WHO Regional Publications, Eastern Mediterranean Series 17

Selection of basic laboratory equipment for laboratories with limited resources

Warren L. Johns
Mohamed M. El-Nageh

WORLD HEALTH ORGANIZATION
Regional Office for the Eastern Mediterranean

WHO Regional Publications, Eastern Mediterranean Series 17

Selection of basic laboratory equipment for laboratories with limited resources

Warren L. Johns
Auckland
New Zealand

Mohamed M. El-Nageh
Quality of Care and Health
Care Technology Unit
World Health Organization
Regional Office for the
Eastern Mediterranean
Alexandria
Egypt

WORLD HEALTH ORGANIZATION
Regional Office for the Eastern Mediterranean
2000

WHO Library Cataloguing in Publication Data

Johns, Warren
Selection of basic laboratory equipment for laboratories with limited resources / by Warren Johns, Mohamed M. El-Nageh

p. (WHO Regional Publications, Eastern Mediterranean Series; 17)

ISBN 92-9021-245-4
ISSN 1020-041X

1. Equipment and Supplies 2. Laboratories
I. El Nageh, M. M. II. Title III. WHO Regional Office for the Eastern Mediterranean IV. Series

(NLM Classification: W 26)

Cover design and layout by A. Hassanein, EMRO

Cover illustration reproduced from a painting by Husam El-Nageh with his kind permission

Printed in Alexandria, Egypt

Contents

Preface

Medical laboratory technology, like any profession, requires the skillful use of appropriate tools; learning about the tools of the trade and their associate techniques is the first and most essential part of any laboratory worker's training. Thereafter, having the right scientific equipment and knowing how to use it are certainly helpful to anyone who wishes to work comfortably and competently.

Originally laboratories used manual methods. Laboratory workers would prepare their own reagents, standards and samples before starting an analysis. The assays used simple, cheap and stable reagents. This work at the bench involved, among other things, the use of a mechanical balance, pipettes, test tubes, a water-bath and a colorimeter. Mechanization was introduced in the 1960s after the invention of the autoanalyser in 1957. Laboratories, especially clinical biochemistry departments, underwent radical and profound change. By using automation, the numbers of tests expanded without a corresponding increase in labour.

A more recent technological development has been the simplification and miniaturization of equipment to enable tests to be carried out at a patient's bedside or at a doctor's clinic. This near-patient testing or point-of-care testing is done with the help of portable glucose meters, whole blood gas analysers and electrolyte analysers.

This same simplification of equipment has brought about the development of appropriate equipment that can be used in developing countries, for example portable water testing kits, haemoglobinometers and battery-operated pH meters. The lack of simple and practical tools for on-the-spot diagnosis often prevents accurate and timely treatment. Manufacturers need to design and provide appropriate equipment at a cost which developing countries can afford.

However, it needs to be established what exactly the appropriate tools are. Also the question has to be resolved of whether developing countries, caught between the old and the new, have to use manual methods and old-fashioned equipment or electronic equipment that is not only expensive to buy but comes with costly consumables only obtainable from the manufacturer. Working in rural areas does not mean that laboratory technologists cannot use good equipment. The need is for the best possible equipment. Often these people working in rural areas do not know what equipment is available: manufacturers' agents do not reach them, suppliers do not send their sales representatives and few subscribe to technical journals and therefore miss out on reading reviews and seeing advertisements. These laboratory workers rarely go to international, or even national, conferences and therefore do not see the range of equipment available.

The scaling back of development aid by some developed countries continues. Some developing countries have only limited financial resources to spend on health care each year. A sensible choice of laboratory equipment and consumables will ensure that money allocated to the laboratory is well spent.

A consumer in a normal economic market is assumed to have sufficient information to make an informed decision regarding consumption of a particular commodity. For the first time buyer the purchase of new laboratory equipment can be confusing. The buyer may not know what questions to ask or where to get useful information about the equipment. The choice may be too wide and therefore choosing will not be easy.

Manufacturers of hi-fi equipment, cars, do-it-yourself tools and cookers make money by bringing out new models and so persuading the purchasing public that new models must be better. In a medical setting this attitude may waste money and harm patients. When an item of laboratory equipment is needed, the laboratory worker may choose one of the old, tried and tested models or be tempted by advertising and promotion to try a newer model. However, it is often difficult to predict how reliable the new ones will prove to be. The authors hope that the information, tables, lists and notes in this book will assist all laboratory workers in choosing basic equipment for health laboratories.

The preparation of this publication would have been impossible without the continuous support and encouragement of Dr Hussein A. Gezairy, WHO Regional Director for the Eastern Mediterranean, and of Dr M.H. Khayat, Deputy Regional Director for the Eastern Mediterranean, to whom we wish to express our thanks and gratitude.

Acknowledgements

A number of people have provided information and acted as advisers for this document. Their contributions are gratefully acknowledged. The authors would like to express their gratitude to:

- John G. Dwen for his guidance and suggestions in the preparation of the computer database during the preliminary stages of information gathering and for encouraging suggestions and his valuable time spent in the critical reviewing of the text.
- Monica Cheesbrough, Tropical Health Technology, Cambridgeshire, United Kingdom (UK), for providing reports and continued encouragement.
- Corinne Lacroix, former Technique sector in charge of laboratories, Médicins sans frontières (MSF), Paris, France for comments regarding the buyer's guides.
- Fay B. Blank, Managing Director, Scientific Supplies Ltd., Panmure, Auckland, New Zealand for advice on laboratory procurement.
- Marilyn Eales, Former Charge Technologist, Haematology Department for her continued interest in the project, and laboratory staff at Middlemore Hospital, Auckland, New Zealand for advice on equipment.
- Nicole Petit, WHO Supply Services, Geneva, Switzerland for suggestions on the layout of the buyer's guides.
- C. Stuart Rennison, Scientific Laboratory Supplies, Hessle, West Yorkshire, UK; RW and SF Dunbar, Scientific and Technical Supplies Ltd., Newmarket, UK; HJ Brey, Sandberg and Schneidewind, Hamburg, Germany; and Otto Knoedlseder, General Manager Europe, Middle East and Africa, VWR Scientific, Greifensee, Switzerland, for contributing material to Chapter 7 on choosing major equipment for intermediate and peripheral laboratories.
- Phil Gilgen and Willie Williamson, Power Technology Group Ltd, Auckland, New Zealand and John Szkolnik, Spectronic Instruments, Inc USA, for technical advice regarding power line conditioners and uninterruptible power sources.
- John P. Goffin, Director, Ampere Technology Ltd., Christchurch, New Zealand and Dr Mike Harper, Derbyshire Royal Infirmary, Derby, UK, for reviewing parts of Chapter 8 on energy supplies and requirements.
- Dr Chris Collins for advice concerning the risks in using home-made microbiological safety cabinets.

Gratitude is also due to the following, who reviewed the first draft:

- Andy Barraclough, Gimlet International, UK.
- Lynn Woolhouse, Auckland, New Zealand.
- Robin Cooper, SGS New Zealand Ltd, Auckland, New Zealand.
- Dr Jane Carter and laboratory staff, AMREF, Nairobi, Kenya.
- John Morrison, Department of Microbiology, The Royal Infirmary, Leicester, UK.
- Jan Aickin and Sharon Cartman, Biolab Scientific Ltd., Auckland, New Zealand.
- Mike Lynch, Pacific Paramedical Training Centre, Wellington, New Zealand.
- Laurence Bonte, Médicins sans frontières (MSF), Paris, France.
- Tom Healy, Paediatric Biochemistry, Royal Hospital for Sick Children, Edinburgh, Scotland, UK.
- Colum Walsh and Noelle Neylon, Independent Micro Lab Ltd.; Portlaoise, Ireland.
- Dr Peter Hill and Peter Wood, Derbyshire Royal Infirmary, Derby, UK.
- Dr Anders Kallner, Karoliska Hospital, Stockholm, Sweden.

The authors would like to acknowledge the use of the following sources by kind permission of the publishers.

Chapter 1: Figure 1.1 is based on one in *Health technology directions*. Vol. 11, No. 1, 1991 published by the Program for Appropriate Technology in Health (PATH).

Chapter 8: Roberts S. *Solar electricity: A practical guide to designing and installing small photovoltaic systems.* Published by Prentice Hall International (UK) Ltd, 1991. Material from this book includes solar cells, types of silicon and the summary of battery features.

Introduction

The aims and audience of this book

The aim of this book is to provide information that the purchaser needs to know to make sensible buying decisions. To get a good deal when buying equipment, the purchaser needs to know at least as much as the seller; to get the best deal, the purchaser probably needs to know a lot more.

This book provides a framework within which laboratory workers in developing countries can choose equipment and consumables. Without the right background knowledge, the purchase of laboratory equipment and consumables can be confusing, time-consuming, and dangerous for patients and staff. Money is wasted when the wrong purchase is made. This reference book is a store of information that is too detailed to remember (for example, the selection criteria when choosing new laboratory equipment) and a summary of what is known about major laboratory equipment.

This book is addressed to two groups of people, all with different degrees of technical expertise. It is written primarily for laboratory staff working in developing countries. These are the people who will be using, maintaining and carrying out minor repairs on the equipment. To make their task of choosing equipment easier, this book has been structured to provide information that is readily accessible, e.g. the buyer's guides.

The second group for whom this book is written is staff involved in the procurement of laboratory supplies. This may include the hospital administrator, the central stores officer or the laboratory supplies officer.

The aim is to assist you, the reader, to know about equipment—to recognize the wrong equipment, and to be able to select and separate equipment. The book is structured to provide easy access to information that will assist in the selection of appropriate laboratory equipment and consumables. It is divided into three sections: Section 1 on choosing and buying laboratory equipment; Section 2 on energy requirements for laboratory equipment; and Section 3 which provides information with regard to equipment specification and manufacturers.

Specifically in Section 1, Chapter 1 gives a step-by-step guide to choosing and buying laboratory equipment, different aspects of which are elaborated upon in subsequent chapters. Chapters 2–4 discuss purchase, consumer problems, supplier relationships and receipt and maintenance of equipment. Chapter 5 is concerned with purchase of second-hand equipment while Chapter 6 gives general information on all the small items you may have to purchase.

Chapter 7 is a buyer's guide to choosing major equipment and provides equipment information sheets on 16 such items. Each information sheet comprises a quick reference guide indicating the questions to consider when choosing each major item, technical points to consider and a form for assessment of quotations.

Purchasers may also refer to the equipment data specification sheets in Section 3, Annex 1. A sample sheet has been prepared for each of the major equipment items and it is recommended that a specification sheet is completed and submitted to the supplier (or manufacturer) at the time of ordering.

Section 2, Chapter 8 covers energy requirements, including safeguards against power disturbances, and solar energy.

Section 3, Information annexes, includes: equipment data specification sheets; ordering and transporting chemical substances; sample forms; equipment donation guidelines; an equipment index with addresses of manufacturers of laboratory equipment; notes about laboratory equipment supply; sources of information and materials; publications by post; a glossary; and useful references.

How to use this book: a quick guide for the reader

This is not a book to read from the beginning to the end, but a book to dip into. The traditional entry points are the list of contents and the index. Other suggested entry points for the reader are:

I want to buy some major equipment for the laboratory–what features should I look for?	See the *Quick reference guides* Photocopy the pages you need and visit the suppliers	Chapter 7
I want to write to manufacturers of microscopes–what companies could I write to?	See the *Equipment index*	Annex 5
We need some safety equipment–what should we look for?	See the notes on *Choosing minor equipment and consumables*	Chapter 6
Our new water bath is leaking–what should we do?	Make a complaint to the supplier. See the notes *Common consumer problems*	Chapter 3
There have been power disturbances in our area–what can we do?	See *Power disturbances*	Chapter 8

Section 1

Choosing and buying laboratory equipment

Chapter 1
Choosing and buying laboratory equipment

Steps in buying equipment

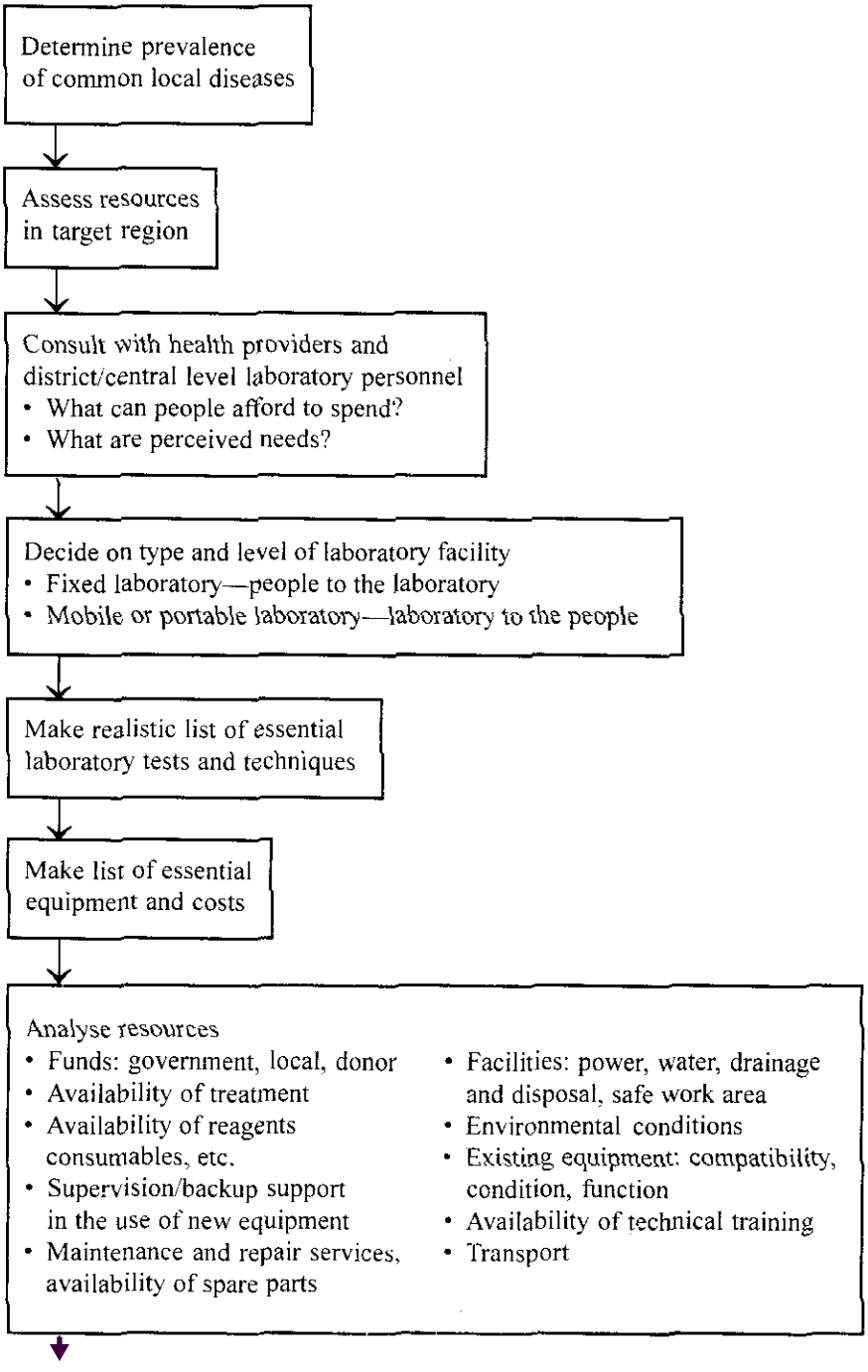
Note: The flowchart in Figure 1.1 illustrates the steps outlined in this chapter.

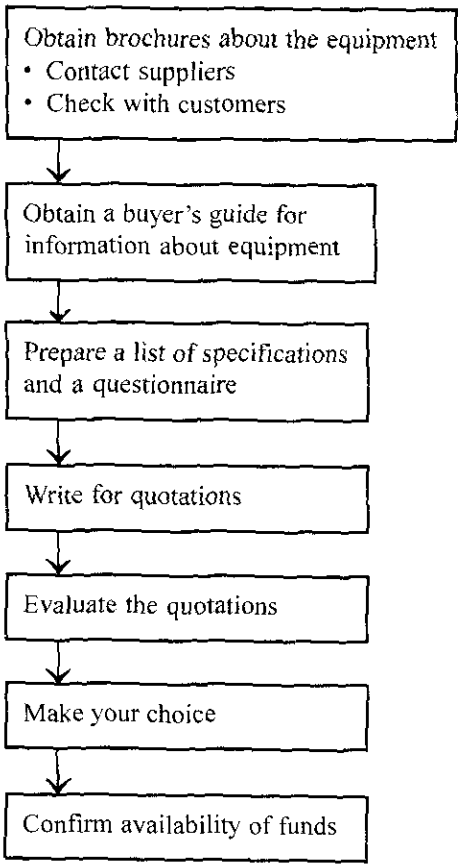
1. Consider your needs

a) A new laboratory

- Have discussions with local health authorities, or community leaders, to gain a thorough understanding of the population's health concerns, their needs and what they can afford. Begin by preparing a list of the common local diseases. Then determine the laboratory tests for each of the diseases and choose the appropriate testing techniques. At this point, consultation with the clinicians or community health workers who will be using the laboratory tests is vital.
- Laboratory services in primary health care should be relevant, accessible and reliable. Laboratory tests should be inexpensive, simple, accurate and easy to perform in settings with limited resources. Wherever there is a stated need for greater involvement at the community level, consider a mobile or portable laboratory service. Look for equipment that is compact and relatively lightweight. Above all, select simple, basic equipment with maximum usefulness that is easy to repair and maintain (see Points to consider when choosing new laboratory equipment).
- Make a list of equipment required for the laboratory. Remember to consult the users. To determine the type of test required, it is important to consult the clinical staff and other laboratory users. For example:
  - for haemoglobin estimation in a busy district (intermediate) hospital, colorimetric analysis is recommended;
  - for haemoglobin estimation in a small health centre, use of a haemoglobinometer might be more practical;

FIGURE 1.1 **Choosing and buying laboratory equipment**




Obtain brochures about the equipment
• Contact suppliers
• Check with customers
Obtain a buyer's guide for information about equipment
Prepare a list of specifications and a questionnaire
Write for quotations
Evaluate the quotations
Make your choice
Confirm availability of funds

– for an outreach antenatal clinic, haemoglobin screening using a comparator method, which is usually performed by nurses, is an acceptable alternative where colorimetric analysis or a haemoglobinometer are not available.

Tip: If it is difficult to choose the most important items on your equipment list, then start by eliminating the least important and see what you have left.

---

b) An existing laboratory

The equipment may be needed to:

- introduce a new test, e.g. a portable kit for the bacteriological testing of water;
- replace worn out, non-functioning or inadequate equipment; or
- improve performance of an existing test.

2. Analyse resources and conditions

Consider the local resources and conditions in the list below. All criteria are relevant and each must be examined in detail.

- Funds: government, local, donor
- Facilities: power, water, drainage and disposal, safe work area
- Availability of treatment
- Availability of reagents, consumables, etc.
- Environmental conditions
- Existing equipment: compatibility, condition and function
- Supervision/back-up support for the laboratory worker
- Maintenance and repair services; availability of spare parts
- Transport
- Availability of technical training in use of new equipment

Read the selection criteria given under Points to consider when choosing new laboratory equipment (page 25). The questions will provide discussion topics for each of the items listed.

3. Obtain brochures about the equipment

Write to suppliers, manufacturers and agents requesting a brochure about the equipment. (See Annex 5, Equipment index and manufacturers, and Annex 6, Laboratory equipment supply.) Take particular note of the technical data and specifications given in

the brochure. You need to understand what the equipment can and cannot do. Manufacturers' glossy publicity literature with nice pictures should not be taken as a guide when defining your requirements. A manufacturer is likely to mention only favourable features not the limitations of the instrument.

Contact the offices of the various suppliers and ask each supplier to give you the names of customers who have purchased similar equipment to that which you are thinking of buying. Visit these customers and ask them if they are satisfied with the equipment and after-sales service and whether they have had any problems. Be cautious of any supplier who shows a reluctance to be open and responsive when giving you the names of customers.

4. Obtain a buyer's guide

You now need up-to-date information about the equipment. Start by examining the manufacturer's brochures. Remember the information from the manufacturers may not mention the limitations of the equipment, e.g. a microscope that cannot be supplied with a mirror unit.

Read the relevant buyer's guides in Chapter 7. Take time to consider all the requirements in the left-hand column of the quick reference guide. These questions are designed to help you and you colleagues define your working and environmental requirements.

5. Prepare a list of specifications and a questionnaire

Make use of the equipment information sheets in Chapter 7 to prepare an equipment data specification sheet. An example follows in Figure 1.2. An equipment data specification sheet, or equivalent, should be prepared by the laboratory and submitted at the time of ordering (requisitioning) a major item of equipment. This will ensure that the person purchasing (administrator, stores officer) can justify the expenditure involved and has sufficient information to buy correctly. In addition, prepare a questionnaire to send to the supplier so that you can obtain relevant information about the product in question (see Figure 1.3).

6. Write for quotations

Approach at least three suppliers in order to get a selection of competitive quotations. Each supplier should submit a quotation on the basis of the information you provide. Refer to the sample letter in Figure 1.4 as a guide.

Equipment data specification sheet for: a microscope

Information about equipment use, local conditions and requirements

To be used in: haematology laboratory including examination of thick and thin films for malaria, to diagnose tuberculosis, etc.

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of microscope required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- A binocular head inclined at 30° (or 45°), and rotatable for 360°
- A widefield eyepiece 10x
- Objectives to be parfocal DIN achromatic, 10x, 40x, 100x oil immersion. The numerical apparatus (NA) of the objectives should be: 10x/NA 0.25, 40x/NA 0.65, 100x/NA 1.30
- The light source should be built in. The lamp should be quartz halogen 6V 10W. There should be a lamp diffusing screen and a graduated lamp brightness control
- The microscope must be able to operate from a battery. A connection for a 12 V battery should be built in to the base. The connections for the mains and battery should not be interchangeable
- Provide a 12 V rechargeable battery (preferably lead-acid) including a lead with battery connectors. These should be a safety device to prevent damage from interchanging of battery terminals
- A lead with car battery connectors to be provided
- The stage should be built-in, mechanical and with coaxial controls
- A mirror, plain and concave, mounted for angling and rotating must be provided. The mirror should fit over the lamp
- Condenser Abbe type with iris, centring screws, and filter holder; condenser positioning indicator
- Recommended spare parts to include spare lamp and fuses
- Where can repairs be made?
- Where can spare parts be obtained?
- Provision for a maintenance contract covering taking the microscope to pieces, cleaning, and reassembling by an expert, to the buyers satisfaction
- The cost of a maintenance contract are to be stated as separate items in the tender price quoted
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

FIGURE 1.2 **Example of an equipment data specification sheet to be completed by the buyer for a microscope**

Questionnaire for supplier for ..... (name of equipment)

- What is the price (FOB and CIF)?
- What currency will be used?
- What will be the period of delivery of the equipment, from the date of a firm order?
- What are the name and address of the manufacturer's local or nearest agent?
- When will the goods be shipped? Please send shipping details including ship or shipping company/airway bill number.
- What are the dimensions and weight of the equipment packed in boxes ready for shipment?

FIGURE 1.3 **Sample questionnaire for supplier**

Dear (supplier),

re: Microscope for haematology laboratory

Your company has been recommended to us as a possible supplier of a microscope for use in our haematology laboratory. You are therefore invited to quote for the supply of a microscope according to the outline specification attached.

Tenders should be forwarded on or before ..... (date), addressed to ..... (buyer) at ..... (address). Please also fill out and return the enclosed questionaire.

Yours sincerely

.....

(Buyer's name)

Enclosures:
Equipment data specification sheet for microscope
Questionnaire for supplier

FIGURE 1.4 **Sample letter to potential supplier**

7. Evaluate the quotations

The more careful you are in establishing your needs and defining your requirements and resources, the easier it will be to evaluate the tenders. Make your choice not only on the basis of the lowest price but also on the availability of maintenance facilities, spare parts etc. Continuing with the example of the quotation for a microscope, the evaluation will include the following.

- **Purchase price**. What exactly is included in the purchase price? At this stage you may wish to discard those microscopes that are grossly outside your price range. In what currency has the price been quoted?
- **Maintenance and servicing**. Is a user's manual provided and, if so, is it of a satisfactory standard and written in plain language?
  - Does the user's manual explain how to set up the microscope for routine use?
  - Are there instructions on changing the lamp?
  - What servicing and maintenance facilities are available locally, nationally or internationally?
  - Is the maintenance performed by personnel trained by the manufacturer or is it subcontracted out?
  - How much maintenance can be done by the user?
  - Is training available?
  - Are spare parts held locally?
  - How long will it take to receive a replacement part?
- **Technical comparisons**. Has a built-in battery connection and a mirror been included? Consider the optics and the objectives and their numerical apertures.
- **Demonstration**. A microscope demonstration prior to purchase is crucial. Using a familiar slide to make sure the image is clear and crisp at all magnifications is the best way to test the instrument. The placement of the focusing controls and the angle of viewing of the binocular tube head should be convenient and comfortable.
- **The form for assessment of quotations**. Each equipment information sheet given in Chapter 7 includes a form for assessment of quotations. Complete the form and make notes of your overall assessment. An example of a completed form is given in Figure 1.5.
- **Narrowing the selection**. Evaluate the quotations by matching them against specifications. It is very important for *the laboratory* to evaluate the quotations rather than an administrator who may look at the price or at some other aspect. Reject quotations which do not conform to the technical requirements of the outline specifications, e.g. quotations which do not have a mirror or built-in battery connector, etc. or which do not supply the full information required in the questionnaire, e.g. no service/maintenance contract price, no delivery period.

The final choice may depend on factors which more than justify a higher initial price, such as the availability of a local agent. Treat quotations which are more than 10–15% lower than the majority with great caution. Study the conditions given in the small print carefully as low prices often indicate that unacceptable economies have been made in the specification. (See Annex 2, sample quotation forms 1 and 2.)

8. Make your choice

The supplier

When trying to decide on a company, find out as much about it as you can. How reliable is it? How many years has it been in business? Does it have a good reputation for after-sales service? Does it carry a good stock of spare parts? Does it have a service telephone number? Does the company have regional accredited standards status?

Do not be pressured into making a quick decision. Do not feel obliged to buy anything you do not really want. If you are interested, get written details and a price from the salesperson and compare it with other companies' quotations.

Condition of sale by quotation

Problems may arise from misunderstandings between customer and supplier over acceptance, price, delivery, installation or warranty. To avoid confusion, make sure that your contract is in writing and that it gives clear, full details of the goods, prices, discount (if offered), cancellation rights (if you have any), warranty/guarantees (how long they will last) and when the goods will be delivered.

Remember that in some countries it is up to the retailer, not the manufacturer, to remedy any fault. Find out about consumer guarantees in your country (see Chapter 3 on consumer protection).

9. Confirm availability of funds

Have you obtained approval from the health institution administration? The administrative bureaucracy may be the first of a number of delays. To avoid the standard answer given by administration staff "We cannot find your papers" make three photocopies of your equipment documents. When depositing these documents give the administration one copy, ask for another copy to be dated and stamped and keep this copy. The third copy will be kept in the laboratory file. On the following visit to the office, if someone says that they cannot find your papers present your date-stamped copy.

Finding your papers, being able to talk to the right person, obtaining a signature all take time. To pass the time, take a book or magazine with you!

Form for assessment of quotations: microscope

	Company 1	Company 2	Company 3
Name of manufacturer	Swing	Hinz	Viso
Model	QBJ 4	Series 20	TT 2000
Power voltage available	110 V/240 V	110 V/240 V	240 V
Is a mirror provided?	Yes	Yes	No
Is the battery connection built in?	Yes, 12 V	Yes, 6 V, 12 V	No
Optics: objectives 10x,40x, 100x oil	10x, 40x, 100x	10x, 40x,100x	10x, 40x, 100x
Optics: high NA for each objective 10x (0.25 NA) 40x (0.65 NA) 100x (1.30 NA) oil	0.25 0.65 1.25	0.22 0.65 1.25	0.25 0.65 1.30
What accessories are available?	12 V battery unit, solar panel	Camera equipment, travel case	Phase contrast
Local agent?	Yes	No	Yes
Maintenance, spare parts (bulbs, fuses) available locally?	Maintenance, bulbs, fuses	Maintenance, bulbs	Maintenance, bulbs, fuses
Cost	US$1400	US$1300	US$1000
Overall assessment of quotation:	Good	Good	Poor

Comments

For use in our laboratory the best buy is company 1.

Company 1: Order sealed battery, charger, solar panel

Company 2: Would have to find suppliers of battery, charger, solar panel

Company 3: No mirror, no battery connection

FIGURE 1.5 **Example of comparing microscopes by value for money**

10. Purchasing

What information should be given to the supplier or manufacturer?

- **A brief description of each item**. As complete a description as possible of each item is essential as it is the only identifying information when a catalogue is not available. In almost every case the supplier needs to know:
  - whether the equipment is meant for general use or if any special application is intended
  - the size of the unit
  - accuracy needed
  - from which material the equipment should be made
  - power requirements, and
  - whether a standard quality is required or an advanced version of equipment is preferred.

For example, when quoting for a centrifuge, the manufacturer would find it helpful to know if it is intended for general laboratory or clinical use, e.g. preparation of blood samples. If no application is indicated, the exact details about, for example, speed range, size of tubes/vessels should be given.

When ordering a standard water-bath, it will usually be sufficient for the manufacturer to know the size or content in litres, and whether it is required with test tube racks (for which tube size?) or as a multiple-place unit having a flat cover with concentric rings.

Writing "spares for pipettor" then a list of part numbers will be of little use to a supplier. If the part number is known, give it with the manufacturer's name, model and description.

- **Quantities required**. State the exact quantities required, whether this is one each, one pack, one case or one dozen.
- **Catalogue number**. Suppliers stress the importance of including their catalogue number. The catalogue number will inform the supplier of all the electrical features, such as operation voltage and power. When a catalogue is not provided, the supplier will rely on your description. Do your best to provide all the details you can.
- **Your dispatch instructions for either sea or air-freight**. Some equipment may be dispatched by rail or truck. Small items may be sent by parcel post or by courier. Some chemicals must go by sea freight—see Annex 4 regarding transport of hazardous substances. It may be cheaper to have all items sent by sea. A single delivery is often advisable. Include about 20% in your budget for packing, freight and insurance.
- **General**. When ordering electrical equipment, give details of local voltages frequencies. When an electronic balance is ordered, it would be useful to include your geographical

location. Because of the influence of gravitational forces, the manufacturers have to adjust the balance for the particular location of its use

It is essential to receive sufficient information from a manufacturer or a supplier before placing an order. This should include an adequate description of the goods, ordering information, current prices, expected delivery time and, where relevant, a list of recommended spares and details of installation, availability of a demonstration, details of the guarantee and servicing arrangements. (See Annex 2, sample order forms 1 and 2.)

Go through the checklist given in Figure 1.6 before finally deciding on a piece of equipment.

Checklist before purchasing

- ☐ The equipment specifications should fit the purpose.
- ☐ The specifications should be suited to local conditions such as power supply, humidity and climate.
- ☐ The advice of other laboratories using similar equipment should be sought.
- ☐ The prices of different brands with similar specifications should be compared, not forgetting prices of spare parts.
- ☐ Running costs should be compared.
- ☐ Availability of after-sales service, including maintenance, should be assured.
- ☐ An operations and maintenance manual including a wiring diagram (preferably in the local language) must be supplied. A circuit diagram should be included for equipment with electronics.
- ☐ On delivery, an extra supply of commonly needed replacement parts (e.g. carbon brushes, fuses, bulbs, electrodes, heating elements) should be obtained.
- ☐ The equipment must be assessed for technical safety.
- ☐ The need for an operator from the laboratory to receive on-the-job training in operation, maintenance and minor repairs must be recognized by the supplier or a competent national agency.

FIGURE 1.6 **Purchasing a piece of laboratory equipment**

- **Delays**. Your order may be delayed simply because you have not given enough information when making a request for equipment. Avoid delays by giving as much information about your requirements.
- **Deposit**. When making a deposit, make sure that there is something in writing to say that the deposit is refundable.
- **Read the contract carefully before signing it.** If there is anything you do not understand, ask for it to be explained. If you have any doubts, get advice before you commit yourself, particularly if the salesperson promises you anything extra or tells you something different from what is in the contract. Read the warranty carefully.
- **When ordering** state clearly exactly what is needed, the agreed price and the agreed delivery date.

  Write to the suppliers who gave unsuccessful quotations.

Tip: If you do not ask the right questions, you will not get the right answers.

Points to consider when choosing new laboratory equipment

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

Durability and robustness

The conditions under which the equipment will be used may have a serious impact on its short-term and long-term performances.

- Will the equipment stand up to the local conditions, i.e. high or low temperatures, humidity, drought or dust?
- Will the equipment be moved frequently?

Safety

- What risks or dangers are associated with this piece of equipment?
- Is there protection, e.g. guards, where needed or safety locks on the lid of the centrifuge?
- Is the manufacturer able to install the equipment and provide advice on maintenance to help ensure safe performance?

Price

Both the initial and operating costs of the equipment, as well as costs of necessary accessories and maintenance, must be assessed. Shipping and insurance will add expense to overseas orders. Both price and quality need to be assessed. Do not buy the cheapest just because it is the cheapest; rather, buy equipment best suited to your laboratory needs. Ask yourself questions, such as whether the equipment will function in high temperatures, high humidity and conditions conducive to the growth of mildew and fungus. A letter of credit is frequently expected by suppliers.

- Find out what exactly is included in the purchase price. Ask what discount the supplier will give. Find out about terms of payment and what deposit is expected. Consider annual running costs.
- Have you set aside enough money for consumables, for one year (or for two years)?
- What is likely to be the cost of maintenance? Allow 10% of the capital value.
- If a service contract is available, what is the cost?
- Set aside between 15% and 20% of the cost price for essential spare parts.
- Are there hidden recurring costs?
- Assess the cost of the reagents, calibrators (standards) and controls and find out whether the equipment can only be used with the manufacturer's reagents.

Sustainability

- Are replacement parts such as bulbs and fuses, as well as other consumable supplies and reagents, still being made?
- How expensive are replacements, spares and consumables?
- Is the equipment covered by a guarantee or service agreement?

Power and resources

The type, source, capacity and reliability of both power and water supplies need to be defined.

- Are constant and reliable local electricity supplies guaranteed? If not, how can laboratory services be maintained during power failure, e.g. by stand-by batteries or a generator?
- If mains electricity is available, is it subject to fluctuations in voltage that are likely to interfere with the performance of the instrument, e.g. colorimeter?
- Is it possible to provide a reliable power supply through batteries charged by solar energy or by intermittent recharging by a generator?

- What are the power requirements of the equipment in relation to the availability of electricity to the laboratory?
- Is the equipment fitted with a voltage stabilizer?
- Can a voltage stabilizer be fitted to the equipment?
- Can the equipment be operated in any other way, e.g. battery, by hand crank?
- If the equipment is battery powered, what type of battery is needed?
- Can the battery be recharged and by what means?
- How often will the battery need replacing or charging?
- If a non-rechargeable battery is required, can this be obtained locally?
- Can the battery be supplied by the manufacturer?
- Are gas supplies available and reliable?
- Is water supplied from a bore-hole (salty) or from rainwater catchment (fairly pure)?

Technical complexity

Equipment that is simple to operate and easily assembled and disassembled for cleaning, repair and decontamination is most appropriate.

- How easy is the equipment to use?
- How easy is the equipment to maintain?
- Can laboratory staff be trained to maintain the equipment or does it require outside expertise?
- Does it have many accessories that are expensive and unlikely to be used?
- Are special tools required to carry out maintenance or repair?

Spare parts

Ask the supplier to obtain from the manufacturer a list of essential spare parts and a guide to the expected life (in years) of the parts. The local supplier must have a demonstrable capacity to service and maintain the equipment. The life expectancy of a part can vary according to how it is used and the local power supply. The cost of spare parts can also vary enormously depending on shipping costs, import restrictions and agents' fees.

