staff Member ask questions which confirm that he or she understands the task?

## 6. Consolidate what has been learnt:

Repeat the main points of the session and identify component parts of the item of equipment

Motivate the Maintenance Staff Member to take pride in his/her new job so that he or she sees it as being a promotion



The same sort of session plan could be used by the Maintenance Staff Member when he or she trains users to use equipment correctly and safely.

## e. SAFETY ASPECTS: ETHICAL AND LEGAL RESPONSIBILITIES

As the law differs from country to country it is almost impossible to be precise about who will be liable and for what should anything go wrong with equipment. This chapter is, therefore, a summary of the principles which are likely to apply. All legal systems contain similar ideas about what types of activity and wrongdoing give rise to claims for damages but the legal principles and bases for claims may differ and there will also be important differences of detail. If any accident does happen, it is essential that you check on what the law is in the country where the accident occurred.

There are two potential areas of legal liability, criminal and civil. Criminal liability is less likely but it is just possible that it might be a crime for a supplier to supply equipment which is unsafe. Alternatively, a repairer who has done a repair so negligently that the equipment injures someone might conceivably, under some legal systems, be treated as having committed a crime. There was a case in England of a contractor who negligently connected the earth for the electrical circuit to a metal pipe and was prosecuted for manslaughter when the householder was killed by a massive electrical shock. Criminal liability will be established by a form of prosecution. If the wrongdoer is found guilty, he or she may be fined or imprisoned, depending on the severity of the offence. However, a conviction is unlikely to give rise to an automatic right to compensation to any person who has been injured.

To obtain compensation or damages, an injured person will use the civil law. The legal systems of many European countries have civil systems of setting out rights to compensation in their civil codes. Common law systems, as in England, Australia or America, also give rights to claim compensation by case law or statute (Acts of the legislative body). Under case law, a wrongdoer will be held liable to pay damages if it can be shown that a duty of care was owed to the injured person, that this duty was broken (by the negligent activity), and that the breach of duty, or negligence, caused the injury or damage.

Under this principle a supplier, or a repairer, of equipment will be liable to pay damages (compensation) to someone who has been injured by faulty equipment, or equipment which has been poorly maintained, or by equipment which has not been maintained at all. The civil system imposes a duty of care on suppliers, manufacturers and repairers of products to exercise reasonable care, in other words, not to be negligent when making or repairing products. This duty extends to anyone whom the supplier or contractor could have foreseen would be affected (in other words, injured) by the negligence. Under this same principle, hospitals and doctors owe duties of care to their patients and, in some instances, to visitors of the hospital. Similarly, employers owe duties of care to their employees and owners and occupiers of premises have responsibility to visitors to their premises.

In the special instance of liability for medical equipment, the duty of care imposed on a manufacturer, or supplier, or repairer, would extend to patients, employees of the hospital or the medical establishment, and to people whom one might expect to be in the vicinity, like visitors or contractors. If someone is injured by faulty or poorly maintained equipment, for example if the equipment explodes, then that injured person has a right to claim damages against the negligent supplier or repairer, depending on who actually caused the injury. Equally, if someone fails to recover, or their condition gets worse, because equipment did not work as well as it should have, perhaps because it had not been maintained, then damages can be claimed. Damages will compensate for injuries, pain and suffering, and loss of earnings experienced by the injured person.

The person suing (the plaintiff) will have to show that the injury was caused by the negligence or wrongdoing. This can sometimes be difficult because accidents can have a number of causes – people causes, as well as equipment failure. Identifying and separating the causes and placing responsibility on the supplier or repairer can be time-consuming, difficult and expensive.

Medical establishments, such as hospitals, have further responsibilities. As employers, they will have responsibilities towards their employees to provide a safe place to work and safe equipment. If an employee is injured by poorly maintained equipment, then the employee would be able to sue the hospital, because the employer is in breach of its duty of care to its employees. If a patient is injured because a hospital employee negligently maintained the equipment, then the hospital is liable 'vicariously' for the employee's negligence.

Hospitals also owe an individual duty of care to their patients to provide a proper system of care. This would include using proper equipment and maintaining existing equipment. If a patient or visitor is injured by poorly maintained equipment, then the hospital will be liable to pay damages, as well as the repairer or supplier, since the hospital will be in breach of its duty to its patient. A hospital could also be liable for damages if it employs as a repairer someone it knows, or ought to have known, is a careless or sloppy maintenance contractor if that contractor's negligence causes injury. It follows that the maintenance system outlined in this book is a means by which the hospital can fulfil its duty to maintain equipment. **The work of individuals carrying out tasks within that system must be supervised in an appropriate manner.**

All this means that an injured person often has a choice of whom to sue. In practice, plaintiffs choose to sue the individual or organisation in the best position to pay compensation. Rather than sue an employee for negligence, it is more likely that the hospital, as the employer, or the repairer, or supplier, if insured, will be sued for negligence. Whichever party is found liable may have a claim indemnified by one of the other wrongdoers.

In England, there are Acts of Parliament which impose obligations on suppliers, as well as case law. Under the sale of goods legislation, sellers have duties to supply goods which are of merchantable quality and fit for their purpose. If the products supplied are defective, then the seller will be liable to pay damages to the injured party.

Under other consumer protection legislation which comes out of a European Union (EU) Directive, and therefore applies to all EU countries, if someone is injured by a defect in a product, then everyone in the supply chain – the producer, importer, manufacturer, component manufacturer, and so on – is liable. This is an important piece of legislation but it will not necessarily apply to non EU countries. One word of warning, though, which is particularly relevant to medical equipment: state-of-the-art, or very new, equipment can often produce unexpected problems despite field testing. There is a specific defence for suppliers in this case which covers development risks. The essence of the defence is that given the state of scientific or technical knowledge when the product was made, tested and put on the market, if the producer could not have known that there was a defect, then the producer will have a defence to a claim for damages.

For a supplier or repairer of medical equipment, the risks and responsibilities are considerable and the consequences, if someone is injured, are likely to be severe. If it can be shown that reasonable care was taken to prevent injury and to make, or maintain safe equipment, then there should be no legal liability. Generally, apart from the EU legislation already mentioned, the standard is one of reasonable, and not absolute, care. However, the courts do interpret this notion of standard of care flexibly. The greater the risk of injury, the higher the standard of care the contractor will be expected to show. Consequently, **it is essential that maintenance personnel are properly trained and that proper equipment maintenance records are kept.**

In many countries, it is a legal requirement that on each occasion before equipment is used the operator completes a checklist on the condition of major items of equipment, such as ventilators or anaesthetic machines. These records are normally completed by the doctor on appropriate forms. The maintenance records should contain equivalent information.

Most medical equipment requires maintenance at two different levels.

1. User maintenance to keep the equipment in working order on a day-to-day basis, perhaps with the replacement of readily accessible spare parts, such as filters or seals. **These activities are normally described in the User's Manual which is an essential part of the equipment.**

2. Technical maintenance, carried out by skilled, trained engineers, which may require dismantling of the equipment to replace worn or failed parts. In most cases these parts are specific to the manufacturer. **These activities are normally described in the Service Manual which should be supplied with each machine.**

Most manufacturers state that all responsibility for the safe functioning of equipment passes to the person or organisation carrying out technical maintenance unless they have been specifically trained for this work by the manufacturer and authentic spare parts are used.

Most of the chapters in this book cover the general principles of user maintenance for various types of medical equipment. However, simple maintenance procedures, which can be carried out locally using locally-trained personnel, are also described.

For some equipment, such as oxygen concentrators and baby incubators, the boundary between user maintenance and technical maintenance is clearly stated in the appropriate chapter. For other equipment, such as the blood pressure manometers, the book describes technical maintenance procedures which are comparatively simple to carry out and which must be checked for effectiveness before subsequent use. Clearly, how far you go in carrying out maintenance has to be a matter for local decision in the light of the information about legal liabilities given in this chapter.



## **2. NEW EQUIPMENT**

### **a. PURCHASE OF NEW EQUIPMENT**

Before purchasing a piece of equipment, several factors should be considered which means asking yourself and your colleagues a number of questions.

#### **1. Uniformity:**

Does the equipment you are proposing to buy match equipment which is already being used locally? Nationally? If so, has it proved to be good?

#### **2. Sustainability:**

How expensive are replacements, spares and consumables? Will replacement parts be available for a reasonable time in the future? Is the equipment covered by a guarantee or service agreement?

How easily can replacement parts be obtained? Does a local agent supply them?

#### **3. Technical complexity:**

How easy is the equipment to maintain?

Is special test equipment needed?

Can hospital staff be trained to maintain the equipment? Does it need outside expertise?

Are special tools required to carry out maintenance or adjustments?

Does it have many accessories which are expensive and are unlikely to be used?

How easy is the equipment to use?

Is a more 'user friendly' and less technical piece of equipment available which will do the job just as well?

#### **4. Training requirements:**

Can staff be trained locally to use the equipment?

Does the equipment come with training, service and installation manuals? If so, in what language are they written?

Does the manufacturer or agent offer a training programme in the use of the equipment?

#### **5. Safety:**

What risks or dangers are associated with this piece of equipment?

Will costly building alterations or services be required to accommodate the equipment? (e.g. radiation protection, sterile water supply, stable electrical supply, air conditioning)

Will there be a need for special protective clothing for the users?

#### **6. Durability and robustness:**

Will the equipment stand up to the local conditions (e.g. temperature, humidity, drought, dust)? Manufacturers should be able to supply relevant records if requested to do so.

## **7. Cost:**

Do not buy the cheapest just because it is the cheapest. The most expensive design or make may be cheaper in the long term. BUY EQUIPMENT BEST SUITED TO YOUR HOSPITAL'S NEEDS.

## **8. Specifications:**

If requested to do so, the World Health Organisation (WHO) will confirm whether or not the equipment you are proposing to buy meets their standards.

**For example, the WHO specification for small oxygen concentrators can be summarised as follows:**

- it must meet the standard of the International Organisation for Standardisation (ISO)
- it must be capable of functioning under difficult conditions including ambient temperatures up to 40°C, relative humidity up to 100%, unstable mains voltage and dusty environments
- it must pass 'military standard' shock, vibration and corrosion tests
- it must be 'incapable' of delivering an oxygen concentration of less than 70%
- it must be supplied with a comprehensive user manual
- it must be supplied with a comprehensive service manual
- it must be supplied with replacement spares for two years

Obviously, buying equipment of such a standard will be more appropriate and cost-effective than buying equipment likely to require frequent attention from trained electro-medical engineering teams.

## **9. Purchase of spare parts:**

Sometimes it is difficult to order a spare part because it has no code number stamped or printed on it. If this is so, send as much information as possible by:

- drawing a diagram of the item you need, giving accurate measurements
- taking a photograph of the item from as many angles as possible (in some instances you may be able to photocopy it)
- making a note of any distinguishing marks
- stating what machine the item is for
- giving details of the machine (these are usually stamped on a plate fixed to the back of a machine). Such details are likely to include the country where the machine was made, machine serial number, voltage, amperes, date of manufacture and machine model number. Without adequate information the supplier may send the wrong spare part.



## **b. CHECKING NEW EQUIPMENT**

All equipment – whether new or second hand – should be accepted into your hospital only *after* specific checks and tests have been carried out and found to be satisfactory.

The equipment should be delivered to the purchasing officer, maintenance engineer (or officer), Maintenance Officer, Maintenance Staff Member, and a user representative. Together they should:

1. Undertake a site inspection to confirm that necessary services (water supply, drainage, electricity supply) are available.
2. Check the delivery note.
3. Keep all packaging materials, in case the equipment needs to be transported again.
4. Check the contents against the delivery note. Make certain any promised spare parts are included, and that the manufacturer's instructions are provided.
5. Check that the serial number on the outside of the package, if any, matches the actual serial number.
6. Check equipment for damage.
7. Report any omissions or damage to the supplier as soon as possible. Register the guarantee if appropriate.
8. Check plug, fuses and earthing.
9. Check the flexible lead complies with the standard national colour code (electrical engineer should check).
10. Include the item on the hospital's equipment register, giving it a serial number.
11. Check that the proposed siting is dry, clean, well ventilated, out of direct sunlight etc.
12. Fit the equipment.
13. Carry out test runs of the equipment. The Maintenance Officer should be present.
14. Organise staff training for Maintenance Officer and users of the equipment.
15. Put equipment into use.



### 3. BASIC TOOL KIT FOR FIRST LINE MAINTENANCE

The tool kit for first line maintenance should be kept very simple to discourage any attempt to undertake repairs outside the capabilities of local staff. As training and expertise increase the tool kit requirements should be reviewed and added to as appropriate. Always purchase the best quality tools if possible.

The tools required to enable maintenance to be carried out as outlined in this publication are as follows:

|                            |                       |       |
|----------------------------|-----------------------|-------|
| Allen keys                 | 2 – 10mm              | 1 set |
| Brush (paint, flat)        | 25 mm                 | 3     |
| Brush (paint, round)       | 2 cm diameter         | 3     |
| Funnel (plastic)           | 100 mm diameter       | 2     |
| Grease gun                 |                       | 1     |
| Hammer (claw)              | 450gm                 | 1     |
| Hammer (plastic/leather)   | 280mm                 | 1     |
| Knife (retractable)        |                       | 1     |
| Knife blades               |                       | 1 set |
| Oil can                    |                       | 1     |
| Pliers (slip, joint)       | 24mm – 2 position     | 1     |
| Pliers (water pump)        | 25mm – 5 position     | 1     |
| Pliers (combination)       | 125mm insulated       | 1     |
| Pliers (longnose)          | 125mm insulated       | 1     |
| Plier cutters              | 125mm insulated       | 1     |
| Screwdrivers (flat)        | 3.2 – 8mm insulated   | 1 set |
| Screwdrivers (star)        | No.0 – No.3 insulated | 1 set |
| Spanners (flat)            | 9mm – 22mm            | 1 set |
| Spanners (ring)            | 9mm – 26mm            | 1 set |
| Tape measure (retractable) | 3 metres              | 1     |
| Tool box (lockable)        | Steel                 | 1     |

Special tools are required for the mercury blood pressure machine.

#### **The following security considerations are important:**

- make sure it is clear who is responsible for the tools
- ensure that all tools are returned to the tool box at the end of the working day
- draw up a check list of all tools in the kit
- carry out tool checks regularly
- never leave tools unattended
- never lend tools
- keep the tool box locked and stored in a secure place



**PART II**

**GUIDELINES FOR THE  
CARE AND SAFE USE  
OF  
HOSPITAL EQUIPMENT**



## 4. GENERAL PRINCIPLES OF MAINTAINING ELECTRICAL EQUIPMENT

Three main factors need to be considered when maintaining electrical equipment:

- the equipment is safe to use
- the equipment works correctly and efficiently when required
- the user fully understands how the equipment works and knows its limitations

### 1. Safety

If it is misused or poorly maintained, electrical equipment can be the cause of death and fire.

If it is well maintained, electrical equipment can save life, improve the quality of lives and reduce capital expenditure.

Electrical equipment should always be treated with respect. Manufacturer's instructions must be provided with every piece of equipment; if they are missing, contact the supplier.

The following are simple maintenance instructions:


#### *Socket outlets and plugs*

Because there are many different electrical socket outlets and plugs in use throughout the world, it is essential that the following questions are considered in relation to any new piece of equipment (Figure 4).

- Is there a convenient socket outlet available?

Long flexible leads are dangerous and leads should be as short as possible. Socket outlets should be at least 2m from a sink or wash-hand basin, and NEVER IN A BATHROOM OR SHOWER ROOM.

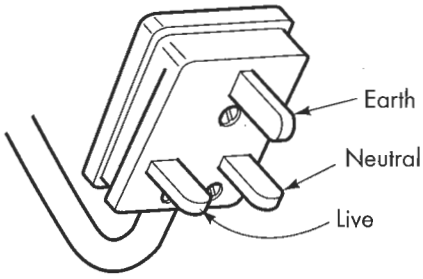
- Has the socket outlet an adequate electrical capacity for the equipment?
- Does the equipment need to be earthed/grounded?

This will depend on the type of equipment being used. If it has only two wires in the power cable and/or the 'box within a box' symbol , no earth connection is needed.

As a general guide, if the flexible cable fitted to the equipment has three conductors then the equipment needs to be earthed. If the lid of the equipment can be removed easily, the earth wire is connected to the case. In many places, a good earth/ground is not available and equipment which does not need an earth is preferable.

- Does the plug match the socket outlet?

### United Kingdom



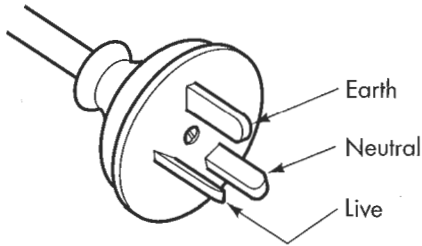
Green/Yellow

13 Amp/250 V ac

Light Blue

Brown

### Australia/New Zealand



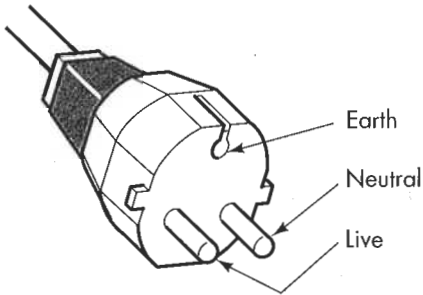
Green/Yellow

15 Amp/250 V ac

Light Blue or Black

Light Brown or Red

### Europe/Saudi Arabia



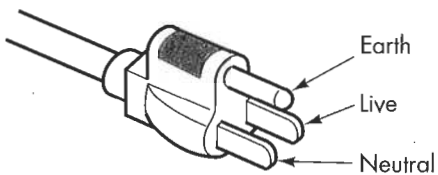
Green/Yellow

16 Amp/250 V ac

Light Blue

Brown

### USA/Canada



Green/Yellow or Green

15 Amp/125 V ac

Brown or Black

Light Blue or White

**Figure 4:** Examples of plugs and associated cable colour codes



Always ensure that the correct plug has been fitted to match the socket outlet. Makeshift arrangements are dangerous.

### *Flexible cables and extension cords*

Different colours identify conductors. These may vary by country.

#### **For example a machine from the USA will have:**

- a brown or black cable which is the live conductor
- a green/yellow cable which is the earth conductor, and
- a light blue or white cable which is the neutral conductor

#### **And a machine from the UK will have:**

- a brown cable which is the live conductor
- a green/yellow cable which is the earth conductor
- a blue cable which is the neutral conductor

It is essential that the correct cable colours are identified and correctly connected to the plug (Figure 5).

## **2. Location of Equipment**

Careful consideration should always be given to the placing of equipment. Damp conditions should be avoided if possible, and, as a general rule, equipment should be positioned in a dry, clean, well ventilated area. It should stand on a solid, level base.

Equipment should always be as near as possible to the electrical supply: extension leads should be discouraged.

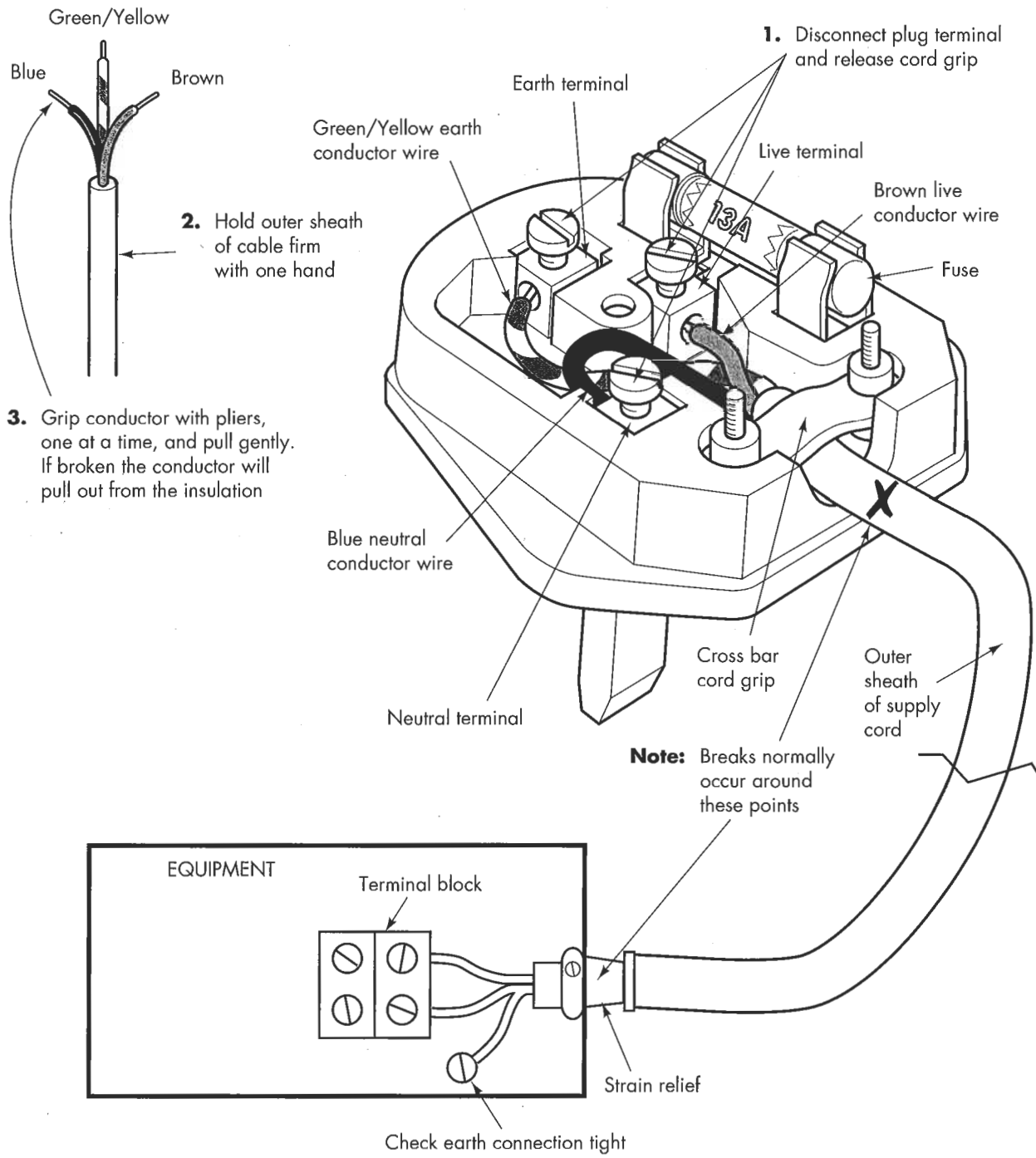
Working instructions and safety instructions should be clearly displayed on or near the equipment.

Maintenance and repair instructions should be kept by an assigned person in a designated place.

## **3. Training**

Staff expected to use the equipment either on a regular basis or occasionally should be given training on:

- how to use the equipment. They should also understand what is expected of the machine
- basic information on how the equipment works
- safety practices
- what action to take in the case of an emergency or if the machine does not function correctly
- how to take care of the equipment on a day-to-day basis



**Figure 5:** Checking mains lead for conductor break

Refresher training sessions should be carried out at regular intervals to ensure that the machine is being used correctly and good practices are maintained. Sufficient 'back up' staff should also be trained to cover illness, holidays and unforeseen staff shortages. It may be best for nurses to be 'back up' staff because they are more static than doctors.

### *Spares*

For a machine to fulfil its task, adequate spare parts should be held in store. Alternatively, a local supplier should be identified so that spares can be acquired quickly.

To help decide which is right for your hospital, answer the question: 'If a machine breaks down, how long will the machine be out of service if the spare parts are not held in store?'

### **The type and number of spares will depend on:**

- the level of technical maintenance expertise available to carry out repairs
- how often particular items are required
- cost of particular items
- whether spares are in the country or whether they have to be imported
- whether spares can be improvised or bought from a local generic source

It is important to keep a list of spare parts held in store. Adopt a re-ordering procedure as the spares are used, paying particular attention to the source of spares.

### *Voltage regulators*

Much modern electrical equipment is voltage sensitive and fluctuations in the electrical supply present a problem in many developing countries.

However, there are many voltage regulators and stabilisers on the market and although in some cases these are expensive, the cost should be judged against the cost of repair or replacement of parts or even the cost of a new machine.

Seek advice from the manufacturer or local experts if available.

**IF THERE IS ANY DOUBT REGARDING SAFETY A QUALIFIED ELECTRICAL ENGINEER SHOULD BE CONSULTED BEFORE ALLOWING EQUIPMENT TO BE MADE OPERATIONAL.**



## **5. CHECKING POWER SUPPLIES, SOCKETS, PLUGS AND SPARES**

If a machine fed from a socket outlet does not work, carry out the following simple procedures:

### **1. If the machine fails to operate when plugged into the socket outlet and switched on:**

- check whether the machine has a mains indicator lamp:

**if yes**

- is it glowing?

**if yes**

- the problem is in the machine

**if no**

- the problem is either at the socket outlet, or in the mains lead, or the indicator lamp has blown and maybe the machine has an internal fault.

### **2. Checking the socket outlet:**

- unplug the machine
- plug in an appliance that is known to be working and switch on
- if this appliance works, the problem is in the mains lead or the plug
- if the appliance does not work the mains socket outlet is not working

### **3. Checking the main circuit fuse or circuit breaker. If its location is not known, call in an electrician:**

The main circuit fuse or circuit breaker should only be replaced or re-set ONCE.

If it should blow for the second time the circuit itself is faulty and an electrician is needed.

Only replace the fuse with the same type and size. Fitting a larger sized fuse could lead to a fire. Fitting a smaller sized fuse will cause the fuse to blow either immediately or shortly after the machine has been re-started. If in doubt call an electrician.

The circuit breaker will not re-set if there is a standing fault in the circuit.

### **4. Checking the mains lead:**

See Figure 5.

### **5. Machine fault:**

The correction of machine faults should be carried out by trained staff only to the levels recommended for individual machines. Otherwise they should be returned to the workshop for expert repair or a repair person should be brought in.

## 6. Overloading the main circuit:

In order to prevent overloading the main circuit a simple calculation can be carried out if two of the following three facts are known:

- the amount of power the machine uses
- the amount of current which flows when the machine is switched on
- the machine's voltage

Usually this information is on the data plate fixed to the machine.

Power will be given as wattage or watts (W)

Current will be given in amperes or amps (A) (normally Alternating Current or AC)

Voltage will be described as voltage or volts (V)

### **Make calculations as follows:**

Number of watts divided by the number of amps = number of volts

or

Number of watts divided by number of volts = number of amps

or

Number of amps multiplied by number of volts = number of watts.

Direct Current (or DC) calculations are the same.

IT IS VERY IMPORTANT TO USE MACHINES ON THEIR DESIGNATED SUPPLY e.g. 240 VAC or 12 VDC.

If there is any doubt obtain expert advice before attempting to use the machine.

#### *Example 1:*

A machine is required to work from a 13amp socket outlet that works on 240 volts AC and the power requirement is 2000 watts:

2000 divided by 240 = 8.33 amps. It may be used.

#### *Example 2:*

A machine is required to work from a 15amp socket outlet that works on 240 volts AC and the power requirement is 4000 watts:

4000 divided by 240 = 16.6 amps. It may not be used.

## **7. Wiring plugs:**

Electrical equipment in hospitals may have come from different countries and therefore may not match the local electrical situation.

However, good practice is the same throughout the world and the method described in Figure 6 is a copy of the British Safety Council's recommendation for the British standard 13amp plug.

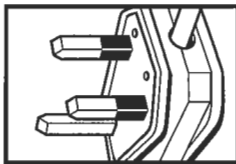
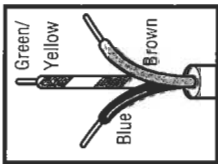
IN ADDITION ALWAYS MAKE SURE THAT THE EARTH WIRE IS LONGER THAN THE OTHER TWO SO THAT IF THE CABLE IS ACCIDENTALLY PULLED OUT OF THE PLUG, THE EARTH WIRE IS THE LAST WIRE TO BECOME DISCONNECTED.

It is very important when fitting a plug to a new piece of equipment to make sure that it is connected correctly. If it is not, the result can be an electric shock or fire.

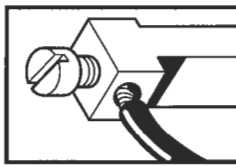
IF THERE IS ANY DOUBT WHATSOEVER, CONSULT A COMPETENT ELECTRICIAN.

## PLUGS

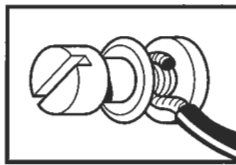
■ The wiring of a plug is colour coded for a very good reason, to help guard against electrical accidents. Remember to ensure that the brown wire goes to the live terminal; blue to neutral; and green/yellow to earth.



■ USE plugs with sleeved pins for extra protection.



■ NEVER tighten pillar terminal screws on to the insulation.



■ ALWAYS wind wire clockwise onto stud terminals to keep them secure.

## Always use the correct fuse

■ DIFFERENT appliances, whether in the work-place or in the home, require different fuses. When purchasing new electrical equipment, be it a computer terminal, a vacuum cleaner or even a basic desk lamp, always check with the manufacturer's instructions that you have installed the right fuse *before* operation. For equipment up to 720 watts, use a 3amp fuse; for over 720 watts, use a 13amp fuse. In addition, if you want to be sure that your equipment is safe, always buy fuses that are approved to BS1362.



## HOW TO WIRE A PLUG

- 1** START off by unscrewing the plug cover and removing the fuse.
- 2** NEXT, remove one of the cross-bar cord grip screws, and loosen the other.
- 3** USE wire strippers to cut away about 5 centimetres (2 inches) of the outer sheath of the supply cord, without cutting into the insulation around the conductor wires. Alternatively, using a sharp blade, cut down the sheath following the line of the green/yellow conductor. Pull the conductor wire through the slit and cut away the outer sheath.

- 4** REMOVE any iron solder on the ends of the wire strands.

- 5** LAY the flex onto the plug, ensuring that the outer sheath can be held by the cord grip. Position the conductors to their correct terminals: brown to live (L); blue to neutral (N); and green/yellow to earth (E). Cut the conductors to the right length, and strip off sufficient insulation to expose the wire strands. For pillar terminals, leave 6mm (0.25 inch), or 13mm (0.5 inch) for studs. Twist the strands of each wire together.

- 6** GUIDE the exposed wire into the terminals, right to the edge of the insulation. Then turn the screw down tightly onto the wire - not the insulation.

- 7** ENSURING that the coloured wires lie flat without sharp bends, fasten the cord grip firmly to the outer sheath of the flex. Screw it down gently, moving from one screw to the other.

- 8** GIVE the supply cord a sharp tug to make sure it is secure.

- 9** CHECK again that the conductors are connected to the right terminals and that there are no loose strands protruding.

- 10** PUT the correct fuse into place, and screw the two halves of the plug back together.

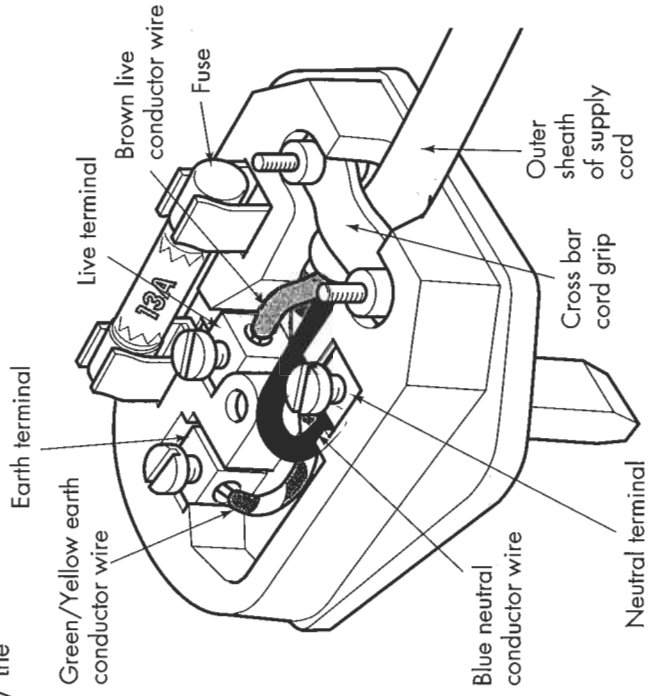


Figure 6: How to wire a plug



## 6. BATTERY MAINTENANCE

Lead acid batteries are used in hospitals to start vehicles and emergency generators or for lighting including mobile theatre lamps. They are also used as part of solar power systems.

It is essential that they are well maintained.

A lead acid battery should be stored in a cool (but not cold), clean, well ventilated place. (In some instances it will be kept where it will be used – for example, if it is a vehicle starter, it will be kept in the vehicle.)

### 1. Care of battery terminals

Battery terminals often become corroded. They should be cleaned as soon as this is noticed. Corrosion forms a white/green powder around the terminal. It will affect the efficiency of the battery. See Figure 7. A smear of vaseline (or similar substance) will minimize corrosion build-up.

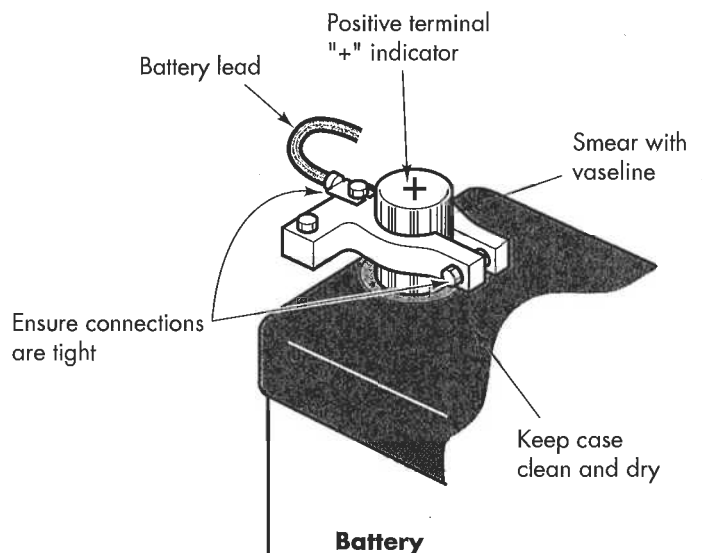
#### i. Before working on or near a battery:

- make sure you are well away from flames and lighted cigarettes
- wear eye protection and rubber gloves as sulphuric acid can burn
- remove metal wristwatches, necklaces etc as they may come into contact with battery acid and cause burns
- never smoke during work. The gases are volatile and inflammable
- always have a container of water nearby in case eyes or skin are affected. If this happens, soak in cold water and seek medical help at once.

Battery safety is illustrated in Figure 8.

The battery terminals often become corroded, this can be identified by the formation of a white or green powder around the terminal.

Once noticed it should be cleaned off as soon as possible as it will damage the termination and affect the performance of the battery.



**Figure 7:** Care of battery terminals

Batteries contain corrosive liquid. **Handle with care.**

**Always** keep battery cells upright.

**Do not** lift battery cells by the terminals.

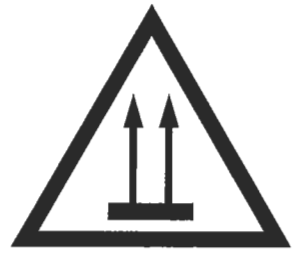
Use the carrying straps provided.

Batteries generate gases that can explode.

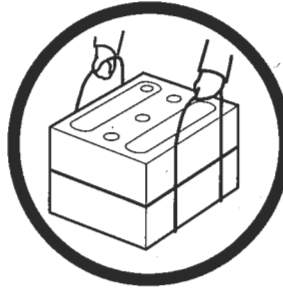
Keep naked flames away from batteries.

Remove all metal from hands, wrists, neck etc. before connecting or disconnecting batteries.

Keep the battery in a well ventilated place.



This way up



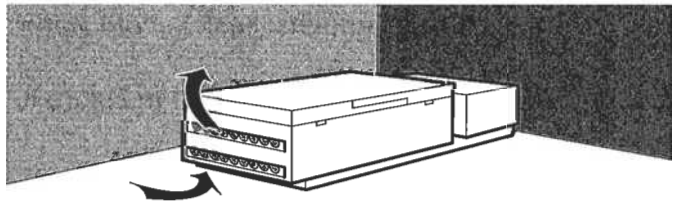
Use the carrying straps



No naked lights



No jewellery



Keep in a ventilated place

**Figure 8:** Battery safety

## ii. To clean a battery:

- disconnect terminal leads one at a time. **MAKE SURE THEY DO NOT COME INTO CONTACT WITH EACH OTHER UNTIL FREE FROM BATTERY.** Any contact with each other will produce a fierce electric arc which can cause burning
- keep battery upright
- remove battery to a suitable table or bench
- brush terminals gently with a wire brush until all powder has been removed. A little hot water is also very effective.
- brush connections on the battery leads until all powder has been removed
- **TREAT THE POWDER YOU HAVE REMOVED WITH GREAT CARE. DISPOSE OF IT CAREFULLY. CLEAN ALL SURFACES ON WHICH YOU HAVE BEEN WORKING.**
- coat terminals and connections with a light smear of vaseline

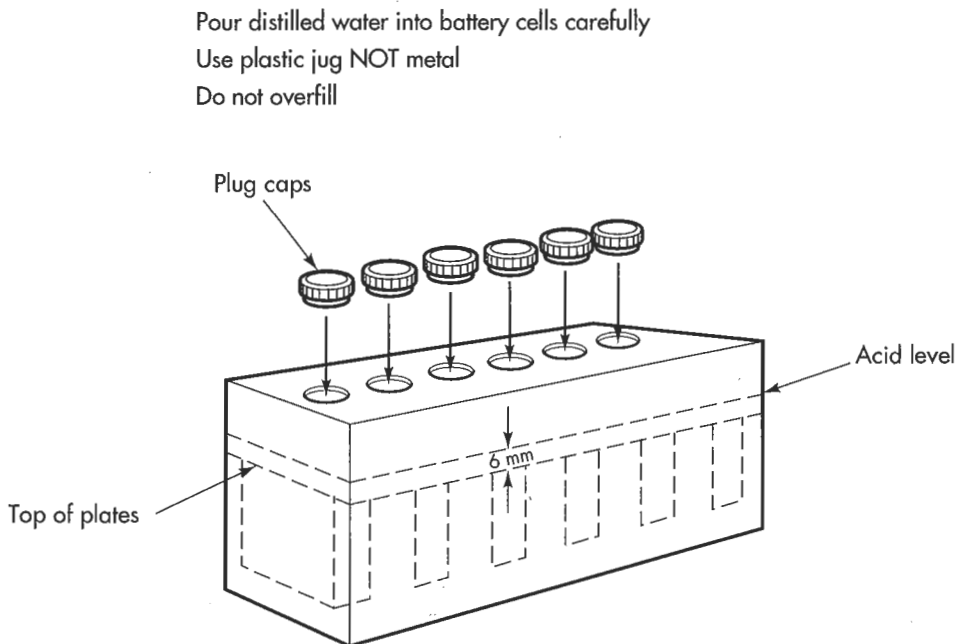
- return battery to its position
- reconnect battery. FIT CONNECTIONS TO TERMINALS ONE AT A TIME. DO NOT ALLOW CONNECTIONS TO TOUCH EACH OTHER. MAKE SURE CONNECTIONS ARE SECURE.
- check that the connections are fitted correctly:  
the positive terminal is marked '+' and the battery lead is RED  
the negative terminal is marked '-' and the battery lead is either BLACK or BLUE
- CHECK AGAIN BEFORE SWITCHING ON THE MACHINE
- wipe the top of the battery case with a dry clean cloth

## 2. Topping up the acid level of batteries

Because water evaporates, the level of acid in a battery drops and should be checked weekly:

- remove vent caps and check that the acid level is approximately 6mm above the battery plates (Figure 9)

DO NOT INSERT ANY METAL OBJECT TO CHECK THE ACID DEPTH



**Figure 9:** Topping up acid (electrolyte)

If plates are not covered:

- top up with distilled water (rain water may be used but distilled water is preferable). Small quantities of distilled water can be produced by using the simple method shown in Figure 10.

DO NOT USE A METAL JUG FOR FILLING THE BATTERY

When the correct level has been reached:

- replace vent caps
- wipe the top of the battery case

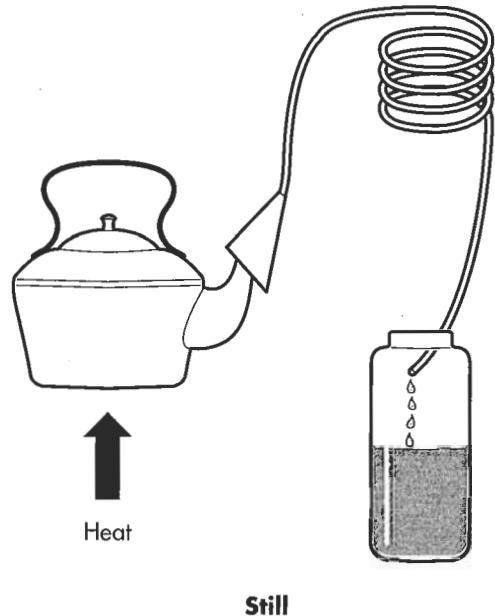
---

If your battery needs water to be added to bring the liquid level to Max. and you do not have a supply of distilled water, we recommend that you follow the instructions below:-

1. Boil a quantity of drinking water in a kettle with a spout.
2. Collect the steam as shown so that it cools and drops as water into a clean container.

Remember that small quantities of certain materials can 'poison' a battery and make it work badly, so it is important not to use untreated water which contains dissolved materials (such as bore-hole water).

Simple materials can be adapted to make distilled water; for example by collecting steam from a boiling kettle and forcing it to condense in a copper pipe coil. This is a simple still, as illustrated.



**Figure 10:** How to prepare distilled water

---

### 3. Checking specific gravity

The specific gravity of a battery indicates its capacity to provide power. This also should be checked weekly. The procedure and the equipment needed are shown in Figure 11.

#### **4. Safety**

Lead acid batteries can be dangerous. **HANDLE AND MAINTAIN CORRECTLY.**

Remember the following SAFETY points:

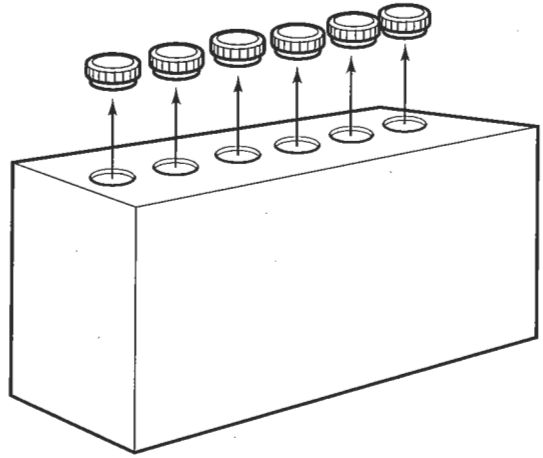
- Do keep battery in a clean, dry, well ventilated place
  - Do remove all watches and jewellery before beginning to work on a battery
  - Do keep flames and lighted cigarettes away from the area
  - Do wear protective gloves and eye shield
  - Do switch off machine before disconnecting battery
  - Do keep the battery upright
  - Do disconnect one battery lead at a time
  - Do make sure leads do not come into contact with each other until both are disconnected
  - Do make sure that correct terminals are used when reconnecting leads
  - Do check again before switching on the equipment
- 
- Do NOT try to test battery strength by short-circuiting battery terminals
  - Do NOT lift battery by its terminals

A list of danger signs for display and for use at training sessions is given in Figure 8.

**Procedure for measuring specific gravity.**

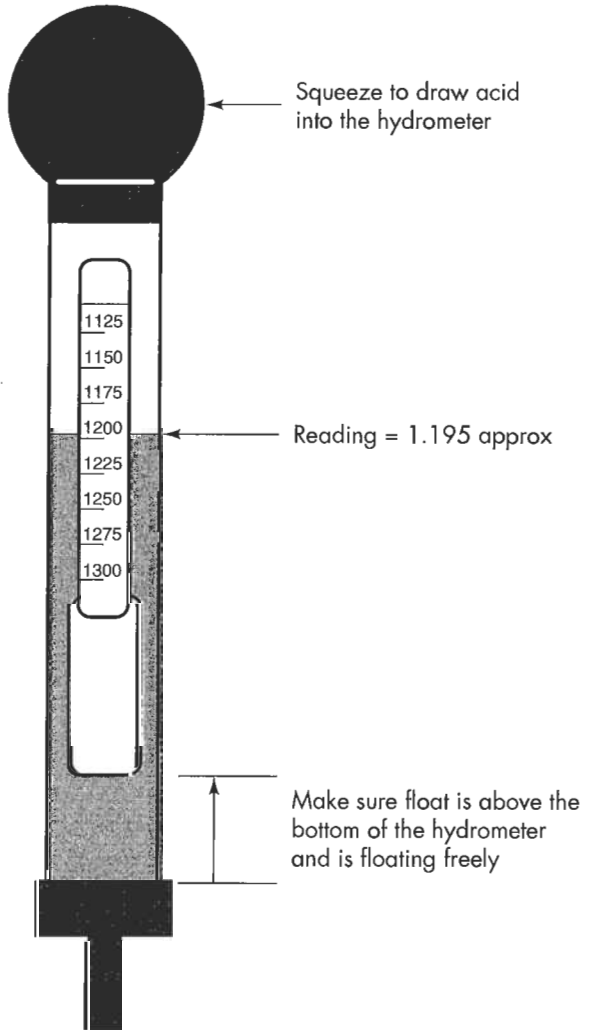
**1. Remove the vent caps**

Put on protective gloves as recommended for any work that may involve contact with battery acid. Remove the battery cell vent caps.



**2. Hydrometer use**

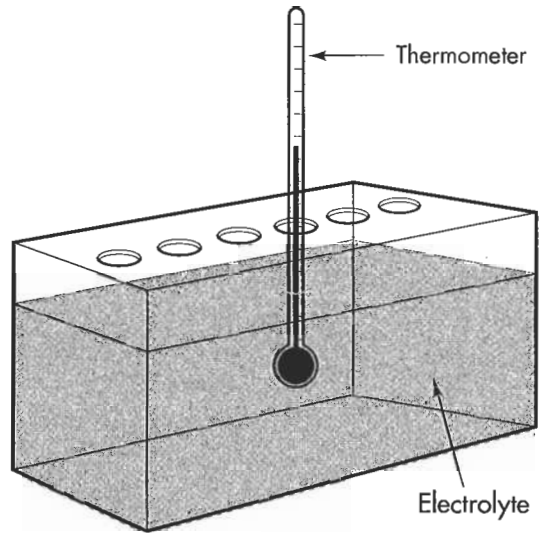
Squeeze the rubber bulb, insert the hydrometer into the electrolyte, then release the bulb to draw enough electrolyte into the hydrometer to make the indicator float freely. Record the reading - for example 1.195. Return the acid to the same cell, being careful not to spill any acid. Repeat the process to obtain a measurement for each cell.



**Figure 11:** Checking the battery

### 3. Thermometer use

Insert the thermometer into the electrolyte. The bulb of the thermometer must be in the electrolyte but not touching the battery plates. Wait until the temperature shown has stabilised. Measure and record the electrolyte temperature. Repeat this procedure for each cell in the battery.



### 4. Temperature correction

Using the table showing the temperature correction to specific gravity, record the correction value.

For 25 degrees celsius the correction is +0.007

Add the value from step 2 to the value from step 4 as follows:

$$\begin{array}{r} 1.195 \\ + 0.007 \\ \hline 1.202 \end{array}$$

- |               |  |
|---------------|--|
| 1.260 – 1.290 | Fully charged battery in good condition  |
| 1.230 – 1.260 | Battery becoming discharged but still serviceable  |
| 1.200 – 1.230 | Battery needs charging   |
| 1.100 – 1.200 | Battery discharged. If left in this condition for any length of time, permanent damage will be caused. |

#### Temperature corrections to specific gravity readings (to 15°C)

| Electrolyte temperature ° C | Correction to specific gravity |
|-----------------------------|--------------------------------|
| 55                          | +0.028                         |
| 50                          | +0.024                         |
| 45                          | +0.021                         |
| 40                          | +0.017                         |
| 35                          | +0.014                         |
| 30                          | +0.010                         |
| 25                          | +0.007                         |
| 20                          | +0.003                         |
| 15                          | 0.000                          |
| 10                          | -0.003                         |
| 5                           | -0.007                         |
| 0                           | -0.010                         |





## **7. BOTTLED MEDICAL OXYGEN AND OXYGEN CONCENTRATORS**

### **a. BOTTLED MEDICAL OXYGEN**

#### **1. Purpose of Equipment**

To provide patients with a reliable supply of oxygen.

#### **2. How the Equipment Works**

**Bottled oxygen supplies comprise the following components:**

- metal cylinder
- gas under pressure
- cylinder valve
- cylinder connector (bullnose, pin-index or other)
- regulator to reduce high, variable pressure to constant low pressure
- connector to fit the cylinder connector
- pressure gauge
- gas outlet
- pressure relief valve
- regulator pressure adjustment

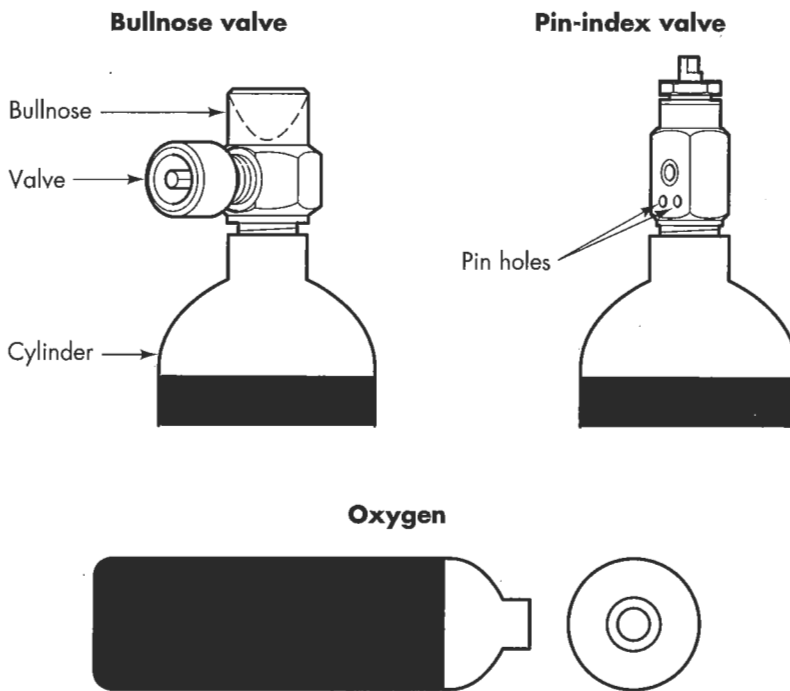
Bottled oxygen is supplied under pressure in specially designed steel cylinders of varying sizes. British Standard oxygen bottles range in capacity from 170 litres to 6800 litres:

| <b>Capacity (litres)</b> | <b>Cylinder reference</b> | <b>Valve type</b> |
|--------------------------|---------------------------|-------------------|
| 170                      | C                         | Pin-index         |
| 340                      | D                         | Pin-index         |
| 680                      | E                         | Pin-index         |
| 1360                     | F                         | Bullnose          |
| 1360                     | AF                        | Bullnose          |
| 3400                     | G                         | Bullnose          |
| 6800                     | J                         | Bullnose          |

Because the types of valves used on cylinders vary, always check that the regulator will fit the cylinder valve before use (Figure 12).

Valves and regulators should be carefully checked when cylinders are changed: ensure that mating surfaces are free of debris. Remember that pin-index valves are different for different gases.

British Standard oxygen cylinders are black with white tops (Figure 12) but colours may vary in other countries. Check each cylinder very carefully for content before use by reading the pressure gauge.



**Figure 12:** Valve types used for medical oxygen and cylinder colour code to British Standards

The pressure and rate at which a patient receives an oxygen supply is determined by the person overseeing his or her medical treatment. The rate is indicated on a flowmeter. The maximum flow rate normally supplied to a patient is about 4 litres/minute.

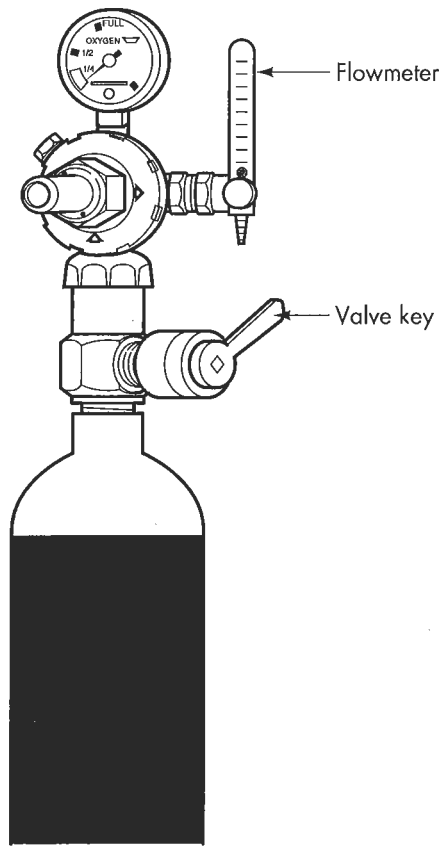
### 3. Routines and Safety

#### i. Routines

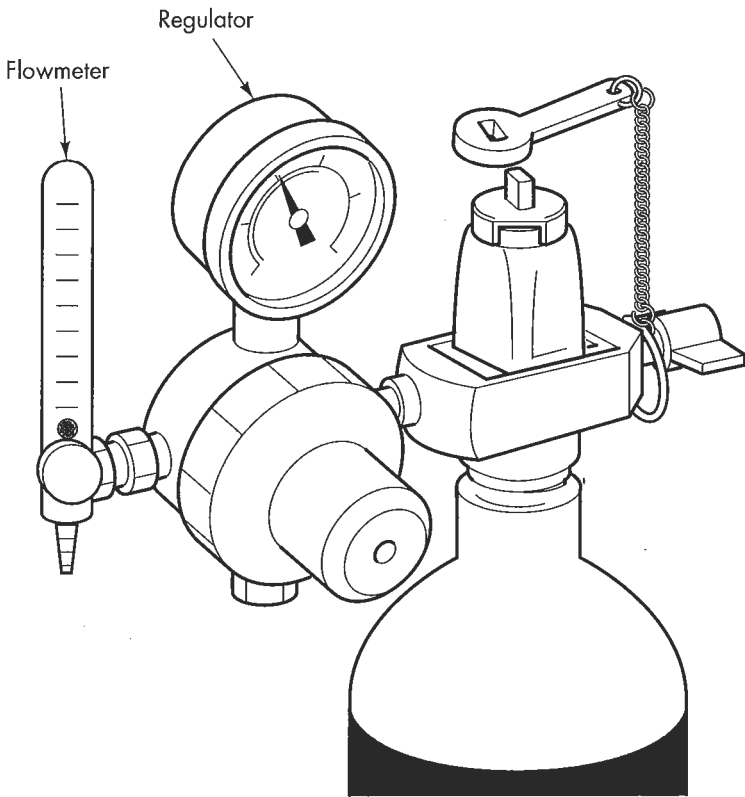
All cylinders should be carefully examined upon receipt from the suppliers and again when taken out of store and put into operational use.

Before putting a cylinder into service, the user should ensure that:

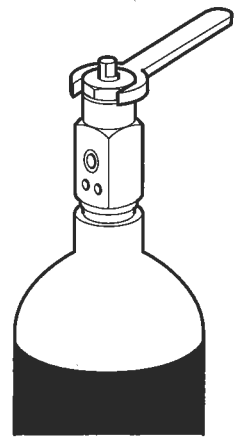
- the cylinder is not damaged or rusted
- the cylinder valves have their protective caps or seals in place and that their threads and pin-indexes are in good order
- the correct cylinder valves are fitted
- the cylinders are colour-coded and stamped correctly according to the standard laid down by the governing authority
- the valves are free from oil, grease, moisture and dust
- the correct key or spanner of similar length (not more than 150mm) is available for opening valves (Figure 13). Severe damage can be caused if the wrong tool is used



13 a. Bull-nose regulator and cylinder combination



13 b. Pin-index regulator and cylinder combination: always keep cylinder valve key physically strapped to regulator



13 c. Tightening the gland nut on a pin-index valve cylinder

Figure 13: Use of correct spanner/key on cylinder valves

## ii. Safety

### a. Personnel safety

Do take great care when handling oxygen cylinders, making sure that there are at least two people to lift and carry large cylinders

Do wear good foot protection when moving a cylinder in case it is inadvertently dropped

Do use a wheeled cylinder trolley to move cylinders

Do NOT allow flames or smoking anywhere near the cylinders as oxygen promotes combustion

Do NOT carry a cylinder by its valve

Do NOT use grease or oil anywhere on the equipment as this can create an explosion risk

Do NOT allow pressurised oxygen to come into contact with the skin

### b. Storage safety

Do keep cylinders in a dry, clean and well ventilated area

Do keep cylinders away from flames, lighted cigarettes, inflammable liquids and combustible material

Do use clear signs as warnings of potential dangers (Figure 14)

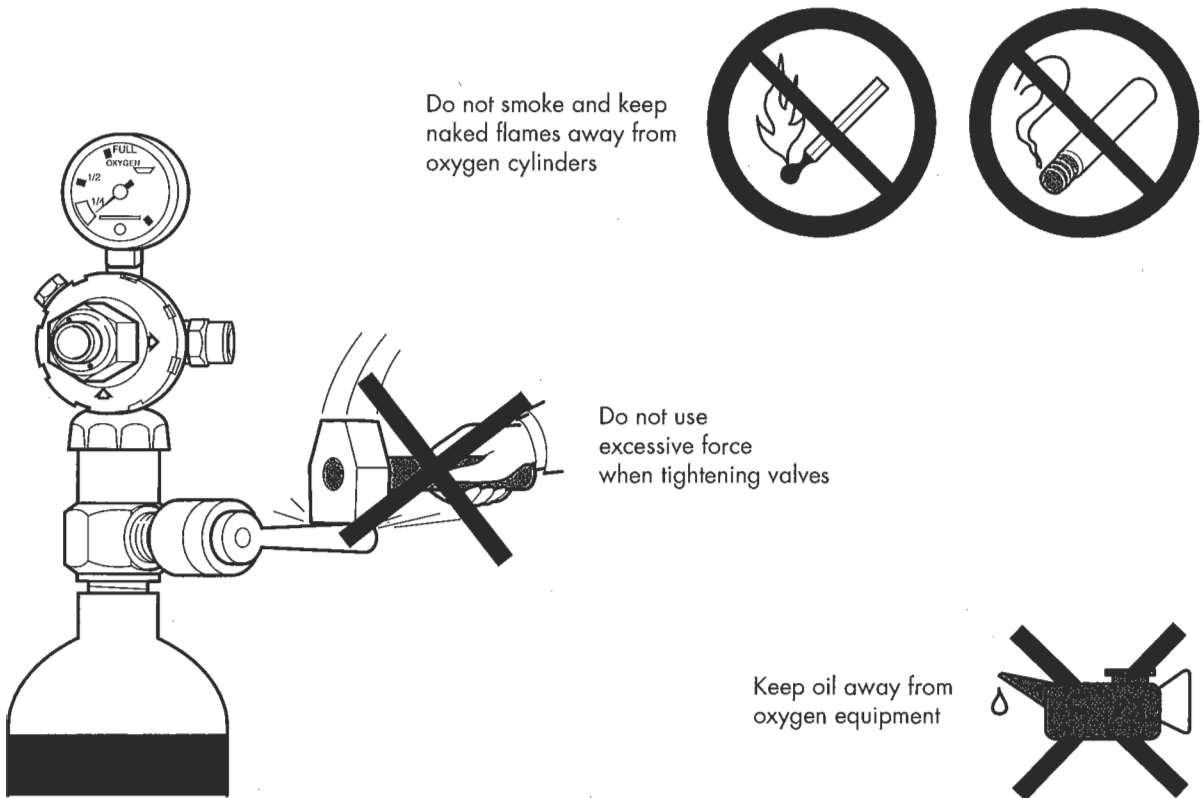
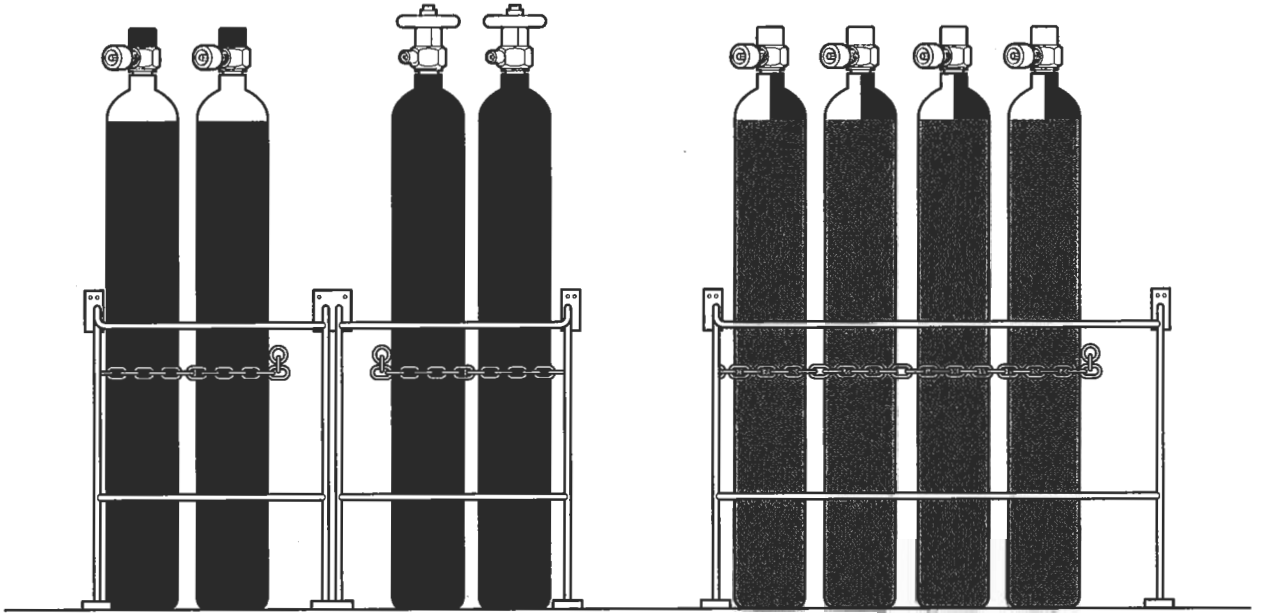


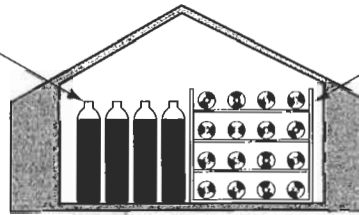
Figure 14: Use of clear warning signs

F-size and larger full cylinders are segregated and stored securely within the cylinder store

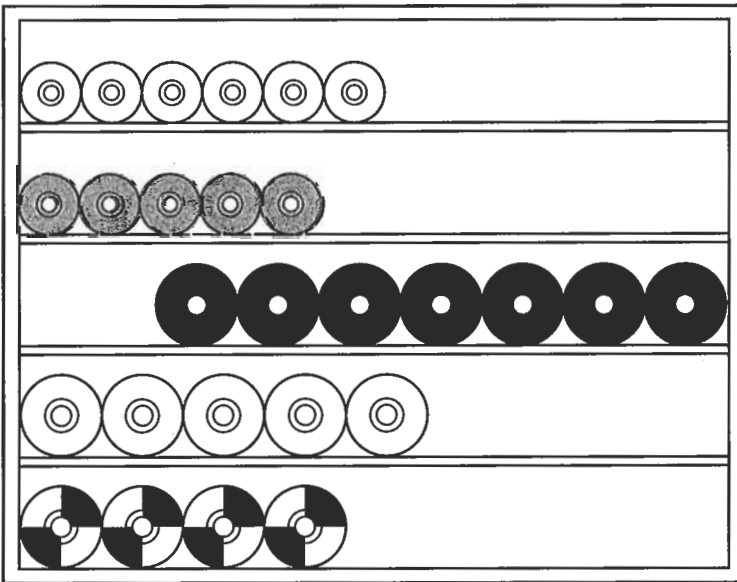
Empty cylinders stored separately ready for collection



Larger cylinders stored in upright position



E-size cylinders and smaller can be laid on their sides



Carbon dioxide

Cyclopropane

Nitrous oxide

Oxygen

Air

Figure 15: Safe storage of cylinders

Do sort and store different gases separately

Do store E-sized and smaller cylinders on their sides and larger cylinders in an upright position (Figure 15)

Do use chains or other methods to prevent the cylinders falling over

Do ensure that cylinders are used in strict rotation by date

Do keep empty cylinders separate from full ones

Do replace the protective covers or caps from the valves of empty cylinders (Figure 16)

Do ensure that empty cylinders are returned to the suppliers

Do NOT store cylinders in direct sunlight as this can cause the gas to expand and the cylinder pressure to increase excessively

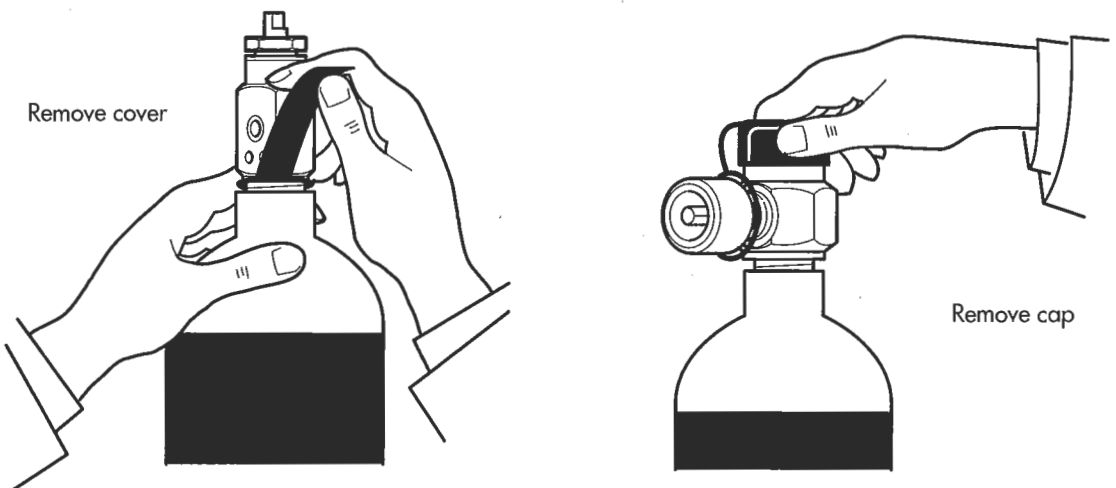
Do NOT use excessive force to shut cylinder valves; tighten by hand tool only

### iii. Fire

In the event of fire, raise the alarm and, unless life is endangered, attempt to move the cylinders away from the area.

If personnel are not trained to use fire fighting equipment leave cylinders in the fire zone and carry out statutory fire drill procedures.

Only trained personnel should handle cylinders which have been affected by fire or excessive heat.



**Figure 16:** Protective caps and seals

## 4. How to Use the Equipment

Always refer to the manufacturer's instructions for specific advice on the equipment you are using. The following are general guidelines only.

### A. Equipment with a bullnose regulator

#### Opening the system:

- i. remove protective cover or seal from the valve and retain this in a safe place (around the cylinder collar)
- ii. with the appropriate key or spanner (Figure 13) open the valve slightly and momentarily in order to blow out any foreign matter which may have accumulated around the valve mouth. Make certain that the oxygen is directed away from personnel when you do this
- iii. check that the regulator is the correct type and is also free from foreign matter
- iv. check that the 'O' ring is in place where there is a groove for it and in good condition (Figure 17)
- v. fit the regulator into the cylinder valve
- vi. if an 'O' ring is fitted, tighten by hand. If an 'O' ring is not fitted, tighten by using the appropriate spanner. Do not use excessive force as that can damage the valve
- vii. open the cylinder valve by turning SLOWLY once only with the correct key or spanner of similar length. If neither key nor spanner is available, do NOT attempt to turn the valve
- viii. check for leakage at the cylinder connection
- ix. check that the gauge is registering and that the pointer has steadied before giving the valve another complete turn
- x. open the flowmeter
- xi. administer the oxygen by selecting the prescribed flow

#### Using the system:

- i. use no oil or grease
- ii. blow out valves to remove dust
- iii. open cylinder valves slowly
- iv. secure cylinders so that they cannot fall over

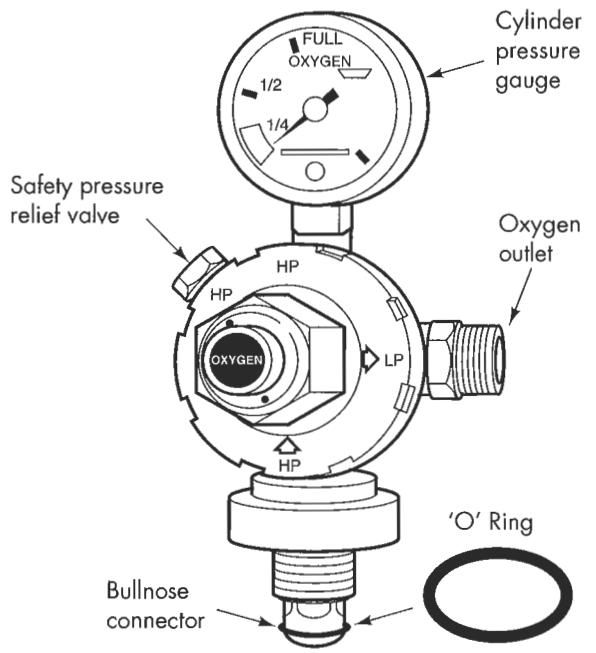
#### Closing the system:

- i. close cylinder valve
- ii. open equipment or machine valves to release any gas held in the system
- iii. when cylinder gauge reading has reached zero and hissing has stopped, close flowmeter valve

Do close the cylinder valve when the equipment is not in use otherwise the life of the regulator will be shortened.

Do NOT attempt to remove the regulator with the cylinder valve open as this excessive pressure will damage the thread.

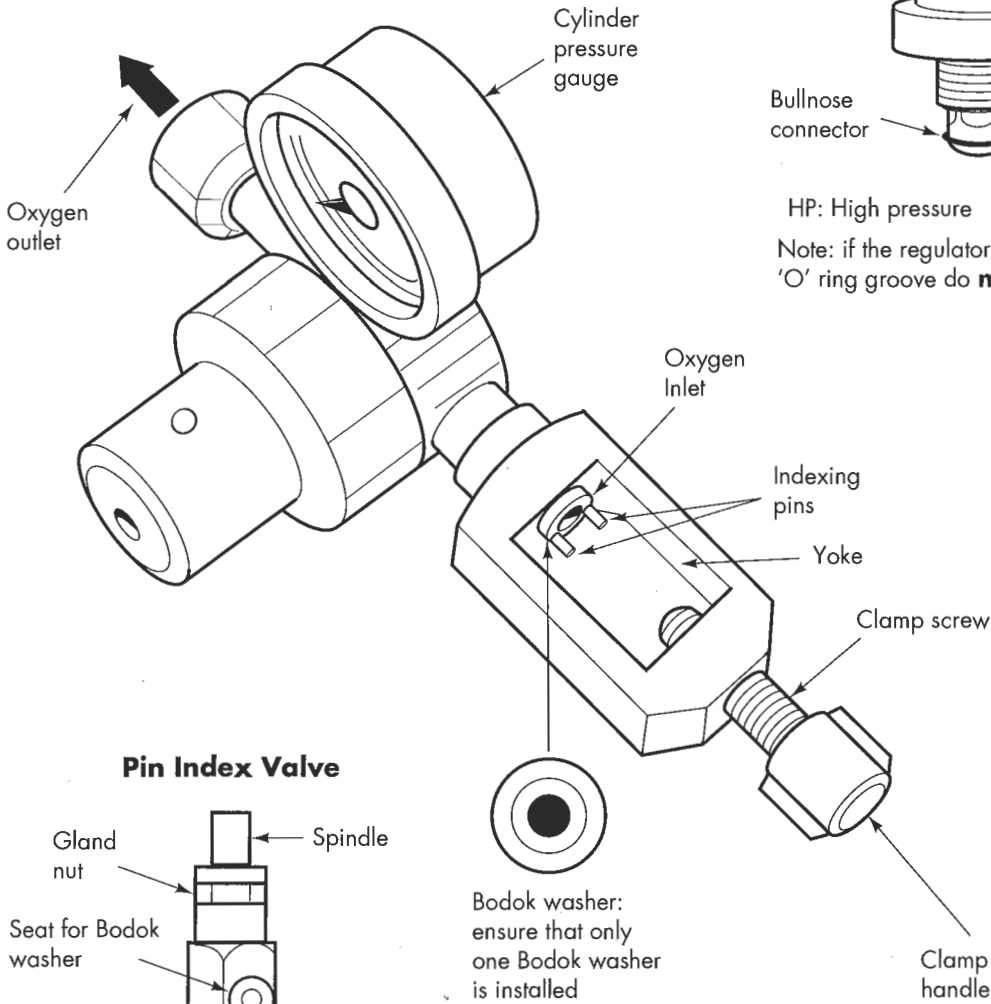
## Bullnose Regulator



HP: High pressure LP: Low pressure

Note: if the regulator does not have an 'O' ring groove do **not** fit an 'O' ring

## Pin Index Regulator



## Pin Index Valve

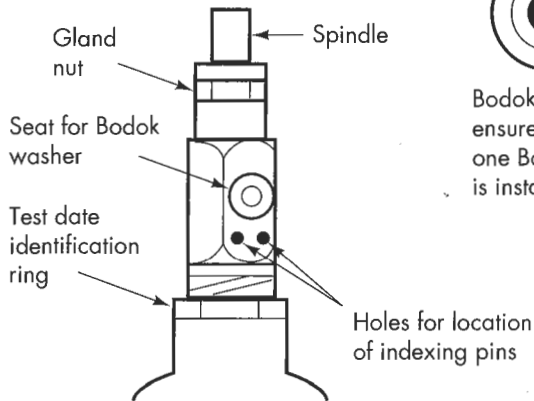


Figure 17: Pin index and bullnose regulators, "O" ring and Bodok washer locations



## **B. Equipment with pin-index regulators**

### **Opening the system:**

- i. remove protective cover or seal from the valve and retain this in a safe place (around the cylinder collar) (Figure 16)
- ii. with the appropriate key or spanner (Figure 13) open the valve momentarily in order to blow out any foreign matter which may have accumulated around the valve mouth. Make certain that the oxygen is directed away from personnel when you do this.
- iii. check that the regulator is the correct type and is also free from foreign matter
- iv. check that the Bodok washer is in place and in good condition
- v. locate the clamp over the pin-index valve
- vi. clamp the regulator to the cylinder, using a Bodok washer as a seal (Figure 17)
- vii. when the Bodok washer is in place, use the handle to tighten the clamp (Figure 17)
- viii. if there is no leakage, open the cylinder valve by turning once only with the correct key or spanner of similar length. If neither key nor spanner is available, do not attempt to turn the valve
- ix. check that the gauge is registering and that the pointer has steadied before giving the valve another complete turn
- x. open equipment or machine valves (flowmeters)
- xi. administer the oxygen as prescribed

Do NOT overtighten the clamp

Do NOT use a spanner

Do NOT use more than one Bodok washer

### **Using and closing the system:**

As for equipment with a bullnose regulator (See A. above)

## **C. Equipment with pin-index cylinders fitted direct**

Some equipment, such as anaesthetic machines, include an oxygen cylinder with a pin-index system. It is important to make sure that all valves on the machine are closed before proceeding as described above.

## **5. Simple Fault-finding and Maintenance**

The Maintenance Staff Member should carry out the following maintenance procedures.

### **Weekly:**

- i. check all associated equipment for signs of mechanical damage or loose connections
- ii. gently tap the regulator dial to make sure that the indicating needle is not jammed
- iii. check all pipes for cracks
- iv. open and close all valves to make sure they are working correctly

## Monthly:

- i. check that washers, caps and seals are in place on cylinders and regulators
- ii. examine regulators and flowmeters for damage
- iii. check that all statutory labels and warning notices are in place and are visible
- iv. check that the 'O' rings on bullnose regulators are fitted and in good condition
- v. check that the Bodok washers are fitted to the pin-index regulators and are in good condition
- vi. examine equipment for oxygen leakages (see below)

## Yearly:

Have the equipment inspected for leaks and accuracy by a qualified technician

### *Oxygen leaks*

If an oxygen leak is suspected:

- i. with the system open and under pressure listen for the usual hissing noise which gas makes as it escapes under pressure

### **If difficult to locate:**

- ii. with a toothbrush, apply detergent solution (e.g. 0.5%) over the suspect area. NEVER use oily soap as this can create an explosive mixture. Small bubbles will appear at the leakage point

### **When the leak has been located:**

- iii. close down the system (as described in Section 4 above)
- iv. tighten pipeline joints

If the leak is from the connection between the regulator and the cylinder, take great care not to over-tighten by using excessive force. These joints are machine manufactured to a high degree of accuracy and are easily damaged. Examine seals and sealing faces for damage. Replace damaged seals

If the pressure relief valve does not shut off automatically, close the valve and send the equipment away for expert repair

Do NOT use jointing compounds or tape to mend a leak

Do NOT dismantle a cylinder valve

Do NOT readjust a pre-set pressure regulator

If either of these develops a leak, replace it.

## 6. Spares

For local maintenance service, the following should be kept in store:

- a full cylinder
  - regulator
  - 'O' rings
  - Bodok washers
  - detergent solution and toothbrush
  - clean cloths
  - cylinder valve keys
- } available from the oxygen supplier

## **7. User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions

Always keep a spare full cylinder in reserve for emergency use

To keep this equipment in good working order for as long as possible:

Before using:

- i. check that you have the correct cylinder
- ii. check that the cylinder is not damaged or rusted
- iii. check that the cylinder contains enough oxygen for your patient
- iv. use the correct valve key
- v. make sure the cylinders are not leaking oxygen
- vi. check that the equipment is free from oil, grease and water

### **Opening the system:**

#### **For a bullnose regulator:**

- i. remove the protective cap or cover from the valve and retain this in a safe place to replace on the empty cylinder
- ii. with the appropriate key or spanner open the valve momentarily to blow out any foreign matter which may have accumulated around the valve mouth. Make certain the oxygen is directed away from personnel when you do this
- iii. check that the regulator is the correct type and is free from foreign matter
- iv. check that the 'O' ring is in place and in good condition. The machined groove on the bullnose will indicate the need for this: some makes do not require the 'O' ring
- v. fit the regulator into the cylinder valve
- vi. if an 'O' ring is fitted, tighten it by hand. If an 'O' ring is not fitted, tighten by using the appropriate spanner. Do not use excessive force as that can damage the valve
- vii. if there is no leakage, open the cylinder valve by turning once only with the correct key or spanner of similar length. If neither key nor spanner is available, do not attempt to turn the valve
- viii. check that the gauge is registering and that the pointer has steadied before giving the valve another complete turn
- ix. open equipment or machine valves (flowmeters)
- x. administer the oxygen as prescribed

#### **For a pin index regulator:**

- i. remove the protective cap or cover from the valve and retain this in a safe place to replace on the empty cylinder
- ii. with the appropriate key or spanner open the valve momentarily to blow out any foreign matter which may have accumulated around the valve mouth. Make certain the oxygen is directed away from personnel when you do this

- iii. check that the regulator is the correct type and is free from foreign matter
- iv. check the Bodok washer is in place and in good condition
- v. locate the clamp over the pin index valve
- vi. clamp the regulator to the cylinder using the Bodok washer as a seal and use the handle to tighten the clamp
- vii. if there is no leakage, open the cylinder valve by turning once only with the correct key or spanner of similar length. If neither key nor spanner is available, do not attempt to turn the valve
- viii. check that the gauge is registering and that the pointer has steadied before giving the valve another complete turn
- ix. open equipment or machine valves (flowmeters)
- x. administer the oxygen as prescribed

**Closing the system (for both bullnose and pin index regulators):**

- i. close cylinder valve
- ii. open equipment or machine valves (flowmeters) to release any gas held in the system
- iii. when the cylinder gauge reading has reached zero and hissing has stopped, close flowmeter valve
- vi. close cylinder valve when the equipment is not in use

Report to Maintenance Officer:

Any apparent damage  
 Any leakage of oxygen  
 Any other fault

Follow these SAFETY points (for both bullnose and pin index regulators):

Do keep cylinders well away from flames and smokers  
 Do make sure equipment is free from oil, grease and water  
 Do follow the 'opening the system' and 'closing the system' procedures carefully  
 Do close the cylinder valve when the equipment is not in use  
 Do return the empty cylinder back to the store

Do NOT move cylinders alone  
 Do NOT lift cylinders by their valves  
 Do NOT point pressurised oxygen towards anyone  
 Do NOT leave the cylinder valve open when the equipment is not in use  
 Do NOT allow oil or grease to come into contact with the equipment  
 Do NOT use more than one Bodok washer on a pin index valve connection  
 Do NOT use jointing components or tape to mend a leak  
 Do NOT dismantle or readjust a regulator or cylinder valve  
 Do NOT attempt to remove the regulator with the cylinder valve open as the excessive pressure will severely damage the thread

## **b. OXYGEN CONCENTRATORS**

### **1. Purpose of Equipment**

To provide patients with a reliable supply of oxygen. It is usually used where oxygen cylinders are difficult to obtain and/or are expensive.

### **2. How the Equipment Works**

Air is drawn into the machine by a compressor. After passing through a series of filters to cleanse it of bacteria and solid matter, the air is pumped into the concentrator where all nitrogen is extracted. The resulting oxygen is then fed into the oxygen reservoir from where it is administered to the patient at the prescribed rate.

### **3. Routines and Safety**

#### **i. Routines**

Before using an oxygen concentrator check that:

- the concentrator is standing in a place which is as dust-free as possible. This will reduce the load on the filters and thus cut operational costs
- the machine is standing at least 30cm away from any obstruction
- the inlet filter is clean
- the exterior of the machine is not damaged
- gauges and switches are not damaged
- the mains lead is not frayed or damaged
- the plug is not damaged
- the machine is clean and the inlets are free of debris
- outlets are clean

Report any damage to the Maintenance Officer

Weekly (or more frequently if the environment is dusty):

if the air intake filter (Figure 18) is washable:

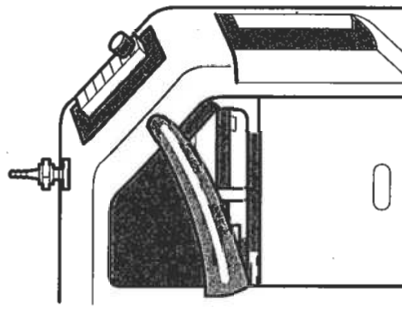
- disconnect machine from mains supply
- remove and wash filter in detergent solution. Do NOT use soap
- dry the filter thoroughly but do not use heat as this may damage the filter
- replace the filter. Never run the machine without this in place. (Some machines have a safety device which prevents the machine from being used without the filter)

If applicable, remove and empty condensation tray. (Not all oxygen concentrators have a condensation tray)

### Intake filter

Check the intake filter daily and clean it whenever it is dirty. Dirt or lint can easily be seen on the filter and must be removed.