When an integrated circuit is faulty, often the entire circuit board will need to be replaced. As a result, electronic failures are often costlier to repair than mechanical ones. Here are some useful tips when you are looking for parts. (See also Annex 2, Equipment problem report and Equipment history record.)

- Make sure that the model number is correct. Check the instrument itself, not just the owner's manual or the packaging documents.
- Try the supplier or local companies for common parts.
- Contact the manufacturer directly for specialized parts.

The number of spare parts that should be ordered depends on:

- how long each part is expected to last;
- how many similar pieces of equipment are in your laboratory or in the network of laboratories to which your laboratory belongs—this will influence your need for the parts;
- the ability to fit the part by local staff or agent—if there is nobody trained to fit the part, there is no point in obtaining the part;
- the reliability of the person keeping the parts;
- the cost of each part; and
- the budget available to buy the parts.

Spare parts are expensive and often take several months to be imported. It is extremely important when you order spare parts from overseas that your order is accurate and clear. When ordering parts, always state:

- the manufacturer's name (shown on the data plate);
- the model or type (shown on the data plate);
- the serial number type (shown on the data plate);
- a description of the part (use the description given in the manufacturer's operation and maintenance instruction manual); and
- the voltage, wattage and cycles/second (Hz) for electric parts.

It is advisable not to rely on local supply only, but also to keep in store parts which are important but hard to get.

Tip: Keep all spare parts in one place in the laboratory.

Training requirements

- What is the level of training and expertise of the staff?
- Can further training be given, if required?
- 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?

Budget

- Is a budget available for the purchase, operation and maintenance of the equipment? For maintenance allow 10% of the capital value.
- Is there likely to be a change in currency value or import restrictions?
- In the case of purchase from a foreign manufacturer, do you have available foreign currency?

Environmental conditions

- Does the equipment require a special dust-free environment?
- What is the manufacturer's recommended operating temperature for the equipment?
- What are the manufacturer's limits of relative humidity for reliable operation?
- Have the electronics been protected against high humidity?

Usefulness

- Desirable equipment must be distinguished from essential equipment.
- Is the equipment compatible with the type and volume of tests being performed?
- Is the equipment compatible with and relevant to local health needs and concerns, and existing diagnostic and treatment services?

Tip: Always ask: "Do we really need this equipment, for what purpose, and what alternatives do we have?"

Maintenance

When ordering new equipment, make a request for the manufacturer (or nominated agent) to provide staff training in operation and maintenance.

- Is there a local supplier or agent able to help you in the event of a breakdown?
- Does the laboratory (or neighbouring laboratory) have the resources to service the equipment?
- What type of manufacturer's guarantee accompanies the equipment?

- Has a circuit (wiring) diagram been included in the equipment manual?
- Have you read and understood the manuf acturer's instructions for use and maintenance?

Location

- Where is the equipment to be located in the laboratory and what are the dimensions of the space available?
- If required, could extra space be provided or the laboratory be reorganized?
- Is there sufficient bench and floor space for the equipment to operate safely?
- Does the equipment require a supply of running tap water or distilled water for its operation and is this available?
- List any other physical requirement as recommended by the manufacturer and check for suitability accordingly.

Performance

- How reliable and exact is the equipment under specific conditions of use (the electronics may not have been protected against high humidity)?
- How accurate must the results be in the target setting? Exaggerated precision does not necessarily lead to better diagnosis and better patient outcome, e.g. the accuracy of haemoglobin levels of 1 g% is more than sufficient in most cases.

Consumer opinion

Talk to actual users of the equipment but remember that they may give you answers that they think you might want to hear. Users of the instrument may omit to tell you about the bad points as they may feel this will reflect on their wisdom when they made their purchase. When you are talking to users, ask specific questions that you want answered (you can refer to the buyer's guide and equipment data specification sheet for the instrument). Also try to find someone else who has the instrument and ask relevant questions.

Specifications

Specifications are details of design and materials used in an item of equipment. There are *your* specifications for an item of equipment required and the *manufacturer's* specifications for each model.

An equipment data specification sheet, or an equivalent, should be prepared by the laboratory and submitted at the time of ordering (requisitioning) and when requesting a quotation for a major item of equipment.

Begin making your specifications by examining in detail the local needs, conditions and resources, as well as the environmental and user requirements. Manufacturer's specifications should be matched against your own specifications, your own requirements and circumstances. A change in environmental and user requirements will necessitate preparing new specifications.

Hands-on evaluation

Ask the supplier or agent to give you a demonstration and, if possible, to leave the equipment with you so that you can evaluate its performance for yourself, judge whether it lives up to its claims, determine if it is acceptable to staff members and see if it meets your specifications.

Capacity

For example:

- For a water bath, what is the volume of the tank?
- For a balance, what is the highest maximum weight?
- For an autoclave, an incubator or an oven, what is the volume?
- What is the anticipated workload?

Energy use

Refrigerators have an energy rating label to allow consumers to compare the efficiency and running costs of similar appliances. Energy use for refrigerators is measured as kilowatts (kW) per year. Refrigerators have a label showing the electrical units used per year so you can calculate the running costs.

Accessories

What additional attachments are available and which of these are necessary? Examples include a centrifuge which may be supplied with a fixed angle or swing out rotor, and a microscope fitted for darkfield or fluorescence microscopy.

Portability

A portable laboratory is a self-contained diagnostic system that can be carried by hand. The equipment used should be compact and relatively lightweight. Examples include a compact mechanical or battery operated balance, a centrifuge operated by hand or battery, a microscope which can be easily dismantled, a battery operated colorimeter. (See Annex 7, Information and materials.)

Chapter 2
The buying business

Procurement

Procurement is the process by which equipment and consumables are obtained. The basic procurement factors are suitability, reliability, timely delivery and low cost. Whenever possible, procurement should be carried out through competitive bids, obtaining prices from not one but several suppliers.

A supplier is someone who acts as a distributor for the manufacturers' goods. Ideally a good supplier should have a demonstrable capacity to service and maintain the equipment.

Quotations

A quotation is a request for the price of goods or services. The request may be for a small or a large number of items. The buyer requiring the prices of equipment and consumables will write to the supplier making a "request for a quotation". When requesting a quotation for equipment, prepare a data specification sheet (see Annex 1). This will convey to the supplier in clear and specific terms what you require. Suppliers will accept a quotation request for a small order by telephone. The supplier in turn will prepare the quotation giving the prices. A binding contract will exist when the purchaser has accepted the quotation. The company may amend or cancel a quotation at any time prior to acceptance by the purchaser.

Most buyers in health care settings will request a quotation. A tender is also a request for costs. A request may be made for tender or quotation—in both case prices are required. Generally a tender is for a large order (over a certain value) and is often requested. (See Annex 2, sample quotation forms 1 and 2.)

Procurement by a supplier

A supplier is engaged to do all the running around. A good supplier will obtain quotations for equipment, consumables and chemicals. A supplier acting as the sole distributor for five or more sources should be able to get the best price. One supplier will

not be able to give the best price for everything. Some manufacturers have their own supply and distribution network but many use others to distribute and market their products.

Procurement by the buyer

Many buyers ask whether they should procure equipment themselves or get it done by a supplier. Procurement of laboratory equipment can be time-consuming. This will involve visits to suppliers, looking through catalogues and writing to manufacturers for user's manuals. This do-it-yourself approach will allow you to make an independent assessment but it can take a lot of time.

How does the supplier get the best price?

The supplier gets the best price by:

- getting a discount from acting as the manufacturer's sole distributor;
- obtaining a discount through ordering in bulk—a bulk purchase discount; or
- getting an additional discount which may be offered by the manufacturer.

Usually, the supplier will charge the laboratory 5–15% of the cost price for its services. Through its network of contacts and largely because of its direct relationship with manufacturers, a supplier is able to offer a favourable price. An intimate knowledge of the various suppliers and manufacturers will mean buying, for example, filter paper from one supplier, glassware from another and chemicals from several suppliers.

Tip: Be aware of the costs involved in freighting hazardous substances.

The supplier acts as a distributor. Choosing a good supplier will save you time spent walking from one office to another. Ask other laboratory workers what makes a good supplier. It may be a supplier who is friendly and professional, someone who has done a good job for others, someone who took an interest in small things as well as big things or someone who asks questions before giving a quotation.

One supplier of chemicals will not be able to supply all your chemical needs. For example, when the company does not manufacturer a particular stain, it will quote the price (often a high price) of another manufacturer of chemicals. Be cautious of chemical suppliers who say they only sell in large pack sizes.

Tip: A good supplier should be able to supply *all* your laboratory needs—equipment, consumables *and* chemicals. It is recommended to ask the supplier, wherever possible, to make up a single shipment with all your requirements. An added advantage is that a single shipment will mean only one set of paperwork and one inspection by customs.

Locating a local supplier

The supplier acts as an agent for the manufacturer, not the purchaser. For the purchaser at the initial stage, the supply service is advisory only. The supplier may have in stock manufacturer's products ranging from equipment to chemicals.

Suppliers receive about a 10% trade discount from the manufacturers they represent. The supplier will buy at trade price (the manufacturer's price less the 10% discount) and then sell at the retail price.

Suppliers have access to manufacturer's catalogues, know which companies offer the lower prices for chemicals and are familiar with regulations regarding the shipping of hazardous chemicals. They have considerable information about equipment and chemicals available from many countries but it still pays to shop around. Ask a friend which supplier they found the most reliable.

What makes a good supplier?

A good supplier shows interest in your enquiry and refrains from bluffing and generalizing. The most that some suppliers want to do is to distribute brochures and subsequently pass on customers' orders. Is the supplier always suggesting to you ways in which you can save costs? Does he or she make suggestions for ways of saving money by buying chemicals imported in bulk and repacked? If not, you should look for another supplier.

Just seeing how the supplier tries to deal with your questions will be revealing. If the counter clerk is keen and is prepared to admit that he or she does not know the answer but will try to find it elsewhere, then you can feel encouraged. Explain what you are looking for and listen closely to the response. Vague sales talk such as "This is the very best", or "Everybody uses this one" should be treated with suspicion. Does there seem to be a genuine understanding of your needs? Does the counter clerk demonstrate knowledge of the subject and a professional attitude? If you feel confident about the level of aptitude and service, then you have probably found your source.

Many suppliers, like their counterparts in other areas of commerce, prefer a quiet life. If they can get away with the minimum amount of work and service, you can be sure that they will be quite happy to do so. Your job is to ensure that your supplier gives you the maximum effort.

Suppliers may occasionally try to give the impression that everything done for you above and beyond writing down your order is done as some kind of personal favour. It might be worth reminding them from time to time that they get their commission for rather more than writing the order. A good supplier will have a good range of stock. The ideal is a friendly local supplier who has strong interest in retaining your business, enjoys working in the trade and has plenty of experience to draw on.

Remember that all too often suppliers (particularly those new to the business) are enthusiastic about what the equipment can do, but they are not realistic about its limitations. A good supplier should be able to:

- talk to you in detail about your requirements
- analyse your needs
- let you know if your expectations are unrealistic and discuss alternatives
- choose the best and most cost effective solution, and settle on a firm price
- make recommendations on the best source of training.

When you visit a new supplier for the first time how can you tell if you are likely to receive good service? A good supplier should have in stock the most commonly used minor equipment and consumables. Some questions you may wish to consider when visiting a supplier or agent are detailed below:

- From the list below what items does the supplier/agent have in stock at the moment?

  Acetone
  Carbol fuchsin
  Centrifuge brushes
  Crystal violet, oxalate
  Fields' stain
  Filter paper
  Giemsa stain, powder
  Hydrochloric acid/sulfuric acid
  Lancets
  Lens cleaning tissue
  Methanol
  Microscope bulbs
  Microscope glass cover slips, 20 × 20 mm
  Microscope glass slides

Microscope oil
Neutral red
Pipettes, glass, 2 ml
Pipettes, glass, 5 ml

Spare parts

Colorimeter bulbs
Colorimeter fuses
Cuvettes
Microscope bulbs
Microscope fuses

- Is the supplier/agent willing to give a short tour of the warehouse/room where the stock is kept? This short tour will give, at a glance, some idea as to the range and volume of stock. Have doubts about a company which says it keeps its stock in another part of town or asks you to come back another day. Are you being offered excuses so you can be prevented from seeing the warehouse?
- Can the supplier provide a multilingual instruction manual for the equipment you want to purchase? If the instruction manual available is not written in a language understood by your laboratory staff, ask the agent to contact the manufacturer and request a copy in your local language or in a language you understand.
- Ask the supplier if solutions/reagents can be made as some suppliers will cheaply make any solutions.
- A veterinarian supplier may be able to provide a haematology quick stain that is cheaper and easier to use than the more traditional ones.
- What spare parts does the supplier/agent have in stock ?
- Ask the supplier to obtain from the manufacturer a list of essential spare parts for the equipment you wish to purchase and a guide to the expected life (in years) of the essential spare parts.
- The stock level for a spare part depends on the rate of use of that part and the time delay in receiving new supplies. Manufacturers should take a lead and offer equipment "packages" with spares, tools and, perhaps most importantly, multilingual manuals with simple maintenance procedures.

The tricks of high pressure selling and how to avoid them

Through the salesperson's logic you may be persuaded to buy the company's equipment. Bear in mind the following points.

- Do not be persuaded by the sales talk; go out and check with other suppliers to see if comparable products are cheaper or more suitable.
- Do not sign up on the spot. Give yourself the chance to consider the decision away from any pressure.
- Check all claims and costs. Visit other suppliers and ask for written verification of any claims made for the equipment.
- Say no if you do not get straight answers.
- Do not get trapped. You do not have to explain yourself and you do not have to do something for the salesperson. If you keep on talking, so will the salesperson.

Note: See also Annex 3, Equipment donation guidelines

Chapter 3
Common consumer problems

What is a consumer?

A consumer is someone who buys or uses things (goods) or services. Goods are things we use like a motor vehicle, foods, clothes and laboratory equipment. A consumer is also someone who uses the earth's resources.

Consumer protection

Consumers should have legal protection against the suppliers of shoddy goods and services. Importers should be responsible for ensuring that goods supplied are of acceptable quality. Suppliers should be required to put right any defective goods. Without complaints, the producer of shoddy goods or services will never know there is anything wrong. Many manufacturers and suppliers of laboratory equipment have complaints resolution practices in place.

Manufacturers and suppliers may be able to opt out of their responsibilities where the consumer is given reasonable notice that repair facilities or spare parts will not be available or may be available for only a limited time.

Consumers are denied the right to claim directly against a manufacturer for faulty goods where there is no contract between them and the manufacturer. In some countries legislation has been introduced to sidestep the rules about contracts and places responsibilities on manufacturers for failure to provide goods of acceptable quality. A consumer guarantee act gives the chance to claim directly against a manufacturer for faulty goods.

In many countries there are laws to give consumers guarantees or promises about the quality of goods and services they buy.

Guarantee that goods are of acceptable quality

When you buy goods the seller and the manufacturer guarantee that the goods are of an *acceptable quality*. *Acceptable quality means that goods are:*

- free from major and minor defects

- able to be used for the purpose for which they are meant to be used
- of an acceptable appearance and finish
- durable and can stand up to reasonable wear and tear
- safe.

Consumers can decide if a particular item they have bought is of acceptable quality if they consider:

- the sort of item it is and what it is normally used for
- the price paid
- statements made about it on the delivery package
- anything the seller or the manufacturer said about it.

This guarantee does not apply if the seller tells you in writing about a problem with the goods when you buy them. This guarantee does not apply if the goods fail or are damaged because you have used them in an unreasonable way.

What if things go wrong?

If the guarantees or promises made to the consumer by the seller or manufacturer are broken, in many countries the consumer has the right to have the problem put right. The remedies available to the consumer are:

- refund
- replacement
- repair
- compensation
- compensation for consequential loss.

Tip: Find out about consumer guarantees in your country.

Returning faulty goods

If you buy something that does not work properly, you can take it back to the place where you bought it. The supplier, the importer, the distributor or the agent should sort out the problem. Some suppliers may take advantage of the customer's lack of information and make you think they do not have to help. Some customers find it difficult to complain and so do not.

If the fault can be fixed, you must give the supplier a chance to fix or replace the goods. If the supplier does not fix the fault in reasonable time, you can choose to:

- have your money back
- have a replacement, or
- take the goods somewhere else to be fixed and charge the cost of the repair to the supplier.

If there are faults that cannot be fixed or serious faults, return the goods. You can choose to:

- have your money back
- get a replacement, or
- not pay for the goods if you have not already done so.

If the seller is unhelpful or has gone out of business, you can go back to the manufacturer for compensation. Compensation is the sum of money that covers the loss in value of the goods.

How to complain about goods and services

Showing anger relieves frustration but will not help you get what you want. Bear in mind the following.

- Remain calm and be organized.
- Prepare yourself.
- Collect anything written down which will help prove what you say, e.g. a receipt which proves you bought the goods at that supplier on a certain date or a quotation for a service.
- Check up on your rights.
- When visiting the supplier or agent ask a friend to come with you for support.
- Decide what the problem is and what you want done about it. For example if the wick in the kerosene refrigerator is difficult to raise, you may decide that you would like the wick carrier to be replaced.

Tip: Focus on the problem, not on the people.

If you visit the supplier or agent

- **Dealing with conflict**. Beginning what you say with "I" rather than "you" will make you sound less aggressive and blaming. "I can't seem to make myself understood" would be better than "You don't understand me". Using an "I" statement makes people far more likely to cooperate with you as they do not feel they have to defend themselves.
- **Make your complaint to the correct person**. Ask to talk to the manager or the person in charge if the manager is away.
- **Be polite but firm and clear**. Adopt the right tone. You should try to be polite but firm and to give a generally businesslike impression. Maintain this approach and avoid having an argument.
- **Explain the problem**. For example, say "I bought this water-bath a month ago and now it is leaking".
- **Know what you want**. Decide what you want to happen. Do you want a repair, an exchange or a full refund? Remember to be reasonable as you may have to compromise on some things.
- **Take a receipt with you**. A receipt can prove that the equipment was bought from that particular company. The agent will want to make sure that the equipment was bought there before considering your complaint.
- **Make your own notes**. If making a verbal complaint take note of whom you speak to, when and the details of what was said.

If you write to the supplier or agent

If there is a complicated problem, it may be better to write first. Include the following in your letter.

- Details of your purchase, what it is, make, model, date of purchase and price.
- State what is wrong with the equipment. Try to be specific.
- Explain what you want to be done, e.g. replacement, repair, refund. If a part is needed, you could take a photograph of the part and enclose this with your letter.
- Keep copies of all letters. Do not send receipts, guarantees or other proof of purchase but rather give reference numbers or photocopies.

If you telephone the supplier or agent

- Make a note beforehand of what you want to say.
- Have receipts and useful facts handy.
- Write down the name of the person to whom you talk.
- Make notes on what is said, the date and time.
- Keep calm.

Tip: Understanding your consumer legal rights can help you avoid problems before you buy rather than trying to get out of a bad deal later.

Chapter 4
Equipment receipt and maintenance

Action on receipt of equipment

- Check the equipment against what you have ordered.
- Check that the voltage shown on the packing list (or on the packing case) for electrical equipment is compatible with your power supply. Check that the fuse rating is correct.
- Check the packing case (or carton) for damage. If you suspect any damage to the new piece of equipment, notify the supplier before unpacking.
- Unpack the equipment carefully. Keep all packaging, supports, labels and booklets as you may have to re-pack the equipment to return it for repairs.
- Check the equipment. If it appears damaged, notify the supplier.
- Check the data plate, and for electrical equipment check that the voltage is correct.
- Look for the user's instruction book (operating manual). A service manual (maintenance manual) for equipment with electronic components should include a wiring (circuit) diagram used by the repair engineer. Keep these manuals together in a dry, cool and safe place.
- Read the instructions and follow them exactly.
- Process a few control samples, or samples of known value, as soon as possible after receiving the equipment, to make sure it is functioning properly.

Tip: In some countries where a fault is found in equipment the consumer is entitled to a replacement or a cash refund. Find out about consumer guarantees in your country.

Equipment care and maintenance

General

- Read the instruction manual carefully.
- Do not disconnect cables or plugs with power switched on.
- When equipment is not in use switch it off or unplug it. Do not switch back on immediately—always wait 15 seconds.
- Before replacing *external* fuses, disconnect equipment from the power supply.
- Before replacing *internal* fuses, disconnect equipment from power supply then wait ten minutes.
- Always pull electric plug out by holding the body of the connector—do not pull using the lead.
- When not in use, store leads in large loops.
- Do not operate switches or buttons with any type of instrument—always use fingers.
- Do not use any flammable gases near equipment.
- Do not attempt to clean equipment with wet cloths unless it is disconnected from the mains.
- Do not put containers of liquid on top of or near to equipment.
- Always place equipment on a firm flat surface.
- Always place equipment horizontally.
- Always use dust covers when not using equipment.
- Always keep carrying cases closed.
- Machine parts will rust in a tropical climate so learn how to clean the equipment and keep it clean.
- Protect against dust by always keeping instruments covered when not in use.

Ventilation

- Leave adequate space all round equipment.
- Do not leave dust covers on when equipment is switched on.

Equipment filters

- Regularly clean filters under running water and pat the filter dry before replacing it.
- Do not reverse the filter.
- Never use more than one filter as the equipment will get too hot.
- Never use the equipment without a filter as cockroaches can enter and cause damage.
- Use a vacuum cleaner or brush to dust inside equipment.

Replacing tungsten halogen bulbs

- Do not touch bulb with fingers. If you do touch the bulb, clean it with alcohol afterwards.
- Always use a cloth or tissue to protect the bulb.

Fuses

- Always replace a fuse with one of the correct rating and type.
- Never use nails, pins or needles.
- Never use silver paper.

Routine maintenance of laboratory equipment

Maintenance services are often regarded as outside help which you call in emergencies rather than as an essential part of daily work. Maintenance services in developing countries tend to be weak and are often only present in major cities. It is estimated that between 70% and 90% of all equipment breakdowns are caused by the users. Users of laboratory equipment must be given training in its correct operation and how to carry out routine maintenance. The laboratory should have a coherent maintenance strategy based on a planned maintenance scheme. Prepare a simple maintenance check-list for each item of equipment. Important issues in training operators are:

- correct equipment use and handling
- correct use of manuals
- cleaning
- storage
- keeping of records
- calibration.

It is essential that the laboratory draws up a maintenance plan to cover all equipment in the laboratory. Staff must be aware of each part of the plan that needs to be followed. One of the objectives of a detailed master maintenance plan is to ensure that any malfunctioning of the instrument is duly and promptly reported. Too often staff will report when the instrument is out of service but will fail to report a minor malfunctioning of the instrument. If staff can be made to understand that malfunctioning—even to a minor degree—can be an early warning sign of a potential major breakdown, then the possibility of such a breakdown is greatly lessened.

The maintenance plan should instruct staff how to record calibration checks, whether in notebooks or on a chart attached to the instrument. Clear written operating instructions and protocols should be provided for each user and these must include the maintenance schedule.

Repairs

If you think you are experiencing unreasonable delays with a repair, ask for the manager of the supply company. Do not accept excuses. Telephone the parts supplier yourself if necessary. When you take the equipment in to be repaired, get the service agent to write down the details of what you want and give you a copy. Ask to keep any parts being replaced. If you are suspicious about the need for replacement, you can have the replaced part checked by the manufacturer. If the repairs are not to your satisfaction, take the equipment back and get the problem fixed.

Standard operating procedures (SOPs)

SOPs, also known as a local laboratory manual, should be prepared by a qualified experienced laboratory officer. The appendix for each SOP should include the following information covering equipment: name (including model) and supplier; instructions for use, including any safety precautions; daily quality control, e.g. cleaning, performance checks; details of how to replace components; maintenance schedule, replacement parts to be kept in stock with part numbers and details of suppliers(s); trouble-shooting and action to take if the equipment fails.

Chapter 5
Buying second-hand laboratory equipment

General

Buying second-hand laboratory equipment will save you money. Some companies claim their prices offer savings of between 40% and 80% of current replacement cost. Second-hand goods are not always perfect so you cannot expect a refund or compensation if the faults are obvious when you make your purchase. You can expect the goods to work and do the job you bought them to do. For example, the purpose of a second-hand refrigerator is to keep the contents cold. If it does not keep the contents cold, you may ask for your money back or payment for the cost of repairs.

The risks are bigger when you buy second-hand equipment. Second-hand goods are sold "as is" meaning that the seller has no responsibility if they are faulty. However, in some countries it is against the law for anyone to sell a dangerous electrical instrument. Be aware of any defects and carry out your own "research" *before* you decide to buy second-hand equipment.

When can you expect the dealer to repair an item or give you your money back? Here are situations you may be faced with when visiting a dealer.

- You buy a second-hand water-bath and it leaks badly the first time you use it. You can ask for it to be repaired or get your money back, as it was not good enough to sell as a working instrument.
- You buy a second-hand incubator and the electrical wiring guard keeps falling off. You complain that this is a dangerous electrical instrument. In this case you should get your money back.

Both these examples show the importance of making sure that the dealer will be responsible for making any repairs or will give a refund if the equipment is defective.

Auctions

Advertisements for auctions often appear in newspapers or trade magazines. An advertisement appearing three or four days before the auction will give you valuable time

to do your own research. You will need to know if spare parts and local servicing are available for any items you want to buy. Use the equipment information sheets (see Annex 1) to find out what spare parts you are likely to need, e.g. for a centrifuge spare parts would include spare carbon brushes, refrigerator thermostat, capacitor, door seal, starting device for compressor. Visit local suppliers/agents and ask about spare parts and servicing. At the same time find out the price of the same or a similar new model. Generally goods will be available for viewing at the auction site the day before the auction. Ask a colleague with experience in purchasing equipment to accompany you for viewing. Obtain a copy of the auction catalogue. Take a good, long look at the equipment. As a buyer you must satisfy yourself as to the condition, type, make, model and year of the equipment being offered, rather than relying on any statement in the catalogue or the advertisement.

Auction goods are sold "as is, where is". Generally auctioneers state that all goods are sold "with all faults in the condition in which they now are", without any warranty. Auctioneers are merely agents for the seller and usually try to avoid disputes with the buyer. The conditions of sale must be displayed at the auction. Read these carefully.

There is no "rule" concerning prices paid at auctions. The selling is influenced by supply and demand—how many people turn up at the auction, how many people show interest in particular items and what price they are prepared to pay. You may be lucky. A "good" price paid at an auction might be between one-half and one-third of the new price.

Remember to check on the manufacturer's nameplate for the voltage (V), current (A) and frequency (Hz).

Home-made equipment: a hazard warning

In some countries parts from old equipment are often cannibalized to serve another purpose. For example, centrifuges have been made by mounting a sewing machine motor on a wooden base. Thin aluminium is used as the rotor head and recycled plastic syringe holders serve as buckets. There is no safety shield or lid. These devices are cheap but dangerous. Another example is the use of unsuitable materials such as plywood and thick glass from an automobile, together with a fan to make a microbiological safety cabinet. Such 'safety cabinets' are not safe and may well be described as 'danger boxes' (see Chapter 6, Safety equipment).

Such products should never be bought.

Chapter 6
Choosing minor equipment and consumables

General equipment

Any laboratory worker who has looked through a supplier's catalogue will realize the range and choice of products is vast. The wrong decision could cost dearly. In this chapter, brief notes are given to help you to make the right choice.

Adhesives

The selection of adhesives for use in the laboratory will depend on the materials to be bonded, e.g. glass, wood, metal, plastics. Some adhesives have exceptional bonding power and short setting times. A slow setting time will allow careful positioning of glass or plastic to give strong bonding. Various materials are added to modify an adhesive's processing and performance properties. These include hardeners, tackifiers to increase stickiness and improve plasticity, stabilizers, adhesion promoters to form a strong bond, and antioxidants to prevent chemical breakdown by oxygen and sunlight. One type of glue will not bond everything. It is useful to keep some multipurpose glues such as epoxy and contact glue handy for small repair jobs. If you do not like the inconvenience of mixing epoxy, superglues are nearly as versatile. Although syringe packs are slightly easier to use than tubes, they cost more. Tubes give better value. Do not use too much glue as thin bonds are the strongest. Table 6.1 summarizes the uses and characteristics of adhesives available.

Clear plastic glue

Clear plastic glues are easy to use as they bond quickly and do not have to be clamped. They should be used with care on plastic as the solvent can damage some plastics.

Contact glue

Contact glues are good for flexible joints and bonding large areas. Special contact glues are available for glueing materials which are dissolved by solvents, such as foam polystyrene.

Epoxy glue

These are mainly used for rigid waterproof joints. They have good gap filling properties but are not heat resistant above 65 °C. Epoxies are less convenient to use as two parts

TABLE 6.1 **Uses and characteristics of adhesives**

Material and characteristic	Clear plastic glue	Contact glue	5-minute epoxies	Standard epoxies	Superglue	PVA glues
Glass	0	0	2	2	0	0
Plastics (solid)	2	0	1	1	1	0
Polystyrene foam	0	0	0	0	0	2
Polyurethane foam	1	2	0	0	0	0
Perspex	2	2			2	
Rubber	0	2	0	0	2	0
Metals	0	1	1	2	1	0
Bonding time	1–2 minutes	Instant	5 minutes	6 hours	1 minute	20 minutes
Curing time	12 hours	14 hours	1–16 hours	48 hours	12 hours	12 hours
Shelf life	Medium	Medium	Medium	Medium	Short	Long
Flexible	Y	Y	N	N	N	Y
Waterproof	Y	Y	Y	Y	N	N
High strength	N	N	N	Y	Y	N
Clamping needed	N	N	Y	Y	N	Y
Gap filling	N	N	Y	Y	N	N
Heat resistant	N	N	N	N	N	Y

2 = Good choice.
1 = May also do the job. Check the instructions.
0 = Not appropriate.
Properties: Y = Yes N = No

have to be mixed together to create the glue. The surfaces need to be clamped together using adhesive tape, elastic bands or weights until the glue has bonded. Epoxies, however, are strong and versatile.

Superglue

Superglues give an almost instant bond, but they generally cannot stand heat or moisture. They are expensive.

Storage of adhesives

Heat and moisture will make most glues deteriorate, so keep them in a cool dry place. Superglues are best kept refrigerated in an airtight container. The glue should be taken out of the refrigerator about four hours before use.

Bonding of adhesives

Once the glue is exposed to air or mixed, it sets by turning solid. The bonded joint will be strong enough to hold the parts together but should not be put under load until the glue has cured.

Polyethylene and polypropylene are plastics used in appliances and refrigerators and one glue will stick to all. If the glue does not hold, it can often be peeled off easily and another tried. Contact glue and clear glue will hold most plastics. Epoxy and superglues hold nearly as many plastics and form a stronger bond. Contact and epoxy glues will give strong bonds if the roughened surfaces of the plastic are passed quickly over a blue gas flame. Do not let the surface soften and keep glue well away from the flame.

Health and safety

Some adhesives and the substances used to make them carry severe health and safety warnings. Some resins cause dizziness and breathing problems, so face masks and protective clothing must be worn when handling them. If used carelessly, adhesives pose a fire hazard, especially the flammable solvent-based adhesives.

Alcohol burner (spirit burner)

An all metal burner with screw cap is recommended for use in the field. A spare replacement wick should be requested at the time of the initial order. In the base laboratory, a glass base burner with metal wick holder and metal cap to extinguish the flame is suitable.

Anaerobic jars

These are made from aluminium alloy, stainless steel and clear polycarbonate. Jars are supplied with automatic safety valves and pressure gauges, catalyst holder and cold catalyst sachets, spare o-rings, two valve cores and valve washers and will accept up to 12 mm × 90 mm plastic Petri dishes.

Bacteriological inoculating loops

These should be completely closed, with a diameter not more than 3 mm. The length of wire from the loop holder to the loop should be short (6 cm) and be held in a metal, not a glass handle.

Batteries

See Section 2 on energy requirements for laboratory equipment.

Beakers

There is a variety of beakers of different capacity, shape (tall, short, conical, straight tapered or sloping sides), material (glass, plastic) and form (transparent, translucent).

Remember that sloping sides will allow one beaker to fit into another. The special rim on tri-pour beakers allow drip-free pouring from three sides. Decide upon your needs and then order accordingly.

Book and box storage

Damage to books can be caused by moisture, heat, bright light and insects. Starch sizing, paste, glue and adhesives used in bookbinding are very attractive food for silverfish and cockroaches. Paper makes a very desirable nesting material for mice. Periodically, clean out bookshelves and carefully spray them with a long-term fly spray.

An ideal situation is a truly archival storage system of boxes made from fluted polypropylene which is acid free, will not support moulds, is unaffected by moisture and is virtually indestructible.

Boxes, air-tight

Rectangular air-tight boxes made from polyethylene with tight fitting snap-on lids, are useful for general use and refrigerated storage. The larger size (61 cm × 46 cm × 26 cm) can be used to hold bacteriological cultures and confine the smell. The larger boxes (also deep trays) can be stacked and kept on a base with wheels.

Bunsen burner

Buy one that is solid, has an anti-splash hood and has a pilot flame that stays on. Alternatives include camping gas burners, butane stoves and butane soldering irons.

Calculator

It is preferable to buy a portable solar powered calculator with battery back-up.

Containers for specimens

Polystyrene, polycarbonate or polypropylene (autoclavable) reusable plasticware containers are used for specimen collection. Wide-neck polypropylene containers with a leak-proof cap are used for sputum, urine and faeces samples (30 ml , 60 ml or 120 ml capacity).

Faeces must be transferred immediately to the specimen container. A leaf fastened with a small twig or a matchbox are not satisfactory containers for the collection and storage of stool specimens. On arrival at the laboratory, specimens can be left on a rigid polystyrene tray.

Cover glasses (cover slips)

Order by size and thickness. For routine use, no. 1 ½ cover glasses 20 mm × 20 mm with a standard thickness of 0.17 mm are recommended (variable between 0.12 mm and 0.22 mm). Most microscope objectives are corrected for a cover glass thickness of 0.17 mm and no. 1½ slips are designed to be most effective in this respect. When ordering special (and expensive) glasses for counting chambers, state the purpose and not the size. The larger 22 mm × 22 mm cover glasses are used to preserve microscope slides. The cover slip is placed over the microscope slide, the edges ringed with DPX mounting medium or nail varnish.

Cylinders

There is a variety of cylinders of different capacity (5 ml to 200 ml), material (glass, plastic) and type (some with detachable foot, spout, stopper). Decide upon your needs and then order accordingly. A wide range of high quality and break-resistant plasticware is available and has largely replaced the use of easily broken glassware. Flasks, beakers and cylinders are graduated .

Dust removal

A long feather is sufficiently firm and sensitive to use to remove dust in inaccessible places in equipment.

Electricity

Most sensitive electrical equipment, i.e. colorimeters, spectrophotometers, pH meters, electrophoresis chambers, needs to be protected against voltage fluctuations. Where there are power cuts (blackouts) an uninterruptible power supply unit is recommended. For voltage stabilizers and uninterruptible power supply units see Section 2.

Flasks

There is a variety of flasks of different shapes (round or flat bottom, Erlenmeyer [conical], wide or narrow neck) and materials (glass or plastic). Flasks are usually supplied with stoppers. Volumetric flasks have the material and temperature characteristics printed on them. Decide upon your needs and then order by capacity.

Funnels

There is a variety of funnels of different shapes (short or long stem) and materials (glass or plastic). Decide upon your needs and then order by size of diameter across the top of the funnel, e.g. 65 mm, 90 mm, 115 mm or 14 mm across. It is best to buy a funnel that has ribs to prevent air locks and to speed filtration.

Immersion oil

The recommended microscope immersion oil should be non-drying, low viscosity, polychlorinated biphenyl (PCB)-free, with a refractive index $n = 1.51$.

Labels

These are available as permanent self-adhesive labels and water-removable self-adhesive labels.

Laboratory box, portable

Portable laboratories are self-contained diagnostic systems that can be carried by hand. A low cost portable laboratory box can be built as follows.