To clean the filter, take it off the side of the concentrator; wash it in mild detergent solution, rinse in clean water, and squeeze out excess water. Never use soap.



### Caution

Do not use heat to dry the filter - heat might damage it.

Do not use the filter until dry.



**Figure 18:** Typical air intake filter, also known as the coarse filter

---

After 5000 running hours (indicated on the counter at the back of the equipment):

- return equipment to maintenance workshop for general overhaul and a change of secondary filters (Figure 19)

If there is no workshop available:

- change filters according to manufacturer's instructions

## ii. Safety

Oxygen concentrators must not be used near flammable anaesthetics such as ether. A concentrator should only be used in an operating room if it is mounted 1.5 metres high on a wall so that it is beyond the zone of risk for flammable anaesthetics.

Do use the equipment in an environment which is clean, cool and well ventilated

Do keep the machine clean by washing with detergent solution and drying thoroughly

Do ensure that all tubing is non-toxic and free of odour

Do switch off and unplug the machine when it is not in use

Do keep a spare cylinder of oxygen to hand, in case the concentrator breaks down unexpectedly

Do NOT use the machine where there are odours or volatile gases or liquids

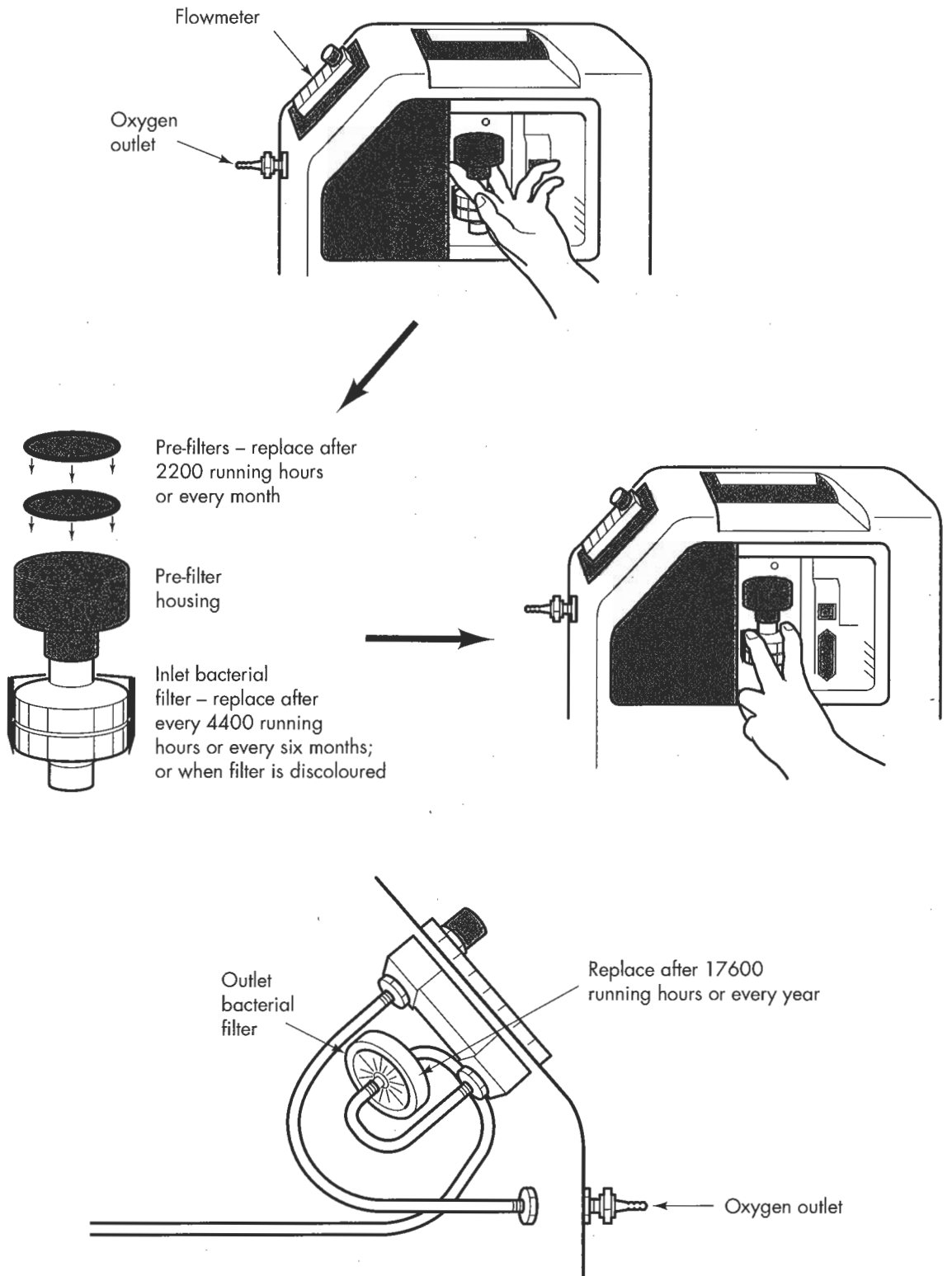
Do NOT allow any liquid to run into the machine

Do NOT use soap or grease on the machine

Do NOT place anything on top of the machine

Do NOT allow smoking or flames near the machine and the oxygen outlets

Do NOT allow children near the machine



**Figure 19:** Typical appearance and layout of secondary filters

If humidifying equipment is being used:

- Do make sure water cannot be fed back into the machine; use only dry filters
- Do use only boiled water in the humidifier
- Do wash and dry the humidifier frequently

#### 4. How to Use the Equipment

Always refer to the manufacturer's instructions for specific advice on the equipment you are using. The following are general guidelines only.

- i. make sure that the equipment is in an upright position and is standing on a level surface
- ii. confirm that the mains voltage is suitable for the machine
- iii. if the model is not insulated, check that there is an earth pin
- iv. make sure that the power source has a capacity which matches the load (400 watts)
- v. carry out a visual check of all external connections to make sure that there is no leakage of oxygen
- vi. check that all hand-operated valves are open
- vii. make sure that the air-inlets are clear (Figure 20)
- viii. plug concentrator into mains socket and switch on  
if either a portable generator or a truck battery with an AC inverter is being used:
  - start generator or inverter and close control switch
  - when satisfied that the generator/inverter is working, plug in concentrator and switch on
- ix. adjust oxygen flow to the prescribed rate

#### 5. Simple Fault-finding and Maintenance

**Example a:** The oxygen concentrator is 'dead' with no sound or lights on:

- check that all the filters are in place and that the inlet filter is clean

If these are satisfactory:

- check that the socket outlet is working

If that is satisfactory:

- check the mains lead

If that is satisfactory:

- check the fuse(s) on the machine

If that is satisfactory:

- send equipment away for expert repair

**Example b:** The flowmeter gauge is not indicating the oxygen flow:

- check tubing for kinks and blockages

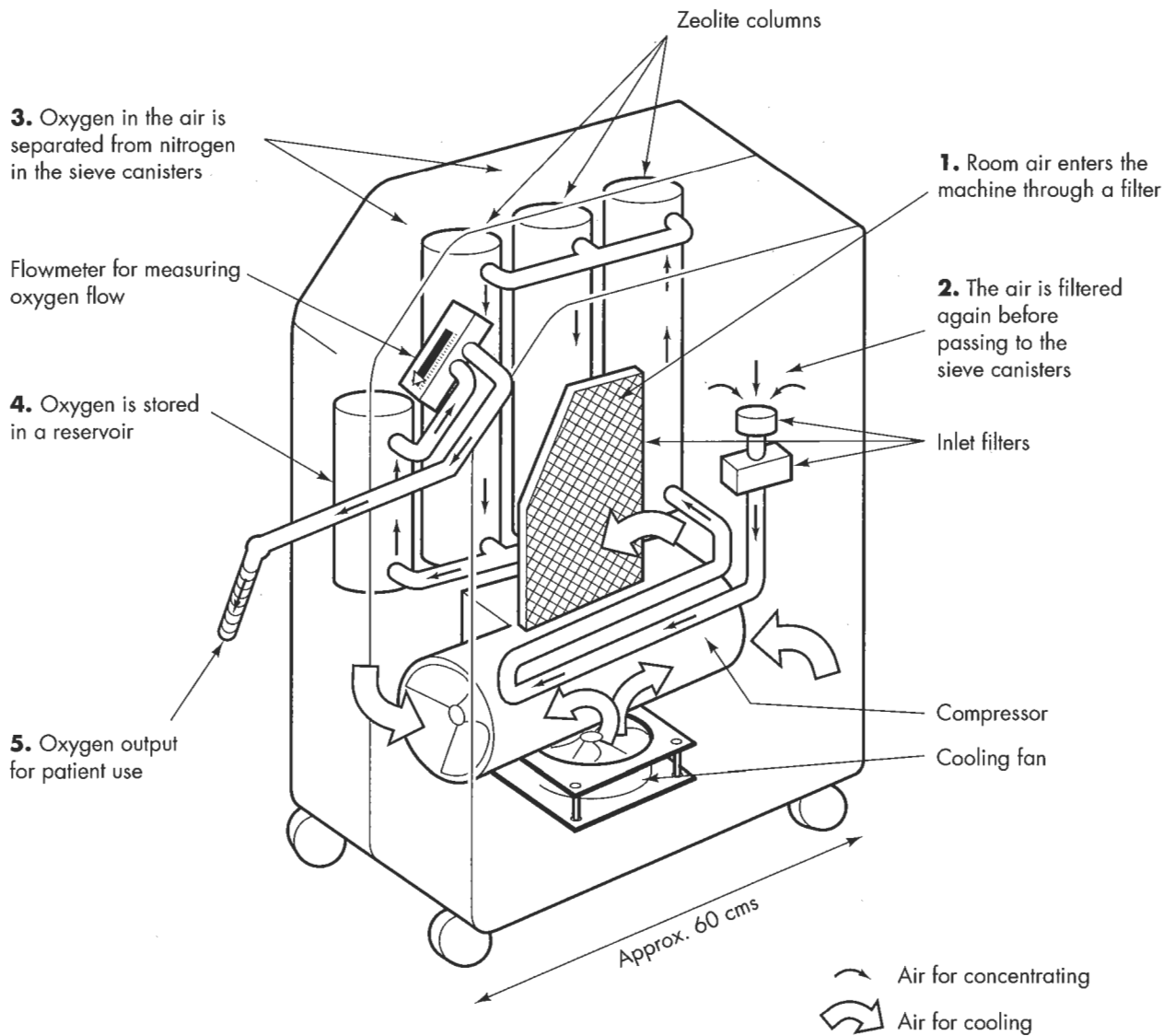
If these are satisfactory:

- check that all downstream valves are open

If these are satisfactory:

- send equipment away for expert repair





**Figure 20:** Oxygen concentrator in operation

**Example c:** Oxygen is not reaching the patient:

- check that the machine is running and the flowmeter gauge is indicating flow of oxygen

If these are satisfactory:

- check downstream tubing and ancillary equipment for leaks, kinks and blockages

If machine is running and the flowmeter is not indicating the flow of oxygen:

- send equipment away for expert repair

**Example d:** Machine stops:

- check the socket outlet is working

If that is satisfactory:

- check the mains lead

If that is satisfactory:

- check that inlets and filters are clean and not blocked

If these are satisfactory:

- machine may have cut out automatically due to over-heating, over-loading or low voltage, so cool room if possible and switch off machine for 30 minutes. Check the voltage supply and use a voltage stabiliser if needed.

If machine fails to start again after 30 minutes:

- send equipment away for expert repair

**Example e:** Machine outlet flow rate drops or is erratic:

- check that the ancillary equipment is not making too high a demand

If it is not:

- check that the machine is standing on a level surface

If it is:

- check that the filters are correctly fitted and the intake filter is clean (Figures 18 and 19)

If they are:

- call the medical officer in charge for advice on adjusting the flow rate

If still not satisfactory:

- send equipment away for expert repair

Some machines have an Oxygen Sensing Device (OSD). This is an alarm which is activated if the oxygen concentration falls below a given level, usually about 80%.

### *Oxygen monitor*

If there is no Oxygen Sensing Device, the concentration of oxygen should be tested using an oxygen monitor.

An oxygen monitor contains a sensor called a fuel-cell, which is like a battery and must be replaced when it is worn out. Because its level of charge varies throughout its life, it must be checked regularly.

### **Daily check:**

Breathe onto the sensor several times. The reading should drop slightly (approximately 3%).

Set up a flow of, say, 4 litres per minute of *cylinder* oxygen into a small (A4 size) plastic bag. Place the sensor in the middle of the open bag (not a corner) for one minute. Then adjust the calibration knob to read 100%. If cylinder oxygen is not available, then an alternative technique is to leave the sensor in normal room air. After a minute or so, adjust the calibration knob on the monitor so that a reading of 21% is obtained.

Any problems are likely to be due to the fuel-cell. The life of a cell (typically seven months) may sometimes be extended by refitting the shorting clip and putting the cell in a small, sealable container when not in use. Dispose of the fuel-cell thoughtfully - they contain some toxic chemicals.

### *Oxygen leaks*

See above under Bottled Medical Oxygen

## **6. Spares**

Oxygen concentrators are sophisticated pieces of equipment and all regular overhauls and major repairs to them should be carried out only by a qualified technician.

For local maintenance service, the following spares should be kept in store:

- a second oxygen cylinder
- air filters
- bacterial filters
- main circuit fuses
- plug fuses (if applicable)
- plug
- toothbrush and 0.5% detergent solution
- oxygen monitor (fuel-cell type)

## **7. User Checklist (to be displayed on or near the equipment)**

Always refer to the manufacturer's instructions.

Always keep a spare full cylinder for emergency use.

To keep this equipment in good working order for as long as possible:

- i. keep the working area as dust free as possible
- ii. make sure that the machine is standing in an upright position and on a level surface
- iii. use only specified tubing and fittings
- iv. keep air inlets clean
- v. keep outlets clean
- vi. never use soap, grease or oil on the machine
- vii. never place anything on top of the machine
- viii. always switch off and unplug the machine when it is not in use
- ix. never run the machine without the filters being correctly fitted
- x. once a week:
  - remove and empty condensation tray (not all machines have one)
  - clean air inlets and filters
  - check tubing and ancillary equipment for leaks

Report to Maintenance Officer:

- any visible damage to mains lead, plug or body of machine
- any leakage of oxygen
- any other fault or breakdown

Follow these SAFETY points:

- Do keep equipment away from flames and cigarettes
- Do keep equipment away from odours, volatile gases and liquids
- Do keep children away from equipment
- Do keep the machine dry
- Do disconnect the machine from the main electricity supply when it is not in use
- Do switch off the machine immediately if fire breaks out
- Do install the machine outside the risk zone if it is being used in an operating theatre
- Do fit the humidifier below the level of the patient's head to prevent condensation flowing to the patient
- Do run the concentrator for five to ten minutes every week, even if it is not in use

## 8. DISINFECTION AND STERILISATION OF MEDICAL SUPPLIES AND EQUIPMENT

### a. INTRODUCTION

**Disinfection** is a process whereby micro-organisms are destroyed to a level which is safe for some purposes but not for others. Heat-resistant spores will not be destroyed.

**Sterilisation** is a process whereby all micro-organisms, including heat-resistant bacterial spores, are removed or destroyed.

#### Which equipment should be disinfected? Which should be sterilised?

**Disinfection** is recommended for equipment that is not intended for piercing the skin, or touching open wounds. Disinfected equipment may safely be in contact with the intact skin and mucous membranes of the body. Equipment which is to be disinfected includes items such as linen, bedpans, crockery, instruments, tongue depressors, etc.

**Sterilisation** is recommended for all items penetrating the skin or which will be in contact with broken skin and mucous membranes or entering otherwise sterile body areas. This includes equipment such as surgical instruments, implants, dressings, gowns, catheters, wound irrigation fluids, syringes, needles and other items which may pierce the skin or be in contact with open wounds.

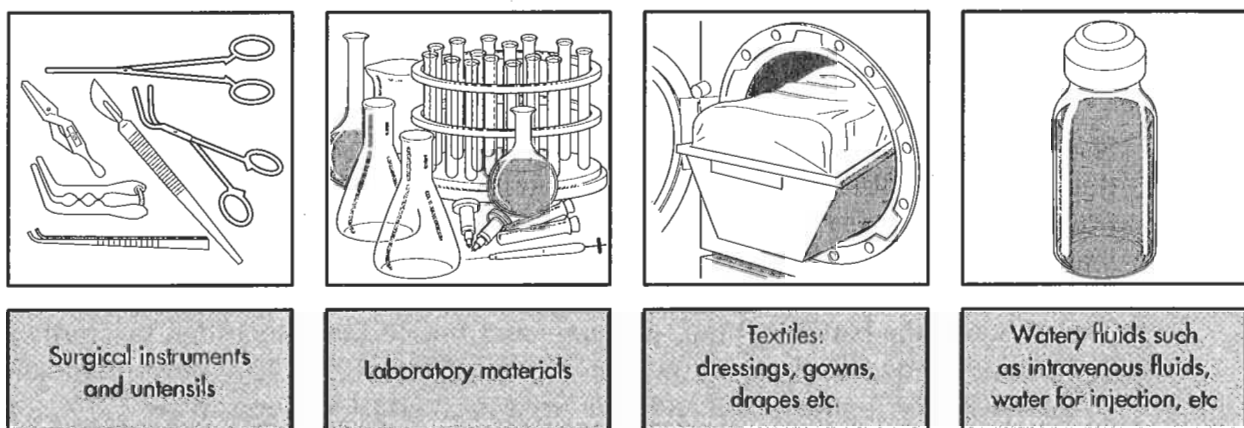


Figure 21: Materials which can be sterilised by autoclaving

## **Importance of cleaning before disinfection and sterilisation**

Before disinfection and/or sterilisation it is essential that all equipment is thoroughly cleaned in order to remove all blood, tissue and other dirt. Cleaning will drastically reduce the number of micro-organisms on the items and thus will ensure an acceptably low level of contamination before disinfection or sterilisation.

Cleaning of instruments and materials may well be the most dangerous work in the sterilisation department: the risk of accidents is highest during this work. Do the cleaning in a deep sink or basin to avoid splashing. Use appropriate protective clothing: wear an apron, strong rubber gloves and a face mask.

## **Disinfection by boiling in water**

The most common equipment for disinfection is the boiling water bath disinfecter. They are also called boiling water 'sterilisers'; however, they do not sterilise. They should be referred to as 'disinfection equipment'. That is, they do not kill heat-resistant bacterial spores. Instruments can be disinfected by boiling in water (100°C) for at least 10 minutes (this applies to sea level, and does not include the warming-up time).

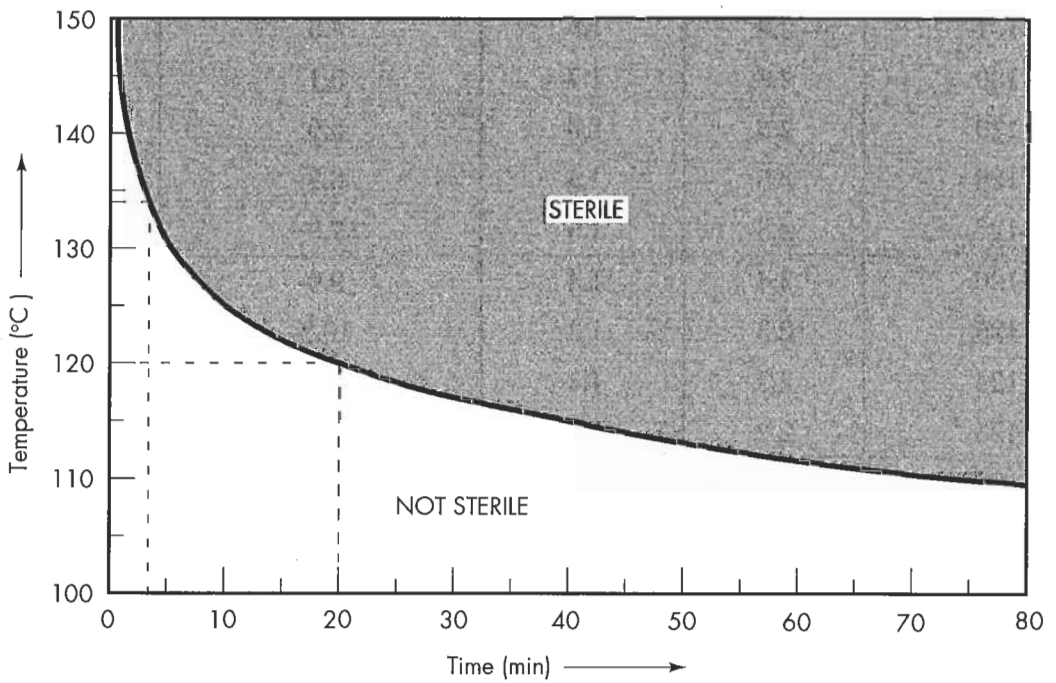
## **Sterilisation by exposure to high temperature steam**

In health care the most common method of sterilisation is by pressurised, high temperature steam. This is the preferred method of sterilisation used by health care professionals worldwide, including the World Health Organisation (WHO), because it is a rapid, simple and effective process. As it does not use any chemicals, it is safer and more environmentally friendly; it is also more cost-effective than other methods.

The machine used in most hospitals to sterilise equipment is the steam autoclave, which basically consists of a pressure vessel in which steam is created under high pressure and temperature. For proper sterilisation it is essential that **all surfaces of the load are directly exposed to the steam at a sufficiently high temperature for a sufficiently long time.**

A well designed and well operated autoclave creates these sterilisation conditions during each sterilisation cycle: in modern, automatic sterilisers, a steriliser control programme regulates these conditions. If a hand-operated autoclave is used, the manufacturer's instructions should be followed strictly.

The relationship between time, pressure and temperature in order to sterilise equipment using steam is shown in Figures 22 and 23. The most common combinations for temperature and time used for sterilising in steam are 121°C for 17.5 minutes and 134°C for 3 minutes. The time during which the load is exposed to the steam at the sterilisation temperature is referred to as the **sterilisation time.**



**Figure 22:** Thermal death curve for steam. The line indicates the minimum sterilisation time at any given temperature. If materials are exposed to steam at a temperature and time which is in the shaded part of the diagram they will be sterile. Example: When an instrument is exposed to steam at a temperature of 120 °C it will be sterile after 20 minutes. If you use a manually operated autoclave, refer to Figure 23 for the recommended sterilisation time at various temperatures.

| Sterilisation Temperature<br>[°C] | Absolute Pressure<br>[Bar <sub>abs</sub> ] | Gauge Pressure<br>(sea level)<br>[Bar <sub>g</sub> ] | Sterilisation time                              |  |
|-----------------------------------|--|--|---|--|
|                                   |  |  | Minimum time<br>(Automatic timing)<br>[Minutes] | When using<br>manual timing<br>[Minutes] |
| 136                               | 3.2  | 2.2  | 2.3   | 10                                       |
| 135                               | 3.1  | 2.1  | 2.6   | 10                                       |
| 134                               | 3.0  | 2.0  | 3.0   | 10                                       |
| 133                               | 3.0  | 2.0  | 3.4   | 10                                       |
| 132                               | 2.9  | 1.9  | 4.0   | 10                                       |
| 131                               | 2.8  | 1.8  | 4.5   | 10                                       |
| 130                               | 2.7  | 1.7  | 5.1   | 10                                       |
| 129                               | 2.6  | 1.6  | 5.9   | 10                                       |
| 128                               | 2.5  | 1.5  | 6.8   | 10                                       |
| 127                               | 2.5  | 1.5  | 7.8   | 10                                       |
| 126                               | 2.4  | 1.4  | 9.0   | 15                                       |
| 125                               | 2.3  | 1.3  | 10.2  | 15                                       |
| 124                               | 2.3  | 1.3  | 11.6  | 15                                       |
| 123                               | 2.2  | 1.2  | 13.3  | 15                                       |
| 122                               | 2.1  | 1.1  | 15.3  | 20                                       |
| 121                               | 2.0  | 1.0  | 17.5  | 20                                       |
| 120                               | 2.0  | 1.0  | 20.0  | 25                                       |
| 119                               | 1.9  | 0.9  | 22.9  | 25                                       |
| 118                               | 1.9  | 0.9  | 26.2  | 30                                       |
| 117                               | 1.8  | 0.8  | 30.0  | 35                                       |
| 116                               | 1.7  | 0.7  | 34.4  | 40                                       |
| 115                               | 1.7  | 0.7  | 39.5  | 45                                       |
| 114                               | 1.6  | 0.6  | 45.1  | 50                                       |
| 113                               | 1.6  | 0.6  | 51.6  | 55                                       |
| 112                               | 1.5  | 0.5  | 59.1  | 60                                       |
| 111                               | 1.5  | 0.5  | 67.7  | 70                                       |
| 110                               | 1.4  | 0.4  | 77.5  | 80                                       |

**Figure 23:** Combinations of temperature and time required for sterilisation by steam. The most commonly used temperatures are 121°C and 134°C (in the shaded rows). If a hand-operated autoclave is used, use the sterilisation time indicated in the far right-hand column (labelled ‘When using manual timing’). The time indicated in this column includes an extra safety margin in order to compensate for the inaccuracies of manual timing. All the values apply at sea level. When you are situated at higher altitudes, refer to Figure 24. For explanations of ‘absolute pressure’ and ‘gauge pressure’ refer to the shaded box on page 79.



Because of the high temperature needed for sterilisation in steam, not all equipment is suitable for autoclaving. Take great care when deciding which items to sterilise, as some could be badly damaged by the high temperature of the steam. Certain plastics in particular are very sensitive to heat and cannot be sterilised in steam; however, items made of nylon, Teflon (PTFE) and silicone rubber can safely be autoclaved.

Rubber goods can also be sterilised in steam. However rubber is affected by the heat and will become brittle after a while. Rubber goods should preferably be autoclaved at lower temperatures, e.g. 121°C.

If in doubt refer to the manufacturer’s instructions for the materials to be sterilised; or test a single item by autoclaving it and observing the result.

**Influence of altitude on cycles for disinfection and sterilisation**

The atmospheric pressure depends on the altitude above sea level: it decreases as altitude increases. The temperature at which water boils also decreases with the altitude. You must therefore make adjustments in the cycle for disinfection. If an autoclave has a pressure control valve or other pressure control system, the cycle for sterilisation has to be adjusted for the altitude at which you are working. Refer to Figure 24.

| Altitude<br>[m] | Atmospheric<br>pressure<br>[Bar <sub>abs</sub> ] | Pressure<br>reduction<br>[Bar] | Disinfection        |               | Sterilisation                |                                |                              |
|-----------------|--|--------------------------------|---------------------|---------------|------------------------------|--------------------------------|------------------------------|
|                 |  |                                | in boiling<br>water |               | Sea-level setting            |                                |                              |
|                 |  |                                | Temp<br>[°C]        | Time<br>[Min] | 121°C/<br>1 Bar <sub>g</sub> | 127°C/<br>1.5 Bar <sub>g</sub> | 134°C/<br>2 Bar <sub>g</sub> |
|                 |  |                                | Temp<br>[°C]        | Temp<br>[°C]  | Temp<br>[°C]                 |                                |                              |
| 0               | 1.0  | 0.0                            | 100                 | 10            | 121                          | 127                            | 134                          |
| 1,000           | 0.9  | 0.1                            | 96                  | 10            | 118                          | 126                            | 132                          |
| 2,000           | 0.8  | 0.2                            | 93                  | 10            | 117                          | 125                            | 131                          |
| 3,000           | 0.7  | 0.3                            | 90                  | 20            | 115                          | 124                            | 130                          |
| 4,000           | 0.6  | 0.4                            | 86                  | 20            | 114                          | 124                            | 129                          |
| 5,000           | 0.5  | 0.5                            | 83                  | 30            | 112                          | 121                            | 128                          |
| 6,000           | 0.5  | 0.5                            | 79                  | 45            | 111                          | 120                            | 127                          |
| 7,000           | 0.4  | 0.6                            | 76                  | 60            | 110                          | 119                            | 127                          |

**Figure 24:** Altitude considerations for disinfection and sterilisation

## Disinfection in boiling water at higher altitudes

- choose the row with the altitude at which you are working
- in the columns headed 'Disinfection', you can read the boiling temperature of water at that altitude and the required boiling time

## Sterilisation at higher altitudes

When you are at significantly higher altitudes you either have to increase the (relative) sterilisation pressure in order to get the same temperature of steam, or extend the sterilisation time.

### *Increasing sterilisation pressure*

If the pressure of your autoclave can be adjusted, you should increase the relative operating pressure by the amount of pressure reduction caused by the altitude. By doing so the temperature which will be reached will be the same as it would be at sea level. Using Figure 24:

- select the row with the altitude at which you are operating the autoclave
- read the pressure reduction associated with the altitude. Increase the sterilisation pressure by this value
- run a sterilisation cycle and check that the required temperature is indeed reached
- the sterilisation time should be the time needed at that temperature (Figure 23)

**For example:** if your autoclave has been set by the manufacturer at 121°C/1 Bar<sub>g</sub> for use at sea level, and you are at 2000m, you should increase the pressure by 0.2 Bar<sub>g</sub> to 1.2 Bar<sub>g</sub>. Use the time as stated in Figure 23 for sterilisation at 121°C: 25 minutes.

### *Extending sterilisation time*

If you cannot change the operating pressure you should extend the sterilisation time when working at higher altitudes. Using Figure 24:

- select the altitude at which you are operating the autoclave
- select the column with the sterilisation pressure at sea-level setting which is closest to that of your steriliser
- read the temperature which will be reached
- in Figure 23 you will find the sterilisation time required for that temperature

**For example:** the pressure control for your autoclave is set for sterilising at 121°C/1 Bar<sub>g</sub> at sea level. You are working at 2000 metres. The table indicates that the temperature will be 117°C. In Figure 23 you will find that the required sterilisation time for that temperature is 35 minutes.

### **Absolute pressure and gauge pressure**

In daily life, when talking about pressure in vessels, we mean an applied pressure which differs from the atmospheric pressure. Pressure gauges indicate this difference in pressure between the vessel they are connected to and the surrounding atmosphere. This pressure difference is referred to as 'gauge pressure'. For these pressures the suffix <sub>g</sub> is used. See Figures 23 and 24. The unit for pressure is Pa or kPa (1 kPa = 1000 Pa). Also the unit Bar is used: 1 Bar = 100 kPa.

In scientific applications, the pressure in vessels is usually compared to the situation in space, where there is no pressure at all (an absolute vacuum). The pressure compared to vacuum is called the 'absolute pressure'. For indicating absolute pressures the suffix <sub>abs</sub> is used. At sea level the pressure of the atmosphere is approximately 100 kPa<sub>abs</sub> or 1 Bar.

In autoclave documentation the gauge pressure is usually stated. However sometimes also the value of absolute pressure is used.

### **Readings of pressure gauges at higher altitudes**

At higher altitudes, the pressure gauge of an autoclave will indicate the same pressures as when at sea level. This is because the pressure controller is set for a pressure difference between the vessel and the atmosphere and the gauge indicates this pressure difference. This difference is the same at all altitudes. However with the same setting of the pressure control of the autoclave, at higher altitudes the absolute pressure in the vessel will be lower and thus the temperature that will be reached during sterilisation is lower. Refer to Figure 24.

### **Keeping goods sterile: packaging**

As soon as goods are taken out of the steriliser, they will be contaminated again by particles in the air. Therefore it is necessary that the items to be sterilised are packaged properly prior to sterilisation. The packaging should allow steam to penetrate to the items inside but should prevent access by micro-organisms after sterilisation. Packaging materials can be sterilising containers, sheets of certain fabrics, paper and non-wovens and pouches made of paper or so called laminate pouches. The design of drums and containers to be used depends on the sterilisation process.

Schimmelbusch drums are used in some hospitals as a method of packaging. They are metal drums which have holes in their sides which can be opened and closed with a metal band. Before sterilisation, the holes are opened and the drum is put into the autoclave. After sterilisation, the drum is taken out of the autoclave and the holes closed by shifting the metal band. Research has shown however that these Schimmelbusch drums are not a suitable method of packaging because air remains trapped inside.

When only using cotton sheets as a packaging material, the goods should be used immediately. For more information about sterilisation packing materials, refer to the book *Sterilisation of Medical Supplies* listed in the Bibliography.

## b. **BOILING WATER DISINFECTORS**

### 1. **Purpose of the equipment**

To disinfect equipment and materials.

### 2. **How the equipment works**

The boiling water disinfector consists of a metal box with a closely fitting lid; in some cases a gasket is fitted between the box and the lid. The water vapour should pass without obstruction via the lid. Inside, the disinfector has a perforated tray which is positioned to allow the water to circulate. The tray may be fitted with removable handles to take it out. Some models of disinfectors are equipped with a handle-operated mechanism for lifting the tray out of the water.

The disinfector stands on four small feet allowing air to circulate around it and preventing damage to the underlying surface. Heating can be provided by electricity, a paraffin stove or any other heat source. In the electric models, heat is generated by an electric heating element, either of the immersion or the panel type.

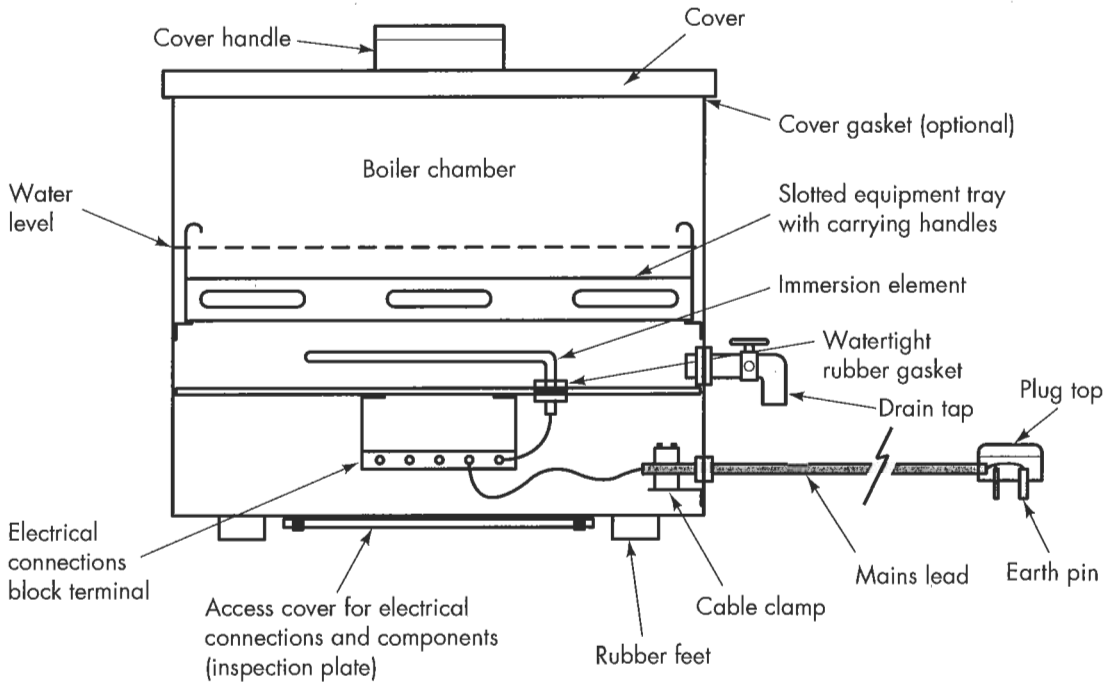
The **immersion-type element** (see Figure 25a) is fitted at the bottom of the boiler, completely immersed in and directly heating the water. Its terminals through the bottom are sealed by watertight rubber gaskets.

The **panel-type element** (see Figure 25b) is clamped under the boiler and does not come into direct contact with the water. To obtain maximum conductivity of heat, the clamp must be secured tightly. Depending on the size and model of the disinfector, one or more elements may be installed.

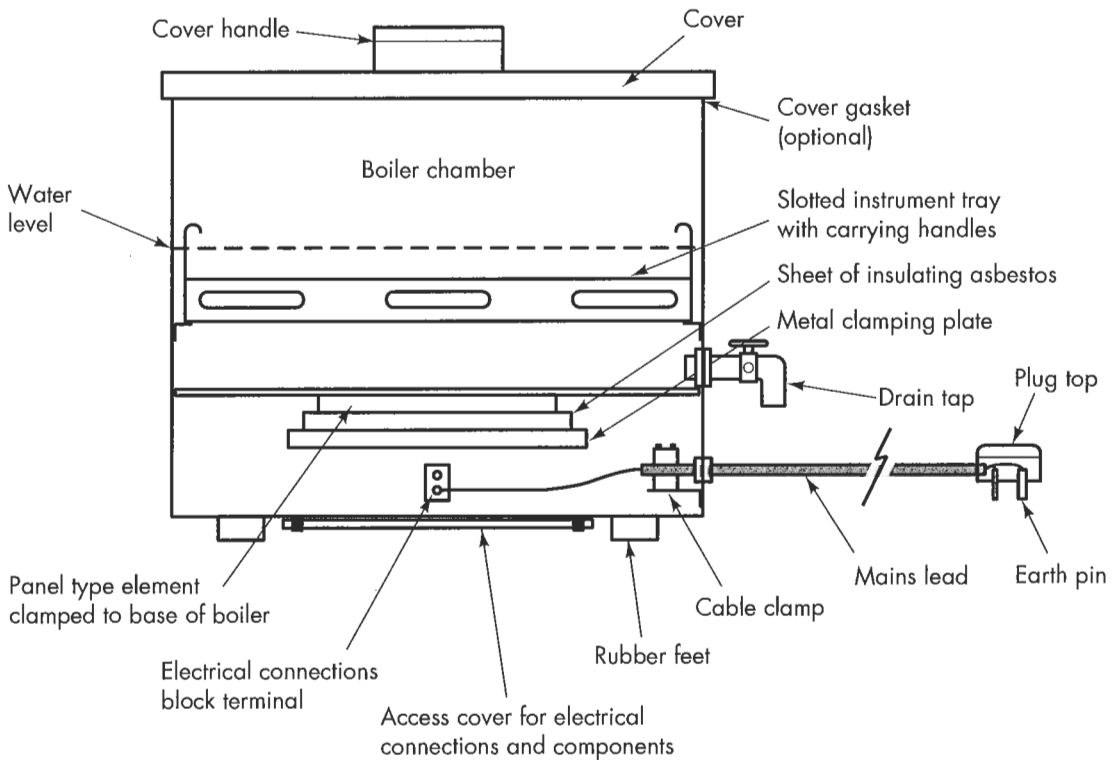
### **Controls**

- i. **On/off switch.** This is the basic control
- ii. **Low/medium/high three-level switch.** This is fitted to disinfectors which have more than one element. As well as acting as an on/off switch, it also controls the heat generated by selecting elements in various combinations. Thus three levels of heat are made available to the user.
- iii. **Bi-metallic controller.** In some models the heat generated by the heating element is regulated by a bi-metal control switch. Depending on the setting of the controller it switches the element on and off for longer or shorter periods, thus controlling the heat which will be generated by the element. It is used in boilers with only one heating element.
- iv. **Simmerstat switch.** This is also an on/off switch, but offers a fine, graduated control of temperature. Attached to the switch is a fine copper tube which is immersed in the water and acts as a temperature sensor. It allows the simmerstat to switch on or off at pre-determined temperature settings (Figures 26 and 27). For disinfection it should be set to 100°C.
- v. **Safety cut-out.** This switches off the disinfector automatically when it is in danger of overheating or boiling dry. There are two types. One type has a metal probe immersed in the water (like the simmerstat switch) and the other has a bi-metal strip fitted under the boiler. Both are usually re-set by hand.
- vi. **Indicating lamps.** Some disinfectors have small indicating lamps. Usually one indicates green when the power is switched on. A second one indicates red when the disinfector is overheated.

**vii. Timer switch.** Some more sophisticated types of disinfectors have a timer switch which allows the disinfection process to be set up by the user over a specified time. The machine switches off automatically.