A plastic box containing laboratory materials may be used in combination with an existing laboratory or mobile laboratory facilities. A heavy duty plastic box is required; length 60 cm, width 41 cm and height 32 cm. The carrying strap and hinges can be made of strips of rubber from car tyres. Stainless steel screws, nuts and bolts should be used throughout. The bottom of the box will have to withstand damage when placed on rocks, therefore a thick plywood sheet is used to protect the base. The box should be waterproof. Rather than making holes in the box, the plywood base can be secured by using strips of car tyre rubber. Rubber strips are bolted to the plywood then attached by bolts at the top of both sides of the box.

Aluminium containers can be used for transport and storage of equipment used for a portable laboratory. A portable laboratory for use in haematology, microbiology and clinical chemistry has been developed by the German organization Technologie Transfer Marburg (see Annex 6).

Markers

Order black permanent markers for writing on all polished surfaces, including glass, and diamond markers, preferably with an aluminium handle for writing on microscope slides.

Microscope slides

Microscope slides can be ordered as plain or with one end frosted (both sides). The size is usually 76 mm × 26 mm and they come in a box of 50, 72 or 100. Slides may be described as "washed" and "pre-cleaned" but they still need to be properly washed and dried. Slides with frosted ends are recommended (for labelling use a pencil).

Plasticware

Plasticware is a viable alternative to glassware because it is break-resistant, less expensive and safer to use than glassware. Plastic goods are resistant to most chemicals used in routine laboratory procedures. Resistance to breakage and low weight are important advantages of plastics. Their physical and chemical properties, however, vary greatly according to their composition; some are reusable.

The conditions of use determine which plastic to select. Many factors have a bearing: exposure time and concentration of chemicals, steam sterilization, exertion of force, exposure to ultraviolet radiation, and aging, which may be caused by the action of detergents or by other environmental effects.

A well informed evaluation of the required properties by the user is therefore of prime importance. Table 6.2 gives a summary of the common forms of plastic as well as their uses and characteristics and is intended as a guide.

Pumps, filter

Single pumps are available which screw onto a water tap and provide a vacuum. They are suitable for filtration, distillation and aeration applications. Select a model supplied with an integral non-return valve to prevent suck-back and flooding. When in operation, water consumption varies from 200 litres to 800 litres/hour. The pumps are made from polypropylene, corrosion-resistant plastic and glass.

Sheeting for use in disaster/emergency situations

Sheeting made from low density polyethylene with a reinforcing mesh of polyester built in to give a virtually untearable strength is recommended for use in disaster/emergency situations. A high strength plastic together with PVC tubular poles (or an aluminium ridge pole) can form the basis of an emergency laboratory tent. Such sheeting is suitable for waterproofing existing thatch shelters and for repairing windows and roofs. The plastic sheeting requires sealed eyelets at regular intervals for tying down and is supplied in different colours. A white/grey material used for an emergency laboratory in very hot climates gives a 10 °C lower temperature inside.

TABLE 6.2 **Laboratory plasticware**

Type	Uses	Autoclavable[a]	Temperature (max.) resistance (up to 15 minutes)	Chemical resistance[b]	Flexibility	Transparency[c]
Polypropylene (PP)	Centrifuge tubes, syringes, funnels, beakers, containers, cylinders, test tube racks, slide mailers, pipettes class B, jugs, trays, flasks, burettes, buckets	Yes	140 °C	High	Rigid	Translucent[d]
High density polyethylene (HDPE)	Reagent bottles, trays, funnels, bins, storage bottles with taps, bins, pump dispensing bottles	Yes (with caution, up to 20 minutes)	120 °C	High	Rigid	Translucent
Low density polyethylene (LDPE)	Washbottles, test tubes, dropper bottles, plastic bulb pipettes, racks, buckets, airtight boxes, reagent bottles, containers	No	95 °C	Medium	Excellent	Translucent
Polystyrene (PS)	Disposable laboratory ware, Petri dishes[e], desiccator cabinet	No	70 °C	Low (but can be disinfected with bleach solution)	Rigid	Clear
Polyvinyl chloride (PVC)	Tubing, tanks, trays	No	80 °C	Low (but can be disinfected with bleach solution)	Rigid	Clear
Polymethyl-pentene (PMP)	Cylinders, reagent bottles, Petri dishes, conical centrifuge tubes, beakers, flasks, jugs	Yes	200 °C	Medium	Rigid	Clear
Polycarbonate (PC)	Eye shields, face shields, flasks, large bottles, vacuum desiccators, reusable Petri dishes[f], specimen containers, centrifuge tubes	Yes (up to 20 minutes)	140 °C	Low	Rigid, static proof, shock resistant	Clear
Polytetrafluoro-etheylene (PTFE)[g]	Joints, beakers, stirring bars, bottles	Yes	300 °C	High	Rigid	Opaque

[a]Autoclaving: 121°C, 15 psi for 30 minutes.
[b]Chemical resistance: high—exceptional resistance to almost all laboratory chemicals; medium—good to excellent resistance to a broad range of common laboratory chemicals: low—moderate to good resistance to common aqueous laboratory chemicals but avoid organic solvents and strong acids and bases.
[c]Transparent: can be clearly seen through allowing light to pass through without diffusion.
[d]Translucent: allowing light to pass through.
[e]Polystyrene Petri dishes are not likely to be used in developing countries owing to bulk and single use.
[f]Polycarbonate Petri dishes can be reused.
[g]Suitable for use in hot air oven sterilization.

Silica gel, self-indicating

Silica gel is a desiccant, a compound with the ability to absorb water vapour from the air. It can be placed in the plastic bag containing the microscope to prevent fungus growth. Self-indicating silica gel is blue when active but becomes pink when it has absorbed all the water it can. To restore its activity, gently heat it until the colour returns to blue indicating it is active once again. When the silica gel cools it can be returned to the airtight container. Only self-indicating silica gel should be used. 100 g of the self-indicating coarse type would be sufficient for a laboratory.

Sleeves and pages, plastic

Plastic sleeves are used for laboratory procedure and method manuals as dampness and heat will soon discolour and weaken paper. Choose protective sleeves or pages made from polyethylene, polypropylene or polyester. Do not use pages made from PVC or vinyl. Avoid getting items plastic laminated because many commercial firms use damaging materials like PVC.

Test-tubes

There is a variety of test-tubes of different shapes (round, cone-point or conical bottom), materials (glass or plastic) and types (graduated or ungraduated centrifuge tubes, with screw or plug caps). Decide upon your needs and then order test tubes by diameter and length, e.g. 12 mm × 75 mm or 13 mm × 100 mm (different sizes are available from different manufacturers). Polystyrene tubes are clear, can be disinfected but not autoclaved and are less robust and less chemically resistant than polypropylene tubes.

Thermometers

These vary according to their use, e.g. for refrigerators/freezers, liquids, maximum/minimum temperature, secured to a wall. Those made of glass are filled with spirit or mercury and for easy reading have a yellow or white backing. State the desired temperature reading range and the length.

Glass thermometers are classified by the length of the thermometer that is exposed to the fluid, e.g. total immersion, partial immersion, complete immersion. Total immersion thermometers have the bulb and entire stem exposed to the fluidmeter. In partial immersion thermometers, the bulb and a specified portion of the stem are exposed to the fluid and the thermometer is immersed to the stem's marked immersion line. In complete (full) immersion thermometers, the entire thermometer, including the expansion chamber, is exposed to the fluid.

Total immersion thermometers should be used whenever possible because they offer the best accuracy when used properly. When immersion depth is limited, a partial immersion thermometer is recommended. Use a complete immersion thermometer only when the entire thermometer is to be exposed to fluid.

A special refrigerator thermometer is needed to monitor the temperature in a refrigerator and freezer. Choose a thermometer with an easy to read temperature display scale. Check the temperature. Put the thermometer in the middle of the top shelf of the refrigerator for a couple of hours and then read the temperature, ideally without taking the thermometer out of the refrigerator. In an up-right freezer, put the thermometer at the top at the front edge, on the side that the door opens. In a chest model freezer, put the thermometer at the top, e.g. in a basket.

Timers

In areas with high humidity or where it may be difficult to obtain batteries, a mechanical timer should be used. The timer should have a clear dial and ringer.

Tools

Draw up a checklist of all tools in the laboratory tool kit. Ensure that all tools are returned at the end of the working day. Keep the tool box locked and stored in a secure place. A general purpose tool kit for laboratory work may include the following.

- Allen keys (also known as Hex keys), nickel-plated, 1.5 mm–6 mm (1/16"–1/4"), set on ring
- Brush (paint flat), 20 mm or 25 mm
- Brush (paint, round), 2 cm diameter
- Bolts (assorted) and nuts
- Drill (hand crank)
- Drill bits (hardened drills for use with metal and wood) set of 12 drill bits, interval 0.5 mm, high stainless steel, sizes 1 mm–10 mm
- Artery forceps, haemostat, straight, stainless steel, 140 mm or 180 mm, multiple ratchet
- File (round), to enlarge holes in corks, 15 cm
- File, bastard (half-round), 300 mm
- File, second cut (flat), 250 mm
- Hammer (sheet metal-worker's), 200 g
- Hammer (claw), 250 g

- Handle (for files), 2
- Knife (trimming knife with retractable blade)
- Knife blades, 1 spare set
- Knife (tungsten carbide), for cutting glass tubing and glass rod
- Lubricating device (oil can)
- Lubricating device (spray can) to displace moisture, penetrate, protect, clean and loosen corroded nuts and bolts
- Pliers (combination), insulated, 180 mm
- Pliers cutters, insulated, 125 mm
- Saw (hacksaw), adjustable frame to accept blades of various sizes
- Saw (hacksaw) blades for metal, medium
- Scissors
- Screws (assorted), slotted, both sheet metal and wood screws
- Screwdrivers (jeweller's), 1 set
- Screwdrivers, insulated handle, M3, M4, M5, M6, set of 4
- Screwdriver, for cross-headed screws, No. 1
- Screwdriver, for cross-headed (Phillips head) screws, No. 2
- Soldering iron (electric), 60 W (or 12 V), with a of tip 1.5 mm or 2.3 mm (or butane equivalent)
- Solder, general purpose electronics grade, wire with flux at its centre (rosin-cored)
- Spanner (adjustable wrench, also known as crescent wrench), chrome-plated, 10"
- Spanners (open end), 6–22 mm, 1 set
- Spanners (ring), 9–26 mm, 1 set
- Level (spirit line level) or circular level
- Tape measure (fibreglass), 5 metres, giving both centimetres and inches
- Tape (Teflon)
- Tool box (lockable), steel
- Voltage tester (also known as a multimeter or multitester)

Note: Always use tools with insulated handles.

Water purification

Purified water is needed to prepare many reagents, reference solutions and stains. The necessary level of purity will depend upon the application for which the water is required. Water purification is expensive; indeed, in the preparation of laboratory chemical reagents,

the water may be the most expensive component. Before purchasing and installing a water purification unit, it is therefore necessary to define the level of purity required, to avoid excessive and unnecessary expense in producing water that is too pure. Similarly, it is wasteful to use the very pure water needed for one task in another application where such pure water is not required.

The cost of producing water to the required standard of purity will depend upon the purity of the starting material, i.e. the tap water. This may vary enormously as regards both organic and inorganic content. Water purification systems should be simple to operate, be of low cost and provide water at the level of purity required.

There are broadly six mechanisms for water purification: filtration, deionization, distillation, reverse osmosis adsorption and ultraviolet sterilization. Three techniques will be dealt with here, filtration, deionization and distillation.

Filtration

Filtered water is not free from dissolved chemicals and therefore, if preparing standards or other reagents that require pure water, the filtered water must also be passed through a deionizer. If the salt concentration of the available water supply is high, it is preferable to use rainwater when preparing clean water for laboratory investigations.

The following types of filter are used:

- ceramic (earthenware)
- asbestos
- sintered glass
- cellulose membrane
- extruded carbon.

In ceramic filters, ceramic elements or filter candles utilize diatomaceous earth to provide a range of pore size. Rainwater that is passed through a ceramic filter is often adequate for routine reagents and preparing stains. Ceramic filter elements remove suspended solids and waterborne bacteria down to 1 micron (1/1000 part of 1 mm). The standard ceramic filter maximum pore size is 1 mm. Ceramic filters can reduce to safe levels bacteria, cysts, chlorine, rust and sediment, taste and odour and organic chemicals—viruses are not removed.

Elements will last for between 6 months and 1 year. Before passing muddy water through the earthenware filter, stand the water overnight or add aluminium sulfate (alum cake) at a rate of about 5 g to 10 litres and allow the deposit to settle. The output varies from between 20 litres and 80 litres per hour, depending on the number of elements. The flow of water can be accelerated by the application of pressure, or suction of water through the filter.

The advantages of ceramic filters are that they are portable, easy to use and maintain and require no mains electricity. Their disadvantage is that the pores of a ceramic filter quickly become clogged by muddy water.

Deionization

Demineralizing systems (producing deionized water) are used to remove ions from water by ion-absorbing cation and anion resins. These resins may be kept in separate columns (two bed), or in a mixed bed column or cartridges. Mixed bed columns cannot be regenerated and the volume of water produced is lower compared with a two-bed cartridge. Ion-free water is ideal for making reagents and solutions for clinical chemistry tests and is essential for preparing reagents and standards for electrolyte tests. Hand-held models are particularly useful at the peripheral level where only small quantities of deionized water are required. Impure water should be filtered before being deionized to prevent the resin from becoming exhausted too rapidly. At the time of making the initial order, spare cartridges for one year should be ordered. These systems do not remove organic impurities and in time may develop bacterial contamination. Each cartridge used in a bench model will produce about 110 litres of deionized water.

The advantages of demineralizing systems are that they do not require mains power if of the hand held or bench type, and require less running water to operate than water stills.

Their disadvantages are that they are ineffective for the removal of bacteria, pyrogens, particles and organics, and replacing the cartridges may be difficult due to cost and unavailability.

Distillation

Note: See also Chapter 7, with regard to purchasing a water still.

Water produced from a still will be free of biological impurities such as bacteria, pyrogens and viruses. During distillation, water is boiled and the condensed steam is cooled, resulting in purified water. About 50 litres of cool running water per hour must flow through the condenser and condense the steam. Water stills produce from 3.5 litres of distilled water per hour.

The advantage of water stills is that they remove non-volatile organic impurities such as bacteria, pyrogens and viruses and all inorganic materials.

Their disadvantages are that they require a large volume of cool running water for the condenser (usually not less than 50 litres per hour). Obtaining such volumes of cool water may be a problem in some tropical countries. The volume of water required can be reduced by reflux (dependent on the ambient temperature) using a column filled with broken glass. Also, they need close supervision, unless fitted with automatic safety devices, and require a reliable energy source. The relatively large volume of boiling water contained in the glass vessel is a safety hazard. Finally, distillation may be impractical for water with a high salt

concentration or for water that is very hard. In this case, desalination by ion exchange may be advisable prior to purification by distillation.

Storage of deionized and distilled water

Glass or metal containers should not be used for the storage of distilled water since ions, such as silica, magnesium, iron and lead will leach from the flasks. Clean containers made from polyethylene, polypropylene or polytetrafluoroethylene are suitable for storage of demineralized and distilled water over long periods.

Note: It is not recommended to use PVC piping for the delivery of laboratory reagent water. Water leaches organic contaminants and trace elements from PVC piping. PVC piping sheds particles, promotes microbial activity and may have sockets sealed by cement that contains solvents.

Safety equipment

Safe health laboratory practices should be ensured regardless of the nature of health laboratory activities. Discussion of health laboratory safety is beyond the scope of this publication. There exists a great number of publications covering laboratory safety procedures, safety management systems and containment of biohazards, including selection, installation and use of biological safety criteria.

Building of low cost microbiological safety cabinets is advised against. Poor and unreliable home-made safety cabinets only increase risks as well as giving laboratory workers a false sense of security. In areas where the local mains electrical supply is poor with frequent interruption, staff may continue to use the poor quality safety cabinet during a power cut in the mistaken belief that they are still being protected, when in fact they will be worse off. In laboratories where only direct smears of sputum (not concentrates) are examined, there is no need for a microbiological safety cabinet unless it can satisfy the appropriate standards for construction, maintenance and testing, and the operator is skilled in its use. Necessary safety equipment includes the following.

Surgical masks

Standard surgical masks may not tie as tightly around the face as particulate respirators and cannot be expected to filter out tuberculosis droplet nuclei. Surgical masks offer protection of the nose and mouth from spattering and splashing, although they soon become saturated if much exposure occurs. Only certain certified respirators will protect against tuberculosis.

Caution: If airborne pathogens are suspected to be present, a paper, cloth or surgical mask is not an effective barrier against droplet nuclei.

Eye shields

Eye shields should take the form of wide vision goggles with a one-piece lens made from polycarbonate. An adjustable head band will allow the goggles to be used by all staff.

Eye wash bottle

With the cup pressed firmly against the face, a slight squeeze on the polyethylene bottle gently sprays the eye through a fine rose (sprinkling-nozzle).

Fire containment

The minimum requirements for the laboratory are buckets containing sand, dry soil or water, a fire blanket, and one or more fire extinguishers. A fire extinguisher will need to act against both chemical and electrical fires. Select a multipurpose dry chemical or carbon dioxide powder model (do not use a carbon dioxide extinguisher to extinguish a fire affecting batteries). A bucket of sand is also recommended. A fire extinguisher should be secured to the wall near the door and in the room where flammable chemicals are stored. Mount the extinguisher upright so that the top is not more than 1.1–1.5 m from the floor. Fire extinguishers should be checked as recommended by the manufacturer. Weigh the extinguisher at least every 6 months and if it is below the weight designated under "Maintenance" on the extinguisher label, the extinguisher should be recharged. All staff should be aware of the escape plan in the event of a fire in the laboratory.

First-aid kit

It should be cheaper to make up your own first-aid kit using items purchased from a local chemist. The kit must be able to deal with burns, bleeding and poisoning. A plastic box can be used as a container for the kit. The kit should be stored in an area that is cool, dark and dry. It should be kept in a prominent position and be easily recognizable. By international convention the first-aid box is identified by a white cross/crescent on a green background. The content of the first-aid box should be inspected regularly to ensure that they remain in satisfactory condition and should be replenished immediately after use. The following are essential items to include in a first-aid kit.

- Instruction sheets giving general guidance on emergency treatment of cuts, bleeding, heat burns, chemical burns, chemical injury to the eyes, swallowing of acids, alkalis and other poisonous chemicals, fainting and electric shock, and how to perform emergency resuscitation.
- Assorted *fabric* (not plastic) plasters

- Conforming bandage, one small (5 cm × 4 m) and one large (10 cm × 5 m)
- Crepe bandage, two of size 7.5 cm × 4.5 cm
- Fine point tweezers
- Painkillers (paracetamol)
- Scissors, blunt ended
- Absorbent cotton wool
- Sterile gauze swabs, small, medium and large
- Individually wrapped sterile dressings, three medium and one large
- Sterile coverings for serious wounds
- Adhesive tape, one reel (2.5 cm × 5 m)
- Thermometer
- Sterile eye-pads with attachment bandages
- Triangular bandages
- Sodium bicarbonate powder (to neutralize an acid burn)
- Boric acid powder (to neutralize an alkali burn)
- Safety pins
- Mouth piece for mouth to mouth resuscitation in cases of suspected infections
- Resuscitation face mask with one-way valve for use in cases of e.g. cyanide poisoning or facial damage

Note: A good plaster keeps wounds moist but not too wet, and allows them to breath. Fabric plasters allow cuts to breathe more than plastic ones. Plastic plasters do not stay on as well as fabric plasters. Do not use antiseptic cream under the plaster, it makes the wound too soggy. Plasters can be used on blisters, but not on burns. For general use, choose a fabric plaster, not a plastic one. It is flexible, usually cheaper, lets the wound breath and forms a better seal against bacteria and dust. Change it when it gets wet.

Fire blanket

Fire blankets provide the easiest means of extinguishing fire on personal clothing although they may also be used to smother fires in small open containers. They should be made of material that does not burn readily, such as cotton.

Gloves

Latex gloves cannot guarantee protection against viruses. One in three gloves lets through viruses the size of HIV or hepatitis. Laboratory workers who have cuts or other breaks in their skin should consider wearing more than one pair of gloves. Gloves made of thin vinyl are not intended to provide protection from puncture wounds caused by sharp instruments. Gloves are intended to cover defects in the skin of the hands. In high-risk situations puncture resistance is provided by wearing heavyweight utility gloves such as those used for dishwashing or by wearing two pairs of thin gloves.

Pipetting aids

Pipetting aids should be selected with care. Their design and use should not create an additional infections hazard and they should be able to be easily sterilized and cleaned. A plastic wheeled pipette filling device is highly recommended. One model has a quick release lever.

Residual current device

A residual current device (RCD) or circuit breaker is recommended in mains systems that are earthed to provide better protection for users. They work by disconnecting the electricity supply when the current imbalance (residual current) exceeds a predetermined level.

Chapter 7
Buyer's guide to choosing major equipment for intermediate and peripheral laboratories

Major equipment selection

When choosing major equipment for laboratories do the following.

- Identify the equipment needed.
- Turn to the equipment information sheets and select the relevant pages, for the equipment you are choosing
- Define the criteria and requirements for your *own* situation.
- Make brief notes defining your requirements on the type or model.
- Visit local suppliers and agents.
- Complete the form for assessment of quotations.
- Make notes to compare the relative merits of each company.
- Evaluate the quotations by matching them against the specifications.

Tip: For quick reference, select the two pages containing the quick reference guide and the form for assessment of quotations. Photocopy them as your own guide.

Equipment information sheets

1. Autoclave

Choosing a laboratory autoclave

Quick reference guide: autoclave

For use in microbiology and blood transfusion. An autoclave produces heat, steam, noise and smell—where is the best site?	Purpose
Electricity: What voltage, frequency, phase? Is supply continuous or not? Gas: Is there a reliable source of bottled gas? Kerosene: Is there a reliable source?	Heat source
When there is a reliable local electrical power source, what kW is available? What voltage? What frequency of current (Hz), number of phases?	Power source
Will a portable model be required?	Portability
Are annual maintenance by an expert and spare parts available for all types?	Reliability
What quality control devices are provided—sterilizer control tubes, Bowie-Dick test packs, chemical indicators, sterilization tape, maximum thermometer?	Quality control
What is the capacity in litres?	Capacity
Is a basic model required or one with additional features?	Performance and safety
Which autoclave meets all the above requirements for lowest cost?	Price

Points to consider

Purpose and site. An autoclave will be used primarily in microbiology. The laboratory autoclave is not to be used for the preparation of items used in conjunction with medical, dental or pharmacological purposes directly concerned with patient care. The site of installation should take into consideration the fact that autoclaves can produce heat, steam, noise and smell—factors not conducive to a good working environment for the laboratory staff. Good ventilation is needed. An extraction hood should be positioned above the autoclave and the unit sited next to an outside wall. Two autoclaves would allow one to be used for the sterilization of "clean" glassware, instruments and media, and the second for the sterilization of dirty glassware, instruments and material to be discarded. To avoid unpleasant smell, this second autoclave may be sited in another building.

Heat source. The choice of heat source will depend on a reliable source of electricity, steam, bottled gas, kerosene or wood. If there is a reliable generator with sufficient fuel to run for several hours each day, then an autoclave with electricity as its sole heat source is suitable. In areas where the local electrical supply is unreliable, a (second) simple autoclave heated by kerosene or gas may be suitable in many cases.

Pressure and altitude. For locations over 1000 m above sea-level, effects of altitude need to be considered. If the autoclave uses pressure switches, these may need to be adjusted for the location. Also for advanced vacuum units using water powered venturi suctions, problems of achieving a good vacuum may occur if there is a reduced water supply at high altitude.

Power source. The electrical requirements of the larger units are 9 kW and 10 kW. It is important to provide the manufacturer with full details of the local power supply, e.g. voltage, frequency of current (Hz), number of phases and number of wires.

Reliability. When commissioning a new autoclave, use typical loads to set cycle parameters. Every 12 months the autoclave should be thoroughly inspected, valves and seals checked and the unit reassembled by an expert. This re-commissioning will ensure that the temperature and pressure gauges are correct. Ask your local supplier to recommend a qualified technician who can carry out regular preventive maintenance and servicing.

Performance and safety. The autoclave should be fitted with an interlocking safety device on the door/lid to prevent opening until the pressure has returned to atmospheric. The reliability and safety of the unit may be improved by additional features found in more advanced models, e.g. fully automatic, cooling cycles, drying cycles, high vacuum pumps, timed free steaming and automatic safety lid locking. Protective insulated gauntlet gloves and a visor are needed.

Training. Some operational training should be given in dealing with internal spillage, draining and cleaning.

Maintenance. To prevent permanent wear and subsequent failure of the sealing gasket, it is essential to lubricate the sealing faces of the gasket with high melting point grease. Do not use an abrasive cleaner on tin plated pressure vessels. Follow the manufacturer's maintenance schedule.

Capacity. The size and capacity of the autoclave will depend on the volume of work carried out. First find out if other departments in your hospital will want to use the autoclave on a regular basis. The chamber capacity should not be larger than required. Autoclaves with excessive capacities are more expensive to operate and need longer cycles. Consider the requirements for the laboratory *and* other departments then calculate the capacity as follows:

$$\text{necessary capacity (litres)} = \frac{\text{average daily workload (litres)} \times 1.5}{\text{daily number of cycles}}$$

A 100 litre or 150 litre model should be adequate for an intermediate laboratory and a 50 litre model for a peripheral laboratory. A short cycle model is desirable. The single chamber, non-vacuum, vertical autoclave is the most common design used in rural hospitals and is suitable for instruments, glassware, media and waste. These portable models are easy to maintain and no plumbing is required. The capacities available are 13, 16 or 30 litres. Do not forget to consider the height of the media bottles used in your laboratory and whether they will fit into the autoclave.

Tip: When only small items are to be sterilized, consider buying a pressure cooker or steam sterilizer.

Spare parts. The manufacturer's operation and maintenance instruction manual (specify the language) should provide clear details on electrical and pipework installation, operation, maintenance and a parts list. In general the following spare parts 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.

The minimum spare parts required for an autoclave are:

Autoclave heating source	**Spare parts required**
Electricity	Two spare sets of heating elements
Gas burner	Spare gas burner, rubber tubing, spare gas bottle and regulator
Paraffin/kerosene stove	Gasket set, nozzle cleaning tool and nozzle spanner

A spares kit (usually supplied by the manufacturer on request) for a top (or front) loading autoclave should include the following:

2 silicone rubber lid (or door) gaskets
1 3-pole, 11-pin relay 240 V
1 pack of 10 bulbs
1 indicator assembly
1 push button switch assembly

1 canopy micro-switch assembly
1 safety bolt micro-switch
2 heating elements 3.5 kW top (or front) loading
1 air purge valve element
1 lid locking solenoid.

Remember to give the manufacturer or supplier the autoclave serial number when ordering parts.

Quality control. Methods for testing the performance of autoclaves include the Bowie-Dick test, sterilizer control tubes (Browne's tubes), chemical indicators, maximum thermometer, sterilization tape, and biological indicators and thermocouples.

Bowie-Dick test. This is the standardized 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. The test pack is made up of a chemical indicator paper placed in the middle of folded cotton sheets (standard size pack). The indicator sheet will indicate the presence of any air inside the pack by a non-even colour change. Mini-Bowie-Dick test packs are now available.

Sterilizer control tubes. These are also known as Browne's tubes. The colour change in the tube (usually red to green) confirms that it was exposed to an appropriate temperature ensuring sterilization for a minimum period of time. It does not distinguish between air and steam. Control tubes are commonly used for testing performance of sterilization of fluids. Different control tubes are available for various sterilization times and temperatures. The tubes must be stored in a cool place, preferably in a refrigerator.

Chemical indicators. 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. Usually the indicators are designed for fast cycle vacuum sterilizers. These are not suitable for the basic non-vacuum sterilizers. When ordering mention the type of sterilizer and the time/temperature for which you want to use the indicators.

Maximum thermometers. A maximum thermometer indicates that the maximum temperature was reached but does not indicate for how long it was reached and whether it was actually steam which reached this temperature.

Sterilization tape. This is also known as Bowie-Dick autoclave tape. It is not a recommended method for assessing autoclave performance as the indicator bands do not relate accurately to temperature or duration. The tape is, however, useful for distinguishing between pre- and post-autoclaved items, such as wrapped tubing or swab cans.

Biological indicators. These contain paper strips impregnated with *Bacillus stearothermophilus* spores. They show the destruction of microbiological life. They do not provide an instant result.

Thermocouples. A thermocouple is in essence an "electric thermometer". The thermocouple probe may be placed at any position in the autoclave chamber and is connected by fine wires to a recorder which produces a time/temperature graph of conditions during the sterilization cycle. Keep the recorder graphs in a log book containing other information such as the number of cycles, problems, repair reports and safety check time-tables.

Form for assessment of quotations: autoclave

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Heat source available: electricity, steam, gas, kerosene			
Power source available: voltage, frequency, phase			
Capacity (litres)			
Quality control devices available locally—which types?			
Local agent?			
Maintenance, spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

2. Balance

Choosing a balance

Quick reference guide: balance	
For use in haematology, clinical chemistry, microbiology and blood transfusion	Purpose
What accuracy is required?	Performance
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power sources
Is the balance simple to operate?	Technical complexity
Will the balance be exposed to humidity or temperature?	Durability and robustness
What will be the working range?	Capacity
Which balance meets all requirements for lowest cost?	Price

Points to consider

Purpose. The balance will be used to weigh chemicals and stains. In addition, a small simple two-pan trip type of balance may be used for balancing loaded buckets before placing them in a centrifuge.

Performance. A balance having a sensitivity (readability) of 0.01 g (10 mg) will be adequate for most situations. For the preparation of some reference solutions, an analytical balance having a sensitivity of 0.001 g (1 mg) may be required.

Power source. When the local electricity is not reliable, a mechanical balance should be selected. An alternative is an electronic lightweight balance which operates from batteries. High humidity may cause an electronic balance to fail. Ask the suppliers if the electronics have been protected from the effects of high humidity, e.g. by lacquers.

Technical complexity. There are several types of mechanical balance: spring balance, sliding weight balance, parallel guidance system and two-knife and three-knife substitution balances. Mechanical models with built-in weights are more convenient to use than those with separate weights. Electronic models with a flat top pan are easier to use and clean.

Durability and robustness. If the balance is to be moved as part of a portable or mobile laboratory, it should be able to be disassembled easily and probably needs to be independent of a power source, i.e. a mechanical model.

Capacity or weighing range. In a peripheral laboratory, the balance may be loaded up to the specific limit of, for example, 50 g, 120 g, or 310 g. Higher capacity may be required in an intermediate laboratory.

Accessories. For an electronic balance these include calibration weights, an alternating current adapter and a draught shield kit.

Care and maintenance. Never apply oil or any lubricant to the knife edges or bearings of a mechanical balance. Keep the balance clean at all times and protect it with a cover when not in use. If necessary, a damp cloth may be used. Do not use detergents. The balance should always be used in an environment which is free from excessive air currents, corrosives, vibration and temperature or humidity extremes. A balance should have a daily check done with a calibration weight in order to detect early drift.

Ordering information. Electronic balances have to be adjusted at the factory for the particular location of their use (influence due to gravitational forces). When placing your order specify your geographical location.

Tip: Think about a good solid base to locate the balance.

Form for assessment of quotations: balance

	Company 1	Company 2	Company 3
Name of manufacturer			
Type			
Model			
Voltage types			
Use with a battery?			
Have the electronics been protected from high humidity?			
Sensitivity of the balance			
Heaviest capacity			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

3. General purpose or microhaematocrit centrifuge

Choosing a general purpose or microhaematocrit centrifuge

Quick reference guide: general purpose or microhaematocrit centrifuge

For use in haematology, biochemistry, blood transfusion, microbiology, mobile and portable laboratory work	Location
What speed and centrifugal force is required?	Speed and centrifugal force
Is the centrifuge fitted with an interlocking lid catch to prevent opening of the centrifuge lid when the rotor is spinning?	Safety
What capacity is required? Used to spin tubes or bottles or both?	Capacity
Rotors required—fixed angle or swing-out?	Accessories
Are spare parts and repair facilities available and for which types?	Reliability
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power sources
Which centrifuge meets all the requirements for lowest cost?	Price

Points to consider

Location. A general purpose centrifuge will suffice for biochemistry and haematology. A microhaematocrit centrifuge is used in haematology. A large refrigerated centrifuge may be required in a blood bank. For portable laboratory work, a hand operated or battery powered model is used.

Speed, centrifugal force and time. The sedimentation achieved at a given speed (rpm = revolutions per minute) depends on the radius of the centrifuge. Most manufacturers specify both the maximum relative centrifugal force (RCF)(*g*) as well as the revolutions per minute of which a centrifuge is capable. Variable speed and time control is desirable. For a general purpose swing-out model, a maximum speed of between 3200 rpm and 6000 rpm is desired; for a microhaematocrit centrifuge a maximum speed of 12 000 rpm is required.

Early designs have an analogue input of speed and running time via rotary knobs. In newer models speed and time are set and controlled by a microprocessor and are commonly digitally displayed. The light emitting diode (LED) display can show time remaining and the required revolutions per minute or relative centrifugal force.

Motor. In the microprocessor-controlled models a brushless induction drive motor will mean no changes of carbon brushes, making the drive maintenance-free and quiet in operation.

Safety. The centrifuge should have a safe lid interlock (to prevent the lid from opening before the rotor has stopped) and a mechanical lid release mechanism (to enable release of the lid in the event of a power failure). It should have an internal windshield to protect the operator from aerosols. A hand operated centrifuge should have a shield to protect the rotating buckets. The cap of a sealed bucket should fit into, not onto, a bucket so that if a breakage occurs, any infected fluid will be centrifuged from the screw thread into, and not down the outside of, the bucket. Flammable chemicals (ether) are potentially hazardous when used close to spark producing electrical fittings; explosion-proof models are available. Sealable buckets (cups) will reduce hazards caused by aerosols, splashing and tube breakage. Most microprocessor-controlled models have an imbalance detection system which will show a warning light and turn off the centrifuge if it is not balanced.

Capacity. You have to decide whether you need to spin large bottles or smaller test-tubes. If a combination of the two, an adapter can be used to reduce the capacity of the rotor or buckets to take smaller test-tubes. When selecting a rotor, it is better to have a large capacity rotor and adapters for smaller tubes as this will make the centrifuge more versatile in the range of tubes that it can accommodate. Remember that the cost of a new rotor and buckets is far more expensive than a new adapter. For most intermediate laboratories a general purpose centrifuge, fitted with a swing-out rotor with six or eight buckets, will be adequate. To achieve a sealed tube effect with a large open bucket, take a small tube and place it in a universal container. A peripheral laboratory may choose a general purpose centrifuge with a microhaematocrit rotor attachment.

Accessories; rotors. A fixed-angle centrifuge applies greater centrifugal force and separation occurs more quickly than with a swing-out model. For many investigations, swing-out rotors are preferred as sediments collect horizontally in the tube. Swing-out centrifuges are preferable for use in blood banks.

Reliability and spare parts. At the time of initial enquiry ask the agent/supplier where the centrifuge can be repaired. To avoid shortages later, at the time of the purchase, order: spare carbon brushes (analogue models), rubber feet (bench models), fuses, extra cushions for the buckets and a sealing gasket (for haematocrit centrifuges).

Power source. When a battery operated model is chosen, assess how long the batteries will last before they must be recharged. Consider buying a spare battery.

Cleaning. A non-corrosive disinfectant such as 2% weight/volume (*W/V*) glutaraldehyde, 70% volume/volume (*V/V*) alcohol or 10% *V/V* formalin solution will be required to clean the buckets and inside the centrifuge.

User's manual. The manufacturer should supply a user's manual (specify the language) which gives a step by step guide on installation, operation and maintenance including motor brush replacement.

Cost. Make sure that price quoted by the manufacturer includes rotors and buckets. Also ascertain the extra cost of spare parts.

Tip: It is better to have a large capacity rotor and adapters for smaller tubes.