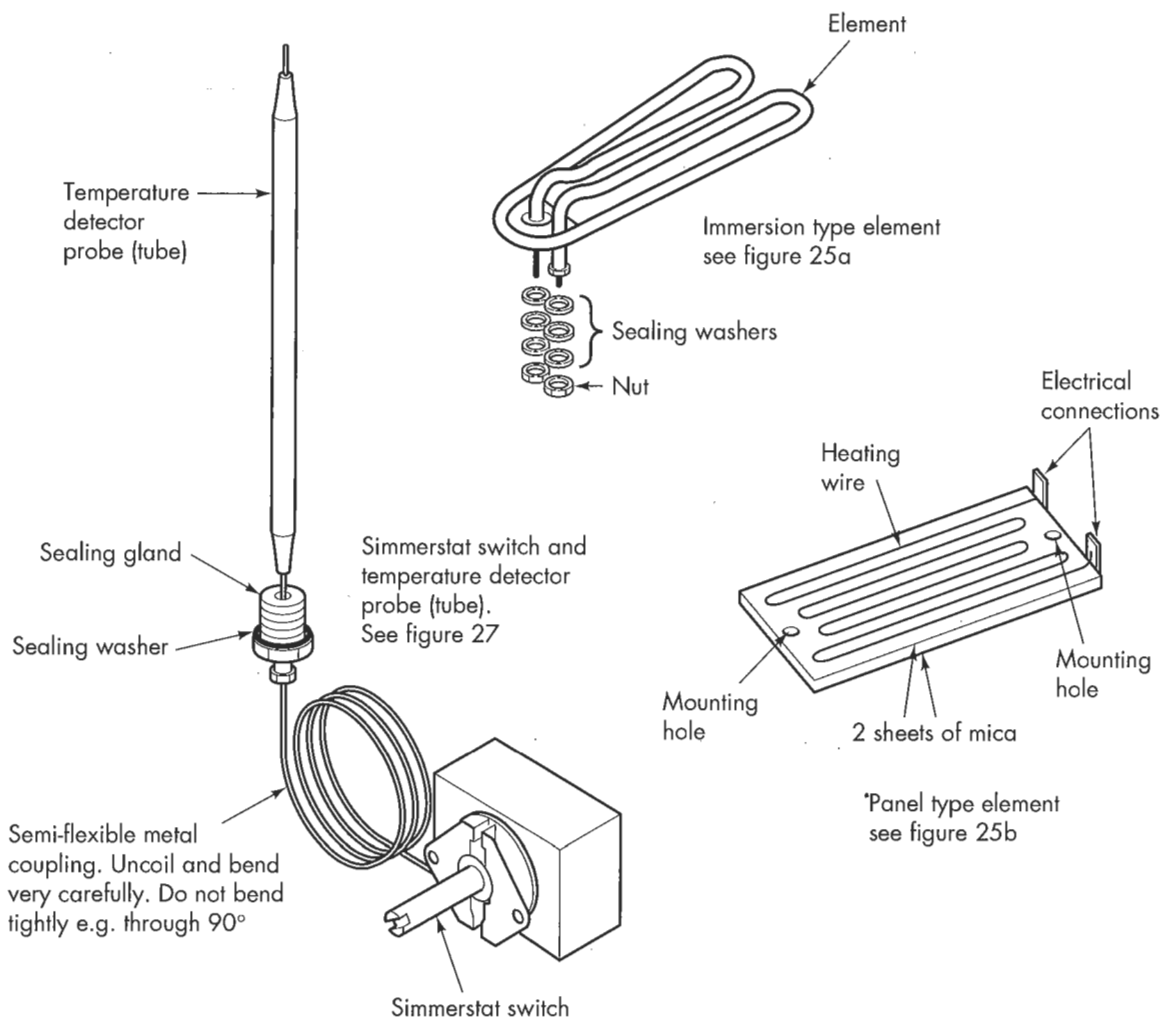


**25 a.** With an immersion-type heating element



**25 b.** With a panel-type heating element

**Figure 25:** Boiling water disinfectors in cross-section



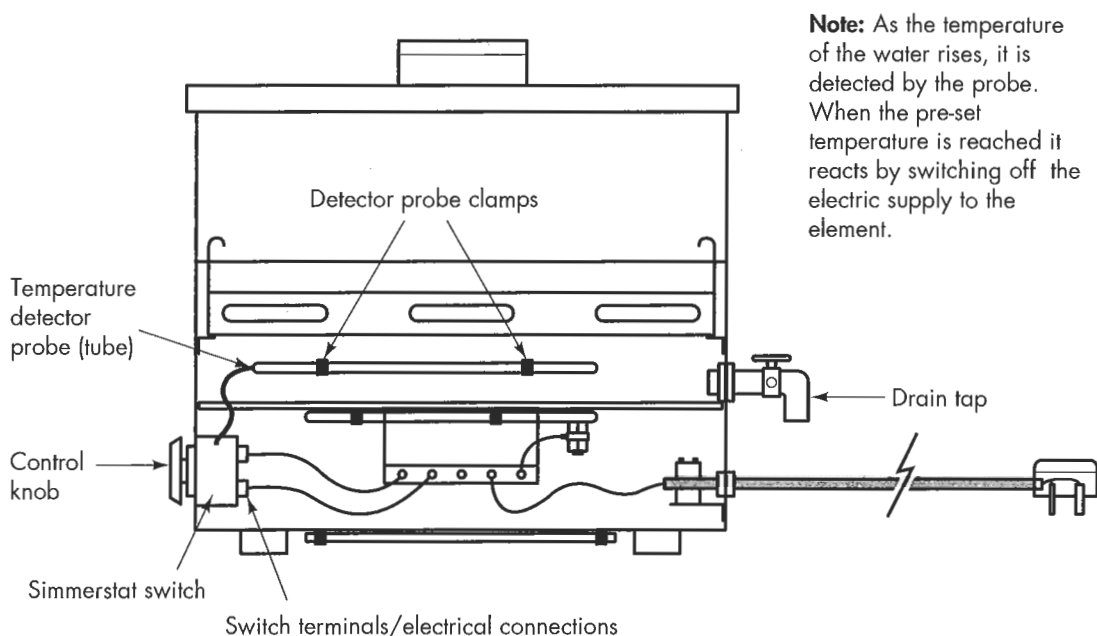
**Figure 26:** Typical heating elements and simmerstat switch

### 3. Routines and Safety

#### i. Routines

##### Always:

- site the disinfector in a clean, well ventilated working environment and on a level surface
- use distilled, demineralised or rain water in the boiler if there is a high concentration of minerals and salts in local water. This will prevent corrosion and scaling ('furring') of the instruments and the disinfector. This is especially important for disinfectors with immersion-type elements
- ensure that the boiler is never switched on without water. Even if there is an automatic cut-out, over a period of time elements and control devices can be damaged
- keep the outside clean and polished
- after each day's use clean the inside of the disinfector
  - wash with liquid soap solution
  - rinse three times
  - dry with a clean, soft cloth



**Figure 27:** Cross-section of a boiling water disinfector equipped with a simmerstat switch. It can be set at different temperatures. For disinfection it should be set at 100 °C. This model is heated by a single panel-type heating element

### Weekly:

- examine the mains lead and plug for visible signs of damage or wear
- check for leaks. These usually occur around the drain tap or immersion element terminals
- check that the inner side of the bath and drain tap is free from debris, limescale and corrosion
- if a gasket is fitted, apply silicone grease, vaseline or talcum powder to the cover gasket to keep it supple
- clean the outside of the disinfector with a mild detergent and soft cloth. Materials such as harsh scouring powders (particularly those containing bleach) and wire wool pads should be avoided. Wire wool pads tend to leave tiny particles of ferrous metal on the surface, which will develop into rust spots.

### Monthly:

- check for 'furring'. If necessary remove the limescale

### ii. Safety

- Do keep children well away from the disinfector
- Do unplug the boiler from the mains socket when not in use

Do make sure the disinfectant is connected to a socket with an earth connection.  
Ensure that the earth connection of the socket is in good condition

Do NOT attempt to fit the instrument tray when the boiler is switched on  
Do NOT overload the tray

#### **4. How to use the equipment**

Always refer to the manufacturer's instructions for specific advice about the equipment you are using. The following are general guidelines only.

- i. check that the inside of the disinfectant has been cleaned since previous use
- ii. ensure that the mains socket is suitable and that there is an earth connection
- iii. check that the drain tap is closed
- iv. if applicable, disassemble instruments to be disinfected into parts
- v. wash instruments in detergent to clean them of any visible blood and debris. Rinse well in clean water. Do the cleaning in a deep sink or basin, to prevent splashing. When cleaning, wear an apron, strong rubber gloves and mask
- vi. load the equipment or instruments onto the tray. Space them so that the boiling water can circulate around each one and each part
- vii. replace the loaded tray in the disinfectant
- viii. fill the disinfectant with water up to the marked level or not more than two-thirds full. All instruments should be covered. Check that no air is trapped inside tubing or hollow instruments by holding the instrument or tubing with one end submerged and the other end above the water so that the air can escape. Then slowly submerge the whole item
- ix. plug the disinfectant into the mains socket and switch on to full heat
- x. when boiling point has been reached, reduce the heat by the three-level switch or other heat controller, but maintain boiling point for the required length of time. The absolute minimum is 10 minutes (at sea level). During the whole period the instruments should remain completely immersed
- xi. switch off the disinfectant, open the lid and raise the tray
- xii. allow the equipment/instruments to dry

Never add instruments or equipment once the disinfection cycle has begun. If the cycle is stopped at any point, it must be restarted from the beginning.

#### **5. Simple fault-finding and maintenance**

**Example a:** Scaling or 'furring' of immersion element

In areas where the local water contains a high percentage of minerals, scaling or 'furring' of the immersion elements and the inside of the boiler may occur. The most common problem is limescale.

To descale (remove scale):

- pour enough pure vinegar into the boiler to cover the furred part and/or the element.
- switch on the boiler and boil for five minutes
- wash out the boiler with clean water
- wipe with a soft dry cloth and allow to dry
- repeat if necessary



If you do not have vinegar you can use a solution of 50 grams of citric acid powder in each litre of water.

**Example b:** The boiler does not heat up

- check the safety cut-out. If the cut-out has been activated, check the water level. If necessary, re-set the safety cut-out and refill with water

If the boiler still does not heat up

- check the mains socket, lead and plug

If those are satisfactory:

- there is an internal fault. Call a qualified technician; see Example c

If a qualified technician is not available locally:

- send equipment away for expert repair

**Example c:** Work with a qualified technician to identify the fault.

Take the following steps. Make a written note of each step you take.

- unplug the boiler from the mains socket
- using a screwdriver, remove the inspection plate (and feet, if necessary)
- place all removed parts in a small container
- inspect all electrical connections
- remake connections which are either loose or burnt
- refit washers and heat-resistant sleeving

If spade connections need to be repaired:

- a special tool is required and equipment should be sent away for expert repair

If all connections are satisfactory:

- check for components fault

If spare components are available:

- change them one at a time, in the order below, until the faulty component is identified:
  - element
  - three-way switch, bi-metallic controller or simmerstat switch
  - on/off switch
  - overheat cut-out switch
  - timer (if installed; the mechanical models usually make a quiet ticking noise if it has been set)

Re-test the boiler as each component is fitted:

- ensure all covers are in place
- copy existing component installation (make step-by-step written notes for each component which you replace)
- before replacing the inspection plate, check that the wires are not touching any surface which will become hot when the boiler is working. Intense heat will damage them and may cause electric shock

If spare components are not available:

- send equipment for expert repair

**Example d:** Boiler overheating with vigorous bubbling of water throughout the disinfection cycle:

- replace three-way switch, bi-metallic controller or simmerstat as described in Example c

**Example e:** Water gets hot but does not boil:

- replace components one at a time as in Example c

Do work with a qualified technician

Do make component changes one at a time, otherwise confusion can lead to unsafe practice

Do NOT make component changes if identical components are not available

**DO NOT TAKE SHORT CUTS!**

## **6. Spares**

The spares required for local maintenance are:

- a second boiler which can be heated over fire
- three-way switch, bi-metallic controller or simmerstat switch
- on/off switch
- element
- sealing washers for element (for immersion-type only)
- cut-out unit
- timer (if applicable)
- heat-resistant wire and/or sleeving for repairs of internal wiring
- bulbs for indicator lights
- lid gasket (if applicable)
- plug (and fuse if required)
- length of mains power lead
- main circuit fuse
- vinegar or citric acid powder (use 50 grams for each litre of water)
- silicone grease/vaseline/talcum powder

## **7. User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions

In order to obtain good and long service from this equipment the following points should be observed:

- i. before use, check that the disinfectant is clean
- ii. use distilled, demineralised or rain water if the local water supply contains a high percentage of minerals
- iii. ensure that the water reaches the marked level or is not more than two-thirds full
- iv. the equipment should be covered throughout the disinfection cycle
- v. ensure that no air is trapped in tubing or hollow instruments
- vi. change the water after each disinfection cycle

### **Report to Maintenance Officer**

- i. any damage to the boiler, mains lead or plug
- ii. any build-up of scale or 'furring' of the element of the disinfectant
- iii. any fault or breakdown

### **Follow these SAFETY points:**

Do take great care when using boiling water

Do keep children well away from the disinfectant

Do ensure the disinfectant is on a firm and level surface

Do use the boiler for unwrapped instruments only

Do ensure that the disinfectant is connected to a wall socket with functioning earth connection

Do NOT use the boiler for rubber gloves and porous loads, e.g. drapes, towels or wrapped instruments

Do NOT overload the tray

Do NOT attempt to put the instrument tray in the boiler when it is switched on

## b. AUTOCLAVES

### 1. Purpose of the equipment

To sterilise instruments and materials.

### 2. How the equipment works

Always refer to the manufacturer's instructions for specific advice about the equipment you are using. The following are general guidelines only.

An autoclave is basically a pressure vessel with a lid. The area in the pressure vessel where the load can be put is referred to as the chamber. Autoclaves use pressurised, high temperature steam in order to sterilise; however it is essential that the steam reaches all surfaces of the load. Air in the chamber and load can impair sterilisation performance.

#### **Problem of air in the chamber and the load**

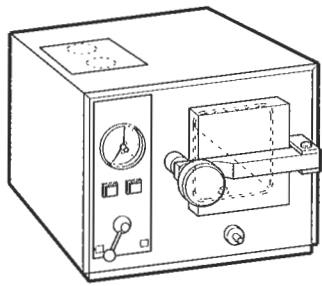
Air transfers heat very poorly, and is therefore much less effective in killing organisms than steam. Air in the chamber or in the load may prevent the load from being in direct contact with the steam, seriously reducing the effectiveness of the sterilisation process. This is why air must be removed from the chamber and the load before the actual sterilisation time starts. Air removal from the load can be significantly improved by steam pulsing (see Section 4: **How to use the equipment**).

#### **Autoclaves designed for various purposes**

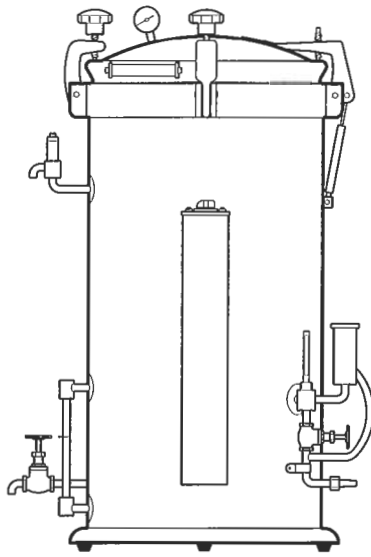
A well designed and well operated autoclave ensures that the air in the chamber and in the load is removed properly before sterilisation begins, and that the load is dry at the end of the sterilisation process. Differences in the design of sterilisers are mainly determined by the way air is removed from the chamber and the load. As the method of air removal depends on the type of load, sterilisers can be grouped according to the load they are to be used for:

- for **non-porous loads**: materials which do not contain air, e.g. unwrapped, non-hollow instruments
- for **porous loads**: materials which do contain air, e.g. drapes, gloves, wrapped instruments, hollow instruments
- for **watery fluids** such as intravenous fluids, water for injections, etc.

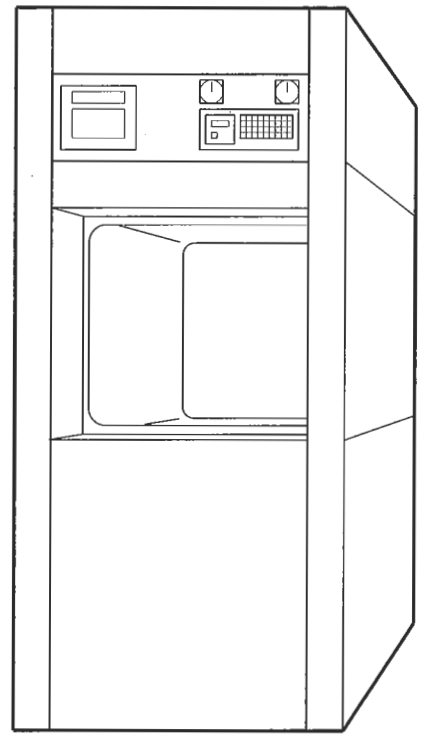
Certain models of autoclave may be suitable for more than one application. To check which application an autoclave is designed for, read the manufacturer's instructions or ask a trained technician.



A small tabletop autoclave for non-porous loads: this type is suitable for sterilising unwrapped, non-hollow instruments. It is an electrically heated, automatic model with a horizontal chamber.



A medium-size, vertical, single-chamber autoclave. It is electrically heated and hand-operated. These models are also available for heating by kerosene. They are common in rural hospitals and are used for various types of loads.



A large, fully automatic autoclave for the Central Sterilisation Department of a major hospital. It has a horizontal chamber and is equipped with a vacuum pump for air removal and drying. There is a vertical sliding door at each end of the chamber facilitating separation of the non-sterile and sterile areas.

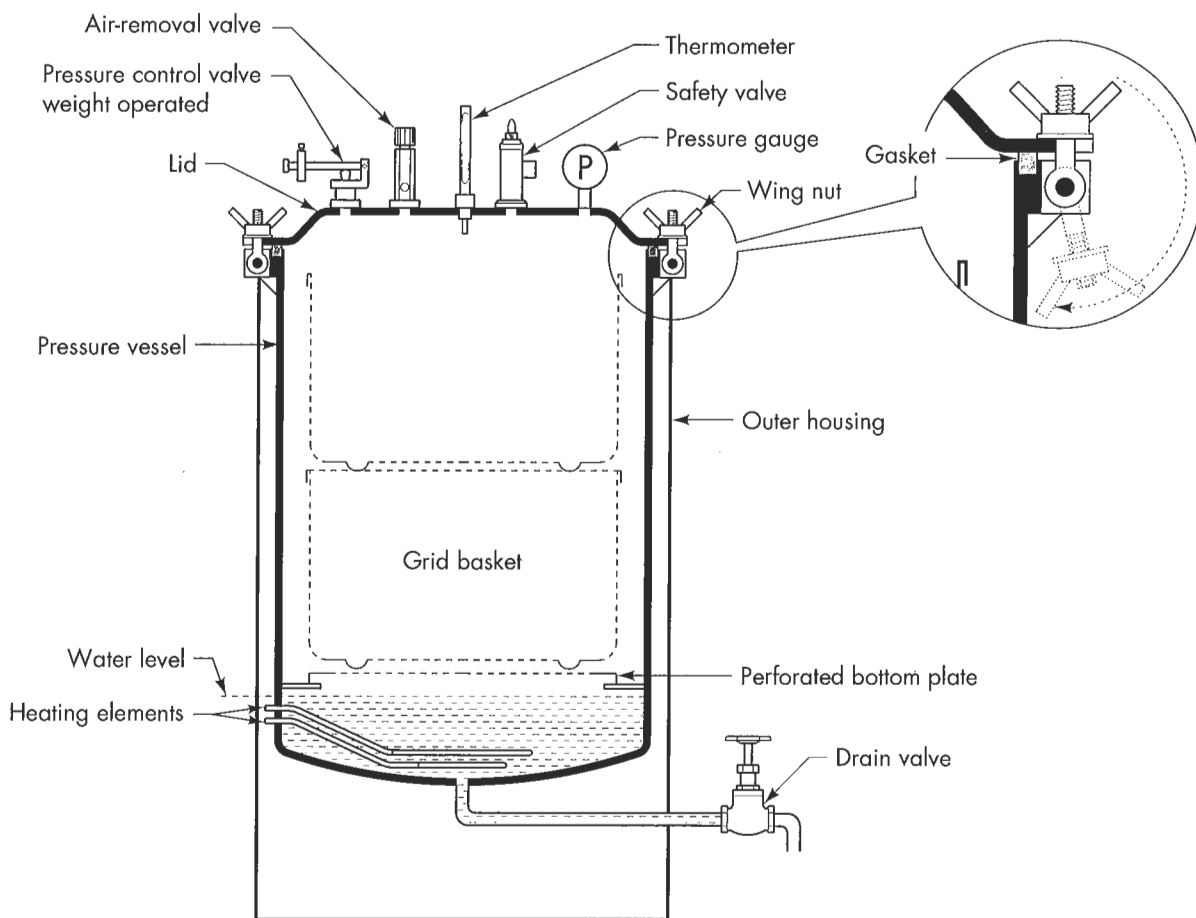
**Figure 28:** Autoclaves are available in a wide range of sizes and for various applications

### Autoclaves for non-porous loads

Autoclaves for non-porous loads can be of fairly simple design, as no special arrangements are necessary for the steam to reach all parts of the load. The most common design used in remote hospitals and clinics is the single-chamber, vertical autoclave. See Figure 29. This mainly consists of a pressure vessel in which the water is filled up to a certain level. The water is fed directly into it by opening the lid and pouring the water into the vessel. During heating-up the air from the chamber and load is removed via an air-removal valve which is opened until the water has been boiling for about five minutes. See Figure 30. A pressure control valve, which may be spring- or weight-operated, or a pressure/temperature sensor ensures the correct sterilisation pressure/temperature. An additional safety valve is installed. It is activated if the pressure control valve fails to operate.

The heating of the autoclave can be by one or more electric heating elements or a kerosene or gas burner. In order to check the temperature and pressure inside the chamber a thermometer and pressure gauge are usually installed.

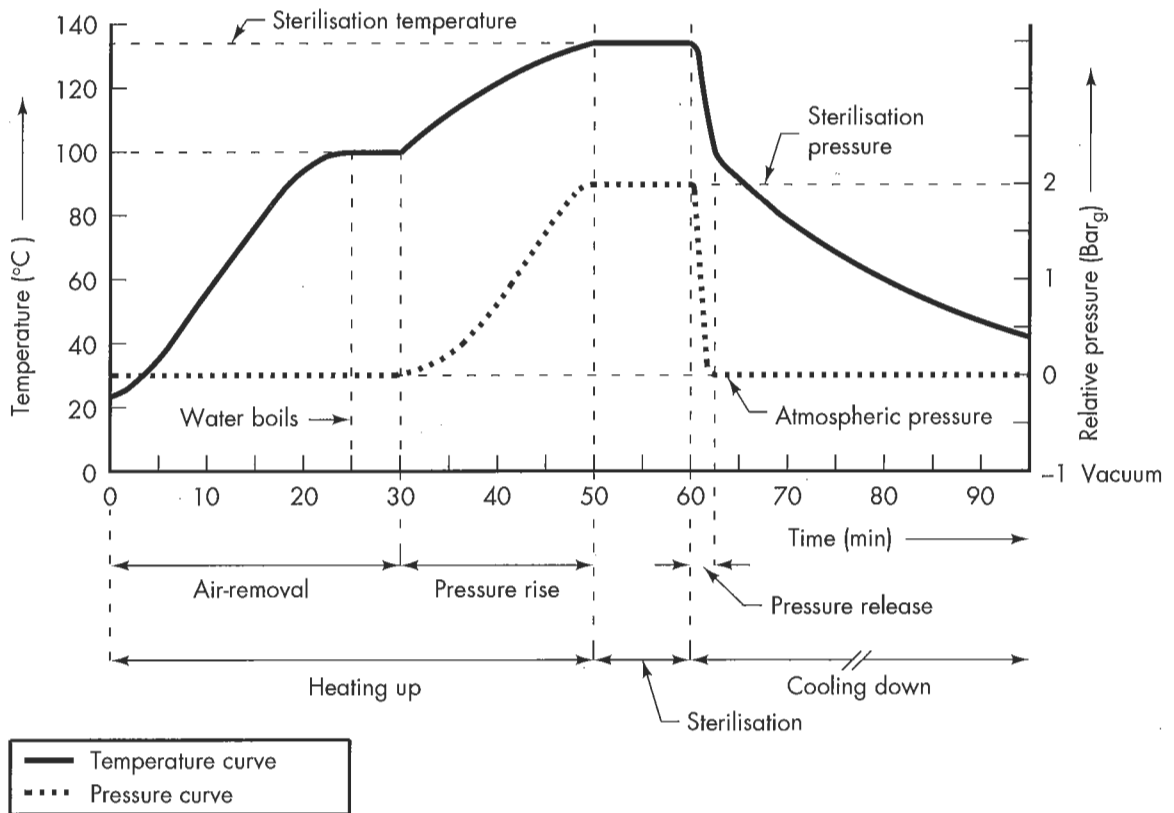
The technology of the hand-operated models is simple; they are easy to maintain and thus suitable for remote hospitals where access to a maintenance service by a supplier is not feasible.



**Figure 29:** Vertical build, single-chamber, non-vacuum type autoclave; electrically heated

The smallest autoclaves are the pressure cooker types. They are available in various sizes and complexity, from simple hand-operated multi-fuel types to advanced, fully automatic cycle, electrically heated models.

For larger loads, autoclaves with bigger chamber volumes are available. They may be equipped with additional features such as a water-level gauge, pressure gauge and thermometer. Steam may be generated inside the chamber, as in the pressure cooker types, or may be supplied from an outer jacket or an external source. Most common in rural hospitals are the vertical autoclaves with a single chamber, approximately 60cm deep and 40cm in diameter.



**Figure 30:** The temperature/time and pressure/time diagram of a typical sterilisation cycle of a non-vacuum autoclave. Sterilisation is done here at 134 °C/2 Bar<sub>g</sub> for a period of 10 minutes.

### If you have to sterilise porous loads in a single chamber autoclave without a vacuum system

Non-vacuum sterilisers are not designed for porous loads and hollow instruments. If however you are in a situation where you have to use such a steriliser for such loads perform two steam pulses before starting the sterilisation time. This greatly improves air removal from porous loads. See Section 4: **How to use the equipment.**

### Autoclaves designed for porous loads

For fast and efficient removal of air from the load, sterilisers designed for porous loads are equipped with a vacuum pump. The vacuum system is also used for drying the load after the sterilisation time.

Basic hand-operated autoclaves with a vacuum system are usually of the double-chamber type, using a steam ejector (steam-jet pump) as a vacuum pump. In order to operate these properly, it is essential to follow the manufacturer's instructions carefully.

Fast cycle, advanced automatic autoclaves are equipped with an electric water ring type vacuum pump. Usually they have short heating-up times and use several cycles of vacuum and steam injections (steam pulses) before the sterilisation time starts. After the sterilisation time a deep vacuum is drawn to dry the load. If you

have such a model, refer to the documentation which came with your steriliser or refer to the book *Sterilisation of Medical Supplies* listed in the Bibliography.

### **Sterilisation of fluids in sealed glass containers**

When sterilising fluids in sealed glass containers (for example, glass bottles containing intravenous fluids), a basic non-vacuum steriliser can be used. Be aware that the heating-up time and time for reaching the sterilisation temperature may take considerably longer than when sterilising other goods. This is due to the high heat-capacity of the fluids.

**After the sterilisation time has passed the pressure should not be released. Do NOT open the air-removal/steam release valve:** the autoclave should be left to cool down by itself. The door must not be opened until the temperature inside the bottles has gone down to 80°C. Opening the door too early could cause the bottles to explode, resulting in serious injuries to the user. Newer models of sterilisers for fluids are equipped with a door-interlock which prevents the door from being opened until the temperature inside the bottles decreases to 80°C. A vacuum must never be applied after sterilisation of fluids. If you cannot measure the temperature inside the bottles, you should leave the autoclave to cool down overnight before opening the door.

Normal autoclaves **cannot** be used for sterilisation of fluids in plastic containers or bags. For these purposes, **only** specially designed autoclaves can be used.

Modern, automatic autoclaves are extremely advanced equipment which require specialist know-how and equipment for installation and servicing. Usually maintenance and repair is done by the supplier or a well-trained steriliser technician.

### **Testing the performance of autoclaves**

Sterilisation of goods is a process in which the steriliser, the sterilisation process and the load all influence the result. The performance of an autoclave for each different type of load must be tested by using the appropriate process. For example, typical loads may be: textile packs, containers with instruments and bottles containing intravenous fluids. Each of these loads has to be tested separately. Available test methods are summarised in Figure 31. Materials for sterilisation performance testing are available through various manufacturers.



| <b>Performance test method</b> | <b>How to use</b>  | <b>Remarks</b>  |
|--------------------------------|--|---|
| Sterilisation tape             | The tape is used as adhesive tape for packaging, or can be stuck on the load as a “was sterilised” indicator.              | Lines of heat/moisture sensitive ink on the indicator tape change colour when the tape has been exposed to a steam sterilisation process. It cannot be used as a real performance indicator as it does not indicate whether all sterilisation conditions were met. When ordering specify that the tape is to be used for a steam sterilisation process.   |
| Maximum thermometer            | Can be put in the most critical location of the load.  | The thermometer indicates the maximum temperature which was reached during a process. It does not indicate for how long the temperature was reached and whether it was actually steam which reached this temperature.   |
| Chemical indicators            | Indicators can be put in critical locations of the load such as the centre of a textile pack or inside hollow instruments. | The indicator is usually a small strip of paper or cardboard which has a spot or area with a special ink, which can change colour. Various types are available. Some types verify the presence of steam at a specific temperature for a minimum period of time. Usually the indicators are designed for fast cycle vacuum sterilisers. These are not suitable for the basic non-vacuum sterilisers. When ordering mention the type of steriliser and the time/temperature for which you want to use the indicators.   |
| Steriliser control tubes       | Can be put in critical locations of the load or inside the fluid in a test bottle.   | The glass tube verifies that it was exposed to a temperature for a minimum period of time by changing colour. It does not distinguish between air and steam. Steriliser control tubes are commonly used for testing performance of sterilisation of fluids. Test tubes are available for various sterilisation times and temperatures.  |
| Bowie and Dick test            | The test pack should be in the centre of the chamber.  | Standardised steam penetration test for autoclaves with a vacuum system. It is used to verify the presence of steam at a specified temperature for a minimum time. It consists of a standard size pack of folded cotton sheets: approx. 22cm (length) x 32cm (width) x 25cm (height). A chemical indicator paper is placed in the middle of the sheets, which are put inside the steriliser and a normal sterilisation cycle is run. The indicator sheet will indicate the presence of any air inside the pack by a non-even colour change. Mini-Bowie and Dick test packs are now available which are much smaller than the standard packs. Their main advantage is that they are easy to use: you do not have to prepare sheets and fold your own full-size pack. |
| Biological indicators          | Can be put in the most critical location of the load.  | They are a direct method of checking the performance of a steriliser as they show the destruction of microbiological life. They do not provide an instant result; they must be incubated or processed to determine ‘pass or fail’. Their reliability depends on strict quality control during manufacture and decreases during storage. This method is not recommended.   |

**Figure 31:** Methods for testing the performance of autoclaves

### **3. Routines and safety**

#### **Installation**

Make sure that the autoclave is installed on a level surface which is well ventilated and dust free. The steam exhaust should be connected to a hose or piping with a gradual fall in the direction of the steam flow. Water should never be trapped inside the piping. Follow the manufacturer's instructions.

In order to limit the possibility of recontaminating sterile goods, plan a routing of the goods to and from the autoclave: crossing of routing of sterile and non-sterile materials should be avoided. This can be done by dividing the sterilisation department into at least three areas:

1. A 'dirty' area for cleaning; if possible in a separate room
2. An area for inspection, sorting and packaging of the equipment. This will be at the 'non-sterile' approach side of the autoclave
3. A clean area, for storing sterile materials. This will be at the 'sterile' approach side of the autoclave.

The autoclave should be installed between the inspection/packaging area and the clean area.

#### **i. Routines**

##### **Daily:**

Before using the autoclave:

- fill with distilled or demineralised water. Clean rain water can be used in emergencies. Do not use water which has a high mineral or salt content as this will corrode the steriliser and instruments
- check that the machine is not damaged and does not have any leaks
- check that the electricity supply/gas ring/kerosene burner is ready for use
- check that the chamber is clean after previous use
- make sure that you follow the correct instructions for each type of load (non-porous load, porous load or fluids)
- when running the autoclave, check that the appropriate temperature and pressure are reached by checking the gauges (if your autoclave is equipped with a thermometer and pressure gauge)
- keep the autoclave clean; prevent damage due to cleaning. Do not use abrasive powders, metal cleaners or bleaches as they will damage the surface

Report any damage or incorrect readings immediately

Enter any abnormalities in the autoclave log book

##### **Weekly:**

- check that the door opens and shuts easily. Lubricate the hinges if necessary as described in the manufacturer's handbook
- test the performance of the autoclave with its load by using indicator strips
- check the lid/door gasket for any deterioration or damage
- check that all valves turn easily, and are not leaking

### **Every three months:**

- when the autoclave is under pressure: check that the safety valve opens and blows off steam when activating the test lever
- the autoclave technician should carry out a complete examination of the autoclave. User entries in the log book over the previous three months can be used as a reference for possible necessary repairs

### **ii. Safety**

An electric autoclave should have a proper earth connection

When you are using a paraffin-heated autoclave:

- immediately wipe up any accidentally spilled fuel with a rag to avoid a fire hazard
- make sure there is sufficient ventilation

Do always make sure there is sufficient water inside the chamber. Heating up without enough water can damage the autoclave beyond repair and may cause great danger to the operator

Do check for steam leakages around the lid, valves and piping

Do make sure that the clamps/fastening bolts of the lid can be secured tightly

Do make sure that personnel operating the equipment are well trained and understand their duties properly

Do keep unauthorised people away from the sterilisation department

Do take great care when opening the lid, as the load may still be very hot, even after a period of cooling down

Do NOT interrupt the sterilisation cycle unless there is an emergency. If a cycle is interrupted, the whole cycle has to be started again from the beginning

Do NOT leave the autoclave unattended when in use

When sterilising fluids:

Do NOT open the air-removal/pressure-release valve at the end of the sterilisation time. Let the autoclave cool down by itself

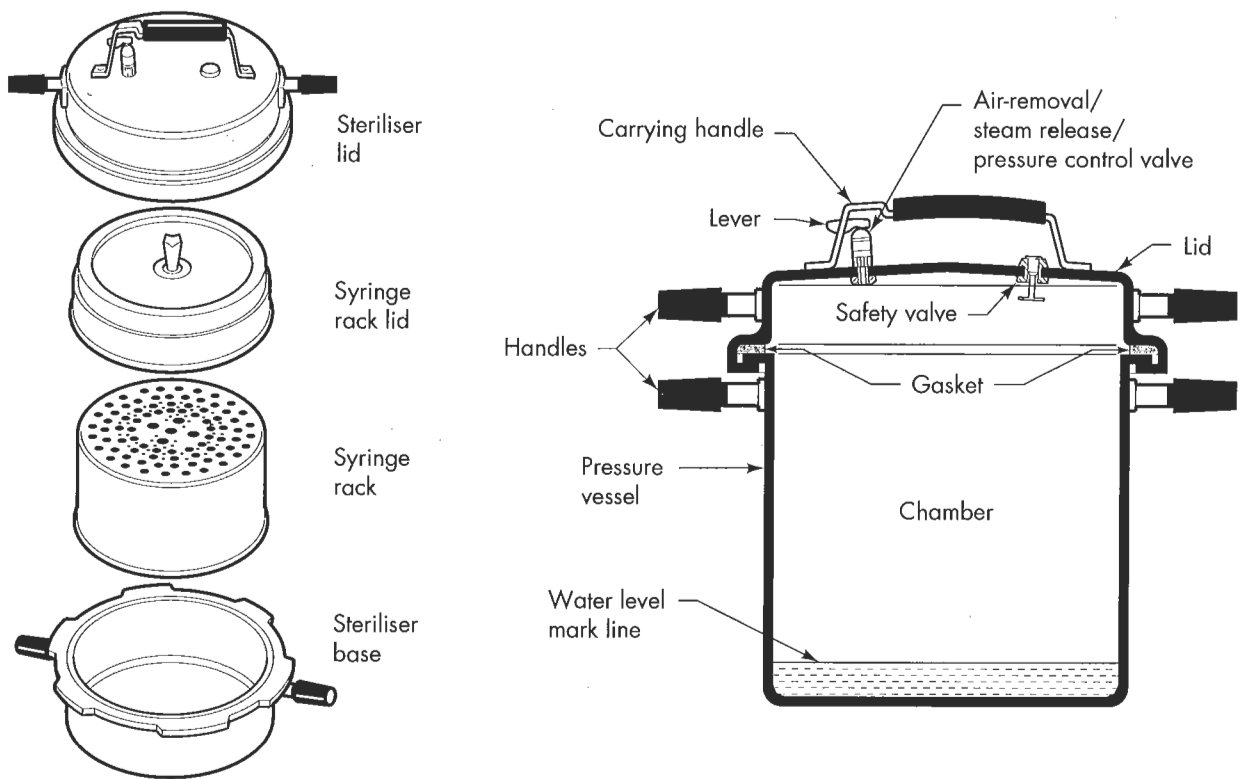
Before opening the lid, do make sure that the temperature inside the fluid has reduced to 80 °C. If you cannot measure the temperature inside the fluid: let the autoclave cool down overnight

## **4. How to use the equipment**

There is a great variety of autoclaves for various applications, a wide range of sizes and different types of control and design. Always refer to the manufacturer's instructions for specific advice on the equipment you are using. The following are guidelines for the use of a typical hand-operated pressure cooker-type autoclave (see Figure 32) and a typical, hand-operated, single-chamber, non-vacuum autoclave for large volumes as shown in Figure 33.

### **A pressure cooker-type autoclave**

This fuel-heated model has been introduced by the World Health Organisation for the sterilisation of syringes and needles for the worldwide *Expanded Programme on Immunisation (E.P.I.)* and it can also be used for sterilisation of other materials. Various sizes are available; it is designed to operate at 121 °C and it can be heated by any heat source. Refer to Figure 32.



**Figure 32:** Fuel-heated, pressure cooker-type autoclave as used in the WHO Expanded Programme on Immunisation

### **i. Preparation of the autoclave and the load**

- if you have water with high mineral or salt content, place the hard water filter pad, which is supplied with the autoclave, in the base of the autoclave
- fill with water up to the water level mark (ridged step mark) on the inside of the steriliser wall
- prepare the load so that it is ready for sterilisation (cleaning, packaging, arranging, etc.)

### **ii. Loading the steriliser**

- put the load in the steriliser
- check that the rubber seal is in place and in good condition
- put on the steriliser lid. The mark on the lid should line up with the handle on the base
- pressing down on the lid, turn it clockwise until it will not turn any more; the handles are now aligned
- check that the small pin in the safety valve is down
- make sure that the pressure-control valve is opened: the lever of the valve should be pushed upward

### **iii. Heating of the autoclave and the load; air removal**

- place the burner on a firm surface. Then place the steriliser on the burner and turn the burner on full
- after a few minutes; water will start boiling and steam will come out strongly from the pressure-control valve
- set the timer to five minutes. During this period, air will be flushed from the chamber with the steam
- when the timer clock rings push the lever of the pressure-control valve down. The pressure in the chamber will start rising. After a few minutes the required pressure is reached and steam will again come out strongly from the pressure-control valve
- turn the burner down until steam can still be clearly heard escaping from the valve

### **iv. Sterilisation**

- reset the timer to the required sterilisation time (refer to Figure 23)
- make sure that the steam can be heard escaping from the pressure-control valve all the time

### **v. Ending the sterilisation**

- when the sterilisation time has passed, turn off the heat and lift the pressure-control valve lever. A lot of steam will escape and the pressure will be reduced
- close the pressure-control valve (lever down) after all the steam has escaped, so that sterility is maintained

### **vi. Cooling down, opening and removal of the load**

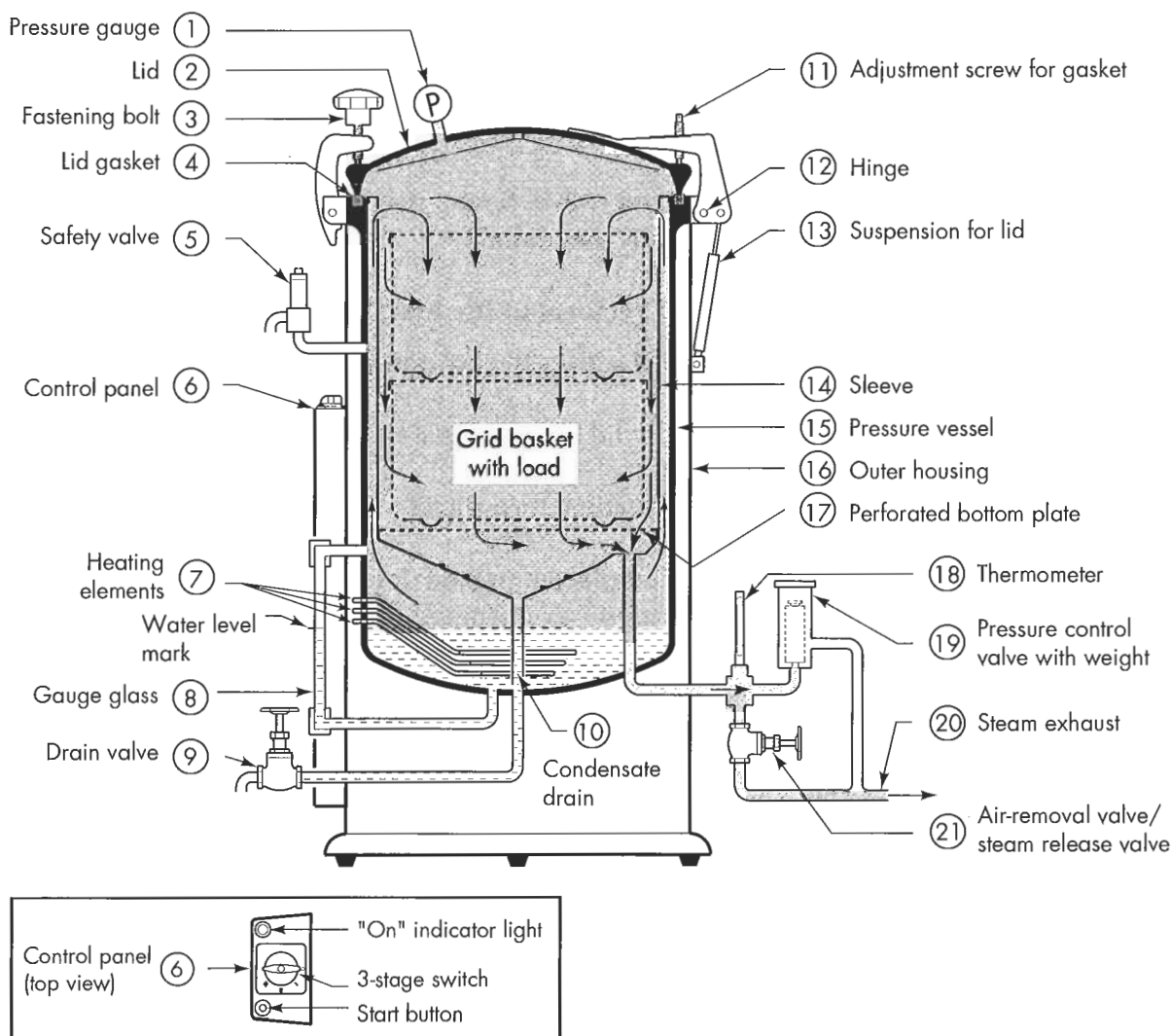
- allow 15 minutes for the steriliser to cool down before opening or draining the water
- do not open the steriliser lid until the materials which you sterilised are about to be used
- when the materials are needed, turn the steriliser lid anti-clockwise until it will not turn any more
- lift the lid off the base and place it upside down on the table
- take the load out of the steriliser chamber

## A basic, larger-volume, hand operated single-chamber autoclave without a vacuum system; electric heating

These instructions for use are specific to the model shown in Figure 33.