Form for assessment of quotations: centrifuge

Name of manufacturer	Company 1	Company 2	Company 3
Model			
Power voltage available			
Use with battery?			
Speed (rpm) and RCF			
Safety: lid safety lock?			
Rotor: fixed-angle or swing-out ?			
Bucket adapter sizes, ml			
Sealable bucket: caps screw into buckets?			
Local agent?			
Spare parts available locally?			
Cost, complete with rotors and buckets			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

4. Colorimeter or spectrophotometer

Choosing a colorimeter or spectrophotometer

Quick reference guide: colorimeter or spectrophotometer

For use in clinical chemistry and haematology	Location
Will a colorimeter be adequate? (See Table 7.1)	Usefulness
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
Will a fully portable model be required?	Portability
What measurement mode: absorbency, % transmission, concentration or kinetics?	Measurement modes
Are repair facilities and spare parts available and for which types?	Reliability
What accessories may be required? Flow-through cuvette and holder? Printer?	Accessories
How much training on equipment operation and maintenance is the agent willing to provide? Can staff be sent to the central laboratory for training?	Training requirements
Which colorimeter or spectrophotometer meets all the requirements for lowest cost? Remember to consider spare parts.	Price

Points to consider

Usefulness. A colorimeter can be used for clinical chemistry tests at the intermediate and peripheral levels. A spectrophotometer is needed at the intermediate level for the recognition and measurement of abnormal haemoglobin pigments (see Table 7.1).

Power source and light source. When operating on mains and there are power fluctuations, a voltage stabilizer should be ordered. When local power sources are not reliable it is highly recommended to purchase an uninterrupted power supply unit (see Chapter 8). When the instrument is to be used for field use, there should be a connection for a 12 V battery. Most instruments are provided with tungsten lamps. A quartz halogen lamp does not darken with age, is more expensive, less widely available and requires no wavelength calibration upon replacement. Some models have replaced the lamp and filters with a light emitting diode that produces light of a specific wavelength. Using a light emitting diode, however, limits the range of measurable analytes due to concentration of particular substances. Ask the supplier if the electronics have been protected from the effects of high humidity by the use of lacquers.

TABLE 7.1 **Features of colorimeter and spectrophotometer**

Characteristic	Colorimeter	Spectrophotometer
Use		
Suitable for clinical chemistry tests in intermediate and peripheral level laboratories?	Yes	Yes
Hb A_2	Yes	Yes
Hb F absorption band 540 nm	No	Yes
Methaemoglobin, absorption band 630 nm	No	Yes
Sulfhaemoglobin, absorption band 620–630 nm	No	Yes
Carboxyhaemoglobin, absorption band 538 and 578 nm	No	Yes
Cost	Less expensive	More expensive
Power source	Can be operated from battery as well as mains electricity supply	Stable electricity supply required. Some models can be operated from main and battery supply
Absorbency measurement	Aborbance measured only within certain wavelengths ranges using coloured filters	Absorbance measurement can be made at specific wave lengths using diffraction grating or prism
Wavelength range available		
Visible light, 400–700 nm	Yes	Yes
Ultra violet, 200–400 nm	No	Yes
Technical complexity	Rugged and simple to use	Less robust; more complex to use, rarely needed at peripheral level

Portability. When the instrument is to be used extensively in the field, select a model which is powered by alkaline or rechargeable nickel cadmium batteries (see Chapter 8).

Measurement ranges. Results are displayed either as absorbency, % transmission, concentration, or kinetics (see Table 7.1).

Wavelength ranges. A suitable spectrophotometer unit will measure in the visible wavelength, i.e. between 330 nm and 900 nm. Ultraviolet measurements are not required for intermediate or peripheral level laboratories.

Reliability. When making the initial order include several spare lamps, fuses, anti-surge fuses, a spare set of cuvettes (state type and path length) and perhaps a photocell. However, remember that a photocell will deteriorate if stored in hot or humid conditions. Where local power surges are common, a voltage regulator is needed.

TABLE 7.2 **Selecting cuvettes to be used with a colorimeter or spectrophotometer**

Plastic	Glass	Quartz
Poorer quality than glass or quartz; cheaper	High quality; expensive	Higher quality; more expensive
Difficult to clean; can be discarded after use	Easier to clean for reuse; does not deteriorate if properly handled	Easier to clean for reuse; does not deteriorate
Suitable for routine use and visible light	Suitable for routine use and visible light	Suitable both for visible and ultra violet light

Visible light: wavelength 400–800 nm
Ultraviolet light: wavelength 200–400 nm

Accessories. The choice of accessories will depend on local needs and the equipment budget. Accessories include filters, flow-through cuvettes, a holder for test tubes and cuvettes, a printer, a cable to printer or computer, a battery charger, a carrying case and a recorder (see also Table 7.2).

Training. Find out from the local agent how much maintenance training will be provided. Technical training provided by the central laboratory should include checking the alignment by observing the absorbance of a known reference solution, checking linearity and preparation of a calibration curve and preventive maintenance and troubleshooting.

Site. Set the instrument up on a level bench where it will be free from vibration and not in direct sunlight.

Technical complexity. When a colorimeter is used it is more convenient to have the glass filters mounted and sealed in a special wheel which is an integral part of the instrument.

Spare parts. These should include a lamp mounted on pre-focused base and a filter.

Cost. The price in some cases includes cuvettes, spare fuses and a lamp. Filters may need to be ordered separately. Find out from the agent what the final price will include.

Tip: If there are frequent power cuts in the local area, include in your budget an on-line uninterruptible power supply unit (see Chapter 8).

Maintenance. Using a hardback exercise book, keep records of standard and reagent blanks. This is useful information of slowly deteriorating performance. Records should be kept of the date when any parts were replaced or other adjustments made. The instrument should be protected from dust with a cover. If the unit is in continuous use, it is recommended that it should be left switched on to obtain maximum lamp life. Do

not switch the instrument on without first ensuring that there is a filter in position—failure to do this may result in damage to the photocell and meter. Always check the linearity of a colorimeter after replacing the lamp, photocell or filter. The manufacturer's instruction manual (specify the language) should give a clear step by step guide on installation, operation, optical alignment check and replacing the lamp and fuses. Precipitates on glass cuvettes from protein solutions may be removed by soaking overnight in a concentrated sulfuric acid/potassium dichromate solution. Subsequently, they must be thoroughly rinsed with distilled water and left to dry. Plastic cuvettes must not be cleaned in strong acid; use a detergent solution. Store cuvettes in a dust-free box and ensure they cannot scratch each other by contact.

Filters. When the filter for use with a colorimeter is specified, choose according to the colour or Ilford number. When only the wavelength is given, choose the filter by referring to Table 7.3. Filters should not be left in the spectrophotometer when not in use, but should be stored in a dust-free box to ensure that they cannot be broken. They should be fitted into position before the lamp is switched on so that the photocell is not damaged.

TABLE 7.3 **Choice of filter for a colorimeter**

Ilford filter to use (No.)	Wavelength required
600 Deep violet (410 nm)	400–419 nm
601 Violet	420–449 nm
602 Blue	450–479 nm
603 Blue-green (490 nm)	480–504 nm
604 Green (520 nm)	505–534 nm
605 Yellow-green (540 nm)	535–564 nm
606 Yellow (580 nm)	565–589 nm
607 Orange (600 nm)	590–639 nm
608 Red (680 nm)	640–689 nm
609 Deep red	690–700 nm

Form for assessment of quotations: colorimeter or spectrophotometer

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power options available (volts, DC or AC, Hertz)			
Use with a battery?			
Colorimeter; filters integral?			
Maintenance training by supplier?			
Local agent?			
Spare parts available locally? (lamps, fuses,cuvettes)			
Cost (what is included?)			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

5. Dry heat block

Choosing a dry heat block

Quick reference guide: dry heat block

For use in clinical chemistry, haematology and blood transfusion	Purpose
Single block or separate with different test-tube hole size? For use with microplates?	Construction
What temperatures are required?	Temperature range
Is a narrow temperature fluctuation required?	Temperature fluctuation
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
What accessories may be required? Right-angled thermometer? Transfer racks?	Accessories
Which heat block meets all requirements for lowest cost?	Price

Points to consider

Purpose. Decide if you want separate heat blocks or if one would be adequate for both haematology and clinical chemistry.

Construction. The aluminium blocks may be fixed or removable. They accommodate tube sizes from 6 mm to 25 mm diameter, offering a combination of small and large holes. Units that accommodate micro-cuvettes and Eppendorf tubes are available. Holes extending right through the block make for easier cleaning.

Temperature range. Most situations require a range of heat of either between 35 °C and 37 °C, or between 56 °C and 100 °C. Available temperature ranges vary from 25 °C to 105 °C (also to 200 °C or up to 450 °C). Remember that the ambient temperature may be higher than that required of the block.

Temperature fluctuation. A small (not more than $\pm$ 0.5 °C) fluctuation is important for coagulation and clinical chemistry work.

Power source. Before selection, it is essential to consider the power requirements of the heat block in relation to the availability of electricity in the laboratory. Can the unit be used with a voltage stabilizer to counteract surges of current, or can alternative power supplies such as batteries be used? A unit with a low power rating, e.g. 100 W or 150 W, would be best suited for use with a solar charged battery.

Accessories. Right angled thermometers; transfer racks are available.

Note: Some manufacturers produce a solid block for the user to drill holes as required. When ordering remember to state the block size/sizes.

Form for assessment of quotations: dry heat block

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available (volts, DC or AC, Hertz)			
Blocks: Fixed Removable Hole size			
Temperature range			
Temperature fluctuation			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

6. Electrolyte analyser (ion selective electrode analyser)

Choosing an electrolyte analyser

Quick reference guide: electrolyte analyser

For use in clinical chemistry	Purpose
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
Will a portable model be required?	Portablility
What is the typical lifetime of the electrodes?	Electrode lifetime
Are spare parts and repair facilities available locally and for which types?	Reliability
What is the current estimated cost per test?	Cost per test
What accessories may be required?	Accessories
Which electrolyte analyser meets all requirements for lowest cost?	Price

Points to consider

Purpose. This instrument will be used in clinical chemistry at the intermediate level. It is used for the measurement of sodium and potassium in body fluids. Some instruments can also measure calcium, chloride, magnesium and lithium.

Power source. A voltage stabilizer to counteract surges of current may be required. Ask the suppliers if the electronics have been protected from the effect of high humidity by lacquers. Some instruments operate from rechargeable batteries.

Portability. When the instrument is to be used extensively in the field, select a model which is powered by rechargeable batteries and supplied with a carrying case.

Electrode lifetime. Ask the supplier when the electrodes(s) will need replacing and what the current cost of a new electrode is. Ask how often the user will need to change the electrode membrane and replenish the analyser with fresh electrolyte.

Reliability. At the time of purchase, order calibrating solutions, diluents, slope standards, electrode filling solutions and, where necessary, printer paper. The manufacturer should supply a user's manual (specify the language) which gives a step by step guide to installation, operation, maintenance, component replacement and spare parts. At the time of initial enquiry ask the agent/supplier where the analyser can be taken for repair.

Cost per test. Ask the manufacturer what the current estimated cost per test is. Where possible compare this figure with the actual cost given by a local user.

Accessories. Auto-sampling tray; automatic wash facility.

Price. The total cost of the analyser is both the initial capital cost and the ongoing operating cost. For a year the operating costs will include the cost of electrodes, reagents and solutions, the service contract and quality control tests.

Supplier. Ask the supplier if the essential products can be purchased from more than one source or only from the manufacturer. Also enquire whether the manufacturer will supply information needed to make your own reagents and decide whether you could actually do this.

Form for assessment of quotations: electrolyte analyser

Name of manufacturer	Company 1	Company 2	Company 3
Model			
Power voltages available (volts, DC or AC, Hertz)			
Can it operate from a battery?			
How often will the electrodes need replacing (6, 8, 9, 12, 18 months)?			
Spare parts available locally?			
Reagents and standards available locally?			
Repair facilities?			
Local agent?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

7. Electrophoresis chamber

Choosing an electrophoresis chamber

Quick reference guide: electrophoresis chamber

For use in haematology and clinical chemistry	Purpose
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
Has the lid been contoured to prevent condensation dropping onto the cellulose acetate or agar?	Technical complexity
Is there a 7 cm minimum bridge gap? Can the bridge gap be adjusted?	Performance and versatility
Are spare parts and repair facilities available and for which types?	Reliability
How much training on equipment operation and maintenance is the agent willing to provide? Can staff be sent to the central laboratory for training?	Training requirements
Which electrophoresis chamber meets all requirements for lowest cost?	Price

Points to consider

Purpose. It is for use in haematology and clinical chemistry. Cellulose acetate is the method of first choice followed by citrate agar.

Power source and supply. The mains source should be continuous. The power supply unit should be a constant voltage direct current adequately earthed to prevent any shock to the operator. It should be capable of delivering up to 450 V and 80 mA. Ideally, it should have a timer (0–60 minutes), continuous operation switch, an automatic shut off and a "quick disconnect" or manual shut-off switch.

Technical complexity. The cellulose acetate method presents fewer technical problems than the citrate agar method. Electrodes should be strong enough not to be easily broken and should be well insulated for the protection of the operator. Care must be taken that condensation does not drip onto the cellulose acetate or agar. Select a cover contoured to prevent dripping onto the running media.

Safety. To prevent electrocution hazard, a circuit breaker must be incorporated, so designed that the chamber cannot be opened without interrupting the flow of electric current.

Performance and versatility. A bridge gap of 7 cm is satisfactory; however tanks with an adjustable bridge gap are more versatile. A surrounding box to avoid draughts/fans

would be useful. Conduct plate developing/spraying in a well ventilated fume cupboard.

Reliability. The initial order will include a chamber (tank) and power supply unit, wicks of filter paper or chromatography paper, blotting paper, cellulose acetate membranes and applicators (microdispensers). Fine microcapillaries may be used as a low cost substitute for applicators. When making the initial order include two spare tank supports (bridge) and some spare platinum electrodes. Remember to specify the language for the instruction manual.

Training requirements. Find out from the local agent how much maintenance training will be provided. Valuable technical training should be provided by the central national laboratory including training on the method of sample application and the preparation and composition (pH and ionic strength) of the buffer used. Check with the central laboratory that you will be able to send samples for confirmation. Ask them to supply regular quality control samples and advice on how to prepare and send samples (either as anticoagulated blood or as dried blood spots on filter paper).

Accessories. These include a densitometer, an incubator/oven and a stainer.

Control. Apply a control sample containing Hb A, Hb F, Hb S and Hb C to each strip containing known samples.

Tip: As the technique for the Hb A_2 and Hb F involves the use of a spectrophotometer, make sure this equipment is well maintained and if necessary have it serviced.

Form for assessment of quotations: electrophoresis chamber

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available			
Contoured lid?			
Adjustable bridge gap?			
Training by supplier?			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

8. Flame photometer (flame analyser, flame emission spectrometer)

Choosing a flame photometer

Quick reference guide: flame photometer

For use in clinical chemistry	Purpose
Which gas supplies are available? Propane butane or natural gas supplies? Is the gas of a high grade? Is supply reliable?	Fuel (gas)
Is there a reliable source of clean air supplied by air compressor?	Air supplies
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
Is the instrument supplied with a flame failure warning light?	Safety
Are spare parts and repair facilities availability and for which types?	Reliability
Which flame photometer meets all requirements for lowest cost?	Price

Points to consider

Purpose and use. This instrument will be used in clinical chemistry. It is used for the measurement of sodium and potassium in body fluids. More sophisticated instruments can also measure calcium, barium and lithium.

Fuel gas supplies. A reliable source of propane, butane, or natural gas is essential. Fuel gas must be clean and dry. Regulators are available from the manufacturers.

Air supplies. Air is supplied by a compressor; (moisture and oil free 6 litres/minute at 1 kg/cm^2 [14 psi]). Compressed air supplied in a cylinder is expensive. In developing countries with high humidity, a water separator will overcome the problem of water condensation in the airline to the flame photometer.

Power source. The fuses fitted to the instrument should be the anti-surge type. A voltage stabilizer to counteract surges of current may be required.

Safety. An automatic flame failure detector which will shut off the gas supply should the flame extinguish is recommended. The instrument needs to be operated in a well ventilated room. The exhaust gases from the chimney are very hot so the instrument should be located in a position that makes accidental contact with the chimney unlikely. Make sure the instrument is earthed. Cylinders of fuel gas should always be stored in another building and used in line with the supplier's recommendations. This store should be locked and identified by a notice.

Reliability. At the time of purchase, order spares such as calibration standards, capillaries, nebuliser cleaning wire 3 (at 150 mm), nebuliser inlet tubing (500 mm), a

nebuliser, a photocell, hose-connecting clips, an atomizer, Allen keys, drain tubing (1 metre) and two types of spare fuses (primary and anti-surge). The manufacturer should supply a user's manual (specify the language) which gives a step by step guide on installation (voltage, fuel, air, drainage) operation, maintenance, component replacement and a spares kit. At the time of initial enquiry ask the agent/supplier where the flame photometer can be taken for repair.

Accessories. These include a printer, a diluter for some models and filters for lithium, calcium and barium. A large volume water separator (for use in high humidity atmospheres) can be ordered.

Maintenance. Use a hardback exercise book to keep records of standards indicating slowly deteriorating performance and records giving details when any parts where replaced. Never use the instruments without a filter in place. Use good quality water (pure distilled where possible) as a blank in the preparation of standards and dilution of samples. Install the instrument on a vibration-free bench away from direct sunlight.

Storage. Store solutions away from direct sunlight in a cool dark place, ideally at temperatures below 25 °C. Glass containers should not be used for storage as they can affect the sodium concentration levels.

Flame photometers versus ion-selective electrode analysers. It is considered that the safety aspects of flame photometers now outweigh their usefulness. The disadvantages of using a flame photometer are the safety risks both in flame operation and in aspirating solutions into the atmosphere. Cheap and reliable ion-selective analysers are available now. Remember to specify additional filters and fuel type when ordering.

Form for assessment of quotations: flame photometer

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available			
Flame failure warning light?			
Regulators available			
Propane/butane/natural gas/LPG			
Fuel available			
Water separator available?			
Repair facilities?			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

9. Incubator

Choosing an incubator

Quick reference guide: incubator

For use in microbiology	**Purpose**
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	**Power source**
Will the incubator operate from a battery?	**Power requirements**
What capacity is required?	**Capacity**
What temperatures will be required? 36 °C ? 42 °C ? Other ?	**Operating temperature**
Repair facilities, spare thermometer and thermostat—for which types?	**Reliability**
Which incubator meets all requirements for lowest cost?	**Price**

Points to consider

Purpose. For use in microbiology. Fieldwork will require a portable incubator.

Power source. A reliable source of mains electricity is essential. An alternative source of power is a 12 V battery powered by a solar array. A well insulated incubator with a power consumption as low as 30 W or 60 W can be powered by a solar charged battery. When operating on mains where there are power fluctuations, a voltage stabilizer should be ordered.

Power requirements. When a battery provides the power source, select a model with a low power demand, e.g. 30 W, 50 W or 60 W.

Capacity and type. The size chosen will depend on the workload. Larger models may require a circulating fan. A gravity unit, a convection model, should give less problems than the more expensive fan assisted (mechanical) model.

Operating temperature. Most laboratories set 35 °C as the standard to allow growth of nearly all organisms. Generally it would be best to select a model with a wide operational range, 5 °C above ambient to between 50 °C and 80 °C. An incubator/oven has a temperature range of between 30 °C and 220 °C. An acceptable operating temperature range is $\pm$ 2 °C. Incubation for *Mycobacterium* will require in addition, an incubation temperature of 30–32 °C and 42 °C.

Note: The ambient temperature may exceed that required for incubation.

Reliability. The local supplier should ensure proper maintenance and reliable supplies of spare parts. Recommended spare parts include a heating element, a main switch, fuses and a thermostat. These spares should be ordered at the time of purchase. Some

workers prefer a door without a catch, i.e. a magnetic seal. The newer temperature controls use bimetallic strips and a micro-switch. Specify the language for the instruction manual. Carbon dioxide incubators are available but the additional cost may not justify their use in developing countries. Double-door designs with a glass inner door and an outer steel door add to the cost of the incubator, but increase its insulation properties.

Accessories. Accessories include perforated galvanized shelves, perforated stainless steel shelves, floor stands with castors, temperature recorders and discs for the recorder. More sophisticated models incorporate components such as digital displays, alarms, optional cooling features, humidity controls, recording devices, exhaust ventilation and electrical outlets allowing shakers and stirrers to be used inside the chamber. Remember to specify if additional shelves are required.

Form for assessment of quotations: incubator

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available (volts, DC or AC, Hertz)			
Operating temperature range			
Capacity (litres)			
Number of shelves provided			
Convection or fan assisted			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

9. Microscope

Choosing a microscope

Quick reference guide: microscope

For use in haematology, microbiology and blood transfusion	Purpose
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
What light source is provided: quartz halogen or tungsten lamps? A mirror is required	Light source
Is a connection for the battery built into the base?	Technical complexity
Are spare parts available and for which types?	Reliability
For most routine work the objectives should be 10x, 40x, 100x (oil immersion)	Objectives
The numerical aperture (NA) of each objective should be high	Resolving power
What accessories may be required? Darkfield, fluorescent, calibrated graticule, solar panel? Strong carrying case with lock?	Accessories
A binocular model is recommended. Would a lower priced monocular model be satisfactory for some uses?	Binocular or monocular
Which microscope meets all requirements for lowest cost?	Price

Points to consider

Purpose. A good quality binocular model should be used.

Power source. When local power sources are not reliable, an alternative light source may be provided by a battery or mirror. The battery may be charged by a generator (when diesel supplies are reliable) or by a solar panel.

Light source. This should be built in. Quartz halogen lamps provide excellent high intensity illumination and, unlike tungsten lamps, do not become discoloured. Halogen bulbs are more expensive, less widely available and burn out more quickly than tungsten bulbs. Halogen bulbs will last longer if the power source is protected by a power conditioner. A mirror unit mounted for angling and rotating should always be supplied. Natural light is generally insufficient when using a binocular microscope with a 100× oil immersion objective.

Technical complexity. A mirror should be provided for all microscopes to be used in developing countries and it is highly recommended that all microscopes include sockets for a 6 V/12 V battery connection which is built into the base. This connection should not be interchangeable. There should be a safety device to prevent damage from

interchanging of battery terminals. The focusing knob should be easily accessible. There should be a built-in mechanical stage.

Reliability. The supplier/agent should have a good stock of lamps and spare fuses.

Objectives. For most routine work 10×, 40×, 100× (oil immersion) parfocal DIN achromatic objectives are adequate. Use non-drying immersion oil (see Chapter 6).

Resolving power. A high resolving power is important and dependent on the numerical aperture (NA) of each objective. The higher the numerical aperture, the greater is the resolving power. Objectives should be: 10× (NA about 0.25), 20× (NA about 0.45), 40× (NA about 0.65) and 100× (NA about 1.30).

Accessories. Accessories are available for darkfield and fluorescence microscopy. A calibrated graticule in an eyepiece is useful when measuring cyst size in faeces samples (a stage micrometer would need to be purchased for use with the eyepiece). The supplier should be able to provide a solar panel, lead-acid battery (lead-calcium antimony is recommended) and a lead with crocodile clips to attach to a battery. A 20× objective is useful when examining plasma in capillary tubes for parasites. Filters for the light source should be available. The eyepiece tilt angle is generally 45° or 30°. An eyepiece with a tilt range adjustable between 10° and 40° is an accessory that adjusts the eyepiece angle to accommodate multiple users.

Binocular versus monocular microscopes. Binocular microscopes are more restful for the eyes when long examinations have to be made. Although binocular microscopes are more expensive than monocular ones, a binocular model is recommended particularly when artificial light can be provided. If a monocular microscope is chosen, eye strain may be reduced with a blank eyepiece attachment.

Tools. These should include a paintbrush (fine and soft), rubber-bulb blower and a set of jeweller's screwdrivers.

User's manual. The manufacturer should supply a user's manual (specify the language) which gives a step by step guide on how to set up and use the microscope.

Preventive maintenance

Humid climates. In hot or humid climates, fungus may develop on the microscope, particularly on the surface of the lenses, in the grooves of the screws and under the paint and the instrument will soon become useless. Protection against fungus growth involves a means of depriving the fungi of the humidity they need to survive and keeping optical surfaces and lens mounts absolutely free of any dust contamination. This may be prevented as follows.

- Place the microscope in a small cabinet or cupboard that is heated continuously from below by a low watt bulb. The bulb must be left on continuously even when the microscope is not in the cupboard. Check that the air inside the cupboard is at least 5 °C

warmer than that of the laboratory. To allow the air to circulate, the cabinet/cupboard should have holes in the bottom, sides and around the top. The doors of the cupboard should be tightly fitting. To avoid penetration by larger dust particles, gauze or cotton wool should be placed in front of the air inlets (bottom) and outlets (top at sides).

- When not in use, keep the microscope under an airtight plastic bag (made from thick polyethylene, not PVC) with self-indicating blue silica gel in a dust-tight linen bag or in a dish. Self-indicating silica gel is blue when active but becomes pink when it has absorbed all the water it can. To restore its activity gently heat it (in a oven or over a fire) until the colour returns to blue indicating it is active once again. When the silica gel cools it must be returned to the airtight container. Do not store the microscope in its carrying case or under plastic hoods in these climates.
- For transportation of a microscope through a hot or humid climate the instrument should be put inside a thick weld-sealed polyethylene bag. Where this proves impossible, twist the end of the bag several times and tie it up with string. Make sure that about 250 g of silica gel (in a dust-tight linen bag) is placed with the instrument inside the polyethylene bag.

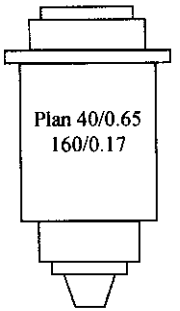
Dry climates. In hot dry climates the main problem is dust. Fine particles work their way into the threads of screws and under the lenses. This can be avoided as follows.

- Always keep the microscope under an airtight plastic bag when not in use, with self-indicating blue silica gel in a dust-tight linen bag or in a dish.
- At the end of the day's work, clean the microscope thoroughly by blowing air over it with a rubber bulb.
- Finish cleaning the lenses with a lens brush or fine paintbrush. If dust particles still remain on the surface of the objective, clean it with lens paper.

Cleaning the microscope.

- Optical surfaces are scratched by dust particles moved around during wiping. Therefore, all solid particles must first be removed using a soft camel-hair brush (protect this against dust by wrapping it in plastic, cloth or paper) or a blower (rubber-bulb syringe). Residues of immersion oil on the lenses should be removed with lens paper, absorbent paper or medical cotton wool wrapped around a small wooded stick or a match. The optics may be finally cleaned with a special solution, consisting of 40% petroleum ether, 40% ethanol and 20% ether. Ethanol (96%) must not be used for cleaning the lenses, since it dissolves the cement.
- For the removal of heavy contamination from the instrument surfaces, use mild soap solutions—never use acetone.
- For normal instrument cleaning use a mixture of equal parts of distilled water and 96% ethanol. This solution is *not* suitable for cleaning the optics.

Objectives, engravings. The numbers engraved on every objective indicate more than the initial magnification alone. An example of the engravings:



Plan = planachromat, i.e. flat-field achromatic
40 = initial magnification 40× (multiplied by eyepiece magnification = total magnification of microscope)
0.65 = numerical aperture 0.65
160 = designed for use with a microscope with a mechanical tube length of 160 mm (distance between objective flange and eyepiece seating face) and with a cover glass of 0.17 mm thickness)
Other abbreviations are:
' / – ' = insensitive to major deviations of the cover-glass thickness
' / 0 '= the objective is corrected for zero cover-glass thickness', i.e. for uncovered specimens

Use and maintenance of the objectives

- Never dip the objectives in xylene or ethanol (the lenses would become unstuck).
- Never clean the supports or the stage with xylene or acetone.
- Never use ordinary paper to clean the lenses.
- Never touch the lenses with fingers.
- Never clean the inside lenses of the eyepieces and objectives with cloth or paper (this might remove the anti-reflective coating); use a fine paintbrush only.
- Never leave the microscope without the eyepieces unless the openings are plugged.
- Never keep the microscope in a closed wooden box in hot or humid countries.
- Never press the objective onto the slide since both slide and objective may break.
- Take care when focusing the microscope.
- Never put the microscope away with immersion oil on the objective. Remove any oil daily. Mild soap suds are suitable for most cleaning.
- Do not dismantle the optical components as this may cause misalignment. The optics should be cleaned by using lens-cleaning tissue.
- Organic solvents should only be used in accordance with the manufacturer's recommendations.
- When changing the bulb, avoid touching the glass with the fingers as fingerprints reduce the intensity of illumination.
- The life of the bulb is extended considerably by adjusting the voltage to give the lowest required light intensity.
- If the mains voltage fluctuates excessively, use a voltage stabilizer (Chapter 8).
- Before bulb or fuse replacement, unplug the power cord from the alternating current outlet.
- Always earth the microscope to prevent electrical hazard.
- Do not exchange lenses from a microscopes from a different manufacturer—even some models from the same manufacturer may have different specifications.

Form for assessment of quotations: microscope

Name of manufacturer	Company 1	Company 2	Company 3
Model			
Power voltage available			
Is a mirror provided?			
Is the battery connection built in?			
Optics: objectives 10x, 40x, 100x oil			
Optics: high NA for each objective 10x (0.25 NA), 40x (0.65 NA), 100x (1.30 NA) oil			
What accessories are available?			
Local agent?			
Maintenance, spare parts (bulbs, fuses) available locally?			
Cost			
Overall assessment of quotation:			

Comments

.....

.....

.....

.....

.....

10. Oven for hot air sterilization (hot air oven)

Choosing an oven for hot air sterilization

Quick reference guide: oven for hot air sterilization

For use in microbiology and haematology	Purpose
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
What capacity is required?	Capacity
What temperatures are required?	Operating temperature
Are repair facilities available?	Reliability
Is a circulating fan required?	Technical complexity
Which oven meets all requirements for lowest cost?	Price

Points to consider

Purpose. For use in microbiology and haematology; used mainly for drying laboratory equipment and surgical devices in dry air. Like the autoclave, the oven is not to be used to sterilize items directly concerned with patient care.

Power source. A reliable source of mains power is essential as sterilization in dry air is only effective when the material is exposed for 180 minutes at 160 °C. Sterilization in dry air is less effective than steam sterilization, despite the higher temperatures applied.

Capacity. The size and capacity of the oven will depend on the volume of work carried out. Find out if other departments in your hospital will want to use the oven on a regular basis. A 60 litre model should be adequate for peripheral level laboratories.

Operating temperature. A common operating range is between 40 °C and 250 °C. Some ovens have a maximum temperature of about 270 °C. Although bacteria are killed at the higher temperatures, some spores can survive and bacterial endotoxins are only partially inactivated. The temperature must be monitored in at least two areas of the sterilization chamber, preferably areas where the conditions for sterilization are the most difficult to achieve. It is important to remember that the timing of sterilization should begin when the air in the oven has reached the required temperature.

Reliability. The local supplier should be able to ensure proper installation and reliable supplies of spare parts, e.g. thermostats.

Technical capacity. The more expensive models include an internal circulating of dry air. A fan is a potential source of contamination and mechanical faults. Only small ovens can work without internal air circulation. There should be a clear temperature

display and anti-tip shelves are desirable. Most models are supplied with two shelves. If you require additional shelves, include this request at the time of making the initial order.

Installation and maintenance. Extremely strong shocks received during transport may necessitate readjustment of the thermostat on delivery. It is recommended lubricating the mechanical parts of the door lock from time to time. Use a heat resistant oil or thin silicone grease. The moveable parts of the thermostat will require lubrication by a service engineer.

Accessories. These should include a stainless steel gridded shelf and a floor stand with castors.

Tip: An oven with a wide temperature range of between 30 °C and 220 °C could also serve as an incubator, but not if fitted with a fan. This, however, would take time to set and stabilize the temperature.

Form for assessment of quotations: oven for hot air sterilization

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available (volts, DC or AC, Hertz)			
Capacity (litres)			
Operating temperature range			
Circulating fan?			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

11. pH meter

Choosing a pH meter

Quick reference guide: pH meter

For use in clinical chemistry, haematology, microbiology and blood transfusion	Purpose
Will a portable model be required?	Portability
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not ?	Power source
Will measurements be outside the range 0–14 pH and resolution 0.1pH?	pH range and resolution
Will temperature affect performance? Is temperature compensation built in?	Temperature compensation
Do you want a basic model or one with additional features?	Performance and versatility
Are repair facilities and spare parts available and for which types?	Reliability
Which pH meter meets all requirements for lowest cost?	Price

Points to consider

Purpose. A pH meter is necessary to give accurate pH measurements when preparing reagents used in all disciplines of laboratory medicine. At the peripheral level when the range of tests has been reduced, pH indication paper may be adequate.

Portability. When extensive field work is to be carried out, a portable model will be needed. Portable pH meters include stick, pocket and card sized models.

Power source. A sensible choice would be a model which offers the power option of a 9 V battery.

pH range and resolution. Most meters read pH values from 0 to14 pH, with resolution 0.1pH and accuracy $\pm$ 0.01 pH. Measurements are made in steps of 0.01.

Temperature compensation. When it is likely that the temperature will affect performance select a model with automatic temperature compensation, using an automatic temperature compensation probe.

Performance and versatility. A basic model with a standard glass or epoxy bodied combination electrode is ideal and low in price. Units have manual temperature compensation over the range 0 °C–100 °C. More sophisticated models offer facilities for automatic temperature control and slope control. Combination meters may measure conductivity, read concentrations and display temperatures.

Maintenance. For long-term storage, use a wetting cap with pH buffer. Always ensure the electrode is used within its specified temperature range. Do not touch the sensitive glass pH membrane during use. Solvents such as carbon tetrachloride, trichloethylene, petroleum, ether, etc. must not be used for cleaning electrodes that have a plastic body or a plastic protective skirt.

Accessories. These include a storage bottle to protect the electrode, a electrode stand and various connectors and adapters. Cables for electrodes come in lengths of 1–10 metres. Probes include thermometers, steel protected spears, epoxy body automatic temperature compensators (ATCs), plate configurations, microstems and HF resistant probes.

Reliability. Select a model with a protective sheath to protect the glass electrode. The agent should have a good supply of electrodes, electrode leads, probes, anti-surge fuse, membranes, battery connectors, electrode stands, buffer solutions and electrolyte maintenance solutions. Repair facilities should be available. The manufacturer should supply a user's manual (specify the language) which gives installation, operating and maintenance instructions with a table giving cleaning agents of glass electrodes.

Tip: Give preference to a meter equipped with a low battery warning device.

Form for assessment of quotations: pH meter

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power options available			
Battery option?			
pH measurement range			
Additional features			
Local temperature compensation: manual/automatic?			
Slope control?			
Local agent?			
Electrode type— combination/reference			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

12. Laboratory refrigerator or freezer

Choosing a laboratory refrigerator or freezer

Quick reference guide: laboratory refrigerator or freezer

Reagents, sera, chemicals, samples—how much must be stored at between 4 °C and 8 °C? At between –20 °C and –30 °C?	Storage capacity
A well ventilated situation to dissipate heat from cooling unit	Site
What external temperatures are reached? Not more than 32 °C? High daytime and low night–time temperatures? Continuous temperatures between 32 °C and 43 °C	Refrigerator/freezer performance
Which power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not? Kerosene or bottled gas?	Power source
Is the electricity consumption about or less than 1 kwH/24 hours?	Electricity consumption
What holdover time is needed if power source fails? Is there a standby power source?	Holdover time
Are repair facilities and spare parts available and for which types ?	Reliability
Will flammable solutions and/or volatile liquids be stored in the refrigerator?	Safety
Which refrigerator or freezer meets all requirements for lowest cost? Remember to consider shipping costs.	Price

Points to consider

Storage capacity. This will be influenced if there are other units being used and the type and size of the laboratory. The recommended capacity is between 75 litres and 120 litres, with a freezer capacity of between 3 litres and 5 litres. Too large a model may be needlessly expensive, besides wasting space and energy.

Performance. For general storage, select refrigerators which remain in the 0 °C to 8 °C range and freezers in the –15 °C to –30 °C range. A full refrigerator operates more efficiently than an empty one.