This type has a sleeve (14) inside the pressure vessel (15), forcing the steam to enter the chamber from the top. The steam passes from top to bottom through the chamber and the load. It leaves the chamber through a pipe in the bottom of the chamber. Air is heavier than steam. By this downward movement of the steam in the chamber, the removal of the air is improved. The pressure is controlled by a weight-operated pressure-control valve (19).

- For sterilisation of non-porous loads follow steps i-iv below without steam pulsing: step iii(a) is not necessary.
- For sterilisation of porous loads and hollow instruments follow steps i-vi including the steam pulses described in step iii(a)
- For sterilisation of fluids perform steps i-iv and step v(a) without steam pulsing. Step iii(a) should not be performed.



**Figure 33:** Vertical, single-chamber, non-vacuum type autoclave for large volumes; electrically heated. This type has a sleeve (14) inside the pressure vessel (15), forcing the steam to enter the chamber from the top. Fuel heated models are also available.

### **i. Preparation of the autoclave**

- close the drain valve (9) and air-removal valve (21)
- open the lid (2) and pour distilled or demineralised water into the chamber up to the water level mark on the gauge glass (8)
- the water flows through the perforated bottom plate (17) and condensate drain (10) into the vessel bottom
- select the sterilisation temperature/pressure. If necessary insert the correct weight in the pressure control valve (19) (for 1 Bar/121 °C or 2 Bar/134 °C)

### **ii. Loading the autoclave chamber**

Keep the following in mind:

- make sure that the load has been cleaned thoroughly
- ensure proper packaging
- make sure there is sufficient space between the items: at least 2cm
- if you use containers or nets, do not pack them too densely. You should be able to put your hand between the sheets of textile packs
- limit the size of the load. No packs or materials should ever touch the chamber wall
- containers/drums should be perforated top and bottom. The perforations should be covered with a bacterial filter
- there should be a distance of at least 2cm between containers/drums
- if the packaging material is textile, use the goods as soon as possible

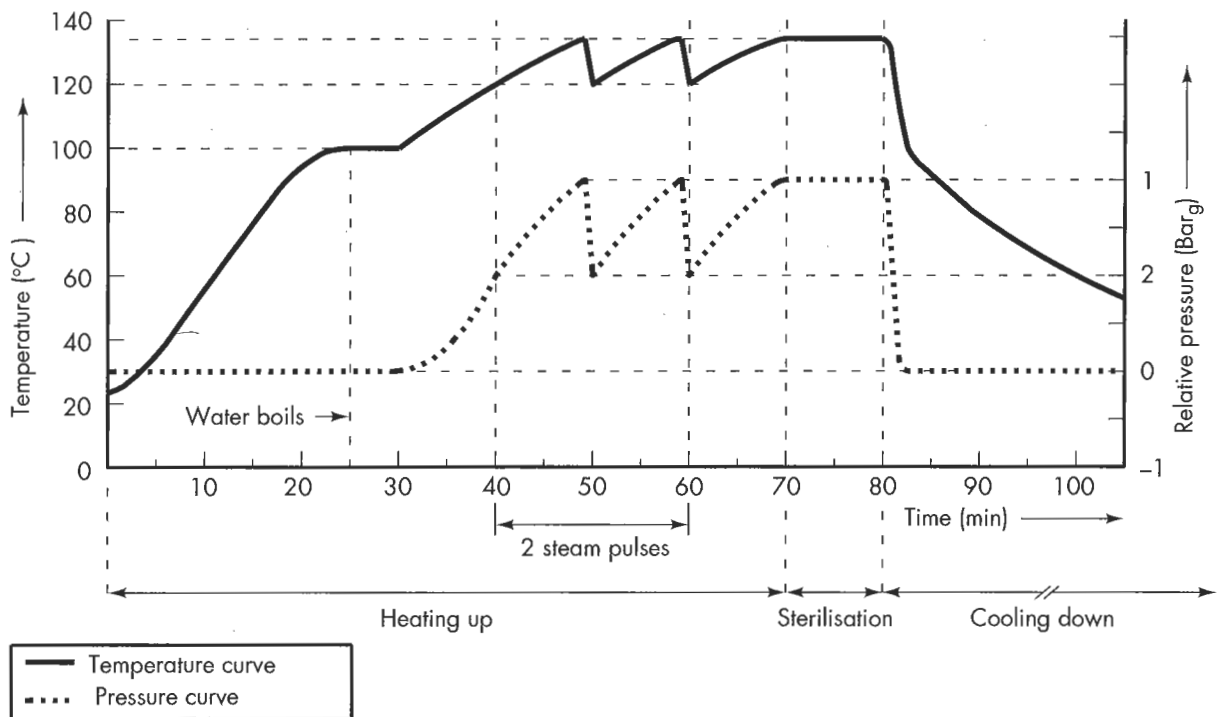
### **iii. Heating of the autoclave and the load; air removal**

- close the lid and tighten the fastening bolt(s) (3)
- open the air-removal valve (21)
- switch on the heating to maximum power by putting the switch on the control panel (6) to position III and pressing the 'start' button. The indicator light will be on
- the pressure will rise. At a certain moment the water will start boiling and the thermometer (18) will indicate 100°C. Steam will be blowing out of the exhaust pipe (20). Let the steam blow off for five minutes
- close the air-removal valve (21)
- now the pressure and temperature in the chamber will start rising. The pressure can be read from the pressure gauge (1)

#### **iii (a). When sterilising porous loads only: additional air removal by steam pulsing**

Porous loads require a more rigorous method of air removal. This can be done by performing two steam pulses. See Figure 34.

- let the pressure increase to the set sterilisation pressure
- open the air-removal/steam release valve (21) quickly. Let the pressure drop by 1 Bar. Then close the air-removal/steam release valve (21) again
- let the pressure increase to the desired sterilisation pressure again
- again open the valve and let the pressure drop by 1 Bar
- close the air-removal/steam release valve (21)
- let the pressure increase to the required sterilisation pressure



**Figure 34:** Process for sterilisation of porous loads in a non-vacuum autoclave. By performing two steam pulses before the sterilisation time the removal of air from the load is greatly improved.

#### iv. Sterilisation

- the moment when the pressure, as set by the weight of the pressure control valve, is reached, the weight will be lifted intermittently and the pressure will remain constant. At this moment the actual sterilisation time starts
- set your timer to the desired sterilisation time. Refer to Figure 23. Throughout the sterilisation time a small amount of steam will blow off from the steam exhaust pipe (20). Operation of the pressure control valve (19) can be heard as a soft hissing sound from the valve housing
- the heating can be reduced by putting the control switch down to position II

#### v. Ending the sterilisation (if sterilising fluids, see v(a). below)

- when the sterilisation time has passed, switch off the heating by turning the control switch on the control panel (6) to zero ('0')
- open the air-removal/steam release valve (21). The steam now escapes through the steam exhaust pipe (20). The pressure will gradually go down.

#### vi. Cooling down and removal of the load

- in order to improve drying, drain residual water by opening drain valve (9)
- to economise on distilled water you can catch the water in a bucket and use it again in a following cycle
- leave the load in the autoclave for about 15 minutes to cool down. The heat will help to dry the load
- loosen the fastening bolt(s) (3), open the lid and remove the load



#### **v (a). When sterilising fluids: ending sterilisation and cooling down**

- when the sterilisation time has passed, switch off the heating by turning the control switch on the control panel (6) to zero ('0')
- do not open the air-removal/steam release valve. Let the autoclave cool down by itself until the temperature inside the bottles has reduced to 80°C. If you cannot measure the temperature inside the bottles, leave the autoclave to cool down overnight

### **5. Simple fault-finding and maintenance**

Autoclaves are potentially dangerous machines. Moreover modern autoclaves, especially the automatically controlled models, are complex equipment. In the majority of countries their use is covered by mandatory regulations which include the rule that repairs and overhauls must be carried out by qualified technicians.

**Example a:** The autoclave does not heat up

#### **i. If the autoclave is heated by electricity:**

- check the power supply and the fuses

If these are satisfactory

- call a qualified technician

#### **ii. If the autoclave is heated by fuel or gas:**

- check the fuel supply
- check that the burner or stove is clean, that it is positioned correctly under the autoclave and that it is not in a strong draught

If these conditions are satisfactory:

- call an autoclave technician

**Example b:** The load is wet at the end of the cycle

Re-run the cycle observing the following points:

- prevent condensation from dripping onto the load below a pack. Put the heaviest materials at the bottom
- do not pack too densely. In textile packs you should be able to put a hand between the sheets
- limit the size of the packs and the total load
- make sure that the chamber wall is not touched. Keep sufficient distance between packs: at least 2cm from the wall and from each other
- after sterilisation drain the water from the vessel (in the case of a single-chamber, non-vacuum autoclave). The residual heat will help to evaporate the condensation left inside the load
- make sure you follow the manufacturer's instructions for use
- if your autoclave has a vacuum system, check that the vacuum is sufficiently deep (see the manufacturer's instructions)

**Example c:** Autoclave does not reach the required temperature/pressure

Re-run the cycle

- check that the door fits accurately and the gasket is in good condition. There should be no leaks
- check the setting of the pressure-control valve or pressure/temperature control system
- check the elements for 'furring'

**If all are satisfactory:**

**i. If using an electric autoclave**

- call an autoclave technician for a further check-up

**ii. If using an autoclave heated by gas or kerosene**

- check that the burner or stove is clean, correctly positioned and not in a draught

**If satisfactory:**

- call an autoclave technician

**Example d:** Door gasket is worn

A new gasket has to be fitted. For small pressure cooker-type autoclaves and also some larger models this may be easy.

- Remove the old gasket by pulling it out of the groove. Remove any bits and pieces that are left behind. Clean the groove carefully
- Replacing the gasket: Insert the new gasket in the groove or inside the rim of the lid. However watch carefully: some have a fixed location point and may have a top and bottom side. Check your instructions for use

In certain models the gasket consists of a length of tubing with loose ends. In that case it may be more difficult to replace the gasket. Follow this procedure:

- put one end of the new gasket in its groove at a suitable point
- push it into place around the chamber, making sure that it is not stretched and that the corners fit smoothly with no kinks
- leave an overlap of approximately 5mm and cut off any excess tubing, ensuring that the butting ends are cut square
- pull the cut end out of the groove for about half the tube's length, then butt the ends together firmly
- work back along the tube, pressing it into the groove until the excess has disappeared

**IF THE AUTOCLAVE IS NOT WORKING PROPERLY, DO NOT USE IT. REPORT TO THE MAINTENANCE OFFICER AT ONCE!**

## 6. Spares

A full set of spare parts as recommended by the supplier should be held in stock. The spares needed will depend on the make and model of the autoclave.

In general the following should be kept in stock:

- door gasket
- silicone spray
- water level gauge glass and gasket kit (if fitted)
- valve washers for each type of valve on the autoclave
- valve gland string

If the autoclave is heated by electricity:

- two spare sets of heating elements

If the autoclave is heated by a gas burner:

- spare gas burner and rubber tubing
- spare gas bottle and regulator

If the autoclave is heated by a pressurised paraffin stove:

- gasket set
- nozzle cleaning tool and nozzle spanner

It is recommended that each health institution has alternative sterilisation facilities or a second autoclave in case of major breakdowns.

## **7 User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions

- i. keep the environment around the autoclave clean
- ii. check that the electricity supply/gas ring/kerosene burner is ready for use
- iii. check that the autoclave chamber is clean
- iv. make sure you follow the correct instructions for each type of load
- v. when running the autoclave, check that the appropriate temperature and pressure are reached by checking the gauges (if your autoclave is equipped with a thermometer and pressure gauge)
- vi. do NOT interrupt the sterilisation cycle unless there is an emergency. If a cycle is interrupted, the whole cycle has to be started again from the beginning
- vii. check the steriliser's performance by using indicator strips at least once a week
- viii. when cleaning the autoclave do NOT use abrasive powders, metal cleaners or bleaches for cleaning as they will damage the surface

Report any damage or incorrect readings immediately.

Enter any abnormalities in the autoclave log book.

### **Follow these SAFETY points**

Do make sure that an electric autoclave has a proper earth connection

When using a paraffin heated autoclave:

Do make sure there is sufficient ventilation

Do immediately wipe up any accidentally spilled fuel with a rag to avoid a fire

Do always make sure there is sufficient water inside the chamber when heating the autoclave

Do take great care when opening the lid, as the load may be very hot, even after a period of cooling down.

Do check for steam leakages around the lid, valves and piping

Do check the operation of the safety valve each month. This can be done by pressing the lever or by letting the valve blow off steam (check the manufacturer's instructions for the proper test procedure). This check should be done when the autoclave is under pressure

When sterilising fluids:

Do NOT open the air-removal/pressure-release valve at the end of the sterilisation time. Let the autoclave cool down by itself

Do make sure that, before opening the lid, the temperature inside the fluid has reduced to 80°C. If you cannot measure the temperature inside the fluid, let the autoclave cool down overnight before opening the lid

Do make sure that personnel operating the equipment are well trained and understand their duties precisely

Do keep unauthorised people away from the sterilisation department

Do NOT leave the autoclave unattended when in use

## **9. THEATRE EQUIPMENT**

### **a. OPERATING TABLES**

#### **1. Purpose of Equipment**

To support the patient undergoing surgery in an appropriate position for the particular operation being carried out.

#### **2. How the Equipment Works**

An operating table has several features which allow the surgical team to position the patient as required (Figure 35).

As there are many models, the following information is presented as a general guide only.

##### **i. Height (P and D)**

The table is raised by slowly pumping the pump pedal (P) and lowered by using the release pedal (D) until the required height is reached.

##### **ii. Brake (B)**

The table runs on small wheels or castors. They must be securely locked while the operation is being carried out.

##### **To lock the wheels or castors:**

- turn the small brake lever (B) through 90° (a right-angle)
- check that the table does not move when pushed

##### **To unlock the wheels or castors:**

- reverse the action, turning the brake lever (B) back to its original position

##### **iii. Lateral rotation (L and R)**

To rotate the table:

- release the locking lever (L) by turning it anticlockwise
- turn the rotation arm (R) clockwise
- return the locking lever to original position

To return the table to the normal position:

- release the locking lever (L)
- turn the rotation arm (R) anticlockwise
- return the locking lever to original position

##### **iv. Back rest (E)**

To put up the back rest:

- slowly turn the elevation arm (E) clockwise until it reaches the required position

To lower the back rest:

- slowly turn the elevation arm (E) anticlockwise

#### **v. Leg rest (H)**

To lower the leg rest:

- release the retention catch and the hinged leg rest position of the table will drop

To raise the leg rest:

- lift hinged portion of table back to normal position. It should lock automatically

#### **vi. Accessories**

Other accessories such as arm rests, leg and chest supports either screw or clip into position, according to the manufacturer's design.

### **3. Routines and safety**

Looked after carefully, an operating table may be used for many years without any maintenance problem.

IT MUST BE CAREFULLY CLEANED AND WELL DRIED AFTER USE.

If it is not dried properly, the facilities described above in Section 2 will corrode and it will not be possible to position the patient correctly. It may even mean that some operations cannot be performed.

#### **a. After each operation:**

- thoroughly clean the table with a mixture of water, detergent and disinfectant, removing all traces of blood and debris to prevent cross infection
- dry quickly and thoroughly

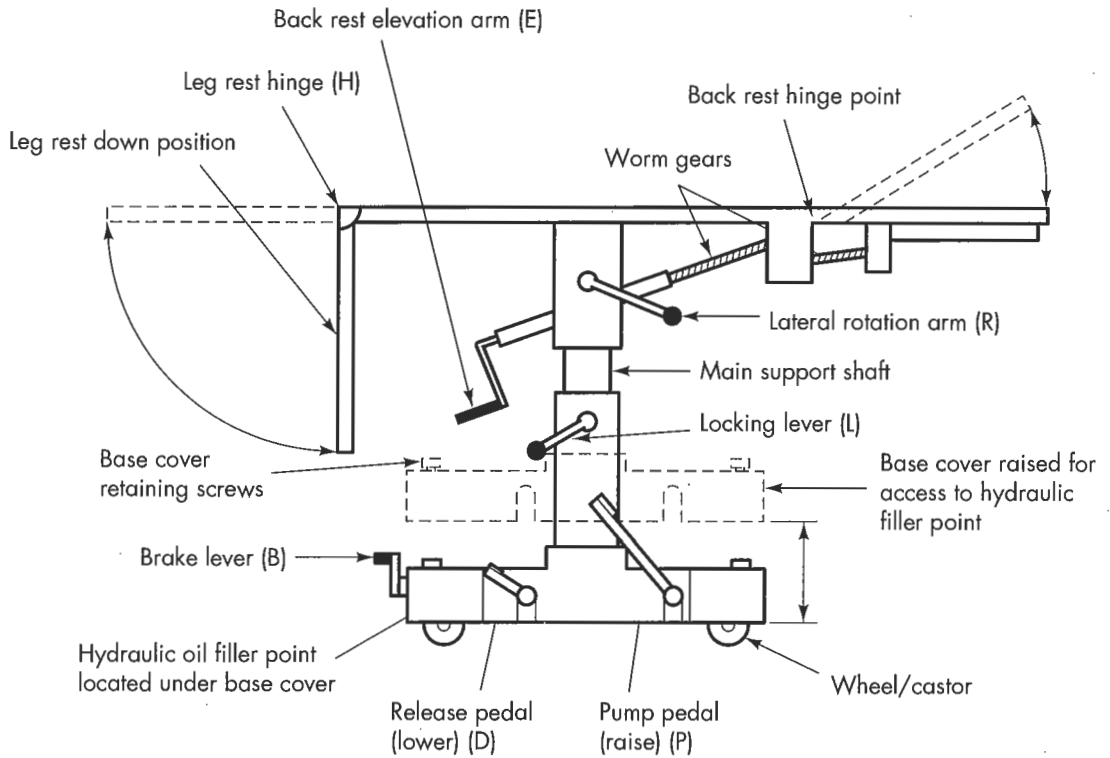
#### **b. Daily:**

- clean and dry the whole table
- inspect mattress for tears or other damage (repairs may be done locally but only antistatic, waterproof material should be used)
- check that all facilities are working easily and safely
- check that the wheel brake works well and that the table moves easily when the brake is released
- check that accessories (arm rest and leg supports) fit correctly and are undamaged

#### **c. Weekly:**

- check the hydraulic fluid level (Figure 35) and fill if necessary. The filler point is usually beneath the base cover. Remove the four corner screws, lift the table support column, unscrew the filler cap and check that the oil level is near the top. If not, fill up with the specified hydraulic oil or (if not available) car brake fluid.  
DO NOT use any other oil. Other oils will destroy the pump seals and the height facility
- with a colleague acting as the 'patient', check that the hydraulic lift and other facilities are functioning. Wear theatre dress for this

- extend worm gears and main support shaft (Figure 35)
- apply a light smear of grease to the worm gears and also to the main support shaft
- check wheels and castors for signs of damage or wear
- check all accessories for damage or wear



**Figure 35:** Hydraulic operating table

#### d. Safety:

The following safety points are of vital importance:

- check that the table functions well daily, weekly and BEFORE EACH OPERATION
- check daily that all accessories are available and in good working order
- clean and dry table thoroughly AFTER EACH OPERATION

#### 4. How to use the equipment

Correct use of the equipment is described above. Always refer to the manufacturer's instructions for specific advice on the equipment you are using. The guidelines given here are general only.

## **5. Simple fault finding and maintenance**

*Example a:*

Table cannot be raised:

- check hydraulic oil level

if oil level is satisfactory:

- call a qualified technician

*Example b:*

Table will not rotate:

- check worm gears are greased

if table still does not rotate:

- call a qualified technician

*Example c:*

Back rest cannot be raised:

- check worm gears are greased

if back rest still cannot be raised:

- call a qualified technician

All other poor functioning or faults will need the skills of a qualified technician.

## **6. Spares**

Always have a second table available for emergency use.

Hydraulic oil

Lubricating grease or vaseline

Set of pump seals



## **7. User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions

To keep this equipment in good working order for as long as possible:

### **Before using the table check:**

- it has been thoroughly cleaned and dried since the last operation
- height control pedals
- brake and mobility of the table
- lateral rotation function
- back raising function
- leg rest is free and can be locked in position
- all accessories, such as arm rests, and leg and chest supports, are available and in good working order

### **Report to the Maintenance Officer:**

- any visible damage to table or mattress
- any fault in the functioning of the table

Follow these SAFETY points:

Do check that all functions are working well – weekly, daily and immediately before use.

Do check that all accessories are available in good condition and fit securely.

Do clean and dry the table after each operation.

Do ensure that the pumping mechanism is regularly exercised if the table is not going to be used daily.

## **b. ELECTRICAL SUCTION APPARATUS**

### **1. Purpose of Equipment**

To provide an efficient means of removing a body fluid (e.g. blood, mucus, vomitus) from wounds, the respiratory tract or a body cavity.

### **2. How the Equipment Works**

There are several types of suction machine. According to the design, different flow rates and different pressures – high, low or dual – can be attained.

It is important to read and understand the relevant documentation for the machine you are using. For example some machines are designed to function for only 1 to 2 hours at a time and will be seriously damaged if they are run continuously over a longer period. These are labelled 'Int', which means they are for intermittent use only.

Each model will have a pump which may be driven either electrically or by hand. This, under carefully controlled conditions, draws fluid from the patient, through a flexible tube, into a glass reservoir jar (Figure 36). To prevent fluids passing back to the pump, a float valve (F) rises until a predetermined fluid level is reached. It then closes off the suction.

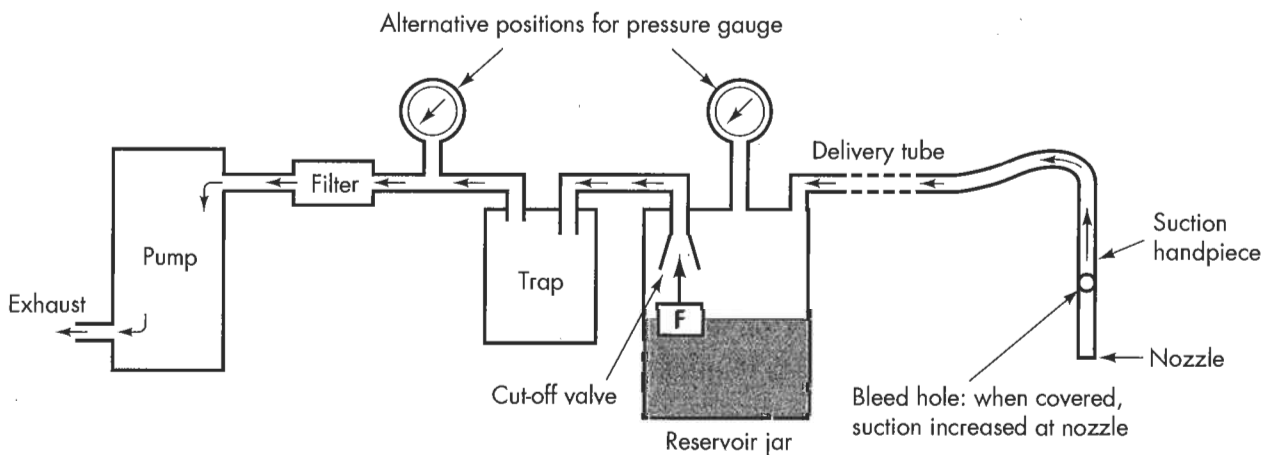
When the float valve operates, the apparatus must be switched off while the jar is changed. If the machine has a dual reservoir (two jars) a quick changeover can take place without switching off the apparatus.

There should be a bacterial filter between the reservoir jar and the pump. This reduces the risk of cross infection and possible damage to the pump. It also provides some safeguard for the maintenance engineer.

### **3. Routines and Safety**

To reduce the risk of cross infection, many hospitals have a suction pump in each of the departments likely to need one. These will be the operating theatre, casualty or accident and emergency department, intensive care and recovery units, post operative wards, dental surgeries, the Ear, Nose and Throat (ENT) ward and the maternity department.

Each ward or department is responsible for its own machine, which should be labelled with the name of the ward or department.



The components of a portable suction apparatus. The pump may be protected from infected material, which could be drawn from the reservoir jar, by a trap and/or filter. There is a cut-off valve within the reservoir jar, which operates when the level of fluid in the jar is sufficiently high to raise the float F, so as to prevent any foreign material being aspirated into the pump. There are alternative positions for the pressure gauge.

**Figure 36:** Typical suction circuit

**i. Routines**

**Before using the suction pump:**

- check that it is the correct machine for the task (e.g. that the pressure is sufficient)
- check details on the information plate or in the manual
- do not pull the machine by the electric power lead

**During use:**

- keep ventilation grills free from obstruction
- do not continue to use machine if the vacuum gauge has a low reading

**After use:**

- unplug the machine from electricity supply
- wipe clean the outside of the machine
- clean and sterilise all jars, float units, tubing and catheters
- change bacterial filters, especially if discoloured

**Daily:**

- keep air vents free from obstruction
- check that there is no visible damage to the machine, electrical lead and plug
- check that machine is thoroughly clean from previous day's use
- check that all equipment (jars, tubing, etc) has been sterilised
- check that bacterial filter has been changed (this should be replaced if it becomes wet or discoloured)

- check there is a good supply of bacterial filters available
- check reservoir jars for cracks or chipped rims
- check there are spare jars available
- before filling reservoir jar, check that float unit moves freely (Figure 36)
- check that tubing is anti-static (it will have a yellow line or flash along its length, or, if transparent tubing, a black line along its length)
- use a defoaming agent in the reservoir jar to prevent frothing, e.g. diesel oil
- make sure the jar is fitted tightly

DO NOT use cotton wool or lint as a bacterial filter. In an emergency, lint-free material (e.g. bandage) may be used.

**One to three monthly:**

- send machine to workshop for testing and general overhaul. The air-intake filter should be cleaned or replaced

Do thoroughly clean the machine and sterilise reservoir jars, tubing, float unit, etc before use. This is to help safeguard the maintenance personnel from infection.

**ii. Safety**

Do use the machine on a firm and level surface

Do disconnect the machine from the mains power supply before cleaning, changing jars, replacing filters or when the machine is not being used

Do ensure that anti-static tubing is used

Do change bacterial filters every day and when they become wet or discoloured

DO NOT use the mains power lead to pull the machine from one place to another

DO NOT continue to run the machine if the pressure gauge reading is low

#### 4. How to Use the Equipment

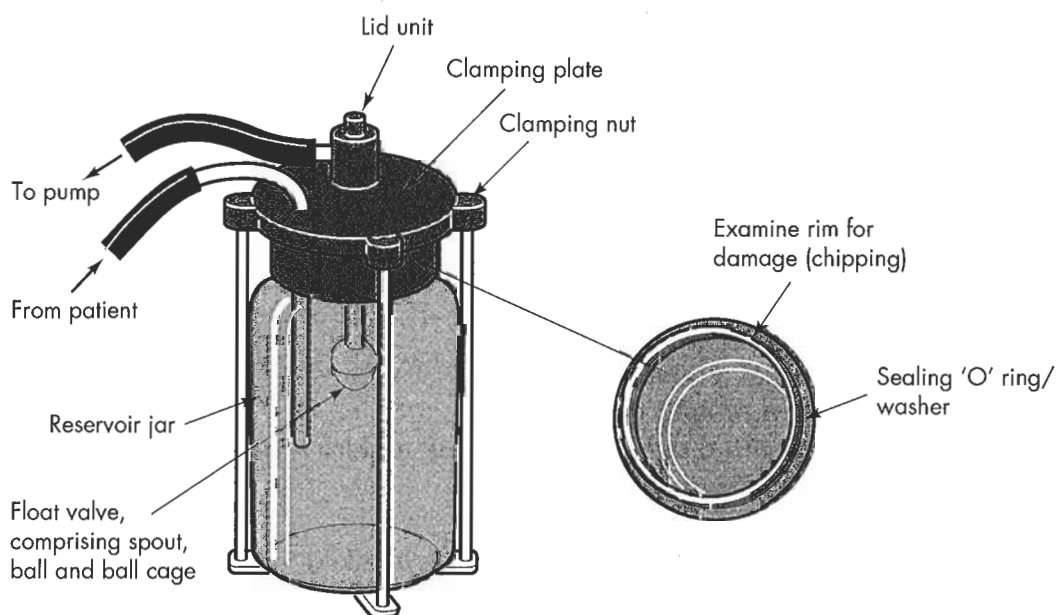
Because there are many designs of suction pump, the manufacturer's instructions should be followed.

##### The following instructions are a general guide only:

- i. make sure that the equipment is in an upright position and standing on a level surface
- ii. confirm that a suitable electric mains power socket is available and that it has an earth pin. (If unsure, check the manufacturer's manual *or* contact the manufacturer if possible *or* call in a qualified technician for advice)
- iii. check that all external connections are tight and there is no obvious leakage point
- iv. before filling the reservoir jar, check the float valve moves freely (Figure 36)
- v. check that the reservoir jar has no cracks and that the rim is not chipped
- vi. check that the jar fits tightly (Figure 37)
- vii. check that anti-static tubing is being used
- viii. plug the machine into mains and switch on
- ix. check the vacuum gauge for correct reading (on some machines the rate can be adjusted)

##### If using a dual pressure machine:

- x. ensure that the correct setting is being used



**Figure 37:** Typical reservoir jar (plastic or glass)

## 5. Simple Fault-Finding and Maintenance

A second machine should be available for emergency use

*Example a:*

The suction pump does not work

- check the socket outlet

**If satisfactory:**

- check the mains lead

**If satisfactory:**

- return the machine to the workshop because there is a major fault which needs to be repaired by a qualified technician

*Example b:*

The machine works but the suction power is poor

- check setting of suction control knob

**If setting is correct:**

- switch off the machine
- remove tubing running from the suction pump to the reservoir jar
- place a finger over the outlet port of the pump from where the tubing has been removed
- switch on the machine

**If the pressure gauge needle does not rise rapidly:**

- return the machine to the workshop for repair

**If the pressure gauge needle does rise rapidly:**

- switch off the machine
- reconnect tubing
- remove jar and fill with water to 'full' level
- refit the reservoir jar
- switch on the machine to confirm low pressure
- switch off the machine

**Visible problems may be:**

- leaking at a joint
- cracked or split tubing
- jar not fitted tightly (jar seal may require replacing)
- wrong type of jar being used
- jar is cracked or chipped
- bacterial or air inlet filter may be blocked
- float valve is not working and the washer, the 'O' ring or the whole unit needs to be replaced

Replacement of the washer or 'O' ring is a simple task. If any one of the other components is thought to be causing the problem, replace it and re-test the machine.

## 6. Spares

If possible, the full range of the manufacturer's spares should be held in store and replenished when used.

### **Local needs:**

Spare machine

Reservoir jar

Reservoir jar seals

Float valve unit

Float valve washers or 'O' rings

Anti-static tubing

Anti-static tubing clamps if fitted (some machines have push-on connections only)

Electrical mains power lead

Mains power plug and fuse (if required)

## **7. User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions

Try to keep this machine in this department/ward to help prevent cross-infection.

To keep the equipment in good working order for as long as possible:

- i. keep it in a clean, well ventilated store
- ii. read and understand the relevant documentation before using the suction pump
- iii. keep the machine clean
- iv. make sure that all external components (e.g. jars and tubing) are sterilised after use
- v. keep air inlet vents free from obstructions
- vi. change bacterial filters after every use and when they become wet or discoloured
- vii. make sure that there is a good supply of bacterial filters available
- viii. check reservoir jars for cracks and chipped rims
- ix. make sure that there are spare jars available
- x. check float unit moves freely before fitting jar
- xi. make sure jar is fitted tightly
- xii. use a defoaming agent in the jar to prevent frothing
- xiii. in machines with two jars, ensure that the tubing connections are correctly made. Wrong connections could lead to the float valve becoming ineffective and damaging the suction unit.

### **Report to the Maintenance Officer:**

- any visible damage to the mains power lead, plug, body of the machine or any of its component parts (e.g. jars, tubing, etc)
- any fault or poor function

### **Follow these SAFETY points:**

Do use the machine on a firm and level surface

Do disconnect the machine from the mains power supply before cleaning, changing jars, replacing filters or when the machine is not being used

Do ensure that anti-static tubing is used

Do change bacterial filters after every use and when they become wet or discoloured

Do NOT use the main power lead to pull the machine from one place to another

Do NOT continue to run the machine if the pressure gauge reading is low



## **c. MANUAL SUCTION APPARATUS**

Modern manual suction apparatus is manufactured using design methods and materials which overcome the need for general maintenance. However, good practices are important.

- i.** All manual suction pumps and their components should be cleaned after each use in a solution of water, detergent and disinfectant. The cleaning solution should be pumped through the pump.

Take particular care with the reservoir jars and tubing. Some reservoirs can be autoclaved, but if in doubt, use the above method.

- ii.** Dry all components thoroughly. Store in a clean area out of direct sunlight.

### **If the pump does not work, check for**

- badly fitting connections
- kinked or damaged tubing

### **Weekly:**

- closely inspect for general wear or damage. In this way, a possible mechanical breakdown can be anticipated and appropriate action taken

Minor repairs may be carried out at the local workshop or by the hospital's handyman.

Do make sure the pump has been thoroughly cleaned and dried before sending it to the workshop or handyman.

### **Report to the Maintenance Officer:**

- any visible damage
- any fault or poor function

### **Spares:**

If the pump is in regular use:

- have a spare suction pump in store for emergency
- anti-static tubing

## d. SHADOWLESS THEATRE LAMPS

### 1. Purpose of Equipment

To provide very bright lighting without shadow over an operating or treatment table.

### 2. How the Equipment Works

Shadowless theatre lamps may be fixed or mobile. The mobile type is used mainly as a reserve lamp. It has a battery and can be moved around the hospital as and where needed.

#### a. Fixed lamp

A fixed theatre lamp is suspended from the ceiling of an operating theatre or treatment room, directly over the centre of the table. It can be positioned by moving the lamp head and its outreach arm (Figure 38).

It has at least four units which produce a very high level of light without shadow. Usually the light is produced by high intensity tungsten halogen bulbs which are similar to the headlight bulbs of motor cars. Voltage of these bulbs varies depending upon the design but it is either 12 or 24 volts AC or 12 or 24 volts DC. This is a safety measure to prevent electric shocks.

At the back of the lamp there is a polished metal reflector which reflects the light and directs it where it is needed. In front of each bulb there are two glass plates which break up the light and spread it evenly. They also prevent glare and filter the heat given off by the bulbs.

The lights are well sealed by rubber gaskets and bezel plates (see Figure 40). The lamp can be thoroughly washed without water entering the electrical circuit.

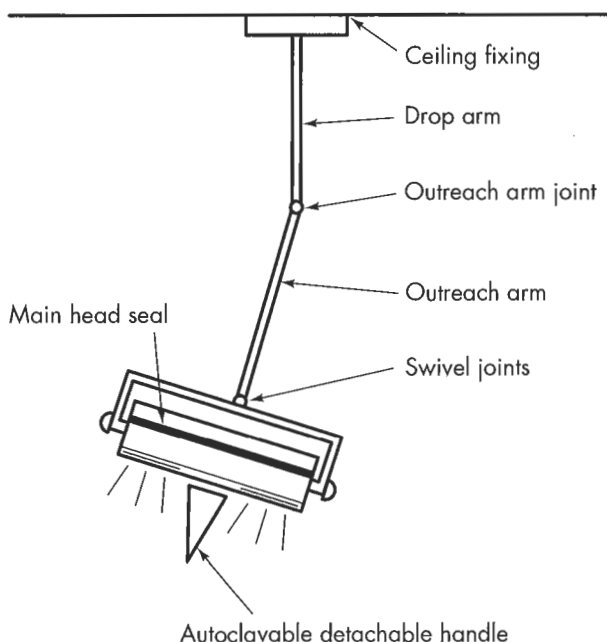
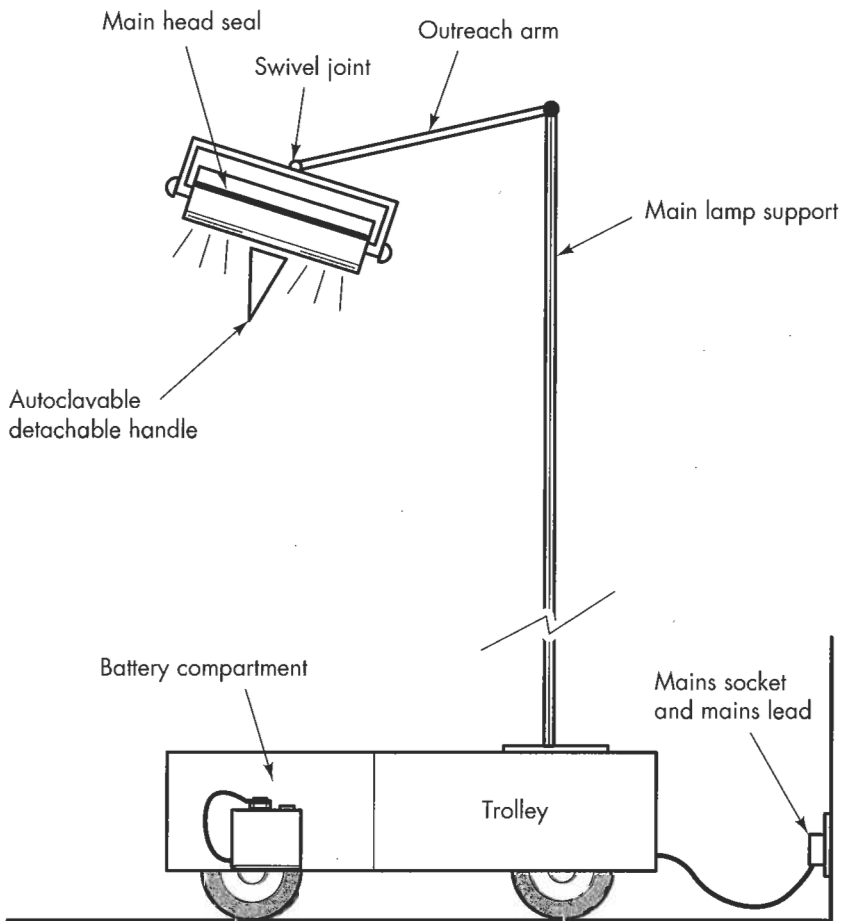


Figure 38: Fixed theatre lamp

**b. Mobile Lamp**

The mobile lamp works in the same way as the fixed lamp (Figure 39). It is built onto a mobile trolley. It has a battery and charger compartment which can provide power if the main electricity supply fails or if the fixed lamp breaks down. It has a maximum of four light bulbs.



**Figure 39:** Mobile theatre lamp

### **3. Routines and Safety**

#### **i. Routines**

##### **Fixed Lamp**

This should be fixed to the ceiling according to the manufacturer's directions. It is heavy and constant repositioning during surgery increases metal stress. It is very important that it is **FIXED VERY SECURELY INDEED**.

In countries where a wide fluctuation of voltage may occur, transformer units may burn out quickly. These are expensive to replace. A voltage stabiliser prevents this wide fluctuation and, in the long term, is cost effective.

The lamp head should be moved carefully. Damage can result in gaps around the main seal through which moisture can enter.

Always switch off the lamp immediately after use. This will lengthen the life of the bulbs and also reduce the room temperature.

Use only water and detergent for cleaning. Do not use abrasive powders, scouring pads or bleach.

##### **Daily:**

Before an operating session begins:

- switch on lamp to make sure it is working
- check that the head swivel and outreach arm joints move easily
- check for damage, including broken glass
- check lamp was thoroughly washed after previous use

##### **Weekly:**

- apply a smear of vaseline to the joints of the arm and swivel head
- check head seal is in position and undamaged. Sometimes if the lamp is knocked, the seal comes out of position. This is easily re-fitted

##### **Yearly:**

- a qualified technician should carry out a full electrical test and confirm earthing is satisfactory

##### **Mobile Lamp**

The battery compartment should be locked to prevent the battery being stolen. When not in use the unit should be plugged into the mains supply and re-charged.