Power source. Whenever there is more than 8 hours of electricity per 24 hours, compression refrigerators are preferred to absorption refrigerators as their thermostat ensures correct temperatures in most conditions and they require less energy. Compression refrigerators are electricity operated. Compression refrigerators are best suited to using solar energy. Absorption refrigerators are operated by electricity, kerosene, or gas. Single absorption models can operate on gas and electricity or on

kerosene and electricity. Solar panels, kerosene or gas may have to be considered as an alternative energy source when the local electrical mains supply is poor.

Reliability and spare parts (see Table 7.4). Your budget should allow for repairs and spare parts. Spare parts and repairs account for 46% of the whole life cost of a refrigerator. All copper tubing will prevent corrosion and exterior condensation. If a glass thermometer is used, order a brass protection case. Some models have a door-lock and key. The following essential spareparts will be required during the first three years of operation:

- Compression type (electric): thermostat, starting device for compressor
- Kerosene type: 6 cotton wicks, 3 lamp glasses
- Gas type: flame failure device, door or lid seal.

Ozone friendly. Look for a model that does not use chlorofluorocarbons (CFCs) in the cooling unit and in the making of the foam insulation. Ask for 100% CFC free. A refrigerator driven by sound waves does not rely on ozone-damaging refrigerants.

Electricity consumption. It is desirable to have electricity consumption of less than 1 kW per 24 hours, per 100 litres gross capacity (total) stable running, fully loaded and at 43 °C ambient temperature. A unit with a low energy usage (kWh/year) will be easier to run on low voltage power sources such as solar power. Choose an energy efficient model, i.e. less than 365 kW. Look for a model with heavy duty insulation, with insulation thickness of 70 mm for a refrigerator and 100 mm for a freezer.

Safety. A domestic refrigerator used in a laboratory may create hazards by providing ignition sources (thermostats, light switches, heater strips, etc.) that can ignite vapours from stored flammable solvents. These hazards may be eliminated or reduced by placing a warning sign on the refrigerator "Do not store flammable solvents in this refrigerator", by relocating the manual temperature controls to the exterior of the cabinet and by sealing all points where wires pass from the refrigerator compartment. However, remember that self-defrosting refrigerators cannot be modified this way. A spark-free model may be ordered. Flammable chemicals include ether, xylene, toluene, methanol, ethanol, other alcohols, glacial acetic acid, acetone and acetic anhydride. Romanowsky stains and acid alcohol solutions are also highly flammable.

Holdover times. Ice-lined refrigerators or equipment with permanent tanks of frozen "eutectic" liquid can provide stable refrigeration even in areas of intermittent power. The holdover time of a domestic refrigerator may be improved by filling the vegetable basket with water bottles and reinforcing the insulation of the door. Voltage fluctuations may be controlled by installing a voltage regulator.

Remember: When placing your order for refrigerator or freezer, include a request for a thermometer (vertical hanging or alcohol stem type). Remember to specify the language for the instruction manual.

Table 7.4 gives a rough guide to the expected life of most essential spare parts. Ask your local agent/supplier to give you the price of each item. The expected life of the parts and the local price will allow you to calculate and prepare a budget for a number of years. Each different model of refrigerator will have its own list of spare parts. This exercise should therefore be repeated for each type of refrigerator in the laboratory. This method of calculation assumes that all your refrigerators have been in use for some time. If all the refrigerators are new, they will, of course, need fewer spare parts. Some spare parts from one refrigerator are interchangeable with products from another company, e.g. compressors. When ordering spare refrigerator parts always state:

- the manufacturer's name (shown on the data plate)
- the model or type of refrigerator (shown on the data plate)
- the serial number (shown on the data plate)
- a description of the part (use the descriptions given in the manufacturer's brochure)
- the voltage, wattage and cycles/second (Hz) (for electric parts).

Maintenance. After defrosting the freezer, clean the inside with a weak solution of bicarbonate of soda and rinse off with lukewarm water. Dry with a clean cloth only. Heaters of any kind should not be used. After defrosting the freezer, wipe vegetable oil, glycerine or alcohol onto the wall to make it easier to defrost next time. Test the magnetic seals by darkening the room where the refrigerator is located, putting a torch (flash light) inside the refrigerator and looking for light leaks around the perimeter. The door seal may be checked by placing a thin paper strip against the cabinet front. Close the door. Pull the paper strip. If it moves easily or falls away by itself, adjust the door sealing. It is good practice to keep a daily record of refrigerator temperatures. Clean the coils about once a month. Remove dirt or dust from the coils and condensers using a soft brush or the brush attachment of a vacuum cleaner.

TABLE 7.4 Expected life of essential spare parts for a refrigerator

Compression type	Life of parts in years*	Local price**	Notes
Electric			
Starting device for compressor	3		
Thermostat	3		
Door or lid seal	3		
Motor protector	3		
Filter drier	5		
Switch	5		
Capacitor	7		
Compressor	7		
Other spares: ice packs, sealed water bottles, main circuit fuse, plug fuse, plug, length of mains lead, bottle of refrigerant gas, coil of copper tubing			
Kerosene			
Wick (cotton)	1/2		
Lamp glass	1		
Wick carrier	1		
Tube cap	2		
Cap	2		
Door or lid seal	3		
Burner	5		
Tank	7		
Cooling unit	10		
For electric operation: thermostat Other spares: ice packs, sealed water bottles, kerosene, filter cloth, funnel, bottle of refrigerant gas, coil of copper tubing			
Gas			
Flame failure device	3		
Door or lid seal	3		
Gas pipe	5		
Burner jet	5		
Thermo-element	5		
Bypass screw	5		
Gas thermostat	5		
Piezo lighter	5		
Spark plug	5		
Cooling unit	10		
For electric operation:			
Electric thermostat	5		
Heater	3		

*The life expectancy of a part can vary greatly according to how it is used and the condition of the voltage.
**The cost of a part can also vary greatly depending on shipping costs, import restrictions and agent's fees.

Form for assessment of quotations: laboratory refrigerator or freezer

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available			
Kerosene, gas, or photovoltaic?			
Capacity (litres)			
Flammable material storage?			
Copper tubes?			
Service and repair technician			
Local agent?			
Spare parts available locally?			
Cost*			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

* When preparing a budget for spares see Table 7.4

13. Serology centrifuge

Choosing a serology centrifuge

Quick reference guide: serology centrifuge

For use in blood transfusion and haematology	**Location**
Is the centrifuge fitted with a safely cover lock to prevent opening of the guard bowl until the rotor has completely stopped?	**Safety**
What speed is required?	**Speed**
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	**Power source**
What capacity is required?	**Capacity**
Are repair facilities and spare parts available and for which types?	**Reliability**
Which serology centrifuge meets all requirements for lowest cost?	**Price**

Points to consider

Location. The serology centrifuge (also known as a sero-fuge) is used for the easy, quick and thorough washing of red cells during red cell serology testing. It is designed for blood grouping, typing and crossmatching, particularly for the Coombs test and other cell washing procedures.

Safety. The rotor should only operate when the cover is closed. A safety lock prevents opening the guard bowl until the rotor has completely stopped. The centrifuge should be mounted on wide rubber feet.

Speed. The standard model operates at a set speed of 3400 rpm (1000 RCF). The two speed model will also operate at half force—2400 rpm for delicate centrifuging of weak agglutination reactions (an electronic break is provided). The motor is controlled by an adjustable 6 minute timer or "hold" button for continuous operation. The timer is graduated in 5 second divisions to 1 minute, and 15 second divisions from 1 to 3 minutes.

Power source. Before selection, consider the power requirements of the centrifuge (115V–120 V, 60 Hz; 150 W) in relation to the availability of electricity to the laboratory. Can the centrifuge be used with a voltage stabilizer to counteract surges of current? Can alternative power supplies, such as batteries, be used?

Capacity. The standard rotor is of transparent polycarbonate plastic and holds up to twelve standard serology tubes, size 10 mm × 75 mm, 12 mm × 75 mm. A six-place

aluminium head will accommodate 16 100 mm tubes, 12 vacutainer blood collecting tubes or 12 10 ml tubes.

Accessories.These include 6 or 8 place rotors and plastic liners which slip into the serology centrifuge to protect it from the corrosive action of blood and saline.

Reliability. At the time of initial enquiry, ask the agent/supplier where the centrifuge can be taken for repair. Make sure an operation and maintenance manual (specify the language) is supplied with the centrifuge. To avoid shortages later, order spare carbon brushes at the time of purchase.

Maintenance. A noncorrosive disinfectant such as 2% *W/V* glutaraldehyde, 70% alcohol or 10% *V/V* formalin solution will be required to clean inside the centrifuge.

Form for assessment of quotations: serology centrifuge

Name of manufacturer	Company 1	Company 2	Company 3
Model			
Use with battery?			
Speed			
Safety: strong lid and safety lock?			
Power voltages available (volts, DC or AC, Hertz)			
Tube capacity			
Speed fixed/two-speed			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

14. Water bath

Choosing a water bath

Quick reference guide: water bath

For use in haematology, microbiology, clinical chemistry and blood transfusion.	Location
Tank capacity in litres	Capacity
Tank construction material	Construction material
What temperatures are required? (Below ambient is not possible)	Temperature range
Is a narrow temperature fluctuation required?	Temperature fluctuation
Is a mixing unit required?	Mixing unit
Are repair facilities and spare parts available and for which types?	Reliability
What power sources are available? Electricity: what voltage? What frequency? Is supply continuous or not?	Power source
Which water bath meets all requirements for lowest cost?	Price

Points to consider

Location. Generally a separate water bath will be required for clinical chemistry, haematology and blood transfusion. In a peripheral laboratory, one water bath should be sufficient for both coagulation and blood transfusion.

Capacity. A bath of capacity between 2 litres and 5 litres should be adequate for biochemistry departments. A bath of capacity between 20 litres and 25 litres will be required for haematology and microbiology departments.

Construction material. A tank made from stainless steel, transparent polycarbonate or with a polypropylene inner will be easier to clean.

Temperature range. This may be fixed or variable (usually between 30 °C and 100 °C). Fixed temperature water baths are generally at 37 °C, sometimes 56 °C and occasionally 70 °C (e.g. when preparing chocolate agar). Remember that the ambient temperature may exceed the required bath temperature.

Temperature fluctuation. Only a narrow temperature range fluctuation (sensitivity of ± 0.5 °C or less) is allowable for coagulation and biochemistry work. To achieve ± 0.5 °C temperature control, an electronic controller is needed, as well as good stirring (air or water). The common vial type thermostat used in a lot of older water baths is suitable for coarse control. A voltage stabilizer is no use for a vial controller. Temperature fluctuation is not very critical when heating stains or preparing chocolate agar—here an unstirred bath would be adequate and cheaper.

Mixing unit. The water is circulated and maintained at a constant temperature by a unit equipped with a propeller—also called an immersion circulator. A fault in the mixing unit is a common cause of breakdown. Where temperature fluctuation is not considered important, a mixing unit may be omitted so choose an unstirred water bath. A low-cost alternative would be to buy a locally made water container and on the side clamp in place an immersion heater.

Heater. The heating unit may project down into the bath or be mounted at the base of the tank. A suitable container filled with water and kept in a 37 °C incubator provides a convenient substitute for a 37 °C water bath.

Reliability. The local supplier should be able to provide a reliable supply of spare parts. Recommended spare parts include a thermometer, a heating element and a main switch. A spare fuse and thermostat should be ordered at time of purchase.

Power source. Before selection, it is essential to consider the power requirements of the bath in relation to the availability of electricity to the laboratory. The bath should be used with a voltage stabilizer to counteract surges of current, or with an alternative power supply such as batteries.

Preventive maintenance. The bath should be filled with distilled water or rainwater (for constantly higher temperatures liquid paraffin may be better). The unit can be cleaned with commercial stainless steel cleaning agents. Weekly or monthly cleaning of the bath is recommended by manufacturers. The heating element should be always be kept clean so that it will last. Objects liable to rust must not be placed in the bath.

Note: If the ambient temperature exceeds 30 °C, a 20 °C incubator may be necessary for procedures, e.g. blood transfusion, that must be carried out at room temperature.

Tip: Baths with lids/covers consume less energy.

Form for assessment of quotations: water bath

Name of manufacturer	Company 1	Company 2	Company 3
Model			
Power voltages available			
Capacity (litres)			
Temperature range			
Temperature fluctuation			
Construction material			
Use with battery?			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

.....

15. Water still

Choosing a water still

Quick reference guide: water still

For use in clinical chemistry, haematology and microbiology	Purpose
Litres of water required per hour to operate?	Water consumption
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	Power source
What output of litres per hour is desired?	Output
What construction material is used for the condenser and boiling chamber?	Construction material
Can the boiler be cleaned without dismantling the glassware?	Technical complexity
What safety features are included to prevent damage to the glassware?	Safety
Are repair facilities and spare parts available and for which types?	Reliability
Which water still meets all requirements for lowest cost?	Price

Points to consider

Purpose. The water still is best sited in the clinical chemistry department where it will get the greatest use.

Water consumption. A large volume of cool running water is required to operate a water still (this may be a problem in some tropical countries). The volume needed is usually not less than 50 litres per hour with a supply pressure of 0.3 kg/cm^2 minimum. When there is not a good mains supply of water (or the local electricity supply is not reliable), deionized or filtered water systems should be considered.

Power source. Electrical consumption is generally 3 kW per hour. When the local power supply is not reliable, consider alternatives such a water deionizer, or using energy from a Bunsen burner or kerosene heater (primus type) to operate a copper still.

Output. The output of a water still may be as small as 2 litres per hour. A unit producing an average of 4 litres per hour should be adequate.

Construction material. The condenser and boiling chamber may be made out of borasilicate glass or stainless steel. The heater may be made out of metal or silica. Some water stills are constructed largely from borasilicate glass. Glass components and pure tin lining reduce the leaching of impurities into the distilled water. PVC piping is not recommended as it sheds particles, promotes microbial activity and may possess cement socket-joining solvents. Water leaches organic contaminants and trace elements from PVC.

Technical complexity. The boiler should be able to be cleaned *without* dismantling the glassware. A still of largely glass construction should be protected by a metal cabinet with a plastic front screen. A siphon tube fitted to the boiler provides for easy desiccating. A double coil condenser will provide low temperature, high output distilled water. Screw thread connectors will allow ease in glassware/tubing replacement. A unit producing single distilled water will be adequate.

Safety. At no time should the electricity supply be turned on until the heating element is completely covered with water. The heaters should be fitted with an over-temperature cut-out which prevents damage to the glassware should the water supply be broken or fail completely. A constant level device will automatically maintain the boiler contents at the optimum level. Other desirable safety features include in-line fuses and a visual water feed valve. The boiling flask and element (when it is integrated into the flask) must be checked for inorganic deposits and desiccated as appropriate. This must be done frequently in hard water areas. The system requires close supervision unless it is fitted with automatic safety devices.

Reliability. A water still requires regular cleaning and maintenance. Ask the supplier/agent to provide a list of replacement glassware and components, together with an indication of the expected life (in years) of the most essential spare parts. Ask for the price of each part: heater, boiler, constant level and condenser. The expected life of the parts and the local price will allow you to calculate and prepare a budget for two or three years. Mechanisms for water purification include filtration, deionization, distillation, reverse osmosis, adsorption and ultra violet sterilization. For notes on water purification see Chapter 6.

Note: The level of purity required will depend upon the use for which the water is intended. Filtered or deionized water may be the most economical way to suit your purified water needs. In an area with water of high salt content desalinate the water by ion exchange. Where the water has a high calcium carbonate, deionization is less of a problem. Remember to specify the language for the instruction manual.

Form for assessment of quotations: water still

	Company 1	Company 2	Company 3
Name of manufacturer			
Model			
Power voltages available			
Water supply required to operate, (litres/hour)?			
Output (litres/hour) ?			
Construction material, largely glass or metal?			
Ease in cleaning boiler			
Heater; over-temperature cut-out switch?			
Local agent?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

.....

.....

.....

.....

16. Portable kit for bacteriological testing of water

Choosing a portable kit for bacteriological testing of water

Quick reference guide: portable kit for bacteriological testing of water

For use in the microbiology laboratory and in the field	**Location**
What incubation temperatures are required? Only 44°C or both 44°C and 37°C?	**Temperature range**
What tests are required in addition to those for detecting faecal coliform?	**Test range**
What power sources are available? Electricity: What voltage? What frequency? Is supply continuous or not?	**Power source**
Are spare parts and repair facilities available and for which types?	**Reliability**
What accessories may be required? Solar charger? Conductivity meter?	**Accessories**
Is the kit a complete unit with built-in battery and incubator?	**Technical complexity**
Which portable kit for the bacteriological testing of water meets all requirements for lowest cost? Will a battery charger be included?	**Price**

Points to consider

Location. Fieldwork will require a kit which can provide results without returning to the microbiology laboratory.

Temperature range. A temperature of 44 °C is required for the determination of thermotolerant (faecal) coliforms in water. An additional incubator set at 37 °C for the determination of total coliforms in water will indicate contamination of a water supply.

Test range. The *Escherichia coli* count (faecal coliforms) is the most valuable test for the routine control of water. Other useful tests are turbidity, free and total chlorine and pH.

Power source. Ideally, the kit should run from mains electricity, an internal rechargeable battery or a vehicle battery. When the local mains supplies or fuel for a generator is not reliable, a solar power pack will provide an alternative means to recharge the battery. It is preferable to have a kit where a fully charged battery will provide enough power to use the incubator over 5 days, i.e. 72 hours between charges.

Reliability. The initial order should include consumables (pads, membranes and culture media) for up to 200 bacteriological tests. A turbidity measuring tube should be included. Some manufacturers include a temperature check kit. Ask the agent to provide a list (with prices) of replacement parts and spares, available repair kits (e.g.

battery replacement kit and electrical repair kit) and a list of consumables. When repair service work is to be carried out, this should be done by qualified local personnel or the kit returned to the manufacturer for repair. Specify the language for the user's manual.

Accessories. These may include a portable conductivity meter used to measure contamination by saline intrusion or sewage pollution, a portable battery pack, a portable sterilizer kit and a solar charger. Optional extras may include testing for shigella, salmonella and *Vibrio cholerae.*

Technical complexity. Some kits require a separate portable incubator. The preferred kit housed in a robust case should be complete with built–in battery and incubator.

Testing. Prior to testing you will need a means of sterilizing the Petri dishes and preparing the culture media. You can use a glass beaker, a metal pot, a pressure cooker, a portable sterilizer or an autoclave. In addition you will need methanol (approximately 1 ml per test), distilled water (or clean boiled water), access to a laboratory balance (to weigh culture media at the base laboratory) and a 1 litre measuring cylinder or beaker. Culture media should be prepared in polypropylene bottles which may be autoclaved repeatedly at 121°C/15 PSIG. These bottles should be included in the kit.

Note: Where the mains electrical supply is 220 V and the portable generator is 110 V, order both a 220 V and a 110 V battery charger. A small magnifying glass (8× or 10×) is useful for examining the colonies.

Form for assessment of quotations: portable water testing kit

Name of manufacturer	Company 1	Company 2	Company 3
Model			
Power voltages available			
Built in battery? 72, 16 or 10 hours between charges?			
Incubator temperature 44 °C or 37 °C?			
Other tests: turbidity, chlorine, pH ?			
Solar charger available?			
Battery charger included?			
Built-in battery and incubator?			
Local agent?			
Consumables available? Culture media, pad dispensers, membrane dispensers?			
Spare parts available locally?			
Cost			
Overall assessment of quotation: good/medium/poor			

Comments

.....

.....

.....

.....

Section 2

Energy requirements for laboratory equipment

Chapter 8
Energy supplies and requirements

General

Energy may be provided by many sources, including hand power, combustion powered generators, batteries and solar energy systems (photovoltaic systems). A main power supply is not always accessible everywhere in some developing countries and generators may not always be available. Portable laboratory equipment powered by batteries are available for use in remote areas and in emergency and disaster situations. In certain situations, the installation of a photovoltaic system will provide a suitable source of energy. Batteries and solar energy supply systems will be discussed in some detail in this chapter.

Hand power

Energy provided by hand power has served laboratories for many years, e.g. the centrifuge operated by a hand crank. The mechanical timer is a familiar item of laboratory equipment. More recent developments are a centrifuge operated by four braided nylon cords and a radio powered by a clockwork spring mechanism (clockwork radio). In many developing countries radio stations are used to spread health messages. The clockwork radio was designed to overcome the problems of people in developing countries where mains power and batteries are hard to find. The clockwork radio is powered by a generator housed in a cassette. Turning the handle winds a steel spring to drive a generator and electric motor, with the speed regulated electronically. By winding for just 20 seconds there is an energy yield of up to 60 minutes of radio transmission.

Greater research and development is needed for appropriate energy sources to provide power for simple, safe and inexpensive laboratory equipment.

Combustion powered generators

Electrical energy can be provided by a diesel, liquid petroleum gas (LPG) or petrol generator. The generator may be alternating current (50 Hz or 60 Hz, single or three phase, 110 V or 220 V) or direct current (12 V, 24 V or even higher), or even a combination of these. Electrical energy is also available from an auxiliary alternator/ generator driven from the engine in a car, truck, or boat, usually at 12 V or 24 V DC. A voltage regulator and sometimes a current regulator will need to be placed between the

generator and the batteries being charged. The electricity can be fed into rechargeable wet cell batteries. The type of current available will limit the selection of laboratory equipment; for example, an instrument that requires direct current can be supplied at the correctly matched voltage with energy from batteries or from an alternating current system with AC/DC converter.

For instruments working with a low voltage direct current, the high voltage from the direct current system has to be converted by means of a DC/DC converter. Alternatively, for instruments running on alternating current, the direct current must be converted into alternating current by means of an inverter. Inverters are heavy and expensive instruments and significant losses of electrical energy occur in the conversion process although modern switch mode types are very light and efficient. Therefore, it is preferable to use DC equipment of appropriate voltage rating to avoid the need for an inverter.

A new option available is fuel cells powered by gas fuel or waste heat from another process, generating electricity without moving parts. Fuel cells which use methanol as their energy source are being developed.

Note: For details on the range of power generators available refer to the UNDP/IAPSO catalogue *Power generators for development assistance.*

Safeguards against power surges and power cuts

Lightning

In areas where electrical storms are frequent occurrences, a strike of lightning may cause damage to electrical laboratory equipment. It can also cause injury to the operator who attempts to use equipment during lightning. The lightning can reach equipment by the power supply cable and other ways. Lightning protection can be provided in various ways.

A lightning rod should be secured on the highest point of the building where the laboratory is located and also at least 2 m higher than the top of any solar panels. The rod has several metal spikes pointing upwards and connected to earth by the most direct and straight route possible (no bends, kinks or joints) by a thick metal conductor. The conductor to earth should be capable of carrying 50 A. A good earth can be made by driving a 2 m metal water pipe or metal rod into the ground, keeping the ground damp and securely bolting the conductor to it. The expectation is that lightning will take the easiest path to earth via the rod, thus safeguarding the building on which it is mounted. The safest method of protection is to always disconnect electrical plugs from the wall sockets before leaving the laboratory and during a thunderstorm. Do not leave the plug within 30 cm of the wall socket.

A metal oxide varistor (MOV) is used in solar module control units to give the circuits protection against lightning strikes.

Power disturbances

Power disturbances may be caused by increases of power, decreases in power and power failure. Laboratory equipment such as colorimeters, spectrophotometers, pH meters and electrophoresis chambers can be damaged by power spikes, surges, sags and noise (see Table 8.1). Although most electronic instruments are fitted with spike protectors, you cannot always rely on them. During a sag the centrifuge motor struggles to operate on the reduced voltage. Frequent, rapid variations in supply voltage may overload the motor, causing permanent damage. Protection can be offered by surge/spike suppressors, filters (or line conditioners), voltage regulators or uninterruptible power supply units. However, a surge suppressor filter that is only connected to the mains socket will not provide adequate protection to equipment that is electronically controlled. It is recommended that you consider taking advantage of the added protection that filter protectors can provide, plus a voltage stabilizer.

Power fluctuations

A voltage stabilizer (surge suppressor plus filter) can offer protection against power fluctuations but does not cover power cuts. A voltage stabilizer monitors the power being provided from the wall outlet, removes surges and spikes and maintains a continuously

TABLE 8.1 **Power disturbances**

Event	Cause
Spike: instantaneous, dramatic increase in voltage; also referred to as an impulse back	Typically caused by lightning strike; can also occur when utility power comes on line
Surge: short-term increase, dip or decrease in voltage, typically lasting at least a 1/20 of a second	High-powered electrical motors, such as air conditioners and appliances in the vicinity; when this equipment is switched off, the voltage is dispersed through the power line
Sag: short-term decrease in voltage levels; also known as a brownout	Typically caused by the start-up power demands of electrical motors and tools or excess load on the system
Noise: more technically referred to as electromagnetic interference (EMI) and radio frequency interference (RFI); electrical noise disrupts the smooth sine wave expected from utility power.	Caused by lightning, load switching, generators, radio tramsmitters
Blackout: total loss of utility power; also referred to as a power failure or power cut	Excessive demand on the power grid, lightning storms, earthquakes, etc.

regulated alternating current output to the load device (laboratory instrument). It is not a "surge suppressor" from an electrical store. It does not provide power back-up if line power fails. Do not get a surge suppressor only—buy a unit that includes a noise filter and EMI/RFI suppression. A good voltage stabilizer should:

- provide a true sine-wave AC current output signal
- suppress spikes and surges, and
- provide line regulation (control the output voltage so it is always within an allowable range regardless of the input line voltage).

Blackouts

Protection against blackouts can be provided by a control system which automatically switches to battery supply when a mains power supply fails. This is known as an uninterruptible power supply unit (UPS) . This unit can also cover power fluctuations. The following can occur if there is a blackout:

- loss of sample; can the sample be recollected?
- loss of time (the time needed to recollect the sample)
- possible damage to sensitive electronic equipment when the power comes back on
- interference from other equipment.

An all too common situation in laboratories in developing countries is when tests have been set up for reading in the colorimeter and then there is a power cut. You do not know how long it will be before the power comes back on but all you need is 10 minutes to read the absorbencies of the solutions. In the event of a power failure, an on-line UPS unit will provide enough time to complete using the equipment. In critical equipment situations where several items are run off a DC system, some form of UPS may also be needed, e.g. separate dedicated battery.

A UPS provides AC filtered power plus surge/spike protection. This emergency power system protects electronic equipment, e.g. colorimeters, spectrophotometers, electrophoresis chambers, pH meters, from damage because of power failures. Anyone who has not been able to read tests in a colorimeter due to a power cut will appreciate that the added cost of a UPS unit is a wise investment.

A UPS corrects line disturbances and maintains power to the load device (laboratory instruments) even if the power line fails completely. The back-up power is provided by a battery; therefore back-up is provided for a limited period of time (usually approximately 5–15 minutes) but can be extended to hours if necessary with extra batteries and internal chargers.

Two types of UPS are mentioned here: "on-line" (full time) and "off-line" (standby or back-up). An on-line UPS is the recommended type of supply. A good UPS should provide continuous monitoring and conditioning of the power and provide a regulated voltage plus battery back-up without any loss of power whatsoever.

An off-line UPS has little or no effect on line voltage until the power line falls out of certain limits, possibly not until a problem has already occurred, and may provide no back-up for a fraction of a second until it starts.

A small 10 W high-efficiency lamp connected to the UPS unit will give instant back-up light during a power cut. To prevent overload when other (non-dedicated) equipment is mistakenly connected to the UPS, use a "different" type of electrical plug for equipment dedicated specifically for the uninterruptible power supply unit. This dedicated plug may have oblique flat blades for earthing whereas all the other plugs have round or rectangular pins. Choose a UPS unit with an overload circuit breaker rather than a fuse.

Consider future needs as well as present requirements when buying a UPS. Where there are a number of electrical instruments requiring protection, it is better to have two UPS units than one.

Link equipment required for urgent work to one UPS unit. Remember to test the unit regularly by pulling the power plug out and seeing if the instrument is working for at least part of the time.

Your decision on the size of UPS unit to choose will depend upon the following:

- the time needed to use the equipment, e.g. for a colorimeter it is the time needed to read the absorbencies;
- the actual electrical *power requirements* (not maximum power rating) of the equipment, the voltage and frequency. For a spectrophotometer this may given as 240 VAC; 50/60 Hz; 90 VA. If you do not know the power requirement, get an electrician to check the power level of the instrument using a clamp meter.

Sizing an uninterruptible power supply unit means determining how big your uninterruptible power supply unit needs to be to protect your power loads. Make a list of all electrical equipment that requires protecting and for how long it needs protecting. Each instrument has a voltage and amperage requirement (these figures can be found on the instrument's data plate). Multiply these figures together to determine VA (line voltage × amps = VA) Some instruments may list their power requirements in watts (W). To convert to VA, multiply watts by 1.4 (or divide by the power factor if given). Add the VA requirements for all your equipment and allow extra for peak surges. Choose a UPS unit with a VA capacity at least as large as your system's total requirements, or larger to provide the run-time needed, and a time capacity to comfortably cover requirements.

Ask suppliers about purchasing a second-hand UPS unit. It may be possible to get a second-hand model for up to half the price of a new one but watch out for old batteries fitted as they may have limited life and be unreliable. Insist on new batteries being fitted and tested.

Residual current devices (residual current circuit-breakers, earth leakage devices or circuit breakers) work by breaking the circuit when a short circuit to earth causes a difference in the current between the two conductors. They are recommended in mains systems that are earthed to provide better protection for users. A good unit will disconnect automatically with the current leakage through a person touching a live conductor, without injury or leakage.

There are many power protection systems on the market and, although in some cases these are expensive, the cost should be judged against the inconvenience of re-collecting specimens and the cost of repair or replacement parts or even the cost of a new machine. Seek advice from the manufacturer or local experts if available.

Recommended means of protecting equipment in the laboratory

- Having an on-line uninterruptible power supply unit (not a stand-by unit) for protection against power failure and blackouts
- Having a voltage stabilizer (surge suppresser plus filter) for protection against surges/spikes and noise
- Having a true sine-wave output
- Matching equipment with the power supply
- Filtering out power spikes

Batteries

Dry cell batteries

Anyone who uses portable laboratory equipment powered by batteries will have to decide which batteries to use. The laboratory worker undertaking regular mobile clinic work may choose rechargeable batteries for the haemoglobinmeter. Someone doing the occasional haemoglobin test will choose a use-once battery. Dry cell batteries are used extensively worldwide to power radios, torches (flashlights) and cassette players in communities without electricity. In the laboratory, dry cell batteries are used to power colorimeters, balances, haemoglobinmeters and pH meters.

Electricity may be stored using two types of dry cell battery: non-rechargeable (primary) and rechargeable (secondary). The following notes set out the characteristics of dry cell batteries with their advantages and disadvantages.

Non-rechargeable dry cell batteries

Primary cells or use-once batteries are the type most common in electronic watches, calculators, torches, radios, cameras and many other portable appliances. Not only is the disposal of these batteries a risk to the environment, but they are the most costly form of electrical energy available.

The larger a cell, generally, the longer its life. D size cells weigh more than six times as much as AA cells, lasting much longer although they both put out similar voltage. When deciding on which battery to buy, the following options should be taken into consideration, in order of preference:

- Use battery packs as supplied and recommended by the equipment suppliers. Remember the warranty might be invalidated by not using recommended batteries.
- Match characteristics of equipment, i.e. voltage operating range, current (peak) requirements, operating time, physical housing, terminal arrangements, when choosing alternative battery packs.
- Match electrical characteristics required but in a separate pack (connected by a lead). This system could be chosen either to use alternate batteries which do not fit the space, or to use a higher capacity battery pack for extended operating time, e.g. five nickel-cadmium cells in place of four zinc carbon cells.

Battery application and selection guide

Certain selection features may be used to indicate your particular operating conditions when ordering a custom-designed dry cell battery. The data sheet in Figure 8.1 can be copied and filled out to assist you in determining what sort of dry cell battery to purchase.

Zinc carbon batteries

Zinc carbon batteries are the most common type of general purpose cell. They are suitable for light to medium load which is not applied continuously. They are also suitable for low drain uses such as in calculators and clocks. They are not economical for most applications. Allow zinc carbon batteries to rest between use and they may recover some capacity. They have a rated voltage of 1.5 volts per cell.

Electrical characteristics of equipment

Voltage range..... V max.....V min. at full charge.....when discharged .....

Continuous drain ..... mA (V max.) ..... mA (V average) ..... mA (V min.)

Intermittent/pulse drain ..... mA (V max.) ..... mA (V average) ..... mA (V min)

Intermittent time conditions: operating time ..... non-operating time .....

Temperature (°C)/relative humidity (%) conditions

During use .....Tmax. ..... min; .....r.h. max. .....r.h. min.

During storage .....T max. .....min.; ..... r.h. max. ..... r.h. min.

Size and weight (able to be accommodated in equipment)

Outer diameter, height, length, width, weight .....

Battery life required by equipment

Total duration time .....

Total use period (including rest time) .....

Storage period .....

Terminal arrangements

Tab, tab-pin or pin, button, can, other .....

Length and gauge of lead wires .....

Lead .....

Type of polarity of connectors .....

Other

Atmospheric pressure .....

Mechanical conditions (vibration, shock) .....

Figure 8.1 **Points to consider when selecting a dry cell battery**

Advantages:

- cheaper to buy per cell
- readily available, but being replaced by the improved types described below.

Disadvantages:

- lose their charge quickly if used to operate high current demand appliances
- short shelf life—lose efficiency after 12 months
- work poorly in very hot or cold temperatures
- have a single use before being discarded
- can leak if left in equipment for some time.

Zinc chloride batteries

Zinc chloride batteries are termed heavy duty batteries. They are adequate for low-drain uses such as in a wall clock. They have a rated voltage of 1.5 volts per cell.

Advantage:

- cheaper to buy than alkaline batteries.

Disadvantages:

- only last between 25% and 33% as long as alkaline batteries
- have a single use before being discarded
- can leak if left in equipment for some time.

Alkaline batteries

Alkaline batteries are good all-round batteries, appropriate for virtually any electrical device. They are best for heavy loads or for long periods of use. They have a rated voltage of 1.5 volts per cell.

Advantages:

- work well in devices requiring a lot of power
- long life—last much longer than zinc carbon batteries
- long storage life so buy when cheap in sales and store them.

Disadvantages:

- cost-effective but still expensive
- have a single use before being discarded.

Alkaline batteries are recommended for most laboratory equipment but rechargeable batteries are cheaper over a long period.

Lithium-manganese dioxide batteries

Lithium-manganese dioxide (Li-MnO_2) batteries are 30% lighter than alkaline batteries. They are extremely reliable, holding their charge longer than alkaline batteries. They have a rated voltage of 3 volts per cell.

Advantages:

- very long storage life—manufacturers claim up to 10 years
- constant voltage during discharge
- do not contain mercury or cadmium
- wide operating temperature range of between –40 °C and +60 °C
- strong leakage resistance.

Disadvantages:

- much more expensive than nickel-cadmium rechargeable batteries
- have a single use before being discarded.

Rechargeable dry cell batteries

Nickel-cadmium batteries

Nickel-cadmium batteries (Ni-Cd) are rechargeable cells which can be used for the same purposes as zinc carbon and alkaline batteries but note the lower rated voltage per cell, i.e. 1.2 volts per cell. Table 8.2 shows the various types of nickel-cadmium battery and their applications.

Batteries with the highest capacity should be chosen. There are nickel-cadmium batteries that are the same size but have different capacities. The AA size battery is available from 500 mAh (milliamp hours) up to 700 mAh capacity. Size D rechargeable batteries are available as 4000 mAh and 5000 mAh. Check the label carefully when buying D size nickel-cadmium batteries as the more expensive 4000 mAh cells give a far longer life (and better value for money) than the cheaper 1200 mAh cells.

Nickel-cadmium dry cell batteries are capable of supplying relatively large currents for their size. Although manufacturers claim they can be recharged up to a thousand times, this is only true if all charge is drained from the battery before recharging. If it is topped up while it retains some charge, it develops a "memory", only delivering back the amount of charge used to top it up. Erase the memory by using the batteries several times in another device, or fully and deeply discharging them occasionally.