**Daily:****Before the day's work begins:**

- make sure that the unit is on charge and ready if required
- check all bulbs are working
- switch off/unplug the unit from the mains
- check all bulbs are working from the battery
- leave switched on for 5 minutes
- check if there is any dimming of light during that time. If so, the battery is low or has a fault. It must be checked
- check mains lead and plug for damage
- check outreach and swivel arm joints move easily
- check lamp has been cleaned after previous use. This is important as dust, if allowed to accumulate, can fall onto the patient being treated

**Weekly:**

- apply a smear of vaseline to outreach and swivel arm joints
- check main head seal for damage
- check specific gravity of battery
- check acid level of battery
- check trolley wheels for wear and mobility

**ii. Safety**

Do switch off lamp and allow bulbs to cool before carrying out any maintenance work

Do unplug the mobile lamp before carrying out maintenance

Do use a clean cloth when handling bulbs

Do protect eyes and wear gloves when handling lead acid batteries

Do keep lead acid batteries in an upright position

Do apply clean cold water immediately to the skin or eyes if acid is spilt. Also seek medical attention at once

Do clean up spilt acid with plenty of water

Do make sure mobile unit is stored and recharged in a well ventilated area

Do NOT handle bulbs with bare hands

Do NOT smoke while working on or near a lead acid battery

Do NOT wear jewellery when working on or near an acid lead battery

**4. How to use the equipment**

Always use the manufacturer's instructions for specific advice on the equipment you are using. The following guidelines are general.

Before the operating session begins, switch on the fixed lamp to make sure all bulbs are working.

At the same time, check the mobile lamp in case it is needed.

Adjust lamp to surgeon's requests.

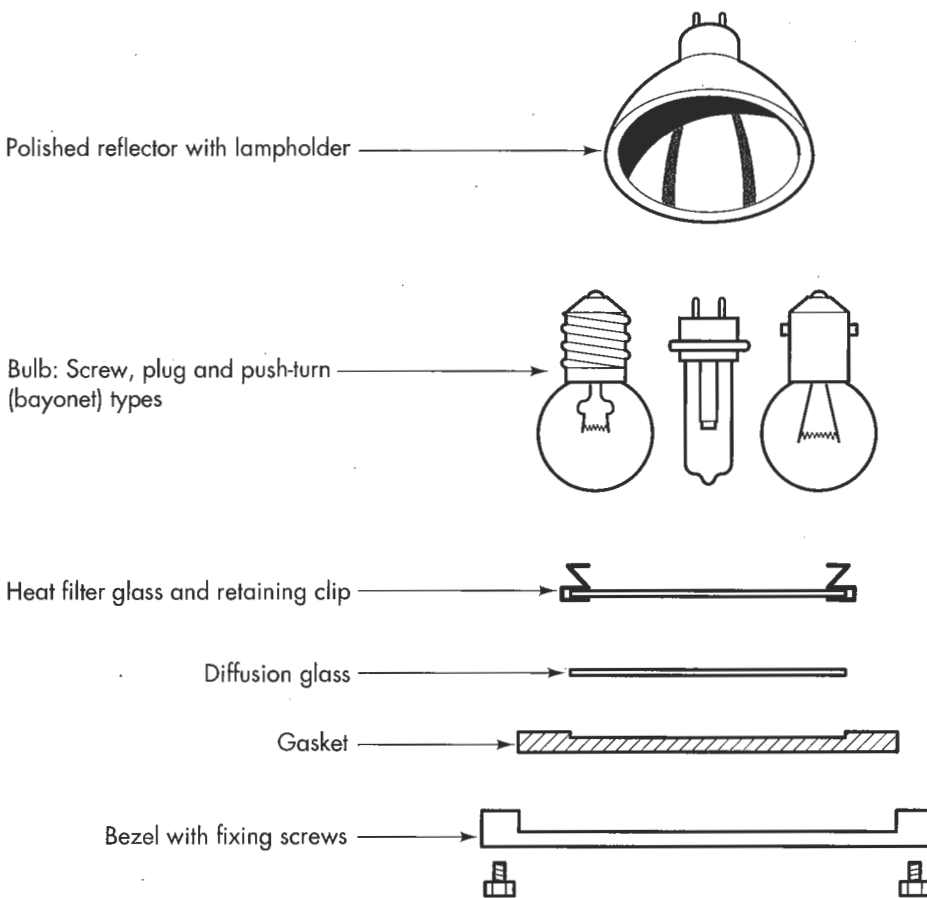
When replacing a theatre lamp bulb always hold it in either a clean soft cloth or tissue paper. This will prevent it coming into contact with the hand and avoid damage from impurities on the skin.

Many differing types of bulb are used but mainly they are either screwed in, plugged in or pushed and turned in. Take care when removing the old bulb to note which type you are dealing with.

Do not over tighten the screw-in type, turn it gently until it comes to a stop.

Bulbs can easily break when they are being removed especially if they are tight. Take great care and wear protective gloves if possible.

Remember to SWITCH OFF MAINS SUPPLY before working on the theatre lamp.



**Figure 40:** Bulb replacement

## 5. Simple fault-finding and maintenance

### Example:

Bulb does not work:

- switch off the lamp (if using the mobile model, unplug from the mains supply)
- allow the lamp to cool
- unscrew the bezel plate (Figure 40)
- remove the bezel plate, gasket and outside glass
- unclip inside glass and remove
- remove the faulty bulb
- clean the polished metal reflector with cotton wool
- remove the new bulb from packing USING GAUZE TO PROTECT YOUR HAND AND THE BULB
- fit the bulb into the holder
- wash the glasses in warm water and detergent and dry well
- refit the glasses
- switch on the lamp

### If bulb does not work in fixed lamp:

- call a qualified technician to find the cause

### If bulb does not work in mobile lamp:

- check socket outlet

### If satisfactory:

- check mains lead

### If satisfactory:

- switch off and unplug from mains supply
- check battery connections

REFER TO CHAPTER 6, BATTERY MAINTENANCE

### If satisfactory:

- check output fuse. This is usually enclosed in a small glass cylinder. Flick it and note whether wire is broken
- replace fuse if necessary

### If lamp still not working:

- check lead acid level

## 6. Spares

### For fixed lamp:

- transformer or rectifier. This must be fitted by an electrician

### For mobile lamp:

- battery (unfilled) and acid (to be filled and charged by qualified technician when needed)
- distilled water
- hydrometer
- thermometer
- vaseline
- spare trolley wheel

### For both lamps:

- bulbs
- bezel plate
- bezel gasket
- inner glass
- outer glass
- head gasket
- clean cloth for handling bulbs
- allen key tool for changing bulbs
- spare autoclavable detachable handle



## **7. User Checklists (to be displayed near the equipment)**

**Always refer to the manufacturer's instructions**

### **Daily:**

- i. check all bulbs are working on fixed and mobile lamps
- ii. check all lamp joints move freely
- iii. check for damage and broken glass
- iv. make sure the lamp has been cleaned since previous use

### **Mobile lamp:**

- v. when checking bulbs make sure there is no dimming of light over a five-minute period if operating on battery power
- vi. check trolley moves easily

### **Report to Maintenance Officer:**

- any visible damage
- any fault

### **Follow these SAFETY points:**

Do switch off lamp and allow bulbs to cool before carrying out any maintenance work

Do unplug the mobile lamp before carrying out any maintenance work

Do use a clean cloth when handling bulbs

Do protect eyes and wear gloves when handling lead acid batteries

Do keep lead acid batteries in an upright position

Do disconnect one battery lead at a time

Do make sure leads do not come into contact with each other until both are disconnected

Do make sure correct terminals are used when reconnecting leads

Do check again before switching lamp on

Do apply clean cold water immediately if acid is spilt on skin or eyes.

Also seek medical attention at once

Do clean up spilt acid with plenty of water

Do make sure mobile lamp is stored and recharged in a dry, well ventilated area

Do NOT handle bulbs with bare hands

Do NOT smoke while working on or near a lead acid battery

Do NOT wear jewellery when working on or near a lead acid battery

Do NOT lift batteries by their terminals

**WORK ON BATTERIES SHOULD BE CARRIED OUT ONLY BY TRAINED PERSONNEL. THE ABOVE APPLIES TO USERS WHO ASSIST THE MAINTENANCE STAFF MEMBER.**



# 10. VACUUM EXTRACTORS

## 1. Purpose of Equipment

To aid the safe delivery of babies.

## 2. How the Equipment Works

See Figure 41.

### The equipment consists of:

- hand vacuum pump
- vacuum bottle
- rubber vacuum tube (from pump to bottle)
- vacuum gauge
- rubber plug (bung) with stainless steel inlet and outlet tubes
- rubber vacuum tube (from vacuum bottle to suction cap) which includes a traction handle with hook and chain

The selected suction cap is placed on the baby's head when it appears. The screw valve on the vacuum pump is closed and the pump is pumped by hand until a vacuum is created. The level of this is indicated on the vacuum gauge.

The suction cap becomes attached to the baby's head.

The traction chain and handle are used to gently draw the baby from the uterus.

When the baby is delivered, the screw valve is opened. Air flows in and breaks the vacuum. The baby is released.

## 3. Routines and Safety

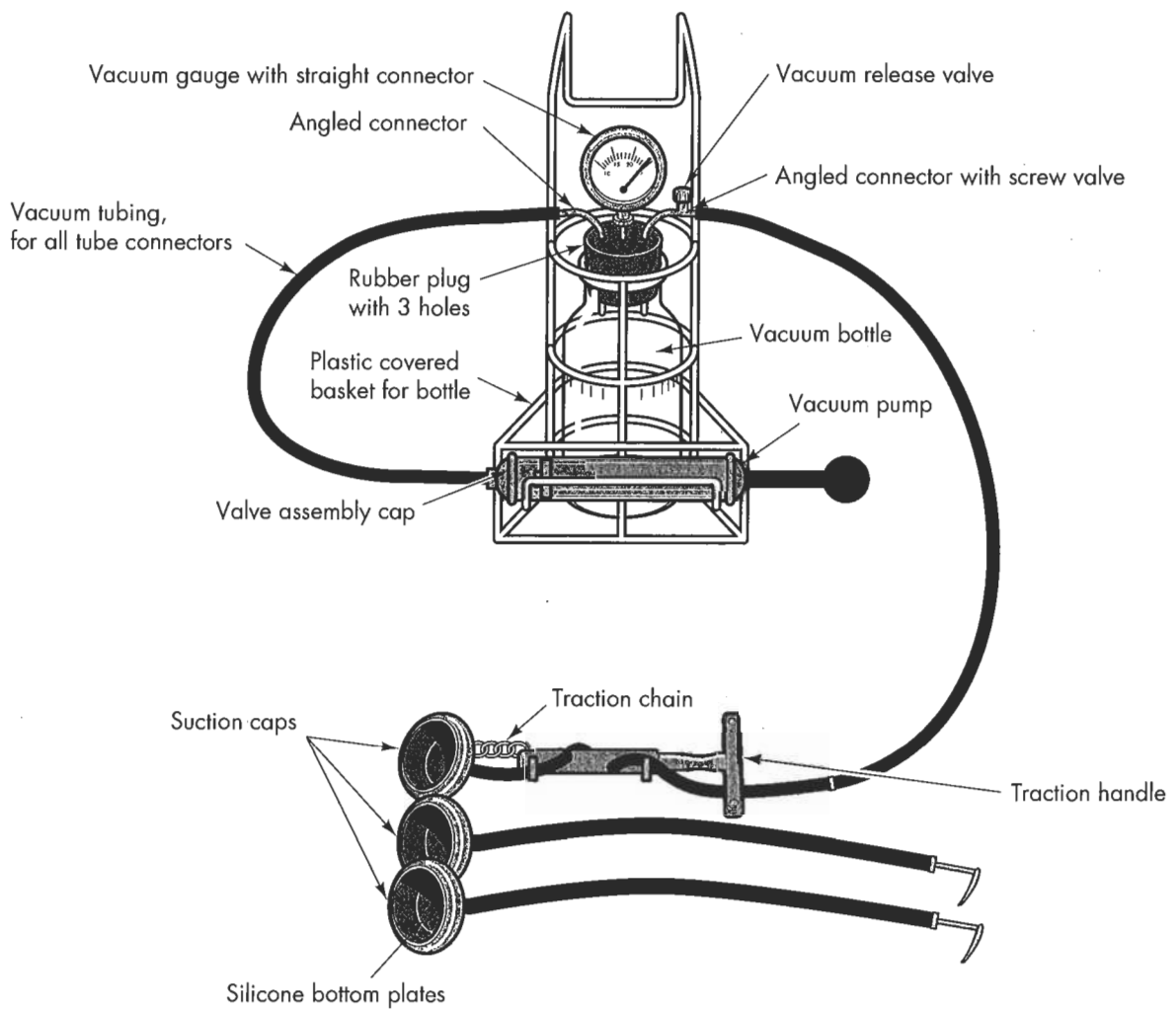
This equipment must be kept in first-class condition.

After each use all parts which can be sterilised should be autoclaved. Check with the manufacturer's manual. The parts are likely to be the suction cap, the vacuum jar and the rubber tubes.

All parts of the machine should be kept together and numbered. They should be stored in a kit box supplied by the manufacturer or made locally, in a clean, well-ventilated area.

### Daily:

- check that a full set of the equipment is available
- check for visible damage to the rubber tubes, vacuum bottle or rubber plug
- check that the vacuum release valve has a knob and washer
- check the traction chain for wear or damage
- check that the stainless steel connector tubes and gauge fit firmly into the rubber plug
- check that the suction caps are not damaged, especially around their rims
- check that the silicone bottom plates are not damaged or split
- check the pump and gauge for external damage



**Figure 41: Vacuum extractor**

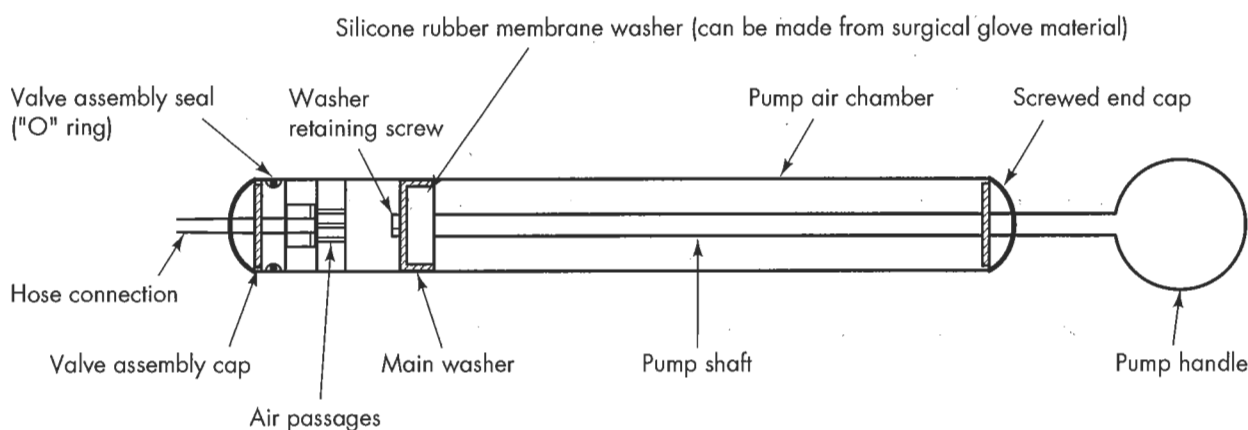
**Weekly** (or monthly if equipment is not often used):

**a. check the vacuum pump:** (Figure 42)

- unscrew the cap and withdraw the pump handle shaft
- check the main washer for wear and apply a little vaseline. This will help produce an airtight seal between the washer and the internal pump case
- refit the pump handle and shaft
- unscrew the valve assembly cap and remove valve
- check the pump seal (this may be an 'O' ring)
- check the silicone rubber membrane washer and replace if necessary (if a spare is not available, use a piece of a surgical glove)
- check any other washers
- refit valve assembly

**b. check the system:**

- assemble the equipment using the 40mm suction cap supplied for checking purposes. Do NOT use the cap from the clinical kit
- make sure all connections fit tightly
- apply a little vaseline to the rubber plug
- close the screw valve
- with the help of a colleague press the suction cap against your forearm and tell the colleague to pump. Check that the gauge is registering a vacuum. Check required levels with medical staff and do not exceed these when testing. Open the screw valve and release vacuum



**Figure 42:** Vacuum pump parts

**4. How to Use the Equipment**

Always refer to the manufacturer's instructions for specific advice on the equipment you are using. The following are general guidelines only.

- i. assemble the equipment as shown in Figure 41
- ii. select the appropriately sized suction cap and place it on the baby's head
- iii. ask a colleague to start pumping
- iv. note vacuum registering on gauge and stop when the predetermined level is reached. The cap will then be 'sealed' to the baby's head
- v. check that the connection is satisfactory
- vi. use traction to draw the baby from its mother's uterus
- vii. open screw valve to release baby

## 5. Simple Fault-finding and Maintenance

*Example a:*

Machine is not working satisfactorily:

- check tube connections are tight
- check rubber plug is fitting tightly (apply a little vaseline to make a tighter seal)
- check connector pipes fit tightly into rubber plug
- check vacuum jar for cracks and rim for chips
- check rim of suction caps for wear
- check silicone bottom plates for cracks and splits
- check pump

*Example b:*

Gauge is thought to be faulty:

- try gauge from another machine (return gauge to original machine after test)
- check screw valve control knob is in place and small washer is fitted inside

**When a fault has been corrected or faulty part replaced:**

- check the system again

Replacing a faulty part is a simple task. Copy the existing fittings.

## 6. Spares

A complete machine for emergency use.

All parts can be changed easily without the help of a qualified technician. Therefore all parts of the equipment should be stocked and replaced when used:

- suction cup 40mm
- suction cup 50mm
- suction cup 60mm
- silicone bottom plate 40mm
- silicone bottom plate 50mm
- silicone bottom plate 60mm
- traction chain with 400mm traction handle
- vacuum bottle
- rubber plug
- complete vacuum pump
- silicone rubber membrane washer (can be made from surgical glove)
- pump washer
- valve assembly seals or 'O' ring
- connector with screw valve
- plain screw cap valve
- gauge
- tubing

## **7. User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions.

Keep this equipment in a clean and well ventilated place.

Each part should be numbered and all parts kept together.

To keep this equipment in good working order for as long as possible:

### **Daily:**

- i. check that the full set of equipment is available
- ii. check for visible damage:
  - cracked or split rubber tubes
  - cracked or chipped vacuum bottle
  - deterioration of rubber plug
- iii. check vacuum release valve has knob and washer
- iv. check traction chain for wear or damage
- v. check stainless steel connector tubes and gauge fit firmly into rubber plug
- vi. check suction caps are not damaged, especially around the rims
- vii. check silicone bottom plates are not damaged or split
- viii. check pump and gauge for external damage

**Weekly (if equipment is not used often, these checks may be made monthly):**

### **a. check vacuum pump:**

- i. unscrew cap and withdraw pump handle shaft
- ii. check main washer for wear and apply a little vaseline to provide an air tight seal
- iii. refit pump handle shaft
- iv. unscrew valve assembly cap and remove valve
- v. check pump seal (this may be an 'O' ring)
- vi. check silicone rubber membrane washer and replace if necessary.  
Use a piece of a surgical glove if no spares are available
- vii. check any other washers
- viii. refit valve assembly

### **b. check system:**

- i. assemble equipment using the 40mm suction cap supplied for checking purposes. Do NOT use cap from the clinical kit
- ii. make sure all connections fit tightly
- iii. apply a little vaseline to rubber plug
- iv. close the screw valve
- v. with the help of a colleague, press the suction cap against your forearm and tell the colleague to pump. Check the gauge is registering a vacuum (check required levels with medical staff and do not exceed these when testing)
- vi. open screw and release vacuum

### **Report to the Maintenance Officer**

- any visible damage
- any fault in pump or system





# **11. INCUBATORS FOR BABIES**

## **1. Purpose of the Equipment**

To provide a controlled environment for the nursing of premature or very ill babies.

The temperature, humidity and oxygen levels can be selected by the user.

## **2. How the Equipment Works**

The many models of babies' incubators work on the same principle but components and controls may vary.

The general principle is that air is processed before it reaches the baby (Figure 43). An electric fan draws room air through a bacterial filter which removes dust and bacteria. The filtered air flows over an electric heating element. The filtered and heated air then passes over a water tank where it is moistened. It then flows on to the incubator canopy. The incubator canopy is slightly pressurised. This allows expired carbon dioxide to pass back into the room via the vent holes and most of the air to be recirculated. It also prevents unfiltered air entering the system.

Temperature is controlled by a thermostat or thermistor in the canopy or air stream.

Humidity is controlled by the user setting deflector plates against a graduated scale of humidity percentage. These plates control the flow of heated air over the element. This determines the amount of water absorbed. Oxygen may be mixed with the warm humid air as it enters the incubator. The oxygen/air gas mixture is then warmed and humidified by the incubator.

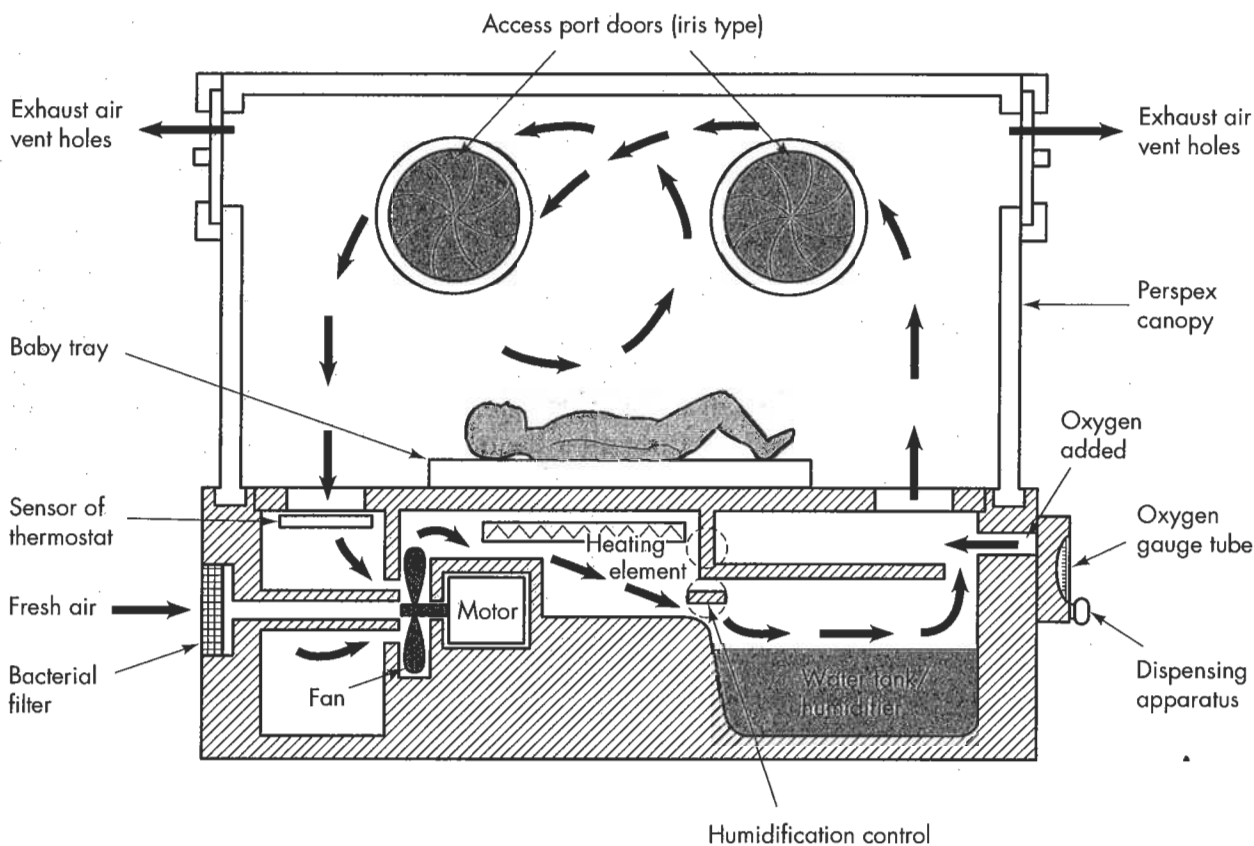
The air pattern is designed to ensure that heat and humidity are distributed evenly.

Incubators have 'access ports' with flaps or diaphragms which fit snugly around the users' arms so that access to the baby is possible. This permits feeding, cleaning, weighing, radiography, transfusing and minor surgery to take place without altering the baby's environment.

## **3. Routines and Safety**

If well cared for, incubators will give 12 to 15 years' good service.

It is very important that they are used in a dust free, well ventilated place. This will reduce the amount of air filtering required.



**Figure 43:** Basic incubator layout and air flow

## **i. Routines**

### **Daily:**

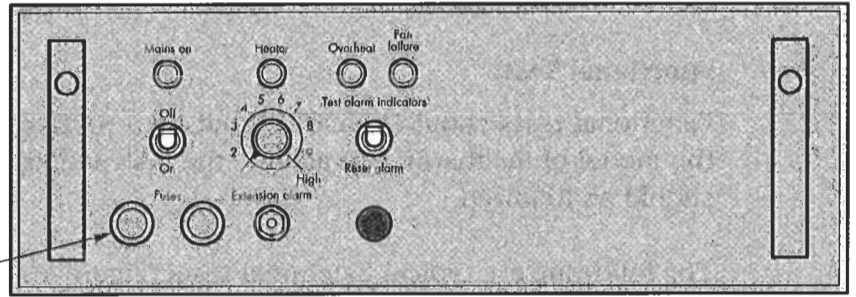
- check incubator is clean
- check access port doors are working satisfactorily and do not spring open
- check electrical mains lead and plug for damage
- check water filler point is in good condition
- check cradle tilt is correct and can be adjusted easily
- drain off water tray. Run machine for 30 minutes to dry tray. Refill tray with sterile water just before re-use
- if oxygen is used, check connection and concentration levels
- check wheels or castors for wear or damage
- carry out functional tests (see below)

An oxygen monitor should be used to measure the concentration of oxygen in the incubator: see the section on the oxygen monitor in Chapter 7b.

### **Daily check:**

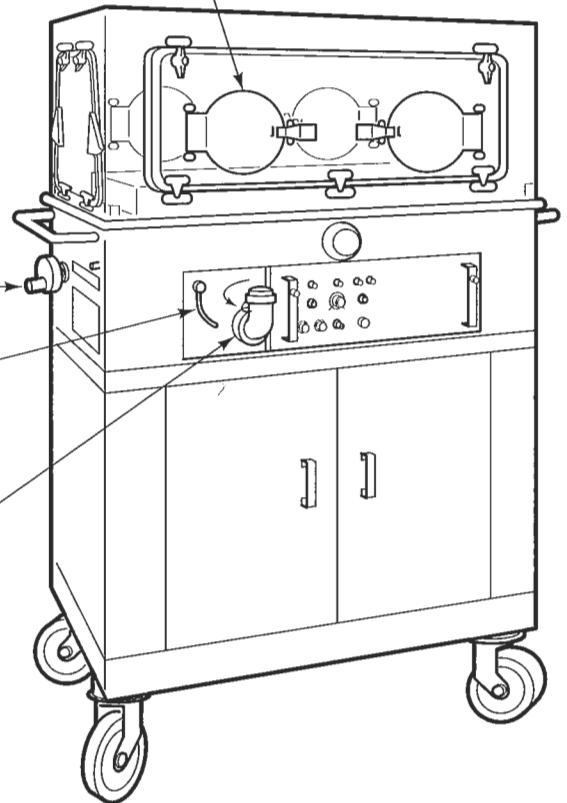
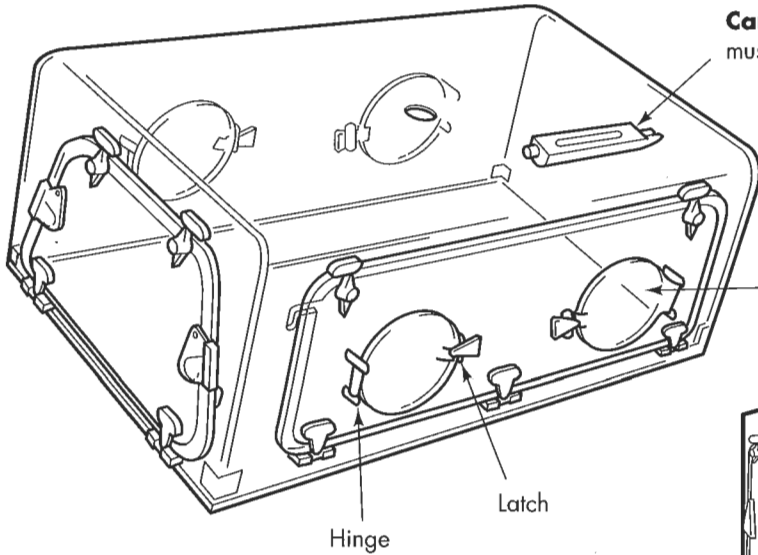
Breathe onto the oxygen monitor sensor several times. The reading should drop slightly (by approximately 3%).

**Panel fuses**  
to remove unscrew by hand anti-clockwise



**Canopy thermometer**  
must be alcohol type, not mercury

**Access port doors**  
They must be a good fit and held firm by the door retaining latches



Hinge

Latch

**Cradle tilt control**

**Humidity control**  
controls the humidity deflectors

**Water tray fill point**

1. The cap should be retained with a small chain to avoid loss
2. To empty the water the fill nozzle turns down 180° thus allowing the water to flow out

**Figure 44:** Typical alarm panel and canopy

**Every other day carry out the following check:**

Put the oxygen monitor sensor in normal room air. After a minute or so, adjust the calibration knob on the monitor so that a reading of 21% is obtained.

**Functional Tests:**

Functional tests should be carried out on a routine basis. They vary according to the model of incubator. If available, the instructions in the manufacturer's manual should be followed.

The following are typical functional tests (Figure 44):

*Test 1: Switching on*

- connect incubator to AC power outlet
- switch incubator power switch ON (leave the heater control switch OFF or at minimum)
- check:
  - power indicator lamp is ON
  - overheat lamp is ON
  - fan fail lamp is ON
  - alarm is SOUNDING
  - heater lamp is OFF

If any one of the above does not occur, withdraw the incubator from service and inform the Maintenance Officer.

*Test 2: Heater operation*

- press down the alarm re-set switch (this will cancel alarms)
- turn temperature control knob clockwise FULLY
- check the heater lamp goes ON
- turn temperature control knob anticlockwise
- check the heater lamp goes OFF

*Test 3: Alarm operation*

- press upwards the test/reset switch
- check:
  - all indicator lamps light up
  - audio signal SOUNDS

*Test 4: Motor operation*

- press test/reset button to reset alarms
- listen to the motor. The sound should be smooth and not loud

*Test 5: Thermometer check*

As the heater lamp does not always indicate that the heater is working check the thermometer in the canopy

## Test 6: Temperature check

### **Before using the incubator:**

- set temperature control to mid-point. Run for 10 minutes
- check:
  - canopy thermometer shows an increase in temperature
  - heater lamp is on (in some machines it pulsates)

*Maintenance of incubator after each patient and before putting back into service after storage:*

After each patient take the incubator out of service for cleaning and checking. Moist warm conditions are ideal for bacterial growth and CLEANING MUST BE THOROUGH.

### **Cleaning:**

- disconnect machine from electrical supply
- dismantle machine down to heater and fan if possible (Figure 45)
- wash each part with a cloth wrung out in warm soapy water (70°C) to which an antiseptic (such as chlorhexidine) has been added
- dry each part thoroughly and quickly
- make a note of the date on which the incubator is cleaned. (When a clean incubator is needed, the most recently cleaned one should NOT be selected)

If necessary and if laboratory facilities are available, swabs may be taken from the incubator after cleaning.

### **Weekly:**

Wash or change filters when dirty: NEVER reverse them. Dirty filters increase oxygen concentrations to dangerous levels

If the air filter is washable

- wash in warm water with detergent. DO NOT use soap
- dry thoroughly

If the air filter is not washable and is dirty:

- replace
- if new filters are not available, cotton wool, lint, coffee filters or filter cones used in suction pumps may be inserted temporarily. Before using such substitutes, check the effect on oxygen concentration levels with an oxygen monitor.

DO NOT use the incubator without the air filter in place

### **Every six months:**

The incubator must be inspected and overhauled by a qualified technician  
This must include a full electrical and earth safety check

## **Calibration Tests (yearly):**

### *a. Temperature test:*

This test should be carried out when room temperature is 20 to 25°C.

- make sure that there is no draught and the incubator is far away from heaters and direct sunlight
- check the incubator is assembled correctly
- check the canopy thermometer is in place
- set baby tray in the horizontal position
- direct the bulb of a test thermometer over the centre of the mattress and supported 50mm above it. The test thermometer should be accurate to  $\pm 1.0^{\circ}\text{C}$  with scale of  $0.5^{\circ}\text{C}$ .
- fill the water tray and set the control to maximum
- allow the temperature inside the incubator to stabilise with room temperature. Check by taking readings of the canopy thermometer and the room thermometer
- note all readings and file for future use

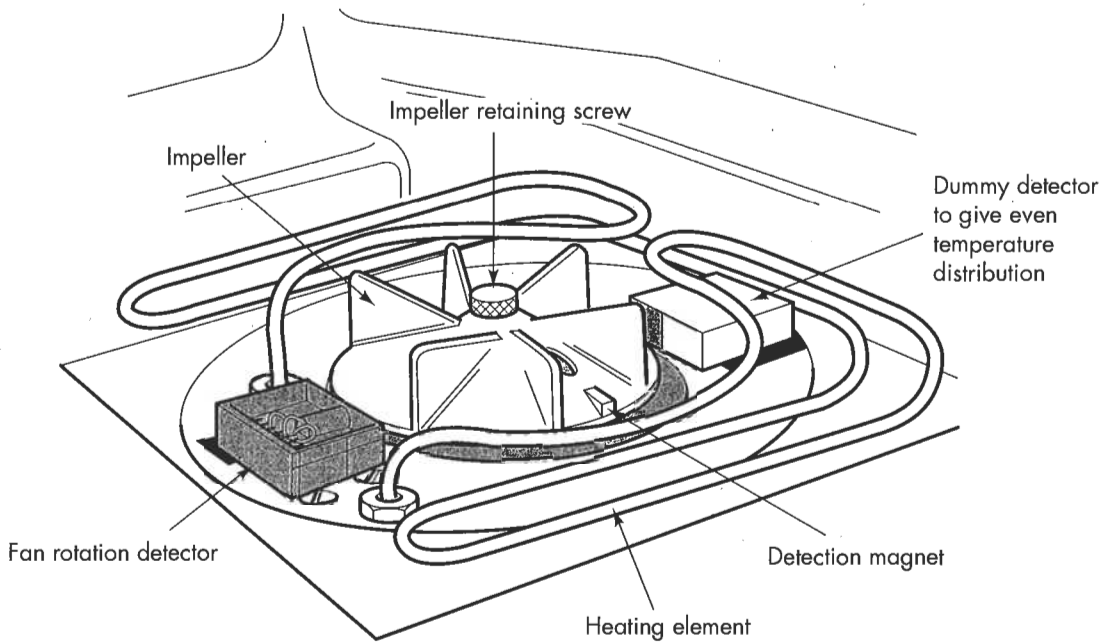
At no time should the canopy thermometer reading and the test thermometer reading differ by more than  $1^{\circ}\text{C}$

Do NOT select maximum temperature when beginning the test. You may damage the control. Select position 8 and wait 45 minutes before changing the setting to maximum.

### *b. Control temperature test*

- set up incubator in a draught free and direct heat free position with room temperature 20 to 25°C
- check incubator is assembled correctly
- connect incubator to electric mains socket
- set temperature control to mid-point
- switch ON power switch. Cancel alarms
- allow 45 minutes for temperature to stabilise
- set temperature control to a high value
- allow 60 minutes for temperature to stabilise
- compare canopy thermometer with test thermometer every hour for six hours
- note readings and file for future reference

At no time should the test thermometer and the canopy thermometer differ by more than  $1^{\circ}\text{C}$ .



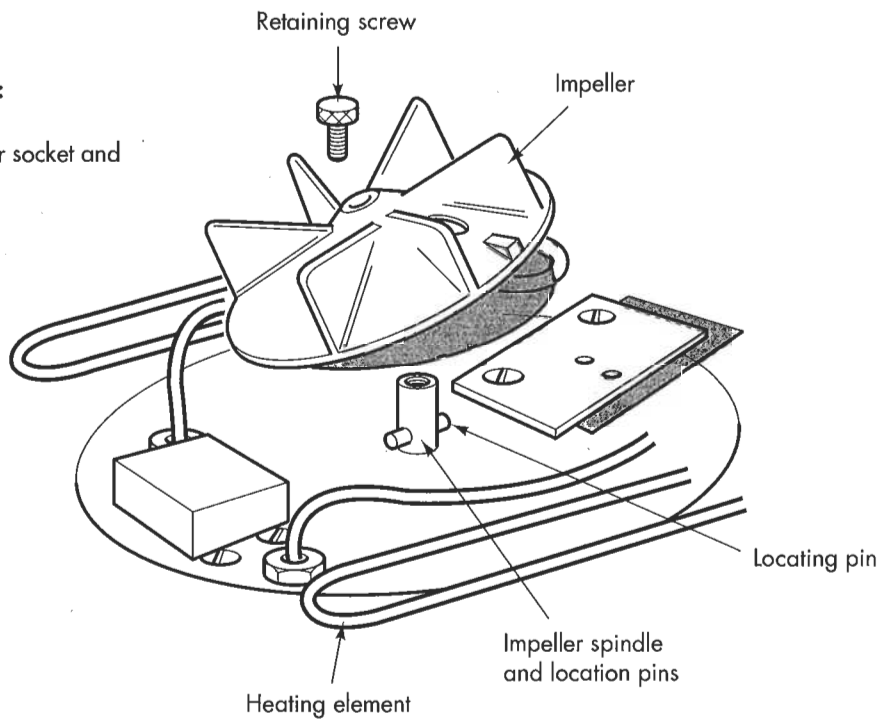
### To remove impeller

1. Ensure the incubator is disconnected from the mains power socket outlet
2. Disassemble incubator to gain access to impeller
3. While holding the impeller with one hand to prevent rotation, unscrew the retaining screw anti-clockwise with other hand
4. Lift off the impeller from its spindle
5. When refitting impeller ensure it is fitted correctly with the locating pins. Firmly tighten down the retaining screw otherwise the impeller will become loose and very noisy.

### To test the fan fail alarm

#### After removing the fan impeller:

1. Plug in incubator to mains power socket and switch on
2. Reset alarms by pressing reset switch
3. Switch on mains power switch on control panel
4. The fan fail alarm light should glow and audio buzzer sound
5. Press reset switch to cancel buzzer
6. Switch off power switch and unplug from mains
7. Refit impeller and reassemble



**Figure 45:** Removing the fan impeller and testing the fan fail alarm

c. *Overheat alarm test*

- set up incubator in a draught free and direct heat free position with room temperature of 20 to 25 °C.
- check incubator is assembled correctly
- set incubator heater to maximum
- using an electric fan heater or hair dryer, gradually increase the canopy temperature by turning the heat source on and off
- check canopy and test thermometers. The alarm should sound and the heater should switch off automatically when the temperature reaches 39-41°C, depending on measurement technique and specific model. Do take care not to overheat the canopy. This could ruin the equipment
- switch off incubator
- allow to cool

d. *Functional test*

Carry out the functional tests as described above.

e. *Fan fail alarm test*

See Figure 45.

- switch off incubator and disconnect from electric power mains
- dismantle the incubator
- remove the fan impeller
- reassemble the incubator (for safety reasons)
- switch ON power switch. Cancel alarms
- check fan fail alarm lamp and audio alarm work satisfactorily
- dismantle the incubator
- refit fan impeller. Make sure this is fitted correctly. If it is not the machine becomes very noisy
- reassemble the incubator

f. *Power fail alarm test*

- disconnect incubator from electric power mains
- switch ON the power switch on control panel
- check power fail lamp and audio alarm work satisfactorily
- if not:
  - replace battery
  - repeat test

**Should any of the above tests fail:**

- the machine must be checked and repaired by a qualified technician



g. *Oxygen flow and leak test*

- remove the air intake filter
- plug the hole
- connect oxygen supply to the incubator
- set oxygen flow rate at 5 litres per minute
- with a finger, block inlet tube where it enters the incubator canopy
- check all incubator joints for oxygen leaks
- apply solution of water and detergent with toothbrush to each joint. Small bubbles will appear if oxygen is leaking
- tighten all joints

DO NOT use soap and water to check for oxygen leaks

h. *Thermometer repair*

Alcohol thermometers, not mercury thermometers, must be used

If the alcohol column becomes broken:

- gently warm the thermometer in the incubator until the column rises to the top of the rise tube
- cool the thermometer, standing upright, in a refrigerator if possible

**ii. Safety**

Do make sure the incubator is used in a clean dust free area away from direct sunlight, radiators and draughts

Do keep the incubator well away from flames and lighted cigarettes

Do use only sterile or distilled or clean rain water in the incubator; change water daily

Do check that all downstream tubing is non-toxic and odour-free

Do keep children away from the machine

Do make sure that any adhesive used to repair the canopy of the incubator is non-toxic

Do use an oxygen monitor to check the oxygen concentration in the canopy, if administering oxygen

Do clean incubator with warm water, detergent and antiseptic ONLY

Do take swabs of the incubator for laboratory examination if there is any possibility of cross-infection

Do keep baby's clothing away from air vents and sensors

Do make sure each machine is cleaned and checked after use and before storage

Do keep chambers dry when not in use

Do make sure the incubator is checked by a qualified technician every six months

DO NOT use the incubator where there are odours or volatile gases or liquids

DO NOT place anything on the canopy of the incubator

DO NOT smoke near the incubator

DO NOT use oil on the incubator

#### 4. How to Use the Equipment

If the manufacturer's manual is available, follow the instructions given.

Because there are many types of incubator in use in hospitals, the following are general guidelines only:

- i. check the incubator is clean and has been checked since its previous use
- ii. check the cradle tray is fitted correctly
- iii. fill the water tray with sterile water (or distilled water or clean rainwater)
- iv. check the air filter is in place
- v. check that the incubator is not in a draught nor in direct sunlight
- vi. plug the incubator into the mains power socket and switch ON
- vii. carry out the functional tests described above

If the incubator passes all tests, it is now ready for use.

REMEMBER to return the incubator for cleaning and checking after use.

#### 5. Simple Fault-finding and Maintenance

If an incubator develops a fault, a spare incubator should be brought into use. If this is not available, an electric fan heater and warm clothing for the baby, including a woolly hat, may be used. Needless to say the incubator should be repaired as quickly as possible.

*Example a:*

The incubator does not work:

- check the machine is plugged into the electric mains socket and that both switches (socket switch and machine switch) are ON

If the mains ON power lamp does not glow check socket outlet

If socket outlet is working check the mains lead

If mains lead is satisfactory the machine has a fault:

- switch off and unplug the machine from the mains socket
- replace fuses on the control panel one at a time
- after *each* change of fuse:
  - plug machine into socket outlet
  - switch on

DO REPLACE EACH FUSE ONCE ONLY. If a replaced fuse blows, then the machine has a short circuit problem and MUST be examined by a qualified technician

DO REPLACE EACH FUSE WITH A SPARE FUSE OF THE SAME SIZE (e.g. a 13 amp fuse should be replaced with another 13 amp fuse ONLY). Do not use a piece of wire as this can be *extremely dangerous*

If machine still does not work call a qualified technician. The machine has an internal fault.

REMEMBER to see that any fuse taken out of stock is reordered so that a supply is always available.

*Example b:*

The alarms do not work:

- replace battery
- recheck

If alarms still do not work call a qualified technician. The machine has an internal fault

*Example c:*

Overheat alarm operates continuously:

- press reset alarm switch

If still not satisfactory call a qualified technician. The machine has an internal fault

*Example d:*

Overheat alarm does not work:

- check the incubator is assembled correctly
- check airducts are not displaced or obstructed

If all are satisfactory and machine still does not work call a qualified technician. The incubator has an internal fault.

*Example e:*

Overheat alarm works at incorrect temperature limits:

- check incubator is not in direct sunlight
- check position of canopy thermometer
- check correct thermometer is in place
- check incubator is assembled correctly
- check air ducts are not displaced or obstructed

If all are satisfactory and alarm still operates incorrectly call a qualified technician

*Example f:*

Fan does not work:

- check fan impeller is fitted correctly
- check fan impeller is not damaged
- check incubator is assembled correctly
- reset alarm switch

If fan still does not work call a qualified technician

*Example g:*

The audio alarm is not working:

- call a qualified technician

*Example h:*

Incubator not heating when heater lamp is ON:

It is likely that the main heating element needs replacing.

In some incubators, the heating element consists of standard light bulbs which are easily replaced.

ONLY replace bulbs with spare bulbs of the same WATTAGE, e.g. 40 watt bulb MUST be replaced by another 40 watt bulb ONLY. IF IN DOUBT USE LOW WATTAGE BULBS ONLY.

If the incubator still does not heat call a qualified technician

*Example i:*

Temperature control is not working correctly:

- check the incubator is not in a draught or near a fan
- check the incubator is not in direct sunlight
- check the incubator is assembled correctly
- check air ducts are not displaced or obstructed

If all are satisfactory call a qualified technician

## **6. Spares**

A full set of spare parts should be held in store. A list of these may be given in the manufacturer's manual or obtained from the manufacturers on request.

If spares are bought locally, they should be fitted by a qualified technician.

Make sure that the faulty part is returned and that you order its replacement at the same time.

Whenever possible have a repair or replacement checked by a qualified technician.

For local maintenance the following spares should be stocked:

- a spare incubator for emergency use
- air filters
- plug
- plug fuses (if required)
- main circuit fuse
- control panel fuses
- 3-core flexible cable
- fan impeller
- access port doors with screws
- castors or wheels
- non-toxic plastic adhesive (for repairing canopy)
- canopy thermometer (alcohol)
- test thermometer
- oxygen flowmeter
- gaskets for access port doors and base
- water tray
- oxygen fuel-cell
- indicator lamps
- batteries for alarm circuit
- toothbrush and detergent (for detecting oxygen leaks)
- paint and paintbrush (to prevent rusting of stand and trolley when paint is chipped)

## 7. User Checklist (to be displayed near the equipment)

Always refer to the manufacturer's instructions

To keep this equipment in good working order for as long as possible, before each use:

- i. check that the incubator is clean
- ii. make sure the electrical mains lead is not damaged or frayed
- iii. check plug
- iv. check the access port doors are fitting well
- v. check the incubator is assembled correctly
- vi. check the cradle tilt can be adjusted
- vii. drain the water tray, allow to dry for 30 minutes and refill with sterile water
- viii. check joints for oxygen leaks:  
with a toothbrush, apply a 0.5% detergent solution over the joints. Small bubbles will appear if there is a leak. NEVER use soap as this can cause an explosive mixture.
- ix. check oxygen concentrations in the canopy
- x. check wheels or castors for damage or wear
- xi. make sure the air filter is in place
- xii. carry out functional tests

Functional tests vary according to the model of incubator. If available, the instructions in the manufacturer's manual should be followed.

The following are typical functional tests

### *Test 1: Switching on*

- connect the incubator to the AC power outlet
- switch incubator power switch ON (leave the heater control switch OFF)
- check:
  - power indicator lamp is ON
  - overheat lamp is ON
  - fan fail lamp is ON
  - alarm is SOUNDING
  - heater lamp is OFF

If any one of the above does not occur, withdraw incubator from service and inform the Maintenance Officer

### *Test 2: Heater operation*

- press down the alarm reset switch (this will cancel alarms)
- turn temperature control knob clockwise FULLY
- turn temperature control knob anticlockwise
- check heater lamp goes ON and OFF

### *Test 3: Alarm operation*

- press upwards the test/reset switch
- check:
  - all indicator lamps light up
  - audio signal SOUNDS

### *Test 4: Motor operation*

- press test/reset button to reset alarms
- listen to the motor. The sound should be smooth and not loud

### *Test 5: Thermometer check*

As the heater lamp does not always indicate that the heater is working check canopy thermometer

### *Test 6: Temperature check*

#### **Before using the incubator:**

- set temperature control to mid-point. Run for 10 minutes
- check:
  - canopy thermometer shows an increase in temperature
  - heater lamp is on (in some machines it pulsates)

#### **Report to the Maintenance Officer:**

- any visible damage to the incubator, the electrical power lead and plug
- any oxygen leak
- any other fault or difficulty with the incubator

Follow these SAFETY points:

Do keep incubator well away from flames and lighted cigarettes

Do make sure that the incubator is used in an area which is clean and as dust free as possible

Do make sure that the incubator is away from draughts and radiators and out of direct sunlight

Do use water for the machine which is sterile, distilled or clean rain water; change water daily

Do make sure all downstream tubing is non-toxic and odour free

Do keep children away from the incubator

Do keep baby's clothing away from air vents and sensors

Do make sure the incubator is cleaned and checked after use and before storage

Do keep chambers dry when not in use

Do wash incubator surfaces with water and detergent to which an antiseptic solution has been added

Do check oxygen concentrations in the canopy when oxygen is being fed into the incubator

Do send swabs from the incubator to the laboratory for testing if there is any possibility of cross-infection

Do make sure the incubator has a full engineering check every six months

Do NOT smoke near the incubator

Do NOT use the machine near odours, volatile gases or liquids

Do NOT place anything on the incubator canopy

Do NOT use toxic adhesives when repairing the incubator canopy; ventilate the canopy well for several hours after performing repairs





## **12. REFRIGERATORS**

### **1. Purpose of Equipment**

To provide a safe and reliable cold storage facility for vaccines, blood, blood derivatives and drugs.

### **2. How the Equipment Works**

A refrigerator consists of a heavily insulated cabinet with an efficient door seal which prevents heat from the outside entering the cabinet.

The temperature inside a refrigerator is kept low by a closed coiled circuit of copper tubing filled with a 'refrigerant gas'. This 'refrigerant gas' absorbs heat which is then discharged at the back of the refrigerator as room air passes over a closed network of copper tubing. This is the condenser.

The two main types of refrigerator are:

#### *Electric Compressor Model*

The electric compressor model has an electric motor and pump. The pump drives the refrigerant gas in a sealed circuit. The required temperature is set by the user and a thermostat controls it automatically.

#### *Kerosene Model*

The kerosene model has a burner which is controlled by the user. Heat from the burner pushes the refrigerant gas around the circuit.

In each model there are storage shelves and many will have a small top 'freezer' compartment also.

The refrigerator cabinet should be kept at a temperature of 4 to 8°C and the freezer compartment should be kept below 0°C.

### **3. Routines and Safety**

Refrigerators are badly affected by problems associated with fluctuating electricity supply. High voltage, low voltage and lightning strikes may all cause damage to the refrigerator, resulting in expensive repairs. The refrigerator should be switched off when there is low voltage or an electrical storm; or, better still, a voltage regulator monitor trip switch may be fitted for protection (see Sollatek under Useful Addresses at the back of this book).

#### **Refrigerators should be installed:**

- in a clean, dust free, well ventilated area out of direct sunlight
- in the case of a kerosene refrigerator, also away from draughts. They will affect the burner's flame
- away from any heating appliance such as a water boiler
- with a space of at least 15cm around the unit to allow air to circulate and the condenser to cool

- in an upright position on a firm, level base. This is very important as kerosene refrigerators will not work efficiently if they are not upright. If adjustable feet are fitted, adjust these by hand. If adjustable feet are not fitted, level the refrigerator by placing pieces of cardboard under each corner
- if possible place the refrigerator on a small timber pallet which will keep it off the ground by about six inches. This helps to prevent rust forming underneath and improves cooling
- place a ball on top of the refrigerator and adjust the refrigerator until the ball stops rolling. You will then know that the unit is standing level
- if the refrigerator is moved, it should not be tilted excessively and must NEVER be laid on its side. If it has already been moved, and you suspect it might have been tilted or laid on its side, leave it upright for at least four days before switching the power on

**Always:**

- lock the door if possible
- avoid damaging the unit, in particular the door and seal as an ill-fitting door will cause the temperature to rise
- forbid storage of food or drinks in the refrigerator
- avoid opening the door unnecessarily
- make sure nothing is placed on top of the refrigerator
- defrost the top chamber regularly (there should never be more than 6mm ice)
- keep condenser pipes and compressor or burner chamber clean
- keep both inside and outside of the refrigerator clean by using water and detergent. Do not use abrasives and bleaches. They will scour the surfaces, leaving grooves for micro-organisms to breed

**Daily:** For both electric and kerosene refrigerators:

- keep a log book, recording the refrigerator's temperature every morning and evening. This will provide a pattern and give you warning of a fault or poor performance when the pattern changes
- check the freezer for excessive ice build-up (6mm thickness is the maximum allowed)
- check that air can circulate well in the cabinet and that it has not been overfilled
- check the door and seal for damage
- check emergency ice packs and water bottles are in place
- check air vents for obstructions such as dust

**For kerosene refrigerator:**

- check the fuel tank is full
- top up fuel if necessary and make a note in the log book. This will provide a pattern so in time you will know how often this needs to be done
- check flame size and colour. Adjust if necessary
- make sure enough spare clean fuel is available

The door seal forms a sensitive barrier to the entry of heat from the outside.

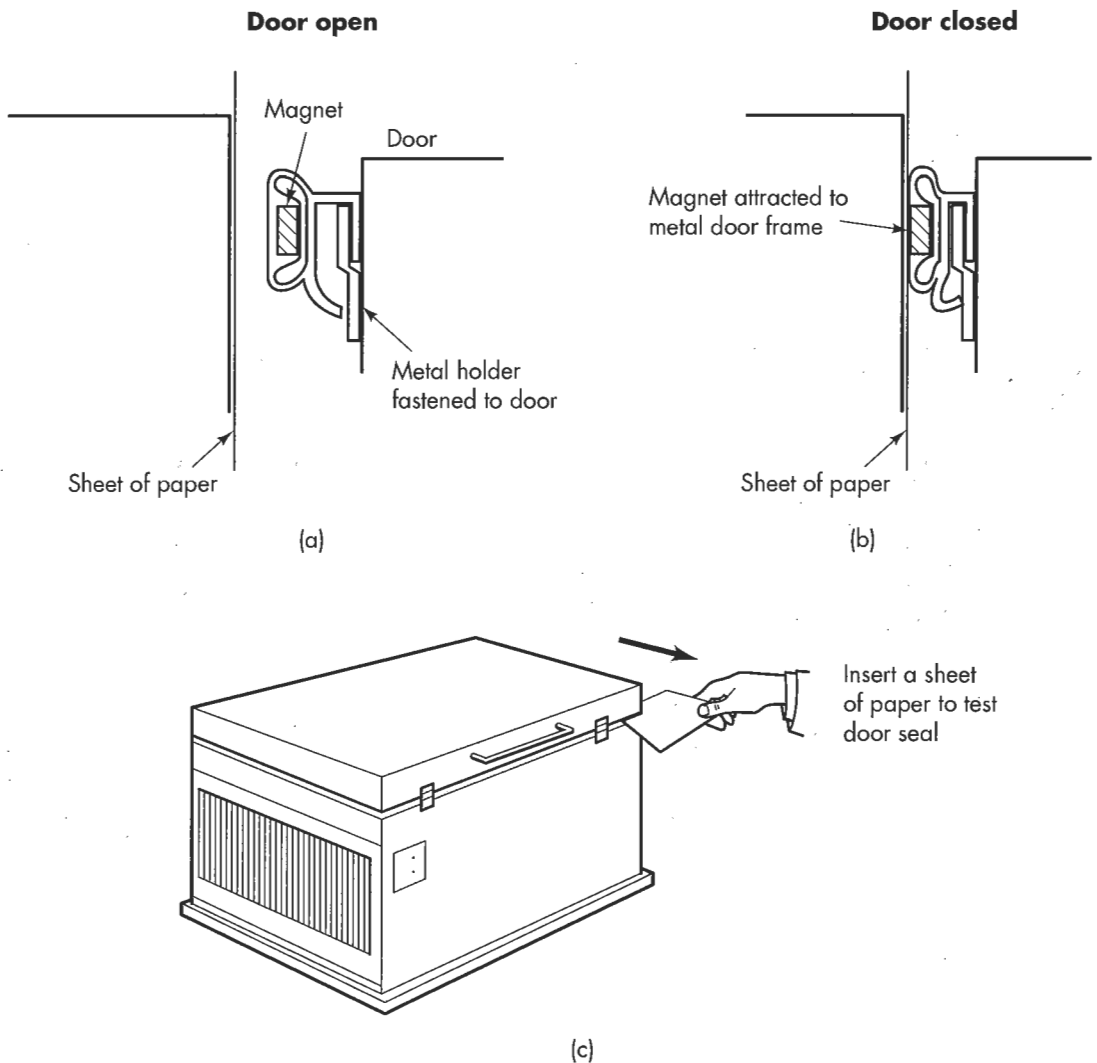
If the door seal is damaged the system will need to work harder to maintain the required temperature and may, if badly damaged, be unable to reach that temperature.

An easy check on the effectiveness of the seal is to place a sheet of paper between the door seal and the cabinet, then close the door.

If the paper remains firmly in place and is not easily withdrawn then the seal should be satisfactory. This check, of course, must be made around the complete seal.

The thinner the sheet of paper the better as this will give a more accurate result.

If the seal is found to be defective then, depending on the model, the door may be adjusted or the door seal replaced.



**Figure 46:** Door seal check

Remove the burner from the refrigerator and wipe over with a clean cloth.

Check the wick and trim evenly or replace if required.

Check the burner glass for damage.

Check the fuel level and top up if required. Filter the new fuel through a filter cloth.

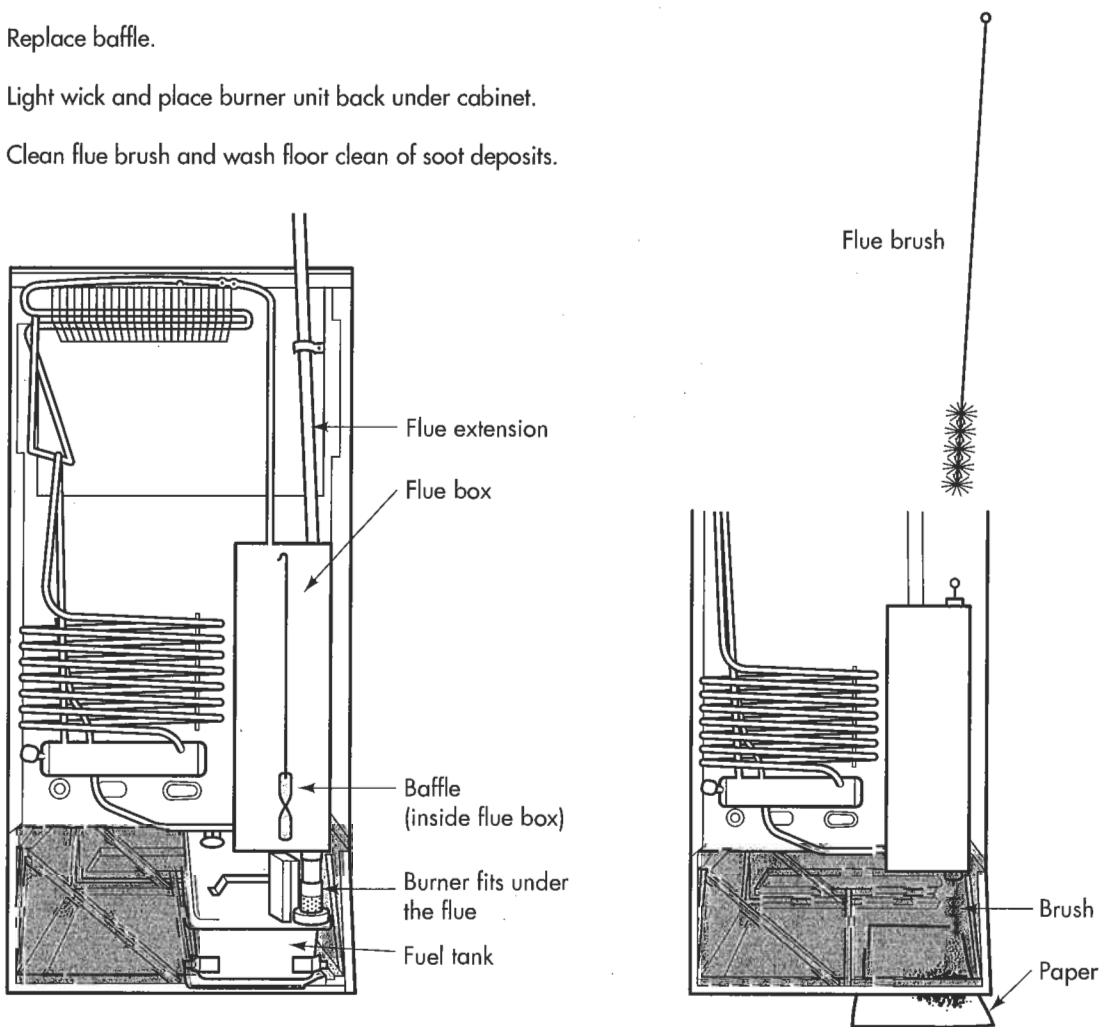
Remove baffle and clean with clean cloth and a small amount of clean kerosene.

Clean flue and flue box with the flue brush.

Replace baffle.

Light wick and place burner unit back under cabinet.

Clean flue brush and wash floor clean of soot deposits.



**Figure 47:** Kerosene refrigerator – cleaning flue and burner

**For electric compressor refrigerator:**

- make sure the refrigerator is plugged into socket and switched ON
- make sure a notice is displayed near the socket outlet which warns everyone (including cleaners) that the refrigerator is not to be switched off under any circumstances. A 'permanent connection' can prevent this from happening. If this is not available, a length of adhesive tape placed over the switch reminds people 'not to switch off' (see Figure 49)

**Weekly:** For electric and kerosene refrigerators:

- check freezer and defrost if necessary. If you find there is a need to de-frost weekly, the door and seal may require adjustment (Figure 46)

**For kerosene refrigerator:**

- clean flue, flue box, and burner (Figure 47)
- trim wick
- check fuel; if dirty, empty and refill with clean fuel
- clean burner chamber

If the refrigerator will not be in use for a long period, drain the fuel tank to prevent corrosion

**Defrosting: for both electric and kerosene refrigerators**

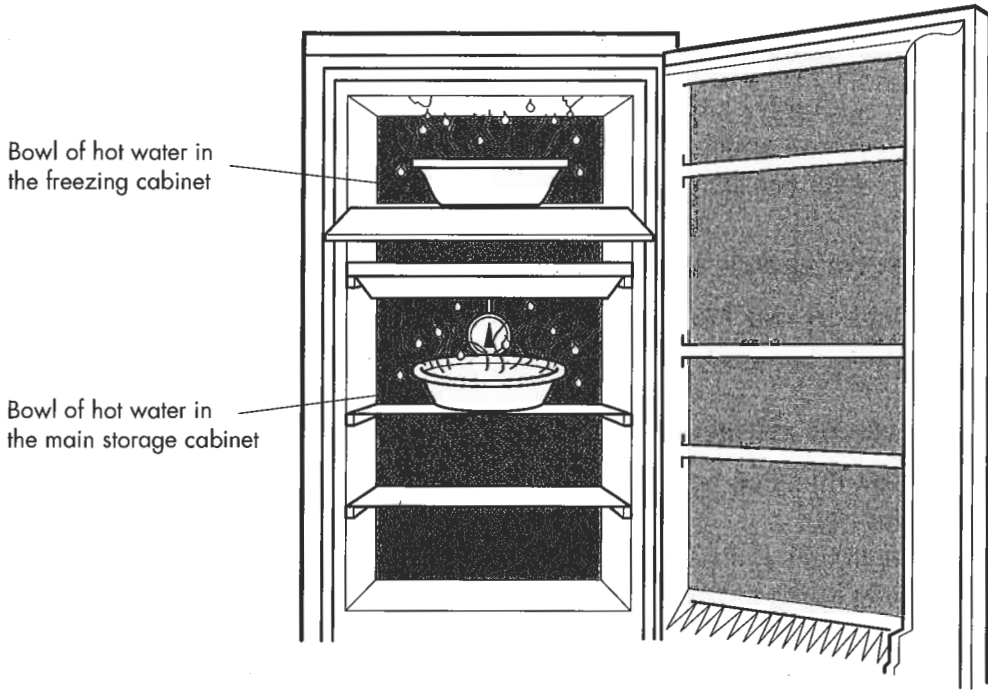
- transfer stock to another refrigerator or cold box
- turn off refrigerator
- open door and leave it open until all ice has melted

**To quicken the melting:**

- place bowls of hot water on shelves. Keep the door open (Figure 48)
- Do NOT use an instrument to dislodge ice as this can damage the unit
- when all the ice has melted, wash all surfaces with warm water and detergent
- Do NOT use abrasives or bleach
- dry all surfaces with a clean, soft, dry cloth
- close door and turn on the refrigerator
- re-stock shelves WHEN REQUIRED TEMPERATURE HAS BEEN REACHED

**Monthly:****For kerosene refrigerator:**

- check for visible damage
- clean off any patches of rust and repaint
- clean condenser tubes with a soft brush
- clean door seal and apply a little talcum powder
- turn off burner and allow to cool
- clean out burner chamber with a soft brush
- relight burner



In order to speed up the defrosting procedure bowls of hot water can be placed on the shelves.

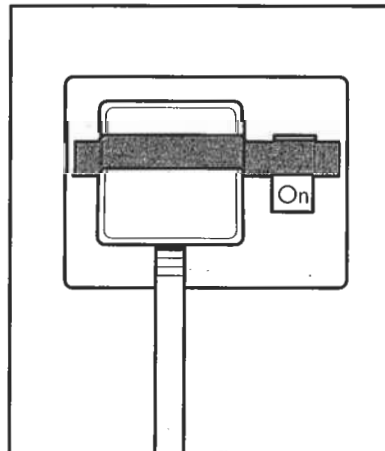
**Figure 48:** Defrosting using bowls of hot water

---

To discourage people from disconnecting the refrigerator from its socket outlet, it is advisable to fix a length of tape over it.

A notice written in bold lettering fixed next to the socket outlet warning people that the refrigerator is not to be disconnected is advised.

The notice should also include the emergency procedure to be adopted if the refrigerator breaks down or there is a power failure.



**Figure 49:** Tape over switch socket

### **For electric compressor refrigerator:**

- check for visible damage
- clean off any patches of rust and repaint
- clean condenser tubes with a soft brush
- clean door seal and apply a little talcum powder
- switch off and unplug
- with a soft brush clean out compressor
- check mains lead and plug for visible damage
- make sure connections have not become loose
- plug in and switch on
- if a permanent connection is not in place, check that a warning notice saying 'Do not switch off' is in place; check that the switch is taped (Figure 49)

## **4. How to Use the Equipment**

Always refer to the manufacturer's instructions for specific advice on the equipment you are using. The following are general guidelines only.

Nothing should be placed inside the refrigerator until it has reached the required temperature.

It is wise to store ice packs in the freezer compartment. If the refrigerator breaks down for any reason, they can be used to delay the temperature rise or used in a cold box when transferring stock to another refrigerator. Sealed water bottles placed in the lower space of the refrigerator cabinet will also delay a rise in temperature. Their contents should not be drunk (Figure 50).

Every hospital should have a plan of what to do if a refrigerator breaks down. It should be displayed on or near the unit and every staff member should be trained to carry it out.

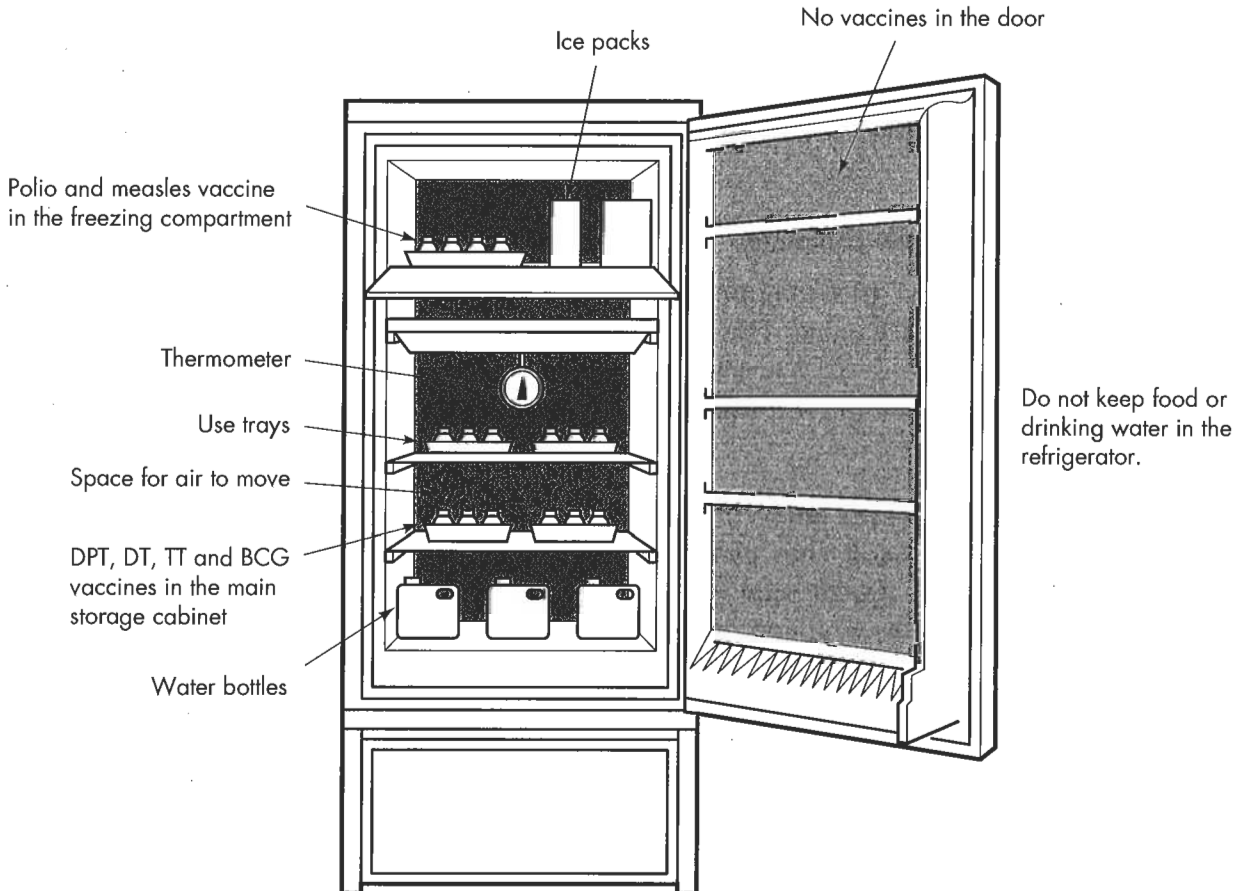
### **Kerosene refrigerator**

As kerosene refrigerators vary, follow the manufacturer's instructions whenever possible. The following are general directions:

- i. remove the burner unit
- ii. check the fuel tank is full
- iii. check the wick is clean and trimmed correctly
- iv. turn the wick up to 5mm
- v. light the wick and adjust the flame. Usually on small refrigerators the flame should be yellow and on large refrigerators the flame should be blue. Check with the manual if available
- vi. make sure the flame spreads around the whole wick and burns evenly. If the flame smokes, lower the wick slowly
- vii. replace the burner
- viii. check the flame, remembering: the larger the flame, the colder the inside of the refrigerator
- ix. place the thermometer inside the cabinet
- x. check the flame every hour, and the temperature every four hours, until required temperature is reached and is stable

- xi. stock shelves, including ice packs and water bottles
- xii. leave the thermometer inside the cabinet and lock the refrigerator if possible
- xiii. check temperature and flame every morning and evening
- xiv. note readings in the log book

The refrigerator should be stocked so that air is allowed to circulate freely. Remember to include ice packs and sealed water bottles.



**Figure 50:** Stocking the refrigerator

### Electrical compressor refrigerator

Follow manufacturer's instructions whenever possible. The following are general directions:

- i. plug refrigerator into electric mains socket
- ii. check 'do not switch off' notice is in place
- iii. place adhesive tape over switch (Figure 49)
- iv. place the thermometer inside the cabinet
- v. switch ON
- vi. run the unit for 24 hours, checking the temperature every 4 hours
- vii. adjust the thermostat control knob until the required temperature is reached and is stable. This may need to be carried out in stages as most control knobs are marked in numbers, not temperatures.



If the manufacturer's manual is available:

- follow instructions

If the manufacturer's manual is not available:

- start at high settings and work down to low settings

- viii. when the required temperature is reached and is stable, stock shelves, including ice packs and water bottles
- ix. leave the thermometer inside cabinet and lock the refrigerator
- x. check the temperature of the refrigerator every morning and evening
- xi. note readings in the log book

## **5. Simple Fault-finding and Maintenance**

In case a refrigerator breaks down or the electricity supply fails for a long time, each hospital must have a plan for maintaining refrigerated stock at the required temperature.

Cold boxes, large enough to contain the complete contents of the refrigerator, should be available for transferring stock to another unit.

The plan must be displayed and staff trained to carry it out.

*Example a:*

The refrigerator is not working:

### **Kerosene refrigerator:**

- check flame: relight or adjust as necessary

If wick will not relight:

- check oil level
- trim wick
- relight

If satisfactory but the refrigerator is still not working, it needs to be repaired by a qualified technician

### **Electrical compressor refrigerator:**

- check electrical main socket outlet

If satisfactory:

- check mains lead

If satisfactory but the refrigerator is still not working, it needs to be repaired by a qualified technician

*Example b:*

Temperature of refrigerator is rising:

**For both kerosene and electrical compressor refrigerators:**

- check refrigerator is not in direct sunlight or near a heater
- check the door is sealed correctly (Figure 46)
- check freezer compartment for ice build up. It should not be more than 6mm deep. Defrost if necessary
- check stock is packed correctly. It should not be packed too tightly. There must be room for air to circulate around it – Figure 50
- check ice packs. Remove unfrozen ones
- check refrigerator is at least 15cm away from a wall. There must be room for air to circulate around the condenser
- check ventilation of the room

**For kerosene refrigerator:**

- check flame for flickering; remove from draught if necessary
- check flame is large enough; adjust if necessary and check again for smoke
- check colour of flame; adjust if necessary
- check flame is even; trim wick if necessary
- check flame for smoke; adjust flame if necessary
- check fuel is clean; replace if necessary
- check lamp glass; replace if broken and reposition if necessary
- check flue and baffle (Figure 47); clean if necessary

**For electrical compressor refrigerator:**

- check thermostat setting and adjust to a higher number if necessary. Check temperature every hour and note readings in log book
- open refrigerator door
- press internal light switch: if the light does not go off, replace the switch. The switch should turn off automatically when door is closed. If it is faulty, the light stays on and raises the temperature inside the refrigerator

## **6. Spares**

**a. Kerosene refrigerator:**

- ice packs
- sealed water bottles
- complete burner unit
- kerosene
- filter cloth
- funnel
- wick trimmer
- wick
- lamp glass
- bottle of refrigerant gas (according to the make and type of refrigerator)
- coil of copper tubing (according to the make and type of refrigerator)

**b. Electrical compressor refrigerator:**

- ice packs
- sealed water bottles
- main circuit fuse
- plug fuse
- plug
- length of mains lead
- thermostat and compressor (according to the type and make of refrigerator).
- bottle of refrigerant gas and coil of copper tubing (according to the type and make of refrigerator).

## **7. User Checklist (to be displayed on or near equipment)**

Always refer to the manufacturer's instructions

### **Kerosene refrigerator**

To keep this equipment in good working order for as long as possible:

#### **Daily:**

- i. check temperature and enter readings in the log book every morning and evening
- ii. check the cabinet is not packed tightly and that air can circulate freely between stock
- iii. check ice packs and water bottles are in place
- iv. check the refrigerator has a space of 15mm to allow air to circulate around the condenser
- v. check that the room is well ventilated and the refrigerator is not in direct sunlight or near a heater (e.g. water boiler)
- vi. check the freezer for ice build-up. Do not let it become more than 6mm deep
- vii. check the door is sealing correctly
- viii. check the fuel tank is full of clean fuel
- ix. note in the log book when fuel is added to the tank
- x. check the flame for size (the larger the flame, the colder the refrigerator)
- xi. check the flame for colour (yellow in a small refrigerator, blue in a larger refrigerator)
- xii. check there is spare fuel
- xiii. check the burner unit is clean and the wick is trimmed
- xiv. check the refrigerator is level

#### **Report to the Maintenance Officer:**

- any visible damage
- any fault or difficulty

#### **Kerosene burner:**

If the burner is not used for long periods:

- drain the fuel tank to prevent corrosion
- check the burner unit is clean

Follow these SAFETY points

Do turn off the burner, allow it to cool and remove from the refrigerator before carrying out any cleaning

Do clean up any spilt kerosene with water and detergent

Do NOT smoke when working with a kerosene burner

Do NOT keep food or drinks in the refrigerator

Do NOT open the door of the refrigerator unless it is necessary

## **8. User Checklist (to be displayed near the equipment)**

### **Electric compressor refrigerator**

To keep this equipment in good working order for as long as possible:

#### **Daily:**

- i. check temperature and enter readings in the log book every morning and evening
- ii. check the cabinet is not packed tightly and that air can circulate freely between stock
- iii. check ice packs and water bottles are in place
- iv. check the back of the refrigerator has a space of 15mm to allow air to circulate around the condenser
- v. check that the room is well ventilated and the refrigerator is not in direct sunlight or near a heater (e.g. water boiler)
- vi. check the freezer for ice build-up. Do not let it become more than 6mm deep
- vii. check the door is sealing correctly
- viii. check refrigerator is plugged in and switched ON
- ix. check notice 'do not switch off' is in place
- x. check mains switch is taped

#### **Report to the Maintenance Officer:**

- any visible damage
- any fault or difficulty

Follow these SAFETY points

Do switch OFF and remove plug from mains supply before carrying out any cleaning

Do NOT keep food or drinks in the refrigerator

Do NOT open the refrigerator door unless necessary



# 13. BLOOD PRESSURE APPARATUS

## 1. Purpose of Equipment

To measure and register a patient's blood pressure.

## 2. How the Equipment Works

See Figure 51. The mercury blood pressure apparatus consists of:

- a rubber pumping bulb
- a pressure relief valve
- an inflatable cuff
- a mercury gauge (or manometer)
- interconnecting rubber tubes

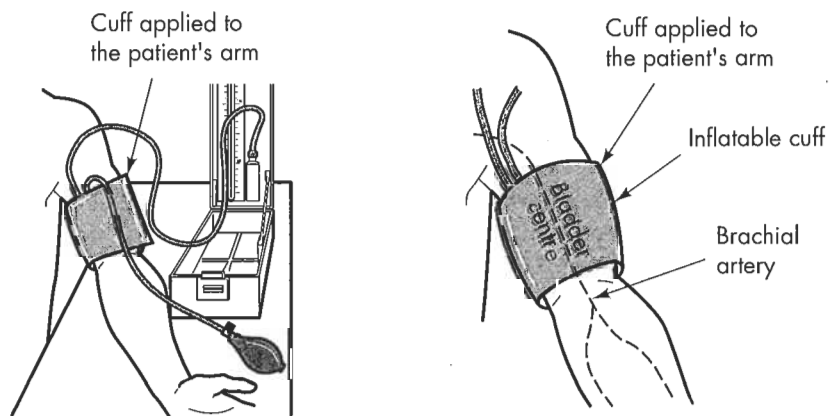
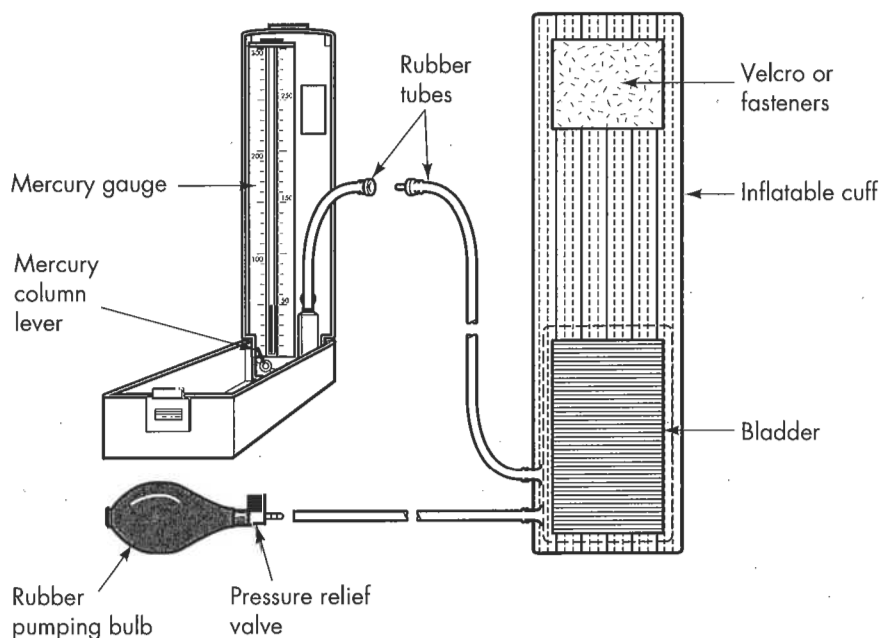


Figure 51: The mercury blood pressure apparatus

The inflatable cuff is wrapped around the patient's upper arm, the pressure relief valve closed (by turning it clockwise) and the mercury column lever opened. The bulb is then pumped rapidly, pushing air through the rubber tubing and inflating the bladder in the cuff. Pumping should cease when the patient's systolic pressure has been exceeded. The mercury column remains supported by air pressure until the pressure relief valve is opened slowly (by turning it anticlockwise). The blood pressure recording is then read by the user and the air pressure fully released until the mercury column returns to zero level.

### **3. Routines and Safety**

The mercury type of blood pressure apparatus is robust and, if well maintained, will give accurate measurements for many years.

Remember, however, that mercury is a poisonous material and take great care when dealing with it.