Discharging each cell to a level where very little energy is left is only partly effective with single cells and with new and well matched cells in battery packs. Not all cells in a battery pack will age equally or charge and discharge equally at different operating

TABLE 8.2 **Nickel-cadmium cell types and their application**

Battery cell type	Features	Applications			
		Scientific	Lights	Tools	Office devices
Standard	Wide range of applications, wide range of sizes; 15 hours standard charge, 5 hours quick charge	Yes	Yes	No	Yes
Rapid charge ("R")	1.5 hours rapid charge	Yes	Yes	Yes	Yes
High rate and rapid charge ("P")	High rate discharge; 1.5 hours rapid charge	No	Yes	Yes	Yes
High capacity ("E")	Capacity is 1.2 times the standard cell; 15 hours standard charge	Yes	Yes	No	Yes
Super high capacity and rapid charge ("S")	Super high capacity (40% more capacity in same size); 1.5 hours rapid charge	No	Yes	No	Yes

temperatures. In the end some cells will only be partly discharged when others are deeply discharged.

A battery should not be put on the charger for a few hours only. It is better to carry a spare nickel-cadmium dry cell battery which can be put on the charger when the other battery is being used. Slow chargers (12–16 hours) are safer than fast chargers (4 hours). Do not try to renew a "tired" nickel-cadmium dry cell battery by dropping it onto a concrete floor.

In tropical climates nickel-cadmium batteries have an increased rate of self-discharge when stored in conditions of high temperature and humidity.

Tip: Store them at a low temperature in a refrigerator, but keep them dry.

Nickel-cadmium dry cell batteries are the cheapest option over a long period. In temperate climates they lose about 1% of their charge daily (more in tropical climates), even when they are not being used, so they are not suitable for laboratory instruments which are idle for long stretches. Check the required voltage rating as their slightly lower voltage makes them unsuitable for some equipment.

Advantages:

- cheapest option over time
- long life—can be recharged hundreds of times

- better for the environment, if recycled
- have flat discharge voltage characteristics.

Disadvantages:

- initially expensive (including charger)
- inconvenience of charging
- rated voltage of 1.2 volts per cell (lower than primary cells)
- short life between charges
- suffer a constant loss of capacity even when not in use
- abrupt voltage drop at end of discharge
- not environmentally safe as they contain cadmium which is a highly toxic metal
- lose their charge more quickly than other types of battery during storage.

Maintenance

Nickel-cadmium dry cell batteries do not always work reliably in tropical climates. The reason for this apparent unreliability is an increased rate of self-discharge rather than less efficient charging of the battery at higher ambient temperatures. This may be partially circumvented by taking the following precautions.

- Nickel-cadmium dry cell batteries should be charged shortly before being used and at low ambient temperatures (e.g. in a refrigerator or in a specially constructed recharging box). For example, only 62% of the potential energy is made available from a nickel-cadmium battery that is charged at 40 °C. Choose a temperature range of between 10 °C and 30 °C for setting the location or placement of the battery during charging. Make sure that the cells and connections are kept dry and clean. Keep a note of when cells are recharged and do so regularly if the storage period is extended (for example, over four weeks).
- Charged nickel-cadmium dry cell batteries should be stored at a low temperature as they have a high degree of self-discharge when stored at elevated temperatures. For example, a nickel-cadmium battery stored under dry conditions for two weeks at 40 °C will have a residual capacity of 32%. High humidity will accelerate the self-discharge of a nickel-cadmium battery. Storage at temperatures below –20 °C, above 35 °C or in high humidity may result in deteriorated performance, leakage or rust. Store charged batteries within the temperature range of between –20 °C and 35 °C where the humidity is low and there is no corrosive gas. After long storage, battery capacity may be reduced. Repeated charge and discharge of batteries should rectify the decrease and result in original capacity.

Tip: Use recently charged nickel-cadmium dry cell batteries when using portable equipment. For back-up take some alkaline batteries.

Nickel-cadmium dry cell battery chargers

If possible, purchase the correct charger as recommended by the battery manufacturer to match the type voltage and capacity of the battery to be charged. Most equipment powered by rechargeable batteries will have a customized battery pack and charger, with the charger sometimes integral with the equipment. Chargers have to charge batteries with the correct amount of current and the correct voltage. If these are too high or too low, the batteries can be damaged. The charging current should be 10% of the capacity (700 mAh = 70 mAh charging current)

Choose a battery charger with a light to show when the batteries are being charged—a useful feature since dirty contacts, for example, would stop the batteries charging without you knowing. Some chargers can charge some battery sizes quickly in 1–5 hours. These use high current and pose no problem unless the batteries exceed the given charging time. Overcharging at this high current can be more harmful to the batteries than leaving a normal charger on for too long. Overcharging is not acceptable if maximum battery life for nickel-cadmium dry cells is desired.

There are several types of dry cell battery charger.

- **The standard constant current charger**. Most nickel-cadmium chargers require the user to take responsibility for switching off the charger and disconnecting the battery at the end of the charge. This makes it practically impossible to avoid overcharging the batteries, thereby reducing their life expectancy. Therefore it is important to keep a note of the time of charging and learn from experience how long a good charge takes.
- **Constant voltage charging**. This is the safest method. The current capacity of the charger should be matched to the battery capacity, e.g. mAh = 10% of battery MAH rating. The actual current will taper off during the latter part of charging, so longer time is required (16 hours or more). The charger may be a two-rate type which switches down to a float voltage near the end, enabling the batteries to be left on float until required.
- **Specialized chargers,** for example the Reflex or BURP charger. The patented Reflex or BURP charge method consists of a positive charge pulse followed by a high current, short duration discharge pulse. By using a charger circuit with the Reflex method it is possible to obtain a dramatic increase in the charge/discharge cycles of nickel-cadmium dry cell batteries. There is no need to run instruments/appliances until the batteries are flat to avoid the memory effect. It is possible to recharge the batteries after each use and to obtain a dramatic increase in the charge/discharge cycles of

nickel-cadmium batteries, to at least 3000 cycles if reasonable care is exercised. This nickel-cadmium and nickel metal hydride fast charger covers a battery voltage range from 1.2 V to 13.2 V at charge currents from 0.1A to 9.0 A.

The batteries should be easily inserted and taken out, the plus and minus poles clearly marked and the charger designed to stop putting the batteries in the wrong way round. Manufacturer's terms for various chargers include standard charge, supercharger, fast charge, high capacity.

Preferably choose equipment with combined mains/battery operation. This equipment may be switched from mains to battery when primary batteries are inserted, or may have an external or internal mains power pack which also charges internal secondary batteries.

When the source of electricity is from a generator which operates for only a few hours each night, choose rapid charge batteries and a charging system.

Lithium-ion battery

Rechargeable dry cell lithium batteries include lithium-ion (Li-ion) batteries that contain liquid electrolytes and the more recently developed lithium battery based on solid materials. These flat and very thin batteries are used mainly for small applications, e.g. small computers and mobile telephone systems. Lithium-ion batteries can be recharged after even brief periods of use with no loss of capacity and there is no memory effect. A specific charger is required. Chargers currently used for nickel-cadmium batteries are not compatible. The storage temperature for lithium-ion batteries is between –40 °C and +70 °C.

Advantages:

- safe—cannot leak gases or liquids because they are entirely solid
- store more power and last longer than nickel-cadmium batteries
- long shelf-life of up to 10 years
- lightweight
- can be recharged more than 1000 times
- environmentally safer as they do not contain lead, nickel, mercury, cadmium or cobalt.

Disadvantages:

- more expensive than nickel-cadmium batteries
- not available in cylindrical form.

Alkaline dry cell batteries

These refer to the rechargeable version. They are available as size AA, C, or D size cells. They require a charger giving a constant voltage and taper charge—a different

charger from that used with nickel-cadmium batteries. They can work over a temperature range of between –20 °C and +60 °C.

Advantages:

- all the advantages of normal alkaline batteries
- no initial charging, unlike nickel-cadmium batteries
- greater capacity than nickel-cadmium batteries
- less expensive than nickel-cadmium batteries
- low self-discharge rate
- environmentally safe as they do not contain mercury or cadmium.

Disadvantages:

- can only be charged 100 times which is less than nickel-cadmium batteries
- require a special charger.

Nickel-metal hydride dry cell batteries

Nickel-metal hydride dry cell batteries (NiMH) require a longer charging time than nickel-cadmium batteries. Nickel-metal hydride batteries make a useful alternative to nickel-cadmium batteries.

Advantages:

- higher capacity than nickel-cadmium batteries and so can outlast them
- do not contain the highly toxic cadmium
- no memory effect.

Disadvantages:

- expensive and cost more than nickel-cadmium batteries
- lower maximum discharge current than nickel-cadmium batteries and so are suitable for low-current devices
- should not be overcharged because of the danger of gas pressure in combination with high charge currents.

Note: A super-iron battery which has a low-drain rate is being developed.

Sealed valve regulated lead acid batteries

Sealed valve regulated lead acid (VRLA) batteries are available in small sizes (e.g. 6 V, 1–3 Ah) equivalent in rating and size to other battery packs and may offer a cost-effective alternative to primary or secondary cells. If extra capacity between charges is

wanted, consider a separate purpose-made battery pack using sealed valve regulated lead acid batteries. This option can also be used if there are several pieces of equipment with the same rated voltage which could be run off a common battery.

Storage of dry cell batteries

To store dry cell batteries, bundle them together with a rubber band and either store in a non-metal container with a tight fitting lid or put in a well-sealed bag to keep moisture out. Do not allow the batteries to touch metal objects during storage or they may lose power. Store batteries in a refrigerator and let them reach room temperature before using.

Environmental issues

Batteries contain toxic heavy metals such as lithium, mercury, lead acid and nickel-cadmium. In the past, dead batteries have been dumped in landfill sites and have caused serious contamination. Batteries containing these substances soon cause serious contamination and need to be disposed of more carefully. The cost of this will raise their price.

The plastic battery

An all-plastic battery is being developed. The components are nontoxic, making the batteries easy to manufacture and dispose of safely. They can be recycled to make new batteries.

Important points

- Change all the batteries used together in one piece of equipment at the same time.
- Do not mix new and recharged cells in the same equipment. The differing capabilities of the cells could result in differential flattening and reversal of the polarities of some of the cells, leading to rupture and leakage.
- Do not use a discharged cell with several other fully charged cells. Label sets with the date as you buy as this way you can keep track of the flat ones.
- Do not attempt to recharge ordinary disposable dry cells with a charger unit.
- Do not open sealed battery packs.
- Remove batteries when the equipment is not likely to be used for several months.
- Do not put batteries in the fire.
- Make sure that disposal of worn out batteries is done correctly and safely, away from children, pets and water.
- Keep batteries away from heat.

- Always charge new batteries for 24 hours before use as they are sold uncharged.
- Give priority to the cost-effective power provided by rechargeable cell batteries such as nickel-cadmium, nickel-metal hydride, lithium manganese oxide and alkaline batteries.
- Store or carry batteries in insulating wrappers or cartons to avoid short circuiting the terminals and risk of fire.

Solar energy

Remote area power supplies

Health facilities do not have to rely on one form of energy. A combination of, for example, generators, kerosene burners for autoclaves and photovoltaic supply for lighting and water pumping are acceptable options.

A laboratory can be supplied with an alternative to mains electricity from a number of other generating sources, the main alternatives being:

- electricity generated by solar cells (photovoltaic modules)
- wind turbines
- small (micro) hydroelectric generators
- petrol or diesel generators.

A combination of two or more of the above can also be used. This is called a "hybrid system". In Cambodia at the Oudong District Hospital the hybrid system consists of a photovoltaic array, battery bank and inverter with a small diesel generator set for back-up. The primary purpose of the power was to provide vaccine storage to meet WHO standards, emergency lighting for the operating theatre and delivery room and power for microscopes, a blood separation centrifuge, other laboratory equipment and a battery charging facility.

African countries have for many years led the way in the use of solar refrigerators for the vaccine cold chain. In Eritrea, Sudan, Uganda and Zaire it is increasingly common to see solar panels on the roofs of health clinics in even the most remote villages. Solar modules that generate electricity for solar refrigerators are also being used for lighting systems and laboratory equipment. Should there be plans to install a solar vaccine refrigerator in your hospital/health centre, there should be a discussion as to the feasibility of extending the system to the laboratory.

Solar pumps are used to pump water from bore holes, open wells, rivers and canals in rural areas. The advantage of a solar pump set-up is that such a system does not need a battery back-up if there is a tank or pond for water storage so long as a tank storage system is used.

If your local administration and health authority are in the process of making the decision of whether to use solar power in your laboratory you need to know the advantages and disadvantages.

Advantages:

- There is a one-time cash outlay to purchase solar panels.
- Modules are reliable, sturdy and lightweight.
- There are no moving parts to wear out or break.
- The modular system design can be enlarged as money permits and needs require (with appropriate engineering design).
- Modules can be used in conjunction with mains power, a generator, wind or hydro-power.
- The reliability of photovoltaic modules is significantly higher than diesel generators or wind generators.
- Operation and maintenance requirements are simple.
- Running costs are low.

Disadvantages:

- The initial cost is very high.
- It requires careful installation and maintenance if it is to function properly.
- Electricity is not produced at night.
- Very cloudy weather significantly reduces power production.
- Specialized batteries are not widely available.
- Storage batteries must be serviced.
- Spares are not widely available.
- Maintenance staff require special skills and technical training.
- An inverter must be used to power standard AC appliances.
- A back-up generator may be needed to maintain batteries if the solar panel system is undersized for the loads.

There is no doubt that, at a technical level, a photovoltaic system can play a significant role in meeting the energy needs of primary health care. It can bring the convenience and versatility of electricity to health clinics and laboratories in areas where it is otherwise unobtainable. Should a decision be made to use a photovoltaic system to power your laboratory give special attention to the following.

- Proper design and installation of the system. Insist that the system is installed by experienced technicians experienced in photovoltaic systems.
- Operator training. Laboratory and clinic staff need training in the operation and maintenance of photovoltaic arrays. Staff should be able to recognize faults. Insist that a staff training course is part of the initial funding request.
- Adequate funding. Too often only the initial capital cost to purchase equipment is included in the project/programme budget. Include in the initial funding request adequate provision for installation, training and/or maintenance.

Solar energy supply systems

Solar power systems are most useful where energy requirements are relatively low. Solar power systems are appropriate for use in developing countries where there are constraints to the effective delivery of basic health services such as:

- no electricity
- no lighting
- no effective water distribution system
- limited supply of fuel
- poor support for laboratory services (especially those concerned with tuberculosis and malaria)
- restriction of microscope use to daylight hours causing delays in diagnosis of disease.

A photovoltaic cell is a basic device that converts light directly into electricity. The electricity generated from solar energy can be stored in batteries or used directly to power electrical equipment. Good photovoltaic cells convert about 13% of the sun's rays into power. The amount of energy which is generated depends upon:

- the site (hours of sunlight and temperature)
- the position of the array (direction and tilt)
- the type and number of modules in the array
- the cleanliness of the array.

The solar panel, in conjunction with the controller or regulator, maintains the battery at full state of charge until it is required. The controller monitors the charging process and prevents overcharging and discharging of the batteries. When AC power is required, the inverter converts the 12 V DC power from the battery to 230 V AC. Equipment/lights can then be plugged into the inverter. The most common situation in small laboratories is to use equipment already manufactured to operate from 12 V DC power without having to use an inverter.

A solar energy supply system comprises three basic functions:

- conversion of daylight into electricity by the solar modules
- storage of energy by solar batteries for use when too little or no energy is supplied by the solar module (e.g. during the night)
- control of the charge and discharge process of the solar battery by an electronic charge controller (regulator) to safeguard the battery lifetime and protect the other system components.

Selection of components

A typical solar system requires solar modules, a mounting structure, a charge controller, batteries, cable and an inverter if an alternating current system is used.

Solar modules

Solar modules come as standard in nominal 12 V packages (36 cells per module). Solar panels can be wired together in parallel which adds current so two will give out twice as much as one and in series which means the voltage doubles; one gives 12 V, two 24 V DC etc. The advantage is that extra panels can be added as more money is available. If possible, allow space on mounting frames for more panels to be added. Do not use so called "self-regulating" panels which simply have fewer solar cells.

Some properties of commercially available solar panels are given in Table 8.3.

Tip: Very often it will be cheaper to use the largest panel for your needs.

TABLE 8.3. **Properties of commercially available solar panels**

Properties of commercially available solar panels	Panel with crystalline silicon cell	Panel with amorphous silicon cell
Power of largest available panel	83 W	20 W
Expected life span	25 years	10 years
Guaranteed life-span	10–20 years	5 years
Mechanical stability	Good	Fair
Reliability	Good	Variable
Power supply from 1 m^2 (in full sun)	130 W	60 W

Most photovoltaic cells are made of silicon, a material extracted from sand. The cells are encapsulated between glass and a tough resin back for protection and are held

together by a stainless steel or aluminium frame to form an electrical module. It is the module which forms the basic building block of a photovoltaic system. Where larger amounts of electricity are required, modules are connected in series to form a solar array. An array may vary from one or two modules, with an output of 10 W or less, to banks producing several kilowatts or even megawatts of power.

There are two different kinds of solar panel commercially available, crystalline silicon and amorphous silicon. The panels differ in their physical properties and cost. Amorphous silicon panels are less expensive but are less effective in producing electricity than crystalline silicon panels. The efficiency of amorphous panels is about half that of crystalline.

Note: A solar cell based on titanium dioxide has been developed with an energy efficiency double that of currently available photovoltaic cells.

All 36 cell panels require a controller (regulator). Smaller panels can be connected directly to the battery, with care to avoid overcharging.

Mounting structure

Solar panels must be installed so that they get the maximum exposure to light all day. To get the most out of the panels they should face the Equator. Shadow will reduce efficiency of the panel. Partial shade of the modules can cause heating of the shaded cells and damage them. The panels should be tilted roughly at the angle of latitude you are on the map, at a tilt angle from horizontal of 15° or more. The minimum tilt of 15° ensures that rainwater does not build up and instead helps to wash dirt off. At latitudes higher than 15°N or 15°S, there is an optimum tilt angle for each site which depends on the weather conditions through the year. You may use a higher tilt angle so the panel works better in winter.

Theft can be minimized by mounting panels high on a pole mount of approximately 6.1 m height, or welding the frames for the panels on the inside and outside of the roof surface. Place the panel on the sunny side of the building.

The back of the panel must be freely ventilated. The minimum distance between the back of the panel and the surface of the supporting construction should be 5 cm to avoid overheating the panel which will reduce the efficiency of the energy production.

Charge controllers

A charge controller or regulator maintains the desired power output from the solar array to the battery bank. It keeps the batteries from being overcharged. This is necessary because properly designed medium or large solar electric systems will produce excess power at certain times simply because of differences in solar input (daily and seasonally) or weather variations. Some controllers also prevent the batteries from being too deeply discharged by shutting off the load circuits which is an essential part of the solar energy

supply system. You will need to regulate your power production to protect your batteries and ensure their long and useful life.

A good controller adapts the maximum voltage of the battery to the change in temperature of the battery environment. This adaptation prevents loss of water in the battery from evaporation. A charge controller is essential to avoid loss of excessive amounts of electrolyte, particularly in hot arid areas, which can result in irreparable damage to the batteries. It is important to keep a spare charge controller in stock in case of breakdown.

Attention must be paid to the stability of the controller under tropical conditions. It is advisable to choose a controller with an integrated digital display indicating the battery voltage and lights to show its operating condition.

Batteries

The main criteria for a solar battery is that it must withstand cycling, that is energy going in each day and energy coming out without greatly reducing life. A 12 V car or truck battery will work with a solar system but not last long. The battery types recommended for use with photovoltaic systems are lead-acid and nickel-cadmium, designed for deep cycling duties.

Cable

Solar system components should be kept close together as power is lost on long cable lengths. Cables should be as thick as possible in low voltage DC wiring. In most cases, separate cabling is needed rather than making use of existing building wiring.

Inverters

A power inverter is used in a solar electric system to convert low voltage DC electricity from the batteries into mains voltage AC power. This is needed when using instruments that only work from mains voltage AC power. The inverter has to be rated to cope with the peak appliance loads (see Power output of inverter). Limitations of operating a laboratory using direct current entirely include the limited availability of equipment which can use DC voltage.

The inverter consumes some power itself. This adds to the total load that the photovoltaic array must operate (see How to calculate your energy consumption).

Types of inverter

- **Mechanical** (the rotary or motor inverter). The older designs used mechanical moving parts and were prone to mechanical failure and low efficiency.
- **Solid state**. These work by using pulse-width modulation and other techniques. In the latest solid-state electronic type (with no moving parts), transistors switch the direct

current input on and off many times per second and are of high reliability. These inverters often are designed to "go to sleep" (to minimize loss of energy) until a minimum load is connected. A pulse-width modulated or switch-mode inverter gives the highest operating efficiency and is the highest surge type of inverter being manufactured today.

- **Square or sine wave.** These are older inverters producing alternating current in the form of a square or modified square wave (for simplicity and cheapness). They are rough on equipment, causing overheating, noisy running, failure to operate or damage. Sine wave inverters using up-to-date technology and microprocessors produce good quality alternating current with high efficiency. They are well worth the extra cost and essential if electronic loads are supplied.

The inverter should be installed in an easily accessible place which is cool and well ventilated. Ideally it should be made in the country in which it is being used or there should be a qualified service agent available locally.

Inverters waste some energy in the process of conversion. Efficiency ranges from 95% (that is 5% loss) at best, down to between 50% and 60%. You need to consider what power you will be using the inverter at most and to make comparison of efficiency in this range.

Disadvantages of inverters

- Good quality inverters are expensive and difficult to obtain in many countries.
- Due to the inefficiency of inverters, more solar modules will be required.
- They make the solar system more complicated by adding another unit that can fail and be difficult to repair.
- There is a reliance on the inverter to power all the loads.

Power output of inverter

An inverter can only supply to a fixed level of power. If you attempt to draw more than this, the inverter is designed to turn off to protect itself. The maximum power rating of the inverter must be higher than the total power requirements of all the instruments you wish to use at any one time. You need to determine the equipment (or equipment combination) which will draw the most power (see Tables 8.4 and 8.5).

Recommendations for inverters

Should the inverter fail you will be without all or some of your load-carrying and the capacity. Include in your plan a direct current system for emergency lights for the room, microscope and water supply.

It is strongly recommended that an attempt is first made to find a supply of low-voltage direct current instruments. If these instruments are not available, then resort to using mains voltage instruments with a power inverter.

In an important site, use two or more identical inverters and share the loads over them. One breakdown will not mean complete loss of alternating current

Selecting an inverter

Know the power requirements for the laboratory. The power requirements identify the loads and how long they will be used for, e.g. microscope lights, lights operating for 8 hours, refrigerator for 24 hours and centrifuge for 3 hours. Remember that refrigerators run on and off intermittently. (See Table 8.4.)

Are there motor and other loads with high starting surges, e.g. refrigerators, centrifuges?

Will you be operating more than one piece of equipment at once? The inverter must be able to handle the combined alternating current loads which will be operating simultaneously.

Is complex electronic equipment to be powered? This will require good quality (sine wave) power.

Installation of inverter

The connections between the battery and inverters should be as short as possible and use heavy duty wire or copper braid.

DC versus AC systems

Most AC laboratory equipment is 220/240 V AC or in the United States of America 115 V AC. All solar systems are inherently DC. It will always be cheaper to use DC appliances and equipment, e.g. 12 V fluorescent lights, a light for a microscope, 12 V refrigerators. A good quality DC refrigerator can run on a surprisingly small amount of power. Some will use as little as 300 Wh per day for a kilowatt hour at best. While DC refrigerators are generally quite expensive, they are more cost-effective.

Lighting

The use of high efficiency fluorescent lamps rather than normal tungsten filament lamps is necessary for efficient use of electricity. A fluorescent lamp can give about four times or more light output than a filament lamp with the same power rating. A fluorescent lamp has a fifth less power requirement than a normal tungsten light bulb. A fluorescent tube cannot operate on the direct current power supplied by a photovoltaic system; it

requires relative high voltage alternating current power to run. Ordinary car headlight bulbs can be used if no low energy consumption bulbs are available. Make sure that insects cannot enter the lighting fixture.

Work through the following questions as applied to the laboratory.

- What is the total number of lights in the laboratory?
- How many lights are on at one time?
- With how few lights can you get by?
- For how many hours are the lights on during each 24 hour period?
- How bright do the lights need to be?

Tip: It will always be better to use fluorescent lamps rather than normal household (tungsten filament) lamps.

The effect of irradiation and cell temperature

The power of a solar panel is dependent on solar radiation and the temperature of the solar cells. The amount of sunshine reaching the solar cells at any moment is referred to by many names: light intensity, light level, solar illumination, solar intensity, solar flux, solar radiation, insulation and irradiation. Irradiation is the term used most often.

The irradiation reaching the ground varies throughout the day with the movement of the sun and the clouds. The current from a module fixed in one position varies through the day, even when the weather is clear with no clouds. The charging current rises during the morning and falls during the afternoon. Most charging of a battery happens over a few hours in the middle of the day.

As light shines on the solar cells, they become warmer than the surrounding air, the electrical output of the module changes and so the voltage falls. Therefore, to get the maximum current output, modules should be mounted so that the air can circulate around them freely and keep the cells cool. In hot areas, more cells are recommended to compensate for this drop in voltage. For average temperatures of 30 °C, modules with two extra cells are recommended (check with the manufacturers).

Maintenance and safety of solar panels

Cleaning

Clean the front of the modules each month. Check for shadowing of the modules, especially between 8 a.m. and 4 p.m.—this may require moving obstacles or cutting back

trees and bushes. Accumulation of dust on the glass face of the solar panels reduces efficiency. Check solar panels regularly, once a week, and clean the surface of the panels with a wet cloth and plenty of water to remove dirt and dust. Do not use any chemical or detergent to clean the solar panels.

Switches, wiring and lights

Always switch off all instruments immediately after use.

Switch off all lights when not required. Time switches may be helpful. Leaving instruments and lights on will drain the batteries of power and may destroy them.

Repairing of switches, wiring and lights should be carried out only by a qualified and licensed electrical engineer.

Safety

All wiring must be of good standard and of correct maximum current rating, with circuits protected by fuses or circuit breakers. Earthing prevents electric shock. In the case of a fault, short circuit or other problem in wiring or equipment, earthing will reduce the chance of electrocution. Make sure all metal in the building where the laboratory is situated has been earthed. The laboratory should have three-wire AC circuitry for proper equipment earthing. All laboratory equipment should be chassis-earthed with at least 6 AWG (American wire gauge) wire (2.5 mm^2).

The negative DC and neutral and third wire DC portions of the system must be earthed. All five earths—the negative DC leg, the AC neutral, the AC earth wire (third wire), the equipment chassis and the array frame—must be attached to a common earth, not separately earthed.

The subject of earthing is complicated. Some people advocate unearthed systems for the DC side. Care must be taken to ensure that devices such as inverters and regulators can be earthed on input or output or both (always check with the manufacturer). Some AC systems, especially in temporary or wet conditions, are better left unearthed and supplied through an isolating transformer. In some equipment, sensitive earth leakage protection circuit breakers (now readily available) are the best protection. Local electricity standards and regulations may dictate the course to follow. Get qualified expert advice on the best system for the circumstances at the site. A metal pipe or rod should be driven at least 60 cm into the earth near the equipment and connected securely by 10 AWG (5 mm^2) wire to the earth.

Batteries for photovoltaic systems

Batteries consist of cells in series, each nominally rated 2 V (lead acid) or 1.2 V (nickel-cadmium). As a result, a 12 V battery will have 6 or 10 cells respectively.

Check-list for earthing

- ☐ Earth on the DC negative
- ☐ Standard earthing on the AC with neutral and earth wire at supply point
- ☐ Array frame earth
- ☐ Equipment chassis earth

Batteries come in two common voltages: 6 V and 12 V and have different capacities. Individual cells are also available. It is possible to connect these batteries into different arrangements to give the required capacity and voltage the laboratory system requires. Usually 12 V batteries, about 100 Ah (weighing about 35 kg), will be most convenient.

The self-discharge rate of a wet lead acid battery is typically between 15% and 20% per month (sealed lead acid about 3% per month). This means that a battery will lose some of its power just without being used. New batteries are about 90% efficient and of lower capacity (70–80%). That is, for every 110 Ah put in, 100 Ah of stored energy can be expected. Batteries near the end of their useful life can be as low as 50% efficient. If you regularly dip deeply into your battery storage, you will not get as many years of service as you would if you just skim a little power off the top and replace it daily.

Batteries with a high depth of discharge capability (DOD) are called deep-cycle batteries and are most suitable for use with photovoltaic systems.

The daily discharge of batteries at a solar site should not exceed 20% of the total capacity of the batteries, otherwise the life span of the batteries, normally about 1100 cycles, will be shortened. See the manufacturer's data for the number of cycles versus depth of discharge capability.

Constant charging of the batteries to maximum overcharge and then discharging the batteries to a flat state day in, day out, quickly shortens life. To minimize this problem, you can use additional batteries so that they are not being cycled to the maximum capacity all the time. This also gives you additional storage capacity for emergencies.

If possible, buy the deep-cycle battery from a reputable local distributor and get a written guarantee. Try and buy a new battery that is not more than six months old. The date of manufacture is stamped on the terminals or on the case. Batteries should be replaced between every three and five years. Battery failure is the most common cause of failure of solar power systems. Replacement of batteries is costly for small health centres and for this reason a complete solar system may be nonfunctional for long periods of time.

When purchasing, find out why one battery is more expensive than another. What is the calendar life of the battery? What is its salvage or trade-in value? What are replacement costs during the life of your photovoltaic system? Basic criteria for battery selection are as follows:

- the number of times the battery can be charged and discharged
- the discharge rate (amps)
- the depth of discharge
- how long is needed to charge
- what voltage is required, 6 V, 12 V or even 24 V
- the cost of the batteries (see How to calculate an index of comparative lifetime cost of batteries).

Tip: Consider buying twice the number of batteries and go to a shallower depth of discharge. By doing so you can often more than double your battery life.

Note: In an emergency, car or truck batteries can be used temporarily to keep a solar system going, provided all the batteries are replaced with car/truck batteries at the same time.

Vented lead acid low antimony or lead calcium batteries. These are most commonly used for automotive applications. The battery is able to deliver a high current, but with a poor cycle life. They are not suitable for photovoltaic use. However, vented lead acid batteries with very low antimony plates give a high number of deep cycles due to the use of antimony and stronger, thicker plates. The battery may be supplied dry-charged. The electrolyte is added at the site when the battery is being installed. This is an important feature if long delays may occur between dispatch of the battery from the supplier and installation at the site. They are recommended for photovoltaic use. Remember batteries need careful handling so follow the manufacturer's instructions carefully.

Advantages:

- high number of deep cycles
- can be supplied dry-charged
- low consumption of distilled water
- only require maintenance twice a year to top up the battery if charging is correct
- reliable
- lower rate of self-discharge.

Disadvantages:

- supply is less widespread (try marine equipment suppliers)
- *medium cost.*

Sealed valve regulated lead acid batteries. Both lead antimony and lead calcium are available in sealed casings. Sealed valve regulated batteries (VRLA) require no topping up throughout their life so maintenance requirements are low. The life of the battery is also dependent on the ambient temperature, reducing as the temperature increases. Sealed cells are very suitable for solar systems because they do not require electrolyte maintenance and are useful for portable instruments, e.g. portable water testing kits. They operate as well as vented batteries in hot or cold climates with correct temperature-compensated charging set ups.

Both flooded/vented and VRLA batteries have their advocates in the market place, and are widely used. The choice depends on the funds available for purchase, the degree of reliance on local technical support, availability of competent regular maintenance of electrolyte and the safety aspects of spillage, corrosion, etc. Note that VRLA batteries (but not flooded/vented batteries) can be carried by air as normal cargo. Managers should weigh these factors carefully before making a choice.

There are two types of VRLA battery: gelled electrolyte and absorbed electrolyte. The gelled electrolyte type is somewhat better for deep cycling and long life. Buy from a reputable manufacturer or authorized distributor.

The overriding advantage of VRLA batteries is the avoidance of acid and distilled water handling, fiddling with topping up, corrosion etc. There are more battery failures caused by incorrect or poor maintenance of electrolyte than any other cause and if much of this is eliminated reliability is greatly increased.

The disadvantage of this type of battery is that maintenance has to be correctly carried out, especially regarding maximum voltages, as the batteries are less forgiving of abuse. Ensure that manufacturer's instructions are obtained and followed.

The use of lead alloy with sealed gelled electrolyte has been developed to provide a sealed, spill-proof battery. This battery requires no topping up and hence maintenance requirements are minimal. It costs about 25% more, but this is more than saved in cost of housings, safety provisions, acid maintenance and better performance.

Advantages:

- high number of deep cycles
- portable and can be used with mobile equipment
- do not spray acid from vents and so there is no corrosion of leads or surroundings

- do not consume distilled water
- require no acid maintenance so there is no damage from poor maintenance, dirty water etc.
- reliable with a long shelf-life (10 months at 30 °C to half charge).

Disadvantages:

- moderately higher cost
- require a quality charge regulator properly selected for the battery
- the state of charge cannot be determined from electrolyte specific gravity therefore monitoring of charge and discharge Ah is required (devices available).

Nickel-cadmium batteries. Nickel-cadmium batteries can be fully discharged without damage and they have a high tolerance to being overcharged. They can operate for long periods without replenishment of electrolyte and they have a long cycle life if shallow discharged. They have a high initial cost and poor availability in developing countries. They are highly recommended for photovoltaic use.

Advantages:

- high number of deep cycles
- do not need a control unit to restrict depth of discharge
- portable and available in sizes to fit portable instruments
- do not spray electrolyte from vents
- do not consume distilled water
- do not require maintenance
- reliable.

Disadvantages:

- in poor supply
- expensive
- only available in small capacities up to 4 Ah
- require a charge regulator and charging is inefficient at low charging currents
- cannot be charged in parallel without own series regulator
- high rate of self-discharge.

Vented nickel-cadmium batteries.

Advantages:

- high number of deep cycles
- do not require a control unit to restrict depth of discharge

- can be left discharged so delays in delivery are not a problem
- can be charged in parallel
- require maintenance only twice each year to top up electrolyte and clean terminals
- reliable.

Disadvantages:

- in poor supply
- expensive
- measuring their state of charge is not simple
- high rate of self-discharge
- very difficult to recycle
- cadmium is toxic.

Note: The battery bank size is constrained by WHO standards for solar powered refrigerator/freezer systems. The requirements for a solar powered vaccine storage facility are that, in the event of the loss of the solar input, there should be sufficient storage of energy in the batteries for five days' continuous operation. Also, if the battery bank is to be used for additional functions (for example, the laboratory) it must be split, with priority charging going to the section connected to the refrigerator.

Battery security, safety and maintenance

Security

You may wish to consider preventing removal or misuse of a laboratory battery by screwing the wooden case in which the battery was transported to the floor of the laboratory. Put the battery in and secure wooden bars across the top to hold it in. If it is a vented battery, there must be room between the bars for making a visual inspection of the acid level and for easy topping up with distilled water. The positive can be painted red and the negative black (or blue) and + and – scratched on the battery as a further means of identifying polarity. The batteries should be positioned inside the building to maintain security.

Safety

Batteries contain acids or alkalis which can cause burns on skin or blindness if there is contact with the eye. If a vented battery is used and it is not housed in a wooden box, then stand it on a solid piece of wood larger than its base or in a plastic tray. This will prevent an overflow of electrolyte from reaching the floor. Avoid spilling or splashing battery fluid, especially in transport.

Batteries give off gases which are explosive. Make sure that the battery containers provided are well ventilated and that they are placed in a well ventilated room. Keep naked flames and sparks well away from batteries. Always keep the batteries upright. Always

use a funnel or plastic bottle with a spout to add distilled water. Always use tools with insulated handles.

Damage to equipment and danger to laboratory workers may occur when battery terminals are accidentally interchanged or shorted. This problem can be overcome by installing fixed sockets on walls, using direct current special power sockets. The polarity of the sockets should always be clearly indicated. Particular care must be taken when some equipment in a laboratory is operated using 12 V direct current power and some using 240 V alternating current power. It is advisable that clear notices are posted indicating direct current power outlets and their voltage.

Maintenance

The acid level of a vented battery must be checked regularly at least once a week. The acid specific gravity should be measured with a good hydrometer (see Annex 6). If the level is down, it must be filled up with distilled water or other substitute, e.g. very clean rainwater collected in a plastic sheet. The battery voltage should be measured with a voltmeter (multimeter). The voltage should be no lower than the equivalent of 2.1 V per cell (12.6 V on a 12 V battery) and on charge should be between 2.2 V/cell and 2.5 V/cell (see manufacturer's data).

Upon receipt of new batteries, do not add water to cells which are low unless to bring the electrolyte to the minimum level. It is best to wait until after initial charging and prior to equalization charging (bringing all cells up to full charge) so that the water will mix with the electrolyte. Note that some new batteries come ready charged but empty of electrolyte.

Ideally batteries need a stable temperature environment of between 20 °C and 25 °C, out of direct sun and rain, with ventilation.

If batteries are connected in parallel, one connecting lead to each battery should include a fuse to prevent a good battery feeding excessive current back into a faulty battery, possibly causing overheating and a fire.

The battery is often the component of a photovoltaic system with the highest maintenance requirements. If sited at remote locations or without frequent maintenance services, a low maintenance or sealed battery should be chosen. Do not remove batteries from the laboratory. Batteries may be destroyed if used to operate machines that have greater power requirements.

Connections

The cables connected to the battery should have proper bolted battery connectors, carefully tightened and maintained. They should have the correct current ratings. Crocodile or other types of clip are not suitable for permanent use as not only do they make a poor electrical connection, especially as their teeth wear away, but they wear

away the battery lug so preventing future use of proper connectors. All metal parts should be covered with a good layer of anti-corrosion grease after the connections are made.

Temperature

As the temperature increases there is an increased rate of self-discharge and reduced cycle life. Every 10 °C rise above 20 °C halves the lifetime of the battery. Batteries should not be operated continuously above about 40 °C otherwise there is permanent damage to the plates. The maximum temperature range is 10–35 °C. In hot climates, the batteries should be kept away from direct sunlight and as cool as possible.

Level of involvement of users

The continuing success of a solar system depends to a large extent on how interested the users are in it. The user may not want to become involved and will simply place an order for a solar system with a supplier. However, it is not recommended to pass all responsibility for planning and installation of the system to an outsider although it is a good idea to make one supplier responsible for the whole system design (solar panels, regulator, battery).

Benefits to be gained from learning more about solar electricity

- Understand exactly what is being offered by suppliers of solar equipment
- Get full sets of literature and instructions
- Keep costs down by investigating local sources of supply
- Appreciate how the system can be run effectively
- Have the knowledge and ability to do the maintenance tasks properly
- Sort out minor problems immediately without the cost and delay of waiting for a visit by an electrician.

Calculations

A supplier may be able to provide you with several batteries. You will need to know the lifetime cost of each battery before deciding which to buy. By following the three steps below, you will be able to calculate the cost of each battery.

How to calculate an index of comparative lifetime cost of batteries

1. Calculate the total energy handled by a battery during its lifetime

$$E = \frac{V \times AH(20) \times n}{5000}$$

where:
E is total energy (in kWh)
V is nominal voltage of the battery
$AH(20)$ is battery capacity in ampere hours at the 20 hour rate (sometimes written AH_{20})
n is the number of cycles to 20% depth of discharge (DOD)

2. Calculate battery performance or life index

$$I = \frac{P}{E}$$

where:
I is life index
P is price

3. Combine the two formulae

$$I = \frac{5000 \times P}{V \times AH(20) \times n}$$

Example
A 12V 200 AH(20) battery costing US$ 900 and doing 3000 cycles to 20% DOD

$$I = \frac{5000 \times 900}{12 \times 200 \times 3000}$$

Therefore index of comparative lifetime cost of battery = 0.625 US$/kWh

How to calculate your energy consumption

It is absolutely essential for a workable, cost-effective system to calculate the daily energy consumption (demand). Energy consumption per day is expressed in watt hours per day (Wh/day).

To calculate the daily DC load, use worksheet no.1. Begin by making a list of equipment to be used in the laboratory. Identify its power consumption in watts (from the manufacturer's tag or label). Note the hours per day it typically operates and the days per week of expected operation.

Multiply the wattage (amperes × volts = watts) by the minutes or hours of use for each device and multiply this by the days per week used. Total the amounts in the Wh column. This will give you the Wh for the week. Divide the figure for Wh for the week by 7 to get the total daily energy demand. Be as careful and accurate as possible. Provide for any load or time increases foreseen. You will also need to calculate and add in the AC load (converted to DC) in order to get the total DC energy required (see worksheet no. 2).

When designing a solar energy supply system, have low power devices, preferably ones which work at 12 V or 24 V direct current, with high efficiency and capacity matched (just sufficiently) to the tasks. Maximize hours of use by careful planning.

The purpose of worksheet 2 is to determine

- the energy consumption of the alternating current loads
- the peak rating required for the inverter.

The latter requires calculating the peak demand (watts) and also some consideration of surges (e.g. starting currents of motors, etc.) to be handled. The peak demand may be less than the total aggregate watts of all equipment because not all equipment may be on at once. If this is the case, a load/demand chart should be drawn, with hours of the day and night across the page, and each item of load listed with a bar drawn through the hours of running, then each hour totalled to find the heaviest hour. Sometimes loads can be planned to avoid heavy peaks, e.g. at the start of the day. Then add the worst surge (probably in a centrifuge or refrigerator motor and possibily at two or three times its normal running wattage). Inverters will have a continuous rating and a short time or peak rating. Select the size appropriate to your calculated continuous and peak loads, with a margin above for safety.

Energy system sizing

The size of system required will have to be determined once it has been decided to install a solar energy system to the laboratory. You will need to know the equipment and its power consumption plus average time on each day to design a suitable system. You need to know for how many hours per day the equipment will be on. Tables 8.4 and 8.5 serve as examples.

Worksheet No. 1: Photovoltaic system sizing (DC system)—How to calculate your energy consumption

Note: If some days have significantly heavier use than others use the Wh/day for these days as the figure, rather than a weekly average.

1. Daily DC load calculations

Equipment	Quantity of units		Watts per unit		Hours per day used		Days per week used		Average watt hours per week
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
Inverter (off load running)	.....	×	.....	×	.....	×	.....	=	.....
							Wh for the week	=	.....

2. Convert load into Wh/day

$$\frac{\text{Wh for the week}}{\text{7 days/week}} = \text{Wh/day DC load}$$

Total daily energy demand $\frac{\qquad}{7}$ = ... Wh/day DC load

Add AC load (converted to DC) from Worksheet 2 .....

Add allowance for losses in regulator and DC system (5%) .....

Total DC energy required _____ Wh/day

Worksheet No. 2: Photovoltaic system sizing (AC system)—How to calculate your energy consumption

1. Daily AC load calculations

Equipment	Quantity of units		Watts per unit		Hours per day used		Days per week used		Average watt hours per week
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....
.....	.....	×	.....	×	.....	×	.....	=	.....

Maximum AC surge..... Wh for the week = ...

2. Convert load into Wh/day

(1.41 efficiency factor[1])

Wh for week × 1.41 ÷ 7 = daily Wh

..... × 1.41 ÷ 7 = ...Wh/day average

[1]Allow for
- 2% wire loss (1.02) or actual loss
- 80% battery efficiency (1.25) or actual efficiency
- 90% inverter efficiency (1.1) or actual efficiency

i.e. 1.02 × 1.25 × 1.1 = 1.41

TABLE 8.4 **Example of energy requirements of a simple solar electric system for a laboratory at the peripheral level**

Equipment (load device)	Quantity of units	Power demand (W) per unit	Daily operating hours of equipment	Daily energy demand (Wh)
Light	4	10	2	480
Refrigerator (110 L)	1	50	24	1200
Microscope	1	10	8	80
HCT-centrifuge	1	10	3	30
Blood centrifuge	1	30	3	90
Colorimeter	1	4	4	16
Incubator	1	30	24	360
Total daily requirement of electricity (Wh per day)				**2256**

TABLE 8.5 **Calculation of energy demands and size of a solar energy supply system for a laboratory at the intermediate level**

Item (load device)	Quantity of units	Power demand[2] (W) per unit	Daily operating hours of equipment	Daily energy demand (Wh)	Voltage
Essential					
Refrigerators	2	50	13	1300	24
Emergency light[1]	1	10	0.3	3	24
Total				1303	
Non-essential (load device item)					
Microscope	2	20	4	160	240
Centrifuge	1	350	1	350	240
Internal lights	1	20	24	480	24
Internal lights	2	20	10	400	24
NiCad battery charger	1	10	24	240	240
Laptop computer	1	50	8	400	240
Computer printer	1	15	1	15	240
12 V battery charger	1	40	24	960	240
Total				3005	
Total daily requirement of electricity (Wh per day)				**4308**	

[1]For use in operating theatre
[2]Also know consumption power

The aim is to replace the power which has been used or lost by recharging and to hold some in reserve. It is important that solar systems are designed properly so that all the loads can be used for most of the year. This is called sizing. Before the system can be sized, it is important to consider what lighting and equipment will be required.

The design of a system is controlled by three major factors: geographical location and meteorological conditions, electrical load types and other power available.

The supplier will need to know about the insulation—or solar radiation—at the location and its ambient temperature (see Laboratory power questionnaire). The supplier will need to know your location in terms of latitude and longitude, to the nearest minute, and height above sea level.

A prime consideration in the design process is the type of electrical load equipment to be used and its power requirements. Make a list of laboratory equipment you want to power. Note how long you want to use the pieces of equipment over a 24 hour period and how much power each uses. You need to know what time of the year you want to use these lights and equipment, as the amount of sunlight at different times of the year affects your calculations. The solar array has to be sized to produce sufficient power for the worst solar radiation period of the year. Do calculations separately according to the season of the year and the highest demand period (see Tables 8.4 and 8.5).

How to calculate daily energy demand for equipment used in the laboratory

Power demand × quantity × hours per day used = Daily energy demand (Wh)

Example

microscope (1)	20 W × 1 × 4 hours = 80 Wh
light, tube lamp (3)	8 W × 3 × 8 hours = 192 Wh
Total daily energy demand	= 272 Wh

Note: This is a very rough method. It is recommended that all site data (see Laboratory power questionnaire and Worksheets 1 and 2) are submitted to a reputable solar panel distributor who will have insulation data, panel characteristics and should have a computer programme or method for sizing. Get the distributor to guarantee a system performance.

To set up a solar power system for the laboratory, the solar peak power required and the battery capacity have to be determined.

How to calculate solar peak power required

Required solar peak power = Daily energy demand (wh/day) ÷ 2

Example

$$\text{Required solar peak power} = \frac{272}{2^*} = 136 \text{ WP}$$

Note: *This refers to a typical panel pointed to the noonday sun; the ratio of the peak power to energy output, 2 being a typical adverse (winter/cloudy) day figure for standard sunshine hours per day (h/day).

How to calculate battery capacity

Total storage capacity of the batteries = Daily energy demand × 5

Example

Total storage capacity of the batteries = 272 Wh × 5 = 1360 Wh

Note: The coefficient 5 results from the fact that the battery can only be discharged by 20% (1/5) maximum daily, if suitably used, and leaves 4 days capacity in reserve for emergencies.

Example

$$\text{Battery capacity required of a 12 V battery system} = \frac{\text{Total storage capacity}}{12}$$

$$= \frac{1360}{12} = 113 \text{ Ah}$$

Note: If a 24 V DC system is opted for divide by 24 to get Ah, but then 2 × 12 V (or 4 × 6 V, or 12 × 2 V) batteries will be required in series and 2 × solar panels in series also.

The energy requirement of a solar power system for the example described would be therefore as follows:

- Solar panels 136 WP (choose combination of panel ratings × number of panels to exceed this)
- 12 V Battery 113 Ah (choose next highest standard size).
- Solar charge regulator 12 V, 123 W

Note: If a 24 V system is chosen, use 2 solar panels in series and the required number in parallel (check supplies on correct wiring method with blocking diodes).

Solar energy supply system design factors

The designer/supplier needs to know the following:

Characteristics of the load

- Size—watts, ampere hours, voltage (DC/AC)
- Power tolerances—voltage, surge limits

Characteristics of the site

- Climate—altitude, temperature, wind, humidity
- Local conditions—dust, sand, snow, lightning, cloud/fog cover and occurrence times
- Terrain—soil conditions, shading

Reliability requirements

- Battery autonomy—days of reserve (no sun)
- Safety factors

Solar energy input

- Latitude and longitude
- Insulation data (get panel supplier to source this)
- Source of data
- Reliability of data
- Measured or estimated

When placing a request for a solar energy supply system to meet your needs, the following site specific information should be given to the supplier. The questionnaire given in Figure 8.2 is designed to enable the supplier to assess your true energy needs and so recommend the most suitable photovoltaic solar power system.

1. Where is the unit to be installed. Please be as specific as possible.

   .....

2. Type of equipment to be powered. Please find attached PV sizing worksheets. (Please tick ✓)
   Worksheet no. 1 [DC system] ☐ Worksheet no. 2 [AC system] ☐

3. Site location ..... Nearest city .....

4. Site latitude ..... longitude ..... altitude .....

5. Peak sun hours per day ..... Worst monthly figure (hours) .....

6. Site temperature range, min ..... max ..... Worst month average .....

7. Do the load requirements vary during the year? If so, how? .....

8. Batteries required? Yes.....No ..... If no, give details (type, voltage, Ah, age of existing batteries)

9. When the site is already powered, give alternative solutions:

   Completely powered by solar. Yes ..... No.....

   A combination of solar/diesel (hybrid system). Yes .....No.....If so state the size of the diesel-generator, e.g. kVA, what other loads it carries (watts) and times of operation current, required number of working hours, etc.

   .....

10. Number of days battery reserve required .....

11. Site location [to the nearest minute]
    latitude ..... longitude .....

12. Customer's name and addresss .....

    .....

    .....

13. Any other information relating to the particular project site that is available and would also be helpful in the design and costing process, e.g. transport, size, weight limitations, lifetime of equipment required.

    .....

FIGURE 8.2 **Laboratory power questionnaire**

Section 3

Information annexes

Annex 1
Equipment data specification sheets

The equipment data specification sheets in this annex are given as examples. The buyer should complete a similar specification sheet to provide the supplier and manufacturer with sufficient accurate information regarding what is needed. A specification sheet should be completed by laboratory staff and medical staff and submitted to the supplier at the time of ordering (requisitioning). Delete items as necessary to suit your requirements and local conditions.

The reasons for using an equipment data specification sheet are as follows.

- To identify correctly the medical, technical, environmental and user requirements.
- To provide a manufacturer (or distributor) with sufficient accurate information regarding what is needed.
- To avoid purchases being made without prior receipt and study of adequate product information, including instructions for use and maintenance and details of guarantee and insurance cover during transit.
- To find out the purchase price, estimated running costs, price of replacement parts and the cost of freighting.
- To avoid hasty purchases due to aggressive marketing by agents.

Equipment data specification sheet for: an autoclave

Information about equipment use, local conditions and requirements

To be used in: microbiology/blood transfusion where it will be used for sterilization of glassware/ instruments/old specimens/media preparation/textiles. The main use of the autoclave will be .....

.....

- The height of the bottles to be placed in the autoclave is.....mm (loading height)
- The largest dimensions of articles to be placed in the autoclave
- Where the autoclave is to be used is more/less than 1000 metres above sea-level

The local mains electricity supply is: .....volts (V AC) .....phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electrical supply is/is not subject to fluctuations in current (if yes, what are the levels of fluctuation?)*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Other local energy sources: a reliable supply of steam/ gas/kerosene (paraffin)*

Description of autoclave required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model.)

Technical and general requirements

- The capacity should be ..... litres and dimensions (h × w × d) .....
- A front loading/top loading model is required
- A non vacuum/vacuum type is required
- Recommended spare parts to provide two years normal operation. What are the type and quantity of proposed spare parts included in the quotation?
- Is load control required?
- Chart recorder required (or other independent monitoring equipment)?
- Baskets/extra shelves etc. required?
- What are the power requirements: ..... volts ..... Hz ..... phase ..... amps ..... kW?
- Where can spare parts be obtained?
- Where can repairs be made?
- What is the working depth (in mm), loading height (mm) and net weight (kg)?
- Provision of a service contract covering routine and emergency maintenance requirements. The cost of a service contract is to be stated as a separate item in the tender price quoted.
- An operating and service manual written in English/French/Spanish/other language is required. The manual should include positioning, installation, commissioning, operating instructions, maintenance schedule, fault-finding procedures, safety features, spare parts list, autoclave pipework diagram and electrical circuit diagram.
- What type of manufacturer's guarantee accompanies the equipment?
- Are suitable drainage facilities available?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a balance

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology/microbiology/blood transfusion laboratory; for portable/mobile laboratory work*

.....

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/ often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Location: The balance will be used in the area of ..... (give nearest city).

Description of balance required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- A balance with a capacity of 50/120/310/or .....g*
- The sensitivity (readability) should be 0.01/0.001 g*
- The balance required is electronic/mechanical*
- Accessories required for the electronic balance are calibration weights/AC adapter draft shield*
- Have the electronics been protected against the effects of high humidity?
- What size dry-cell battery is required?
- Where can spare parts be obtained?
- Where can repairs be made?
- The cost of a maintenance contract is to be stated as a separate item in the tender price quoted
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a centrifuge

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology/microbiology/blood transfusion. The centrifuge will be used for mobile/portable laboratory use. The centrifuge will be used for general use/to spin down units of blood/for microhaematocrit work.*

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of centrifuge required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- A centrifuge with speed up to ..... rpm
- The centrifuge is required to spin tubes only/tubes and bottles
- The size of the tubes is ..... and bottles is .....
- The rotor should be fixed angle/swing out; the large capacity rotor should have adapters for smaller tubes
- There should be sealed buckets with the cap fitting into the bucket; number of buckets required is 6/8/other ..... and bucket adapter size .....ml*
- A refrigerated model is/is not required*
- A portable model is/is not required*
- A battery operated model is not/is required. Can rechargeable batteries be supplied? How long will the batteries last before they must be recharged?
- There should be a safety lid interlock
- Spare parts required: spare carbon brushes, rubber feet (bench models), fuses extra cushions for buckets and sealing gasket (for haematocrit centrifuge)
- A brushless induction motor is/is not preferred.
- When a microprocessor-controlled model is available, please indicate safety features (imbalance detector/ warning light for imbalanced load/ other.)
- Where can repairs be made?
- What are the dimensions (h x w x d, cm)?
- Where can spare parts be obtained?
- An operating manual written in English/French/Spanish/other language is required. The manual should include a step by step guide on installation, operation and maintenance including motor brush replacement.
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a colorimeter or spectrophotometer

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology for the following tests

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of colorimeter/spectrophotometer required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- Measurement modes required: absorbance/% transmission/concentration/kinetics
- A fully portable model is/is not required
- A battery operated model is/is not required. Can rechargeable batteries be supplied? How long will the batteries last before they must be recharged?
- The following accessories are required: filters/flow through cuvettes/holders for test tubes and cuvettes/printer/battery charger/carrying case/recorder
- Spare parts to include spare lamp and fuses, anti surge fuses, cuvettes (plastic/optical glass/ quartz non UV/quartz UV)*
- Can training in operation of the instrument be provided?
- Where can repairs be made?
- Where can spare parts be obtained?
- We intend to use a voltage regulator/on-line UPS with this instrument. Please state the allowable voltage range of the colorimeter/ spectrophotometer in V AC*
- Have the electronics been protected from the effects of high humidity?
- An operating manual written in English/French/Spanish/other language is required.* The manual should give a clear step by step guide on installation, operation, wiring diagram, optical alignment check and replacing the lamp and fuses.
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a dry heat block

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology/blood transfusion laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of dry heat block required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- Temperature range .....°C to .....°C
- Heat block to be fixed/moveable; as a single block/separate with different tube holes
- The blocks should accommodate tube sizes ..... mm
- A unit that accommodates microcuvettes/Eppendorf tubes is required
- The temperature ranges not more than ± 0.5 °C
- Accessories required: right angle thermometer/transfer racks
- Where can repairs be made?
- Where can spare parts be obtained?
- We may have to use a voltage regulator/on-line UPS with this instrument. Please state the allowable voltage range in V AC*
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: an electrolyte analyser (ISE)

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of electrolyte analyser required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- An electrolyte analyser (ISE) to measure sodium/potassium/chloride/ calcium/magnesium/ lithium
- A portable model is/is not required
- A battery operated model is not/is required. Give details of battery type How long will the batteries last before they must be recharged?
- Accessories required: auto-sampling tray/(other)
- What is the current estimated cost per test?
- What consumables are needed (calibrating solutions, diluents, slope standards)?
- Can these consumables be obtained from sources other than the manufacturer?
- Where can these consumables be obtained locally?
- Please supply information (from the manufacturer) on how to make our own reagents
- What are the storage requirements for the reagents? What are the manufacturer's stated expected shelf life of the reagents?
- Provide a list of recommended spare parts. Where can spare parts be obtained?
- We may have to use a voltage regulator/on-line UPS with this instrument. Please state the allowable voltage range in V AC*
- Where can repairs be made?
- An operating manual written in English/French/Spanish/other language is required. The manual should give a step by step guide on installation, sample preparation, operation, maintenance, main circuit board layout, component replacement and spares kits
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: an electrophoresis chamber

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of electrophoresis chamber required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- An adjustable bridge gap
- A contoured lid
- A circuit breaker incorporated in the instrument
- The initial order to include: chamber (tank) and power supply unit, two spare tank supports (bridge), platinum electrode; wicks of filter paper/ chromatography paper/blotting paper/cellulose acetate membranes/ applicators (microcapillaries)
- We intend to operate the instrument using the following support media: cellulose acetate/ citrate agar/other .....
- With regard to the power supply unit please supply details of the following: power output, V DC and power output mA
- We intend to use an on-line UPS with this instrument. Please state the allowable voltage range in V AC and also V DC*
- Have the electronics been protected from the effects of high humidity?
- Provide a list of recommended spare parts. Where can spare parts be obtained?
- What are the dimensions (h x w x d, cm)?
- Where can repairs be made?
- Can training on equipment operation be provided?
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a flame photometer

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

The local gas is: natural gas/propane/butane; supply is reliable/not reliable

Humidity in the local area is: high/moderate/low

Description of flame photometer required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- A gas regulator for propane/natural gas/butane*
- A flame failure warning light
- As the humidity is high a small volume water separator (for removing water from the air compressor) is required
- Provide filters for sodium/potassium/calcium/lithium/barium*
- The initial order to include: calibration standards, capillaries, capillary cleaning wire, nebulizer, photocell, hose connecting clips, atomizer, Allen key, 2 lengths of drain tubing and both primary and anti-surge fuses
- Provide a list of recommended spare parts. Where can spare parts be obtained?
- We may have to use a voltage regulator / on-line UPS with this instrument. Please state the allowable voltage range in V AC*
- Where can repairs be made?
- An operating manual written in English/French/Spanish/other language is required. The manual should give a step by step guide on installation (voltage, fuel, air, drain), sample preparation, operation, maintenance, main circuit board layout, component replacement and spares kits
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: an incubator (aerobic)

Information about equipment use, local conditions and requirements

To be used in: microbiology laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of incubator required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- The operating temperature to be from .....°C to.....°C
- Capacity of .....litres
- A model with/without a circulating fan
- Accessories: Lowenstein shelf (for tuberculosis)/perforated galvanized shelf/perforated stainless steel shelf/floor stand with castors/temperature recorder/7 days discs for recorder
- Spare parts to include heating element/main switch/fuse and thermostat
- Where can spare parts be obtained?
- Where can repairs be made?
- What are the dimensions (h x w x d, cm)?
- We may have to use a voltage regulator/on-line UPS/battery powered by solar array with this instrument. Please state the allowable voltage range in V AC and V DC*
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a microscope

Information about equipment use, local conditions and requirements

To be used in: haematology laboratory including examination of thick and thin films for malaria, to diagnose tuberculosis, etc.

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of microscope required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- A binocular head inclined at 30° (or 45°), and rotatable for 360°
- A widefield eyepiece 10x
- Objectives to be parfocal DIN achromatic, 10x, 40x, 100x oil immersion. The numerical apparatus (NA) of the objectives should be: 10x/NA 0.25, 40x/NA 0.65, 100x/NA 1.30
- The light source should be built in. The lamp should be quartz halogen 6V 10W. There should be a lamp diffusing screen and a graduated lamp brightness control
- The microscope must be able to operate from a battery. A connection for a 12 V battery should be built in to the base. The connections for the mains and battery should not be interchangeable
- Provide a 12 V rechargeable battery (preferably lead-acid) including a lead with battery connectors. These should be a safety device to prevent damage from interchanging of battery terminals
- A lead with car battery connectors to be provided
- The stage should be built-in, mechanical and with coaxial controls
- A mirror, plain and concave, mounted for angling and rotating must be provided. The mirror should fit over the lamp
- Condenser Abbe type with iris, centring screws, and filter holder; condenser positioning indicator
- Recommended spare parts to include spare lamp and fuses
- Where can repairs be made?
- Where can spare parts be obtained?
- Provision for a maintenance contract covering taking the microscope to pieces, cleaning, and reassembling by an expert, to the buyers satisfaction
- The cost of a maintenance contract are to be stated as separate items in the tender price quoted
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: an oven

Information about equipment use, local conditions and requirements

To be used in: microbiology/haematology laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of oven required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- The operating temperature to be from .....°C to.....°C
- Capacity of ..... litres
- A model with/without a circulating fan
- Accessories: stainless steel shelves/floor stand with castors
- Spare parts to include a thermometer and thermostat
- Where can spare parts be obtained?
- Where can repairs be made?
- What are the dimensions (h x w x d, cm)?
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a pH meter

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology/microbiology/blood transfusion

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of pH meter required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- The range of the pH meter should be from ..... to .....
- The electrode type should be standard glass/epoxy bodied combination/ reference
- The electrode should be protected with a protective sheath
- A portable model is/is not required
- A battery operated model is/is not required. Give details of battery type
- A model with manual/automatic temperature compensation
- A model with/without slope control
- A combination meter to measure conductivity/read concentration/display temperature
- Accessories required: a storage bottle to protect the electrode/a cable with length ..... metres/ a stand for the electrode/a ..... connector/..... adapter
- A probe for temperature/steel protected spear/epoxy body automatic temperature compensator (ATC)/4 plate configuration/microstem/HF resistant
- Where can a supply of the following spare parts be obtained: electrodes, electrode leads probes, antisurge fuse, membrane, battery connector, electrode stand, buffer solutions and electrolyte maintenance solutions
- Where can the pH meter be repaired?
- An operating manual written in English/French/Spanish/other language is required. The manual should give instructions for installation, operation, and maintenance instructions with a table giving cleaning agents of the glass electrodes
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a refrigerator or freezer

Information about equipment use, local conditions and requirements

To be used for the storage of: laboratory reagents/samples/sera/chemicals vaccines/whole blood/ icepack freezing/flammable materials/other .....

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

The local supply of: bottled gas is reliable/not reliable*

The local supply of: kerosene is reliable/not reliable*

The hospital/health centre is/not connected to a solar array; the health authority has/does not have plans to install a solar energy system*

The temperature in the local area varies between: .....°C and .....°C

Description of refrigerator/freezer required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- The operating temperature to be from .....°C to .....°C
- Capacity of ..... litres
- The model required should operate from: AC electricity only/DC electricity via solar
- energy/electricity and gas/electricity and kerosene/kerosene only/gas ..... only
- A model with copper tubing
- As we may store flammable solvents in the refrigerator we require the manual temperature controls to be relocated to the exterior of the cabinet and the sealing of all points where wires pass from the refrigerator compartment
- Spare parts required (for the first three years of operation):
  - electric (compression) type – thermostat, starting device
  - kerosene (absorption) type – wick x 6 (cotton), lamp glasses x 3
  - gas (absorption) type – flame failure device, door/lid seal
- Where can spare parts be obtained?
- Where can repairs be made?
- What are the dimensions (h x w x d, cm)?
- What is the electricity consumption in kWh per 24 hours?
- Does the refrigerator/freezer have a voltage regulator trip switch?
- Please send information about solar photovoltaic refrigeration
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a serology centrifuge

Information about equipment use, local conditions and requirements

To be used in: blood transfusion and the haematology laboratory

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of serology centrifuge required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- A single/two speed model*
- A standard rotor, made of polycarbonate plastic holding 12 tubes size 10 x 75 mm; an aluminium rotor holding 6/8 tubes, size 13 x 100 mm/8 place, Vacutainer tubes
- The lid should be fitted with a safety lock
- Accessories: replacement 12 piece plastic rotor/disposable plastic inserts (to cover the guard bowl)
- Where can spare parts be obtained?
- Where can repairs be obtained?
- What are the dimensions (h x w x d, cm)?
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a water bath

Information about equipment use, local conditions and requirements

To be used in: haematology/microbiology/clinical chemistry/blood transfusion

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of water bath required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs.Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- The operating temperature to be from .....°C to.....°C; or fixed temperature of .....°C
- Temperature fluctuation of ±.....°C
- Tank capacity..... litres; made from stainless steel/transparent polycarbonate; with a polypropylene inner*
- A model with/without a mixing unit*
- The heating unit should be of the immersion type/enclosed in the casing of the bath
- Spare parts to include: fuse, thermostat, heating element/main switch/thermometer
- Where can repairs be made?
- Where can spare parts be obtained?
- What are the dimensions (h x w x d, cm)?
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a water still

Information about equipment use, local conditions and requirements

To be used in: clinical chemistry/haematology/microbiology

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

The local water supply is/is not less than 50 litres/hour with a supply pressure of 0.3 kg/cm^2

Description of water still required: .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- Output should be ..... litres/hour
- The condenser and boiling chamber should be made out of borasilicate glass/stainless steel
- The heater should be made out of metal/silica and fitted with an over temperature cut-out switch
- There should be in-line fuses and visual water level feed valve
- The connectors should be of the screw thread type
- A siphon tube fitted to the boiler is preferred
- Please provide a list of recommended essential spare parts with the expected life of thepart in years; where can spare parts be obtained?
- The cost of replacement spare parts: heater, boiler, constant level device, condenser to be stated as separate items in the tender price quoted
- How many litres of water per hour is required to operate the water still?
- Please send information about a water deionizer/a copper still (alembic)
- Provision of a maintenance contract covering taking the water still to pieces, cleaning, and reassembling by an expert, to the buyer's satisfaction
- Please give the name and address of the nearest local agent and service technician
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Equipment data specification sheet for: a water testing kit

Information about equipment use, local conditions and requirements

To be used in: microbiology laboratory (and in the field) to test drinking water for the presence of faecal coliforms (*Escherichia coli*)

The local mains electricity supply is: ..... volts (V AC) ..... phase

- The local current frequency is 50 Hz/60 Hz*
- The local mains electricity supply is/is not subject to fluctuations in current*
- Where these power fluctuations exist, they occur rarely/sometimes/often*
- The local power supply is: good (no interruptions)/limited (occasional failures)/poor (frequent interruptions)*

Description of water testing kit required .....

.....

(When known, give manufacturer's name and reference code/catalogue number of the preferred model that suits your needs. Where the preferred model is not available the supplier will try to find an alternative model).

Technical and general requirements

- The incubator temperature should be set at 44°C for faecal coliforms
- An additional incubator is/is not required: it should be set at 37°C for total coliforms
- The kit should be able to test for turbidity/free and total chlorine/shigella/ salmonella/vibrio cholera/pH/other .....
- A solar power pack is/is not required*
- A 110 V and/or 220 V battery charger is/are required
- A lead to connect the kit to a vehicle battery is/is not required*
- Consumables required are: pads, membranes, culture media for up to 200 tests
- A temperature test check kit is/is not required
- Accessories to include: portable conductivity meter/battery pack/sterilizer kit*
- Please give the name and address of the nearest local repair technician
- Where can spare parts be obtained?
- Please provide a list of recommended spare parts with prices
- Is the battery built-in; is the incubator built-in?
- An operating manual written in English/French/Spanish/other language is required
- What type of manufacturer's guarantee accompanies the equipment?

* Include according to laboratory requirements and local conditions

Annex 2
Sample forms

Sample Equipment Problem Report

DATE	Problem	Action Taken

Equipment history record

A separate equipment history record is recommended for each piece of equipment in the laboratory. Keep a record of the detailed equipment information as suggested on the sample form on the next page.

The record should include

- model number
- serial number
- date of purchase
- cost
- manufacturer information
- dealer information
- warranty details including expiration date
- technical service information including the name and telephone number of the service representative
- a service record listing the date, person contacted, action taken and comments.

Equipment history records may be provided by manufacturers. These individual equipment history records should follow the summary equipment in-use pages in the manual.

Sample Equipment History Record

EQUIPMENT HISTORY RECORD Equipment .....

Model No ..... Serial No .....

Date Purchased ..... Cost .....

Manufacturer .....

Address .....

.....

Telephone: ..... Contact person .....

Agent .....

Address .....

Telephone ..... Contact person .....

Warranty ..... Expiration Date .....

.....

Technical Service Representative .....

Telephone .....

Service record

Date.....Comments.....Who contacted, action taken

.....

.....

.....

.....

Sample Order Form 1

Date ..... Date received .....

(Office use)

Hospital .....

Invoice address .....

Delivery address .....

Attention .....

Order number ..... Authorized signature .....

Office Use	Qty	Pack/Size	Description	$/UNIT	

Sample Order Form 2

Please print or type	**Order Form**
Order Date	**Terms: net 30 days. Orders are subject to standard terms and conditions of ABC Co.**
Customer Order No.	
Sales Tax No. (If applicable)	**Order should be signed by authorized official**
Authorized Signature	
Invoice to:	**Deliver to:**
Company Name	Company Name
Department	Person Title
Address	Address
City Post Code	City Postcode

Quantity	Catalogue No.	Description (include size)

Sample Quotation Form 1

QUOTATION

Quotation No......

Note: The number must be quoted on all orders otherwise no claim recognition for incorrect charges.

Your ref:..... Date:.....

Item No.	Catalogue No.	Item Description	Quantity Required	Unit Price	Dis-count	Net Total	Delivery Time

Terms	Payment	**TOTAL**
Import Licence	This offer expires	

This Quotation is in US$ / Sterling / Local Currency .....

Sample Quotation Form 2

FAX QUOTATION

Quotation No_____
Note: The number must be quoted on all orders otherwise no claim recognition for incorrect charges.

Your ref:_____ Date:_____

To	City	Country
Fax No.	Total # Pages (including this page)	
Attention	Date	
From ABC Company	Fax No.	Representative

Item No.	**Catalogue No.**	**Item Description**	**Quantity Required**	**Unit Price**	**Dis-count**	**Net Total**	**Delivery Time**

Terms	Payment	**TOTAL**
Import Licence	This offer expires	

This Quotation is in US$ / Sterling / Local Currency .....

Sample Shipping Form 1

(A form similar to this should be sent to the buyer by the supplier)

FAX TRANSMISSION		
To Company:		Date:
City:	Country:	Fax No:
Attention:		Your Ref:
From:	Dept:	Our Ref:
Number of pages including this header		

IF YOU DO NOT RECEIVE ALL THE PAGES, PLEASE CALL BACK AS SOON AS POSSIBLE

Message:

Shipping Details

Your reference:

Our reference:

We estimate your goods will be shipped to you in the month of

by: ✍ Air
✍ Sea

A second shipment will be necessary ✍ Yes
✍ No

Estimated month:

We trust this meets with your approval.
Please contact us if you have any questions or comments.
Specific shipping details will follow.

Kind regards

Export Division

Sample Shipping Form 2

(A form similar to this should be sent to the buyer by the supplier)

FAX TRANSMISSION		
To Company:		Date:
City:	Country:	Fax No:
Attention:		Your Ref:
From:	Dept:	Our Ref:
Number of pages including this header		

IF YOU DO NOT RECEIVE ALL THE PAGES, PLEASE CALL BACK AS SOON AS POSSIBLE

Message:

Final Shipping Details

Your reference:

Our reference:

Your shipment is ready to be delivered.