#### **i. Routines**

##### **Weekly:**

- check the bulb, cuff and tubes for cracks or other signs of deterioration
- check the bulb is pliable and works well
- check that all tubing connections fit tightly
- check that when the column lever is open the mercury level is at zero
- check for leakage of mercury
- check that the mercury is bright silver in colour
- carry out function test

##### *Function Test*

- i. fit the cuff to your bare upper arm (or around a suitable bottle)
- ii. close the pressure relief valve (turn it clockwise)
- iii. pump the bulb until the mercury column reaches 200mm Hg on your arm, or 300mm Hg on a bottle
- iv. hold it at this level for 10 seconds
- v. watch the mercury level to check that it does not fall more than 2mm Hg during that time
- vi. open the pressure relief valve slowly (turn it anticlockwise)

If the mercury level falls more than 2mm Hg in 10 seconds:

- check washer on mercury tank
- replace if necessary

If satisfactory

- check the cuff, bulb, pressure relief valve and tubing for air leaks
- replace if necessary

##### **Six monthly:**

- get the apparatus checked by a qualified technician

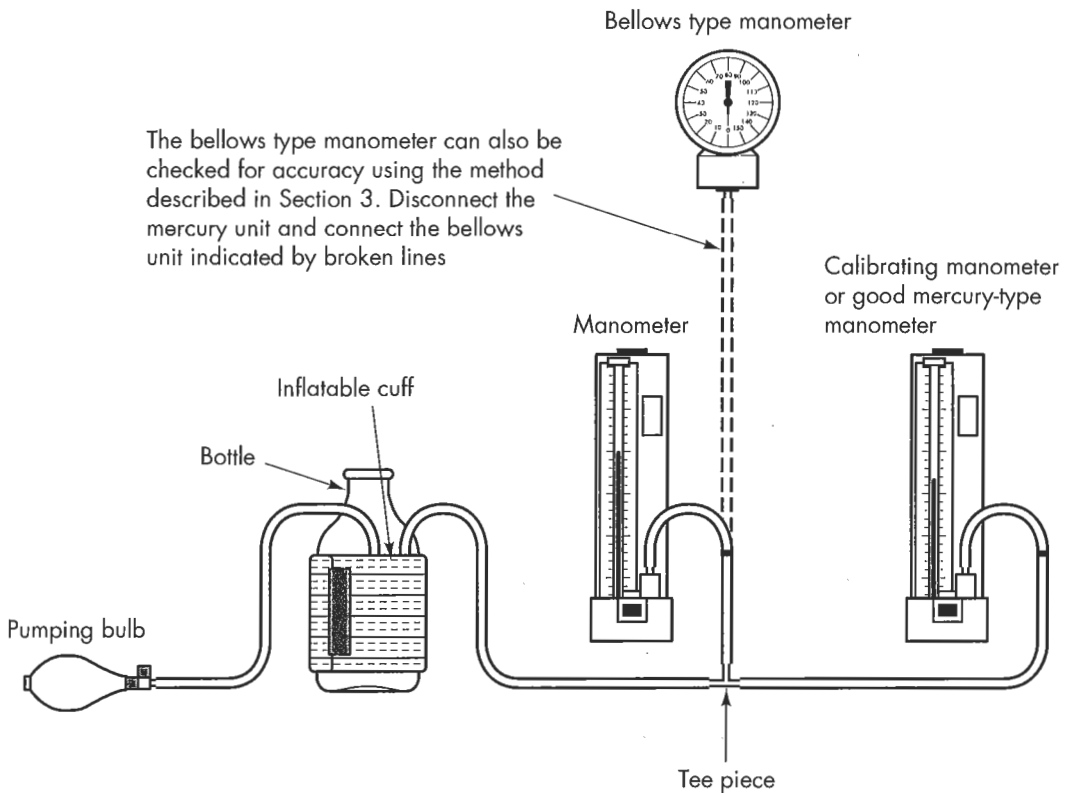


If this is not possible, compare the apparatus with a similar one which is known to be accurate and kept for testing purposes only. Assemble the following testing kit:

- bulb
- pressure relief valve
- adult size cuff
- tee-piece
- suitable bottle

These should be kept in a locked box as a permanent testing kit. To compare two manometers:

- set up the test equipment (see Figure 52)
- close the pressure relief valve
- with both column levers open, squeeze the bulb until you have pumped the mercury up to the maximum, usually 260 or 300mm Hg
- hold at this level for 10 seconds. The mercury column should not fall more than 2mm Hg in 10 seconds
- check that the column on each machine is registering the same level
- operate valve and close it at 150mm Hg, 100mm Hg and 50mm Hg, checking that the readings are the same on both gauges



**Figure 52:** Testing/calibrating manometer arrangements

## ii. Safety

Remember that:

- when exposed to air, mercury vaporises and mercury vapour is poisonous.
- mercury is very difficult to recover when spilled as it flows very quickly indeed. It can fall into small cracks and remain undetected. Therefore when repairing apparatus:

Do place it on a tray with raised sides, or in a specially made watertight box with a mesh grill standing over water (Figure 53). When mercury is spilt into water, it cannot vaporise

Do recover mercury with a large syringe (kept locked and used for this purpose only)

Do wear rubber gloves when working with mercury

Do wash skin thoroughly if it comes into contact with mercury

Do work outside if possible. If not, work in a well ventilated room, preferably one with an extractor fan

Do avoid inhaling the vapour from mercury

### *Spillage of Mercury*

If mercury is spilt:

- wearing rubber gloves, push the mercury into one pool
- recover the mercury with the syringe used ONLY for this purpose
- wash the affected area with a thin paste of calcium hydroxide and powdered sulphur (equal parts) mixed with water
- allow to dry for 24 hours, keeping the area well ventilated
- wash the area with water
- dry thoroughly
- keep the area well ventilated for at least another 24 hours

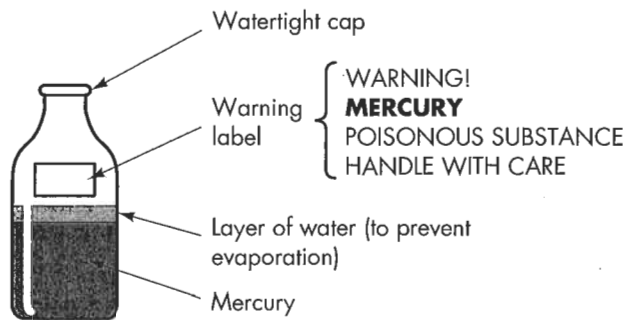
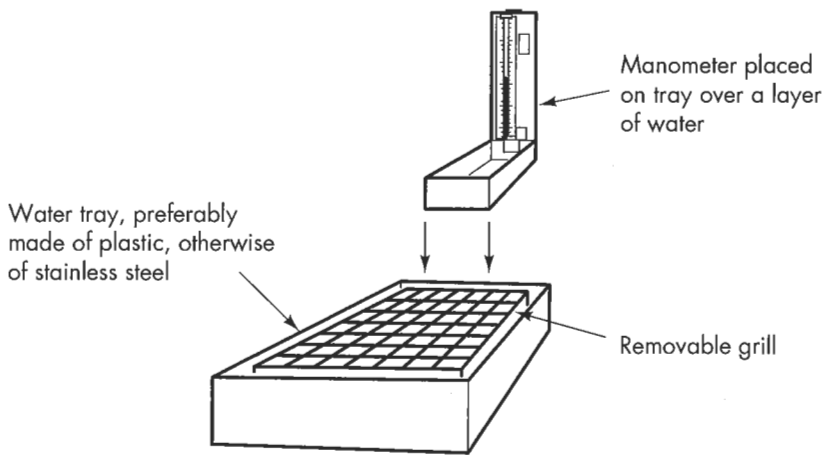
## 4. How to Use the Equipment

Please note that these are basic technical instructions only. They are NOT clinical directions.

Always refer to the manufacturer's instructions for specific advice on the equipment you are using.

### **To take a patient's blood pressure:**

- i. fit the cuff around the patient's bare upper arm in the correct position
- ii. check that the cuff is the right size and allows two fingers to be inserted between the cuff and the arm
- iii. close the pressure relief valve
- iv. check that the mercury column lever is open
- v. squeeze the bulb until you have pumped the pressure up to the 200mm Hg reading
- vi. with the stethoscope in position, slowly open the valve, deflating the cuff at 2 to 3mm Hg per second (or per heart beat)
- vii. take the reading when you hear the soft thumping of the patient's pulse. This is the systolic pressure
- viii. take the second reading when the sound of the pulse begins to fade. This is the diastolic pressure
- ix. open the pressure relief valve completely
- x. remove cuff



Mercury storage bottle, strong plastic preferred

**Figure 53:** Water tray and mercury storage bottle

## 5. Simple Fault-finding and Maintenance

*Example a:*

Head of mercury not on zero level when the apparatus is not in use:

If below zero:

- carefully add mercury to the tank with the syringe (kept for this purpose only) until the head of mercury reaches the zero marking

If above zero:

- carefully draw off mercury from the tank with the syringe until the head of mercury drops to zero

*Example b:*

Mercury bubbles when pressure is applied to the system:

The mercury level is too low, so carefully add mercury to the tank with the syringe

*Example c:*

Mercury is leaking from the apparatus:

- disassemble apparatus observing precautions listed below
- check gaskets and filters
- replace if necessary
- reassemble apparatus

*Example d:*

Mercury surface on the manometer is not clean:

- tilt apparatus on its tank side
- disassemble apparatus observing precautions listed below
- clean rise tube and mercury (see page 170)
- reassemble apparatus

#### **A. To disassemble the manometer:**

See Figure 54

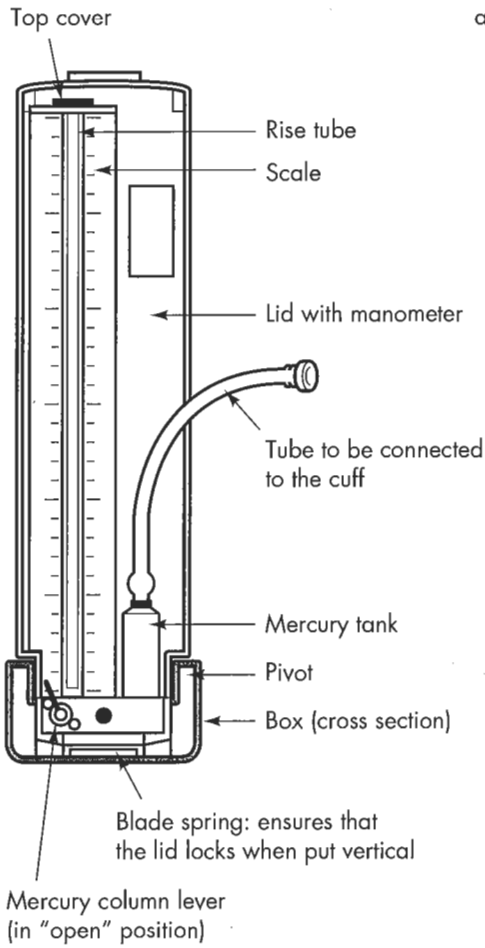
#### **REMEMBER:**

- wear rubber gloves
- work in a well ventilated area
- place the apparatus on a tray with raised sides or over a purpose-made water bath
- wash skin immediately if it comes into contact with mercury
- have cleaning materials ready in case of spillage
- have ready the syringe kept for mercury use only

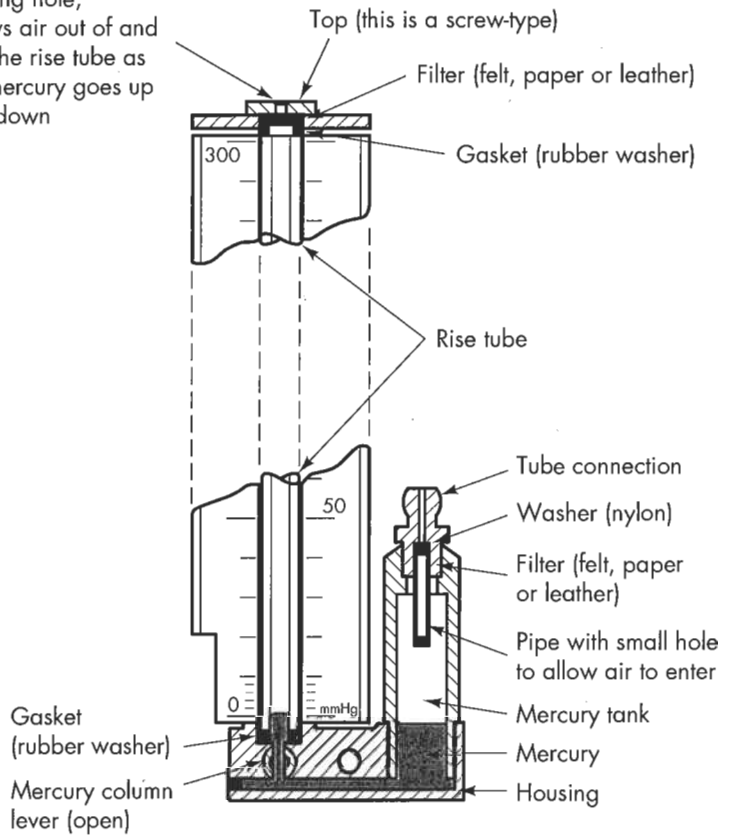
#### **THEN:**

- i. remove the cuff and tubing
- ii. open the mercury column lever, tilt apparatus and allow any mercury in rise tube to run back into the mercury tank
- iii. remove the mercury tank cover. You will require either a small screwdriver or the correct spanner for this
- iv. with the syringe, remove all mercury from the tank
- v. pour the mercury into a clean container with a lid to prevent vaporisation. A small amount of water may be kept in the container which will float on the surface of the mercury and also prevent vaporisation. The container must be clearly labelled to the effect that it contains mercury. It should be kept for this use only
- vi. remove the cover over the rise tube. This may be fitted by screws or by springs. Note how it comes apart
- vii. withdraw the rise tube. If the manometer is to be removed from its case remove hinge screws or pins
- viii. place all parts in a clean cardboard box to prevent losing them
- ix. clean or replace parts of the apparatus as necessary

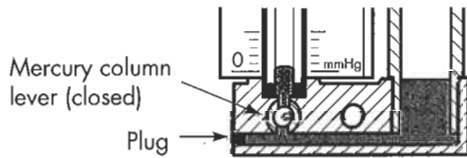
### Details of the top cover



Venting hole; allows air out of and into the rise tube as the mercury goes up and down

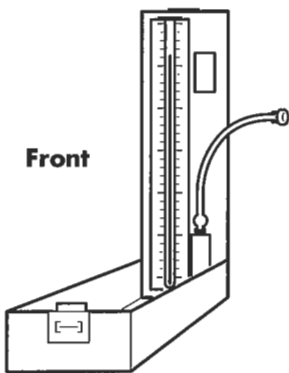


**Details of the meter base and mercury tank.**  
The mercury column lever is open. The mercury in the rise tube should indicate "zero"(0).



### Meter base

The mercury column lever is closed. Before folding the lid with the manometer down into the box, the apparatus should be tilted to the tank side, so that no mercury is left in the rise tube.



Please study this diagram as a guide before removing any parts from the manometer.

Although all the machines work on the same principle each manufacturer's designs are different therefore great care must be taken to note every step taken.

Remember to place any parts removed in a clean cardboard box for safe keeping.

**Figure 54:** Disassembly of blood pressure apparatus

## **B. To clean the rise tube and mercury tank**

- i. using a stiff wire, push a small piece of cotton wool through the rise tube several times
- ii. gently tap mercury tank (with opening facing downwards) onto tray to make sure all mercury has been removed
- iii. wash tube and tank in a detergent and water solution
- iv. dry thoroughly
- v. reassemble

## **C. To clean mercury**

There are two methods for cleaning mercury. They are shown in Figure 55

## **6. Spares**

**The following should be kept in stock:**

- spare machine or machines
- clean mercury
- cuffs in both adult and child sizes
- rise tube
- rubber tubes
- pressure control valve
- rubber bulb
- washer and filter set. Some small washers and filters may be made from local materials such as cycle inner tubes, plastic sheeting and tack paper
- calcium hydroxide powder and sulphur powder for cleaning up spilt mercury
- pipe cleaner

If possible, hold in stock one or more blood pressure machines which have undergone a full maintenance check. In this way, all machines can be checked every six months on a rota basis.

Each machine when in use and in store should have an identification number and its own log book. Log book entry headings should include the following:

- identification number
- manufacturer
- supplier of spare parts
- date and location of first issue
- dates of six-monthly maintenance checks
- date received for current maintenance check
- date of re-issue and current location
- date due for rechecking

### Method 1

In this method the mercury is cleaned by passing it through a funnel of rough paper. Requirements for this method are:

A sheet of rough paper. Normal newspaper, toilet paper or filter paper will do. Do not use shiny paper.

A bottle to catch the mercury.

Perform the following steps:

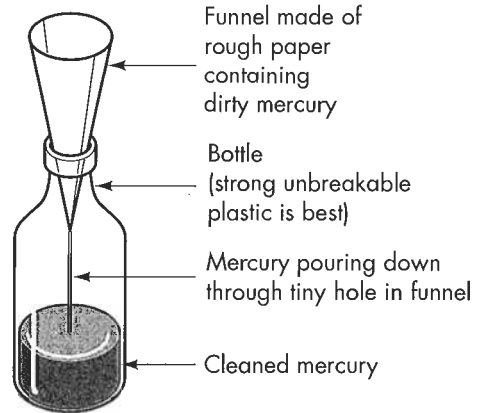
Roll the paper into a funnel as shown (right).

The pointed end should have a tiny hole.

Put the funnel in a bottle.

Pour the mercury into the funnel and let it pass through.

Most dirt will be caught by the paper.



### Method 2

In this method the mercury is pushed through cotton with a syringe.

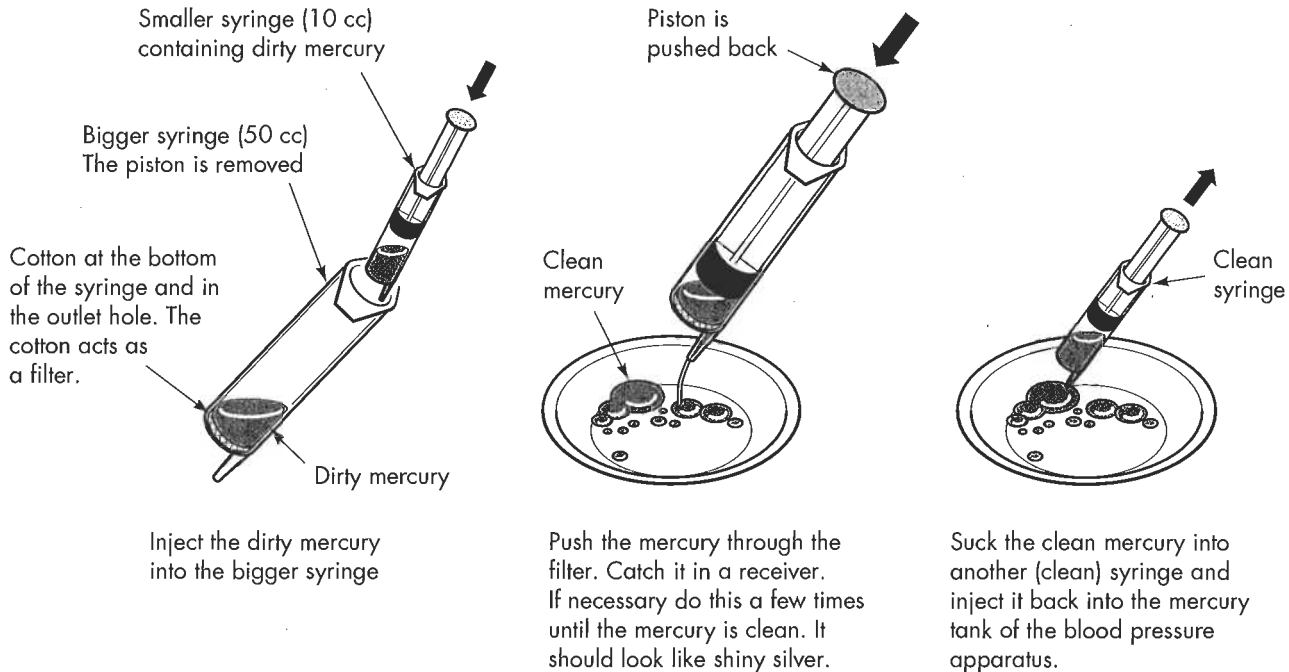


Figure 55: Cleaning mercury

## **7. User Checklist (to be displayed near the equipment)**

Always refer to the manufacturer's instructions

To keep this equipment in good working order for as long as possible:

### **Daily:**

- i. check for any visible signs of wear or cracks in the bulb, cuff and tubes
- ii. check the bulb is pliable and works well
- iii. check that all tubing connections fit tightly
- iv. check that when the column lever is OPEN the mercury level is at ZERO
- v. check for leakage of mercury
- vi. check that the mercury is bright silver in colour
- vii. carry out the function test

### **Function Test:**

- i. fit cuff to your bare upper arm (or around a suitable bottle)
- ii. close the pressure relief valve by turning it clockwise
- iii. pump the bulb until the mercury column reaches 200mm Hg on your arm, or 300mm Hg on a bottle
- iv. hold it there for 10 seconds
- v. watch the mercury level to check that it does not fall more than 2mm Hg during that time
- vi. open the pressure relief valve slowly by turning it anticlockwise. The mercury column should fall at 1mm Hg per second

If the mercury column drops more than 2mm Hg during those 10 seconds:

- report fault to Maintenance Officer

Also report to Maintenance Officer:

- any leakage of mercury AT ONCE
- if mercury looks dirty (is not bright silver)
- any sign of wear or damage
- any other fault

### **Every six months:**

- return the apparatus to stock for a maintenance check and collect newly overhauled apparatus in return
- enter actions in individual log book kept for each machine



### **Follow these SAFETY points**

When exposed to air, mercury vaporises, and mercury vapour is poisonous  
Spilt mercury is very difficult to catch

If spillage occurs:

Do report it AT ONCE

Do open windows and doors to keep the area well ventilated

Do wear rubber gloves

Do collect the mercury in a large syringe kept ONLY for the purpose

Discharge the mercury into a clean container with lid. LABEL the container

Do take care not to inhale the vapour

Do wash skin with soap and water AT ONCE if it comes into contact with mercury

Do wash the affected area (floor, table, etc) with a thin paste of calcium hydroxide and powdered sulphur mixed with a little water

Do ventilate the area for at least 24 hours

Do inform Maintenance Officer of your actions

## **THE BELLOWS TYPE BLOOD PRESSURE APPARATUS**

Due to the delicacy of this apparatus and the fact that special equipment is needed to reset it after repair, it has not been included in this publication.

However if you have one in use, you may check it for accuracy by using the same method as described for the mercury type apparatus (Figure 52)

Should the unit have a fault, it should be replaced.

*Advantages over the mercury type apparatus:*

- it is cheaper
- it is small and lightweight
- it does not use poisonous mercury
- it responds quickly to pressure change

*Disadvantages:*

- it is less accurate
- it is delicate and its many moving parts wear out
- often it cannot be repaired
- it needs very careful handling

As it is a less accurate machine than the mercury apparatus, especially at low pressures, it should be checked regularly (Figure 52).

When not in use, the machine should be returned to its case and stored in a safe place.

## SELECTED BIBLIOGRAPHY

### Research

Abel-Smith, B. and Rawal, P., *Report on the potentiality for cost-sharing. First report - user charges*, Health sector financing study for the Government of Tanzania, c/o ODA, London, 1992.

Bloom, G. et al, 'The right equipment in good working order', round table discussion, *WHO Forum*, Vol 10, 1989.

Bloom, G. and Temple-Bird, C., 'Medical equipment in sub-Saharan Africa - a framework for policy formulation', IDS research report, 1988.

Cheng, M., 'Priority for maintaining essential medical equipment', *WHO Forum*, Vol 15, 1994.

Dobson, M. B., 'Oxygen concentrators for the smaller hospital - a review', in *Tropical Doctor*, No 22, 1992.

Frize, M., 'A clinical engineering experience in Bangladesh', in *Clinical Engineering Update*, No 3, 1989.

Frize, M., 'The need for integration of clinical engineering and sociological perspectives in the management of medical equipment within developing countries', in *Journal for Clinical Engineering*, Vol 19 No 4, 1994.

Gammie, A., 'Heat and dust - Medical equipment maintenance in the Punjab', in *IEE Review*, June 1992.

Halbwachs, H., 'The Madagascar experience and maintenance of health care equipment - principles and policies in the district hospital', workshop report, WHO/IMT/GTZ, Cameroon, 1992.

Halbwachs, H. and Korte, R. (Eds), 'Maintenance strategies for public health facilities in developing countries', workshop report, WHO, Geneva, 1980.

Halbwachs, H. and Werlein, R., *Training health personnel to operate health care equipment - how to plan, prepare and conduct user training*, GTZ, Eschborn, 1993.

*Health care technology in the sub-Saharan region - Challenges and collaboration possibilities*, workshop proceedings and report, Health Technology Research Group, Medical Research Council, Cape Town, 1994.

Health Manpower Development Staff, John A. Burns School of Medicine, *Curriculum adaptation, instruction preparation, programme management*, Medex Primary Health Care Series, University of Hawaii, 1983.

'Interregional meeting on the maintenance and repair of health care equipment', unpublished document, WHO/SHS/NHP/87.5, WHO, Geneva, 1986.

Kingman, S., 'No more white elephants', in *New Scientist*, June 1994.

Koris, K., 'Transfer of medical technology from a developed to a developing country', in *Journal of Biomedicine*, Vol 10, 1988.

'Manpower development for health care technical service', report, WHO/SHS/NHP/90.4, WHO, Geneva, 1990.

McKie, J., 'Management of medical technology in developing countries', in *Journal of Biomedicine*, Vol 12, 1990.

Mdoe, S. L. C., 'Nuclear and related medical equipment quality control activities', in *Tanzania Clinical Engineering Update*, No 18, July 1994.

Mrhida, M. et al, 'Medical equipment in Bangladesh', in *Clinical Engineering Update*, No 1, 1988.

Nolker, H. And Schoenfeldt, E., *Teaching curriculum-planning*, Expert Verlag, Württemberg.

Platt, A. S. and Porter, D., 'Report on a mission to Swaziland - A review and evaluation of SCOT programme', unpublished report, Commonwealth Secretariat, London, 1985.

Rickman, R., 'Diagnostic instruments for primary and veterinary health care', in *Appropriate Technology*, Vol 21 No 1, June 1994.

Riley, C., 'Hospital maintenance in developing countries', *The Lancet*, September 1978.

Siebenhuhner, P, *Planung und Organisation von 'Preventative Maintenance' Seminaren und Projekt-Workshops*, GTZ, Eschborn.

Spacelabs Inc USA, 'Technology assessment', Spacelabs, 1993.

Topley, E., 'Testing degree of anaemia - methods for developing countries', in *Tropical Doctor*, No 16, 1986.

Von der Mosel, H., 'Der Klinisch-biomedizinische Ingenieur', in *Schweizerische Ärztezeitung*, No 51, December 1971.

### **Publications suitable for preparing training material**

*Appropriate technology*, British Medical Journal, 1985.

Barclay, Ellen J. (Ed), *Easy to make teaching aids*, UNESCO Nutrition Education Series 10, UNESCO, Paris, 1984.

Bergveld, P., *Electronics for the everyday user - electro-medical instrumentation*, Cambridge University Press, 1980.

*Blood Pressure Measuring Equipment*, Tool Publications, Amsterdam, 1992.

- Broughton, P. M. G., 'Self-instruction sheets for users of laboratory instruments in intermediate hospital laboratories', WHO, Geneva, 1987.
- Brown, M. et al, *Dictionary of medical equipment*, Chapman and Hall, London, 1986.
- Care of surgical instruments*, Downs Ltd, Sheffield, 1994.
- Cheesbrough, M., *Medical laboratory manual for tropical countries*, Vols 1 and 2, ELBS, London, 1987.
- Dobson, M. B., *Anaesthesia at the district hospital*, WHO, Geneva, 1988.
- Elford, J., *How to look after a refrigerator*, AHRTAG, London, 1992.
- Guide to servicing regulators and flowmeters*, East Healthcare Ltd, Oxford, 1990.
- Halbwachs, H. and Temple-Bird, C. (Eds), 'Spare parts and working materials for the maintenance and repair of health care equipment', workshop report, GTZ, Eschborn, 1991.
- Hankins, M., *Small solar electric systems for Africa - a guide for planning and installing solar electric lighting systems in rural Africa*, Commonwealth Science Council, London, 1991.
- Hart, G., *Medical physics for Advanced Level*, Simon and Schuster, London, 1992.
- How to make basic hospital equipment*, 2nd edition, ITDG, London, 1979.
- Huys, J., *Blood pressure measuring equipment*, TOOL Publications, Amsterdam, 1992.
- Huys, J., *Hospital sterilisation equipment*, TOOL Publications, Amsterdam, to be published late 1996.
- Huys, J., *Sterilisation of Medical Supplies*, European Society for Hospital Sterile Supply eV, to be published 1996.
- King, M. et al, *Primary anaesthesia*, Oxford Medical Publications/GTZ/Oxford University Press, 1986.
- Kuaimoku, E., *Photocopier maintenance and repair made easy*, TAB Books, 1994.
- Lee, P. D., 'Get it right! Pictorial guidelines for medical equipment users', ECHO, 1994.
- Lee, P. D., 'Guidelines for donors and recipients of donated, new and used equipment', unpublished paper, ECHO, 1991.
- Loveday, G. C., *Electronic fault diagnosis*, 2nd edition, Longman Scientific and Technical, Harlow/UK and John Wiley & Sons, New York, 1982.

*Manual of basic techniques for a health laboratory*, WHO, Geneva, 1980.

*Manual of darkroom techniques*, WHO, Geneva, 1985.

Neureiter, J. and Tschank, A., *Technician's handbook for hospital engineering*, Ministry of Foreign Affairs, Austria, 1989.

Roberts, S., *Solar electricity - a practical guide to design and installation of small PV systems*, Prentice-Hall, New York, 1991.

*Where there is no telephone*, Baptist Missionary Society, UK, 1994.

## **Other**

ECRI, *Product categories thesaurus, Universal Medical Device Nomenclature System*, ECRI, USA. See Useful Addresses.

S&W Vickers produce various guides on patient monitoring, infant incubators, phototherapy, paediatric ventilation etc. UK. See Useful Addresses.

TNO (Centre for Medical Technology), international list of reports on comparative evaluations of medical devices. The Netherlands. See Useful Addresses.

WHO produces technical guides on maintenance of refrigeration and cold chain technology. Geneva. See Useful Addresses.

## **Useful journals**

*Africa Health*, published monthly, FSG Communications, Vine House, Fair Green, Reach, Cambridge CB5 0JD, UK. Fax (+44) 1638 743998.

*Biomedical Technology Management*, published monthly, Second Source Pubs Inc, 207 High Point Avenue, PO Box 930, Portsmouth, Rhode Island, USA. Fax (+1) 401 683 7510.

*Clinical Engineering Update*, published quarterly with MBEC News, Peter Peregrinus Ltd, Michael Faraday House, Six Hills Way, Stevenage, Hertfordshire SG1 2AY, UK.

*Directions*, published annually, PATH USA, 4 Nickerson Street, Seattle, WA 998109-1699, USA. Fax: (+1) 206 285 6619.

*Health Equipment Management*, published annually, WHO, 1211 Geneva 27, Switzerland. Fax (+41) 22 791 07 46.

*Journal of Clinical Engineering*, published monthly, Quest Pub Co, 3151 Titan Way, Brea, California, USA, Fax (+1) 714 525 6258.

*Tropical Doctor*, Royal Society of Medicine, Publications Department, 1 Wimpole Street, London W1M 8AE, UK. Fax: (+44) 171 290 2989.

*World Health Forum*, WHO, 1211 Geneva 27, Switzerland. Fax (+41) 22 791 07 46.

## **USEFUL ADDRESSES**

### **General**

AHRTAG (Appropriate Health Resources and Technologies Action Group)  
Farringdon Point  
29-35 Farringdon Road  
London EC1M 3JB  
UK  
Fax: (+44) 171 242 0041

Baptist Missionary Society  
PO Box 49  
Baptist House  
129 Broadway  
Didcot  
Oxfordshire OX11 8XA  
UK  
Fax: (+44) 1235 811537

British Medical Journal  
BMA House  
Tavistock Square  
London WC1H 9JR  
UK  
Fax: (+44) 171 383 6418

Centre for Medical Technology (TNO)  
Zernikedreet 9  
PO Box 430  
2300 AK Leijden  
The Netherlands  
Fax: (+31) 71 18 19 00

Downs Aesculap Ltd (supply booklet Care of surgical instruments, free of charge)  
Parkway Close  
Parkway Industrial Estate  
Sheffield  
South Yorkshire S9 4WJ  
UK  
Fax: (+44) 1742 701840

ECRI - a WHO Collaborating Center for Information Transfer on Medical Devices  
5200 Butler Pike  
Plymouth Meeting  
PA 19462  
USA  
Fax: (+1) 215 834 1275

Equipment for Charity Hospitals Overseas (ECHO)  
Ullswater Crescent  
Coulsden  
Surrey CR5 2HR  
UK  
Fax: (+44) 181 668 0751

FAKT  
Ganseheidestraße 43  
70184 Stuttgart  
Germany  
Fax: (+49) 711 2109515

Gesellschaft für Technische Zusammenarbeit (GTZ)  
PO Box 5180  
65726 Eschborn 1  
Germany  
Fax: (+49) 6196 79 1226

Her Majesty's Stationery Office (HMSO) - distributor of WHO publications  
49 High Holborn  
London WC1V 6HB  
UK  
Fax: (+44) 171 873 8463

Jan Huys - HEART Consultancy  
Health Care Through Appropriate and Reliable Technology  
Quadenoord 2  
6871 NG Renkum  
The Netherlands  
Fax: (+31) 8373 16756

Intermediate Technology Development Group (ITDG)  
Myson House  
Railway Terrace  
Rugby CV21 3HT  
UK  
Fax: (+44) 1788 540270

Intermediate Technology Publications (ITP)  
103-105 Southampton Row  
London WC1B 4HH  
UK  
Fax : (+44) 171 436 2013

Medical Research Council  
Health Technology Research Group  
PO Box 19070  
Tygerberg 7505  
South Africa  
Fax: (+27) 21 938 0385



Overseas Development Administration (ODA)  
94 Victoria Street  
London SW1E 5JL  
UK  
Fax: (+44) 171 917 0797

Program for Appropriate Technology in Health (PATH)  
4 Nickerson Street  
Seattle  
WA 998109-1699  
USA  
Fax: (+1) 206 285 6619

Second Source Publications  
207 High Point Avenue  
Portsmouth  
Rhode Island 02871  
USA  
Fax: (+1) 401 683 7510

Science Policy Research Unit (SPRU)  
Mantell Building  
University of Sussex  
Falmer  
Brighton BN1 9RF  
UK  
Fax: (+44) 1273 685865

Sollatek Ltd (suppliers of voltage protection devices for refrigeration equipment)  
Walton-upon-Thames  
UK

S&W Vickers Ltd  
Sidcup  
Kent  
UK

Voluntary Service Overseas (VSO)  
317 Putney Bridge Road  
London SW15 2PN  
UK  
Fax: (+44) 181 780 1326

World Health Organisation (WHO)  
Division of Strengthening of Health Services (SHS)  
1211 Geneva 27  
Switzerland  
Fax: (+41) 22 791 07 46

## **Training Centres**

Department of Medical Electronics and Physics  
St Bartholomew's Hospital Medical College  
Corterhouse Square  
London EC1N 6BQ  
UK

Dulas Engineering Ltd  
Machynlleth  
Wales  
UK

Hospital Maintenance Project  
PO Box 1021 MCPO  
1299 Makati  
Metro Manila  
Philippines

Institut International Supérieur de Formation des Cadres de Santé  
Hospices Civils de Lyon  
162 avenue Lecassagne  
69003 Lyon  
France

Medical Engineering Training Centre  
via GTZ-PVB  
PO Box 9 26238  
Amman  
Jordan

Mombasa Polytechnic  
Department of Medical Engineering  
PO Box 90420  
Mombasa  
Kenya

NHS Training Authority  
Eastwood Park  
Falfield  
Wotton under Edge  
Gloucestershire GL12 8DA  
UK

Training of Hospital Maintenance Technicians  
BP16  
Diourbel  
Senegal

West of Scotland Health Boards  
Department of Clinical Physics and Bio-Engineering  
11 West Graham Street  
Glasgow G4 9LF  
UK

WHO Regional Training Centre  
Higher Technical Institute  
PO Box 2423  
Nicosia  
Cyprus

## EVALUATION QUESTIONNAIRE

In order to help us improve future editions, please return this evaluation questionnaire or any comments to: VSO Books, VSO, 317 Putney Bridge Road, London SW15 2PN, UK.

This book aims to be a resource for both hospital managers and users. This evaluation questionnaire is divided into two sections, one for managers and another for users.

### A. Managers' questionnaire

1. Has this book been useful? Yes  No

2. In what way was it useful?

---

---

---

---

---

3. Did it leave out any topics which you would have found useful? Yes  No

If yes, which ones?

4. In what way did you use this book? (Please tick all that apply.)

- To inform yourself and the management team about equipment maintenance problems?
- To start systems of fault-reporting?
- To set up user training?
- To post the User Checklists near equipment to ensure that it is used correctly?

Other – please describe.

5. Which sections or which aspects of the book did you find most useful?

6. Which sections of the book or which aspects did you find least useful?

---

---

---

---

7. Is the format of the book suitable? Yes  No

If not, which format would you have found more useful (eg different book size, different print size, different spine etc)?

---

---

---

---

---

---

8. This book tries to cover the most common types of hospital equipment at district level. Please list other equipment which should be included.

---

---

---

---

---

---

9. Hospital buildings, generators, etc also require maintenance - would a similar book covering buildings maintenance be useful to your hospital/health centre?

Yes  No

10. Finally - how did you obtain this book?

Who paid for it?

In what currency?

How did you hear about this book?

**B. Users' questionnaire**

1. Has this book been useful? Yes  No

2. In what way was it useful?

---

---

---

---

---

---

3. Did it leave out any topics which you would have found useful? Yes  No

If yes, which ones?

---

---

---

---

---

---

4. Did the book cover the most common types of breakdown of equipment that you find in your work? Yes  No

If no, which ones should it cover?

---

---

---

---

---

---

5. The book provides User Checklists which can be posted near equipment.

Did you use these checklists? Yes  No

Were the checklists useful? Yes  No

If they were not useful, why not?

---

---

---

---

---

---



VSO Books is the publishing unit of Voluntary Service Overseas. Since 1958 more than 22,000 skilled volunteers have worked alongside national colleagues in over 60 countries throughout the developing world. VSO Books draws on the wide range of professional experience of volunteers and their overseas partners to produce practical books and Working Papers in education and development. Care is taken to present each area of volunteer experience in the context of current thinking about development.

A wide readership will find VSO Books publications useful, ranging from development workers, project implementers and teachers to project planners, policy-makers and ministry officials in the South.

Information from VSO Books can also be found on VSO's web site: [www.oneworld.org/vso/](http://www.oneworld.org/vso/)

## **Current VSO Books titles include:**

### **Books for development workers**

*Adult Literacy - A handbook for development workers*

Paul Fordham, Deryn Holland and Juliet Millican, £8.95, 192pp, VSO/Oxfam Publications, ISBN 0 85598 315 9

*Agriculture and Natural Resources Manual*

Penelope Amerena, £9.95, 117pp, VSO, ISBN 0 9509050 3 8

*Culture, Cash and Housing - Community and tradition in low-income building*

Maurice Mitchell and Andy Bevan, £8.95, 128pp, VSO/ITP, ISBN 1 85339 153 0

*Introductory Technology - A resource book*

Adrian Owens, £9.95, 142pp, VSO/ITP, ISBN 1 85339 064 X

*Made in Africa - Learning from carpentry hand-tool projects*

Janet Leek, Andrew Scott and Matthew Taylor, £5.95, 70pp, VSO/ITP, ISBN 1 85339 214 6

*Managing for a Change - How to run community development projects*

Anthony Davies, £9.95, 164pp, VSO/ITP, ISBN 1 85339 399 1

*Participatory Forestry - The process of change in India and Nepal*

Mary Hobley, £14.95, 338pp, VSO/ODI, ISBN 0 85003 204 0

*Water Supplies for Rural Communities*

Colin and Mog Ball, £6.95, 56pp, VSO/ITP, ISBN 1853391123

*Using Technical Skills in Community Development*

Jonathan Dawson, ed. Mog Ball, £5.95, 64pp, VSO/ITP, ISBN 1 853399 078 X

## **VSO/Heinemann teachers' guide series**

### *A Handbook for Teaching Sports*

Anne Simpkin (The National Coaching Foundation), £6.50, 160pp,  
VSO/Heinemann, ISBN 0 435 92320X

### *How to Make and Use Visual Aids*

Nicola Harford and Nicola Baird, £5.99, 128pp, VSO/Heinemann, ISBN 0  
435 92317 X

### *The Maths Teachers' Handbook*

Jané Portman and Jeremy Richardson, £5.25, 108pp, VSO/Heinemann,  
ISBN 0 435 923 18 8

### *The Science Teachers' Handbook*

Andy Byers, Ann Childs and Chris Lainé, £4.50, 144pp, VSO/Heinemann,  
ISBN 0 435 92302 1

### *Setting Up and Running a School Library*

Nicola Baird, £4.99, 144pp, VSO/Heinemann, ISBN 0 435 92304 8

## **Forthcoming publications**

Publication date: April 1998

### *How to Grow a Balanced Diet - A handbook for community workers*

Ann Burgess, Phil Harris, Stephanie Harris and Grace Maina, VSO

Publication date: 1998/1999

### *The Agricultural Science Teachers' Handbook*

Peter Taylor, VSO/Heinemann

Publication date: 1998/1999

### *Primary Health Care and Rational Prescribing Manual*

Dr Keith Birrell and Dr Ginny Birrell

---

## **To order or for more information about current and forthcoming titles from VSO Books, please contact:**

Penny Amerena, Silke Bernau and Alison Sen at

VSO Books

VSO

317 Putney Bridge Road

London SW15 2PN

UK

Tel: +44 0181 780 7200

Fax: +44 0181 780 7300

email: sbernau@vso.org.uk