The goods will depart by: ✍ Air
✍ Sea

Booked on:

a. Aircraft:

Air Waybill Number:

Housebill Number.

b. Seafreight:

Ship or Shipping Company:

ETD:

ETA:

Kind regards

Export Division

Annex 3
Equipment donation guidelines

Introduction

Equipment donations can end up causing the recipient more problems than benefits, for example:

- People who become involved in donating medical equipment may have no background in health issues, no understanding of the structure of health services of the recipient, and no recognition of the need to seek the advice of experts.
- Companies, hospitals or private doctors may donate outmoded equipment either because it provides them with tax exemptions or as a means of getting rid of redundant equipment.
- Potential donors may consider it not worthwhile to consult the recipient. The recipient may feel obliged to accept any help, even if the equipment is not required, and even if charges, such as import taxes and transport costs are involved.

What can be done?

The donor and the recipient must get together as equal partners to work out how the effort and goodwill involved in making a donation can be put to best use. Recipients should have a clear policy on their equipment requirements, which should be known to their staff as well as their donors.

The right to give and receive a *no, thank you* should be used, appreciated and accepted. A refusal (or acceptance) that is justified by a comprehensive statement of requirement (e.g. Equipment Data Specification Sheet) is often much appreciated by the donor. FAKT (Association for Appropriate Technologies), a non-profit German organization (see Annex 7) with a consultancy service operating in the field of hospital technology, has produced the following guidelines in the form of recipient and donor responsibilities for those accepting and making donations.

By working through the list of points for the recipient, it may be easier to decide whether or not to accept a donation (or to make a purchase). By working through the list of points for the donor, it should make it easier to decide whether or not to make a particular donation. However, both partners need to understand what is expected of them and what is expected of their counterpart.

Cost, environmental and operational conditions, the availability of supplies of spare parts and the quality of maintenance services will limit the final choice of equipment (see

Chapter 1, List of selection criteria: Points to consider when choosing new laboratory equipment).

Recipient responsibilities

Standardize equipment

This ensures a greater likelihood of:

- economical purchasing and stocking of equipment and spare parts
- availability of instruction manuals
- availability of local expertise in operation and maintenance procedures
- selection of appropriate equipment

Involve technical departments

Hospital-based service technicians can be asked to consider and advise upon:

- installation, operation and maintenance requirements
- staff and training requirements for users and technicians
- essential spare parts requirements
- appropriateness of equipment, based on economical operation and technical design

Specify clearly items to accompany the equipment

These should include:

- a full set of technical documents in a suitable language
- a reasonable quantity of spare parts
- a warranty document for new equipment

Make a checklist including the above points

- This will ensure that you provide donors with enough information to enable them to respond appropriately (make use of the Equipment Data Specification Sheets)

Donor responsibilities

Communicate with the recipient

- Make sure that the recipient has provided a full description of the equipment required

Supply equipment, which is in full working order

- Test the equipment and make sure all necessary spare parts and supplies are included in the package before making the shipment
- Second-hand equipment should be fully rebuilt or reconditioned

Supply all technical documents

- Installation, operation, maintenance and repair manuals and diagrams should be made available in a language understood by the users and the technicians

Supply enough consumables and spare parts to last at least two years

- Include a complete list of spare parts and indicate the name and address of the authorised dealer

Ensure proper packing and shipping

- Use strong, sturdy and easy-to-handle packing materials
- Include a comprehensive packing list
- Supply shipping documents promptly

Offer technical assistance

- This should include promoting, recommending and providing training for users and for maintenance personnel. Onsite training is usually very useful

Understand the import regulations in the recipient's country

- Make sure that the recipient is able to cover the costs of custom duties and any other charges associated with importation

Annex 4
Ordering and transporting chemicals, reagents, stains and dehydrated media

Placing an order

When ordering products, be sure of what you want. Agents will be able to give you access to a catalogue and a price list from a manufacturer to ensure that the correct name of the product is used. When ordering chemicals give the formula of the chemical whenever possible.

Strict transport regulations (see below) can mean certain chemicals can only be shipped by cargo aircraft or by sea freight. The regulations for the segregation of dangerous goods inside a shipping container mean certain dangerous chemicals may have to be placed in different containers. The trained staff of your supplier or their shipping agent will know these shipping rules.

Some chemicals can be obtained in both hydrated and anhydrous forms, salts and free acids and therefore the required form must also be stated. You should note the following.

- Quote the complete ordering number which is unique to each package size.
- Check the amount you wish to order from a supplier. Many chemicals can only be obtained in minimum quantities of 250 g or 500 g. Should you want only, for example, 100 g of a particular chemical, ask your local agent or dealer as some suppliers import chemicals in bulk and repackage them in smaller quantities. However, it is often cheaper to purchase larger quantities of chemicals.
- Check that the shelf-life of the chemical is acceptable and that the conditions of storage can be met to ensure stability and safety.
- Check that national regulations allow importation of the chemical and that it is not listed by the manufacturer as an unstable chemical which is unsuitable for import.
- Check transport regulations of transport of chemicals by aircraft.
- Check that the total cost of the chemicals can be afforded. Some companies may also have a minimum order value, making it impossible to buy just a few chemicals at a time.
- Order quantities of dehydrated media that will be used up in six months or at most one year. The total quantity should be packed in containers that will be used up in one or two months. If quantities for a longer period have to be ordered, make an agreement with the supplier for them to be sent in shipments at acceptable intervals.

- Be aware of the costs involved in freighting hazardous substances. Many suppliers have a minimum order value for many chemicals. Freight charges make it uneconomical to order small quantities of chemicals.

Tip: If you need 160 g of a chemical, and the chemical will store well, order a larger quantity, e.g. 500 g.

Anyone working in a laboratory will be aware that dangerous chemicals are used directly or incorporated into stains and reagents. These include highly flammable (easy to catch fire) chemicals, corrosive (able to attack the skin and destroy solid matter) chemicals and toxic (poisonous) chemicals. Chemical manufacturers are required to label dangerous chemicals with hazard symbols—explosive, oxidizing, flammable, toxic, harmful or corrosive.

The correct handling, storage and transport of hazardous chemicals is essential to prevent injury and damage. Some dangerous goods are too dangerous to be carried by aircraft, others may be carried on cargo aircraft only and some are acceptable on both cargo and passenger aircraft.

When dangerous goods are transported by sea, the shipper must follow requirements for storage and segregation between the various classes of dangerous goods in shipping containers, e.g. separating explosives from flammable liquids. The shipper must ensure the segregation of non-dangerous goods, e.g. poisons from foodstuffs. These requirements for the segregation of dangerous goods may mean the laboratory chemicals you ordered are stored in more than one shipping container.

Transport regulations of hazardous substances

The ordering of chemicals is fairly straightforward but the transport of chemicals can be fraught with delays, loss of time and added cost due to transport regulations. This section gives an outline of the significance of the transportation regulations of hazardous substances.

Each year the International Air Transport Association (IATA) publishes its reference manual, *IATA Dangerous Goods Regulations*. This is an indispensable reference manual used by companies involved in the shipment of chemicals by air or sea. It gives rules for classification, identification, packaging, marking, labelling and documentation.

A supplier will first check in the IATA manual to see if any of the chemicals you have ordered are considered as dangerous goods forbidden in aircraft under any circumstances. The IATA manual gives a list of not less than 240 such chemicals.

Steps to be taken when preparing for transport by air

When preparing to send a consignment by air, the supplier or shipper will do the following.

- Determine the correct technical name or composition of the chemical and check if the chemical is forbidden on aircraft.
- Check whether the name of the chemical appears on the list of dangerous goods in the IATA manual.
- Determine the class and division into which the chemical falls, assuming that it is not on the list of dangerous goods.
- Determine whether the chemical should be transported on passenger or cargo aircraft. If the chemical is forbidden for transportation on passenger aircraft, determine whether it can be transported on cargo aircraft.
- For shipments intended for carriage on passenger aircraft, determine the packing instructions, quantity limitation and whether there are any applicable state or operator variations.
- For shipments intended for carriage on cargo aircraft, determine the packing instructions, quantity limitation and whether there are any applicable state or operator variations.
- Select, where permitted, a method of packing from the packing instruction and ensure the chemicals have the correct packaging and appropriate markings and labels.
- Prepare the air waybill and complete and sign the shipper's declaration for dangerous goods.
- Offer the complete consignment for transportation by air.

The following classes apply to all means of transport.

Class	Meaning
1	Explosive substances (avoid shock, friction and heat), e.g. picric acid
2	Gases
3	Flammable liquids (keep away from sources of ignition), e.g. ether or methanol
4.1	Flammable solids
4.2	Substances liable to spontaneous combustion
4.3	Substances which develop flammable gases in contact with water
5.1	Oxidizing substances and organic peroxides (can ignite combustible material or accelerate existing fires). Keep away from combustible dichromate, chlorates and strong peroxides
5.2	Organic peroxides
6.1	Toxic substances, (very hazardous to health when inhaled, swallowed or in contact with the skin and may even lead to death), e.g. formaldehyde solution
6.2	Infectious substances
7	Radioactive material
8	Corrosive substances (may cause damage to living tissue or equipment upon contact), e.g. sodium hydroxide, sulfuric acid, acetic acid
9	Miscellaneous dangerous goods

Each chemical is assigned an air, road or sea transport category according to its hazard properties. Only dangerous chemicals belonging to the same transport class and the same packing category may be packed together for transport. For example sulfuric acid and sodium hydroxide are not allowed to be packed together for transport but hydrochloric acid and acetic acid are allowed to be packed together.

Packing instructions give details of the packaging required and the quantities allowed for transport by passenger aircraft.

Remember: When your supplier says there will be a delay in the arrival of your chemicals, do not immediately blame your supplier as very often the delay is caused by the strict transport regulations that must be followed.

Freight

Freight costs can add a lot to the total price of an order. As many manufacturers of laboratory equipment are in Europe, Japan and North America, the distributor will have heavy freight costs. The freight costs when ordering some chemicals may be four times the actual cost of the chemical. It is uneconomical to freight any goods under about US$ 140, especially if they are chemicals carrying a hazard certificate. Ask for advice about freight costs from the supplier. The supplier will be familiar with pack sizes and shipping and air waybills, will consider freight costs and will be familiar with regulations concerning transport regulations for dangerous substances.

Annex 5
Equipment index and manufacturers

This chapter lists some manufacturers of laboratory equipment. The list is not exhaustive, and the source companies listed may carry other equipment. Manufacturers addresses are also given.

Note: The mention of specific companies or of certain manufacturers equipment does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned.

Manufacturers of laboratory equipment

Autoclaves
- LMS
- Life Sciences International
- Lte Scientific
- Pbi international
- *Priorclave*
- Swiftlock
- Tuttnauer

Balances
- Bosch 2
- Gottl. Kern & Sohn 1
- Mettler
- Ohaus 1
- Sartorius 2
- Toledo

Centrifuges (electric)
- Beckman
- Centurion Scientific
- Degas gumbo
- Fireball
- GFMD Ltd.
- Hamilton Bell Co Ltd.
- Hawksley
- Heraeus Instruments GmbH
- Hermle
- Hettich
- Ionetics
- Jouan
- Life Sciences International
- Primary Diagnostics
- MSE (Sanyo Gallenkamp)
- Record Townson Mercer
- Sigma Laborzentrifugen GmbH
- Sorvall Inc.
- Spintron
- Technical Research Associates
- Techne
- Vulcon Technologies 1
- Wifug

Centrifuges (mechanical)
- Hettich
- Primary Diagnostics

Centrifuges (microhaematocrit)
- Hawksley
- Hettich
- Jouan
- MSE (Sanyo Gallenkamp)
- Volcon Technologies

Colorimeter
- Ciba-corning
- Hatch
- Jenway 1, 2
- La Motte
- WPA

Counting chambers
- Brand GmbH

Dry heat blocks
- Barnstead/Thermolyne
- Grant
- Stuart
- Techne

Electrolyte analysers (ISE)
- AVL Medical Instruments
- A&T Corporation
- Analyser/industries
- Ciba-Corning
- Dade Lytening Systems Inc.
- Fresenius A G
- Ionetics Inc.
- Instrumention Laboratory Company
- Kone Instruments Corp.
- Liston Scientific
- L. Eschwenler & Co.
- Nova Biomedical

Electrophoresis chambers
- Beckman
- Ciba-Corning
- Helena Lab.
- Hoeffer
- Labconco
- Olympus
- Sebia
- Vogel

Filters
- Millipore
- Sartorious

Filters (HEPA)
- M.C. Air Filtration Ltd.
- Farr Company

Flame photometers
- Ciba-Corning
- Jencons
- Jenway
- Bacharach/Coleman

Glassware
- Schott
- S. Murray & Co
- Hamilton
- Heinz Herenz

Gloves
- Sentinel Laboratories

Incubators
- Firlabo
- Lte Scientific
- LMS Ltd.
- Jouan
- Memmert
- Record Townson Mercer
- Sanyo Gallenkamp PLC
- WTB Binder Labtortechnik GmbH

Incubators (portable)
- Enklab
- GQF
- Millipore

Incubator/ovens
- Memmert

Microbiological Products
- Difco Laboratories

Microscopes
- Ken-a-Vision
- A. Kruess
- Leica
- Leitz

Meiji
ELE International Ltd (Paqualab)
Nikon
Olympus
Prior
Southern Precision Instruments
Speed Fair Co Ltd (Motic)
Swift
Technical & Optical Equipment Ltd
Wesco

Microscopes (including socket for battery connection built into the base)
Carl Zeiss
Gillet & Sibert
Helmut Hund GmbH
Primary Diagnostics

Ovens
Barnstead/Thermolyne
Firlabo
Jencons
Jouan
Record Townson Mercer
Sanyo Gallenkamp
Lte Scientific

Packaging (for dangerous goods)
Express Export

Plasticware
Bibby Sterlin
Kartel Plastics
Nagle
Nunc

pH meters (also replacement electrodes)
Beckman Instruments
Ciba-Corning
Hanna
Jenway [1, 2]
LaMotte
Mettler
Reagecon
Russell [1, 2]
Walden Precision Apparatus [1, 2]

pH meters (portable) [2]
Beckman
Hanna
Jenway
Orion
Russell
Tintometer
Warden Precision Apparatus

Refrigerators and freezers
Electrolux
Fisher Scientific
Forma Scientific
Leec
Revco
Sanyo Gallenkamp

Refrigerators (for flammable materials storage)
Fisons
Leec
Revco

Safety cabinets (microbiological)
Clyde-Apac
Envair Ltd.
Labcaire
Labconco
Reagecon
UVS Ultra Violet Pty Ltd.

Serology centrifuges
Becton Dickinson (Clay Adams)

[1] battery or AC power models available

[2] battery only models available

Spectrophotometers
- Camspec
- Ciba-Corning
- Coleman
- Hatch
- Light Path Optical
- Jenway
- Jouan
- Phillips Scientific
- Spectronic Instruments (Milton Roy)
- Walden Precision Apparatus

Solar energy equipment
- Able Solar
- Ampere Technology
- BP Solar
- Dullas Engineering
- Eurosolare
- Morningstar Corp.,
- NAPS (UK)
- R&S Renewable Energy Systems
- RIF Industries
- Selectronic
- Siemens Solar
- Solar Charge Pty
- Solarex
- Solenco
- Sonnenschein
- Trace Engineering

Uninterruptible power supply (UPS) units and voltage stabilizers
- American Power Conversion
- Anton Piller (UK) Ltd.
- Best Power Technology, Inc.
- Sollatek UK Ltd.

Water testing kits
- ELE (Paqualab)
- Gudimani Enterprises
- Hach
- Leeds
- Millipore
- Oxfam-Delagua
- Potapak (Potalab) Ltd.
- Welsh Water Marketing

Water baths
- Firlabo
- Grant
- LTE Scientific
- Memmet
- Record Townson Mercer
- Jouan
- Techne
- Walden Precision Apparatus

Water deionizers
- USF Permutit

Water filters (ceramic)
- Fairey Industrial Ceramics

Water stills
- Aquatron
- Bibby Sterlin
- Hamilton
- Jouan
- Barvan Pty Ltd. (Solar still)

Addresses of manufacturers of laboratory equipment

Note: The mention of specific companies or of certain manufacturers equipment does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned.

A&T Corporation
320-11 Hino
Hino-shi
Tokyo 191
Japan
Tel: (0081) 425 86 3111
Fax: (0081) 425 83 7999
Electrolyte analysers

A. Kruess, Werkstaetten fuer Optik
Feinmechanik und Elektronik GmbH
Alsterdorfer Strasse 220
D-22297 Hamburg
Germany
Tel: (0049) 40 51 8008
Fax: (0049) 40 51 2522
Microscopes

Able Solar
Unit B/13-15 Collard Place
Henderson,
Waitakere City
Auckland
New Zealand
Tel: (0064) 9 837 2211
Fax: (0064) 9 837 2212
Solar energy equipment

Air Sea Containers Ltd.
Staniford Building
318 New Cheshire Road
Birkenhead,
Merseyside L42 1LE
United Kingdom
Tel: (0044) 151 645 0636
Fax: (0044) 151 644 9268
Containers and packagings for dangerous goods, i.e. infectious substances, diagnostic specimens

Albert Browne Ltd.
Chancery House, Rosebery Road
Ansley
Leicestershire LE7 7EL
United Kingdom
Tel: (0044) 116 234 0730
Fax: (0044) 116 234 0533
Autoclaves, Browne's tubes for quality control

American Power Conversion
132 Fairgrounds Road
West Kingston
Rhode Island 02892
USA
Tel: (001) 401 789 5735
Fax: (001) 401 789 3710
Uninterruptible power supply units; voltage stabilizers

Ampere Technology Ltd.
PO Box 827
Christchurch
New Zealand
Tel: (0064) 3 343 1144
Fax: (0064) 3 343 1144
Solar energy equipment

Analyser Industries
Zuiddijkweg 4
4315 PC Dreischor
The Netherlands
Tel: (0031) 1112 1851
Fax: (0031) 1112 2183
Electrolyte analysers

Anton Piller (UK) Ltd.
Chesterton Lane
Cirencester
Gloucestershire GL7 1YE
United Kingdom
Tel: (0044) 285 657721
Fax: (0044) 285 654823
Uninterruptible power supply units and voltage stabilizers

AVL Medical Instruments AG
PO Box 1140
CH-8207 Schaffhausen
Switzerland
Tel: (0041) 53 34 1666
Fax: (0041) 53 33 1617
Electrolyte analysers

Barnstead/Thermolyne
PO Box 797
Dubuque
Iowa 52004-0797
USA
Tel: (001) 319 589 0538
Fax: (001) 319 589 0530
Dry-heat blocks; ovens

Barvan Pty Ltd.
24 McLean Street
Beverley SA 5009
Australia
Tel: (0061) 8 8346 6699
Fax: (0061) 8 8346 3086
Water still (solar still)

Beckman Instruments (UK) Ltd.
Progress Road
Sands Industrial Estate
High Wycombe
Buckinghamshire HP12 4JL
United Kingdom
Tel: (0044) 1494 441181
Fax: (0044) 1494 447558
Centrifuges; pH meters

Becton Dickinson
PO Box 370
Sparks
Maryland 21152-9976
USA
Tel: (001) 410 316 4000
Fax: (001) 410 316 4066
Serology centrifuges (Clay Adams)

Best Power Technology, Inc.
PO Box 280
Necedah
Wisconsin 54646
USA
Tel: (001) 608 565 7200
Fax: (001) 608 565 2221
Uninterruptible power supply units; voltage stabilizers

Bibby Sterlin Ltd.
Tilling Drive
Stone
Staffordshire ST15 OSA
United Kingdom
Tel: (0044) 1785 812121
Fax: (0044) 1785 813748
Water stills; bench deioizers; plasticware (Azalon)

Bosch & Sohn GmbH Co.
PO Box 34
D-72417 Jungingen
Germany
Tel: (0049) 7477 1011
Fax: (0049) 7477 1021
Balances

BP Solar
PO Box 191
Chertsey Road
Sunbury-on-Thames
Middlesex TW16 7XA
United Kingdom
Tel: (0044) 1932 779543
Fax: (0044) 1932 762686
Solar energy equipment

Brand GmbH & Co.
PO Box 1155
D-97861 Wertheim
Germany
Tel: (0049) 9342 8080
Fax: (0049) 9342 808219
Counting chambers (Neubauer), improved bright-line

Camspec Ltd.
11 High Street
Sawston
Cambridgeshire CB2 4BG
United Kingdom
Tel: (0044) 1223 836971
Fax: (0044) 1223 836414
Spectrophotometers

Carl Zeiss
PO Box 1380
D-73444 Oberkochen
Germany
Tel: (0049) 7364 202865
Fax: (0049) 7364 202382
Microscopes

Centurion Scientific Ltd.
Unit 10
Thorgate Road
Lineside Industrial Estate
Littlehampton
West Sussex BN17 7LU
United Kingdom
Tel: (0044) 1903 731511
Fax: (0044) 1903 731522
Centrifuges

Ciba-Corning Diagnostics Ltd.
Northern Road
Chilton Industrial Estate
Sudbury
Suffolk CO10 6XD
United Kingdom
Tel: (0044) 1787 880022
Fax: (0044) 1787 880033
pH meters; flame photometers; colorimeters; spectrometers

Clyde-Apac
Unit 62
170 Forester Road
Mount Waverly
Victoria 3149
Australia
Tel: (0061) 3 9548 9435
Fax: (0061) 3 9548 9460
Microbiological safety cabinets

Dade Lytening Systems Inc.
35 Cherry Hill Drive
Danvers
Massachusetts 01923-4391
USA
Tel: (001) 508 777 8690
Fax: (001) 508 777 8695
Electrolyte analysers

Desaga GmbH
Postbox 1280
D-69153 Wiesloch
Germany
Tel: (0049) 6222 9288 0
Fax: (0049) 6222 9288 92
Centrifuges

Difco Laboratories Ltd.
PO Box 14 B
Central Avenue
West Molesey
Surrey KT8 2SE
United Kingdom
Tel: (0044) 20 8979 9951
Fax: (0044) 20 8979 2506
Microbiology products: culture media, antisera, instrumentation

Dullas Engineering Ltd.
The Old School
Eglwysfach
Machynlleth
Powys SY20 8SX
Wales
United Kingdom
Tel: (0044) 1654 781332
Fax: (0044) 1654 781390
Solar energy equipment

ELE International Ltd. (Paqualab)
Eastman Way
Hemel Hempstead
Hertfordshire, HP2 7HB
United Kingdom
Tel: (0044) 1442 218355
Fax: (0044) 1442 252474
Portable water testing kits; microscopes

Electrolux (Luxembourg)
4 rue de la Frontière
L-9412 Vianden
Luxembourg
Tel: (00352) 84595
Fax: (00352) 848 11 300
Refrigerators

Envair Ltd.
York Avenue
Haslingden
Rossendale
Lancashire BB4 4HX
United Kingdom
Tel: (0044) 1706 228416
Fax: (0044) 1706 831957
E-mail: envair@dial.pipex.com
Internet: http://www.envair.co.uk
Safety cabinets (microbiological)

Eurosolare
Via A.D'Andrea 6
00048 Nettuno
Italy
Tel: (0039) 6 985601
Fax: (0039) 6 9850267
Solar energy equipment

Express Export
8 rue des Fours
PO Box 77230
Thieux
France
Tel: (0033) 161 6026 8600
Fax: (0033) 161 6026 8462
Containers and packaging for dangerous goods, i.e. substances, diagnostic specimens

Fairey Industrial Ceramics Ltd.
Filleybrooks
Stone
Staffordshire STI5 OPU
United Kingdom
Tel: (0044) 1785 813241
Fax: (0044) 1785 818733
Water purification systems; gravity filters

Farr Company
PO Box 92187
Los Angeles, Airport Station
California 90009
USA
Tel: (001) 310 536 6300
Fax: (001) 310 643 9086
HEPA air filters

Firlabo
50 rue Rachais
69007 Lyon
France
Tel: (0033) 7872 2715
Fax: (0033) 7869 4945
Centrifuges; water baths; ovens; incubators

Fisher Scientific (UK) Ltd.
Bishop Meadow Road
Loughborough
Leicestershire LE11 ORG
United Kingdom
Tel: (0044) 1509 231166
Fax: (0044) 1509 231893
Refrigerators

Forma Scientific Inc.
PO Box 649
Marietta
Ohio 45750
USA
Tel: (001) 614 373 4763
Fax: (001) 614 373 8466
Refrigerators; freezers; thawing baths

Fresenius AG
Critical Care International
Hohemarkstrase 152
61440 Oberursel
Germany
Tel: (0049) 6171 60 5504
Fax: (0049) 6171 60 5649
Electrolyte analysers

GFMD Ltd.
2280 Springlake Road #106
Dallas
Texas 75234
USA
Tel: (001) 214 919 1780
Fax: (001) 214 247 3690
Centrifuges

Gilbert & Sibert
Kirktonfield Road
Neilston
Glasgow G78 3PL
Scotland
United Kingdom
Tel: (0044) 14 881 5825
Fax: (0044) 141 881 5828
Microscopes

Gottl. Kern & Sohn GmbH
PO Box 48
D-72421 Albstadt 1-Ebingen
Germany
Tel: (0049) 7431 93890
Fax: (0049) 7431 938949
Balances

GQF Manufacturing Company
PO Box 1552
Savannah
Georgia 31498
USA
Tel: (001) 912 236 0651
Fax: (001) 912 234 9978
Portable incubators

Grant Instruments (Cambridge) Ltd.
Barrington
Cambridgeshire CB2 5QZ
United Kingdom
Tel: (0044) 1763 260811
Fax: (0044) 1763 262410
Water baths; dry heat blocks

Gudimani Enterprises
403-404 Saraswati House
27 Nehru Place
New Delhi 110019
India
Tel: (0091) 11 641 7353 11 641 9834
Fax: (0091) 11 622 8013
Portable water testing kits

Hach Company
PO Box 389
Loveland
Colorado 8053-0389
USA
Tel: (001) 970 669 3050
Fax: (001) 970 669 2932
Portable water testing kits

Hamilton Laboratory Glass Ltd.
Europa House
Unit 1 Westwood Industrial Estate
Ramsgate Road
Margate
Kent CT9 4JA
United Kingdom
Tel: (0044) 1843 23263
Fax: (0044) 1843 232644
Water stills; glassware

Hawksley & Sons Ltd.
Marlborough Road
Lancing
West Sussex BN15 8TN
United Kingdom
Tel: (0044) 1903 752815
Fax: (0044) 1903 766050
Microhaematocrit centrifuges; counting chambers, parasitology chambers;

Heinz Herenz
PO Box 80 04 05
D-21004 Hamburg
Germany
Tel: (0049) 40 739 2040
Fax: (0049) 40 730 4148
Glassware, microscope slides; instruments; bacterial sample collecting sets; lancets

Helena Laboratories (UK) Ltd.
Seventh Avenue
Team Valley Trading Estate
Gateshead
Tyne and Wear NE11 OLH
United Kingdom
Tel: (0044) 191 487 8855
Fax: (0044) 191 491 0602
Electrophoresis chambers

Helmut Hund GmbH
Wilhelm-Will- Strasse 7
D-35580 Wetzlar
Germany
Tel: (0049) 6441 2004 0
Fax: (0049) 6441 2004 44
Microscopes

Hemocue AB
Box 1204
S-262 23 Angelholm
Sweden
Tel: (0046) 431 58200
Fax: (0046) 431 83035
Haemoglobin photometer; glucose photometer; ESR mixer

Heraeus Instruments GmbH
Postbox 1563
D-63405 Hanau
Germany
Tel: (0049) 6181 35 300
Fax: (0049) 6181 3559 73
Centrifuges

Hermle-Labortechnik GmbH
Gosheimer Strabe 56
D-78564 Wehingen
Germany
Tel: (0049) 7426 96220
Fax: (0049) 7426 962249
Centrifuges

Hettich
Gartenstrasse 100
D-78532 Tuttlingen
Germany
Tel: (0049) 7461 7050
Fax: (0049) 7461 705122
Centrifuges (including hand operated)

Hoeffer Phamacia Biotec Inc.
PO Box 77387
San Francisco
California 94107-0387
USA
Tel: (001) 415 282 2307
Fax: (001) 415 821 1081
Electrophoresis chambers

Hook & Tucker (Instruments) Ltd.
Vulcan Way
New Addington
Croydon
Surrey CR0 9UG
United Kingdom
Tel: (0044) 1689 843345
Fax: (0044) 1689 841792
Diluters; dispensers; vortex mixers

Instrumentation Laboratory Company
PO Box 9113
Lexington
Massachusets 02173-3190
USA
Tel: (001) 617 861 0710
Fax: (001) 617 861 1908
Electrolyte analysers

Ionetics Inc.
10574 Belcher River
Fountain Valley
California 92708
USA
Tel: (001) 714 378 8383
Fax: (001) 714 378 8386
Electrolyte analysers; centrifuges; refurbished instruments

Jencons (Scientific) Ltd.
Cherrycourt Way Industrial Estate
Stanbridge Road
Leighton Buzzard
Bedfordshire LU7 8UA
United Kingdom
Tel: (0044) 1525 372010
Fax: (0044) 1525 379547
Ovens; flame photometers

Jenway Ltd.
Gransmore Green
Felsted
Dunmow
Essex CM6 3LB
United Kingdom
Tel: (0044) 1371 820122
Fax: (0044) 1371 821083
pH meters; colorimeters; spectrophotometers; flame photometers

Jouan
rue Bobby Sands
Case Postale 3203
44805 Saint Herblain
France
Tel: (0033) 4016 8080
Fax: (0033) 4094 7016
Water baths; centrifuges; incubators; ovens

Kartell Plastics UK Ltd
Unit C Broad Lane
Cottenham
Cambridgeshire CB4 4SW
United Kingdom
Tel: (0044) 1954 251341
Fax: (0044) 1954 251951
Plasticware; cuvettes

Ken-a-Vision
5615 Raytown Road
Kansas City
Missouri 64133
USA
Tel: (001) 816 353 4787
Fax: (001) 816 358 5072
Microscopes

Kone Instruments Corporation
Ruukintie 18
Espoo
SF-02320
Finland
Tel: (00358) 9 802 766
Fax: (00358) 9 802 766
Electrolyte analysers

L. Eschweiler & Co.
Holzkoppelweg 35
D-24118 Keil
Germany
Tel: (0049) 431 5465 80
Fax: (0049) 431 549423
Electrolyte analysers

Labcaire Systems Ltd.
International Division
15 Hither Green,
Clevedon
Somerset BS21 6XU
United Kingdom
Tel: (0044) 1275 340033
Fax: (0044) 1275 341313
Microbiological safety cabinets

Labconco Corporation
8811 Prospect Avenue
Kansas City
Missouri 64132-2696
USA
Tel: (001) 816 333 8811
Fax: (001) 816 363 0130
Microbiological safety cabinets

La Motte Company
PO Box 329
Chestertown
Maryland 21620
USA
Tel: (001) 410 778 3100
Fax: (001) 410 778 6394
Water testing kits (pH, chlorine); colorimeters; pH meters

Leec Limited
Private Road No 7
Colwick Industrial Estate
Nottingham NG4 2AJ
United Kingdom
Tel: (0044) 115 961 6222
Fax: (0044) 115 961 6680
Refrigerators

Leeds Portable Incubator
Department of Civil Engineering
University of Leeds
Leeds West,
Yorkshire LS2 9JT
United Kingdom
Tel: (0044) 113 233 2269
Fax: (0044) 113 233 2265
Portable water testing kits

Leica Inc.
PO Box 123
Buffalo
New York 14240-0123
USA
Tel: (001) 716 686 3000
Fax: (001) 716 686 3085
Microscopes

Leica Microscope Ltd. (Shanghai)
Jinquiao Export Processing Zone
Block 20, Building 1
Pu Dong,
Shanghai 201206
China
Microscopes

Life Sciences International (UK) Ltd.
Unit 5
The Ringway Centre
Edison Road
Basingstoke
Hampshire RG21 2YH
United Kingdom
Tel: (0044) 1256 817282
Fax: (0044) 1256 817292
Autoclaves (Denley)

Light Path Optical Co. Ltd.
Division of Buck Scientific Inc.
Unit 3
Elms Industrial Estate
Church Rd
Harold Wood
Essex RM30JU
United Kingdom
Tel: (0044) 708 349136
Fax: (0044) 708 381638
Spectrophotometers; spectrophotometer cells (cuvettes); spectrophotometer lamps

LIP (Equipment & Services) Ltd.
111 Dockfield Road
Shipley
Yorkshire BD17 7SJ
United Kingdom
Tel: (0044) 1274 593411
Fax: (0044) 1274 589439
Laboratory consumables: plastic test tubes, pipette tips, vials

Liston Scientific
18900 Teller Avenue
Irving
California 92715-1617
USA
Tel: (001) 714 756 1632
Fax: (001) 714 756 1635
Electrolyte analysers

LMS Ltd.
The Modern Forge
Riverhead
Sevenoaks
Kent TN13 2EL
United Kingdom
Tel: (0044) 1732 451866
Fax: (0044) 1732 450127
Incubators, autoclaves

Lte Scientific Ltd.
Greenbridge Lane
Greenfield
Oldham
Lancashire OL3 7EN
United Kingdom
Tel: (0044) 1457 876221
Fax: (0044) 1457 870131
Autoclaves, incubators, water baths, ovens

M.C. Air Filtration Ltd.
Motney Hill Road
Gillingham
Kent ME8 7TZ
United Kingdom
Tel: (0044) 1634 388333
Fax: (0044) 1634 379384
HEPA air filters

Meiji Techno Co. Ltd.
6, Oi-670
Iruma-gun
Saitama 354
Japan
Tel: (0081) 492 67 0911
Fax: (0081) 492 69 0691; 492 69 0692
Microscopes

Memmert
PO Box 1720
D-91107 Schwabach
Germany
Tel: (0049) 9122 9250
Fax: (0049) 9122 14585
Water baths; incubators; incubator/ovens.

Mettler Toledo Ltd
64 Boston Road
Beaumont Leys
Leicester LE4 1AW
United Kingdom
Tel: (0044) 116 235 7070
Fax: (0044) 116 236 6399
Balances; pH meters; electrodes

Millipore Corporation
80 Ashby Road
Bedford
Massachusetts 01730-2271
USA
Tel: (001) 617 275 9200
Fax: (001) 617 275 5550
Filters

Millipore Corporation
Intertech Division
PO Box 255
Bedford
Massachusetts 01730
USA
Tel: (001) 781 533 8622
Fax: (001) 781 533 8630
Portable water testing kits; portable incubators

Monaflex Ltd.
Lyon Way
St Albans
Hertfordshire AL4 OLB
United Kingdom
Fax: (0044) 1727 830116
Fax: (0044) 1727 868045
Plastic sheeting used for disaster situations

Nagle Company
PO Box 20365
Rochester
New York 14602-0365
USA
Tel: (001) 716 264 3898
Fax: (001) 716 586 3294
Plasticware

Naps UK
PO Box 83
Abingdon
Oxfordshire OX14 2TB
United Kingdom
Tel: (0044) 1235 529749
Fax: (0044) 1235 553450
Solar energy equipment

Nikon UK Ltd.
Nikon House
380 Richmond Road
Kingston upon Thames
Surrey KT2 5PR
United Kingdom
Tel: (0044) 181 541 4440
Fax: (0044) 181 541 4584
Microscopes

Nova Biomedical
200 Prospect Street
Waltham
Massachusetts 02254-9141
USA
Tel: (001) 617 894 0800
Fax: (001) 617 893 6998
Electrolyte analysers

Nunc
PO Box 280
Kamstrup
DK-4000 Roskilde
Denmark
Tel: (0045) 4635 9065
Fax: (0045) 4635 0105
Plasticware

Ohaus Corporation
PO Box 900
Florham Park
New Jersey 07932-0900
USA
Tel: (001) 201 377 9000
Fax: (001) 201 593 0359
Balances

Olympus Optical Co. (UK) Ltd.
2-8 Honduras Street
London EC1Y OTX
United Kingdom
Tel: (0044) 20 7253 2772
Fax: (0044) 20 7251 6330
Microscopes; electrophoresis chambers

Orion Research Incorporated
529 Main Street
Boston
Massachusetts 02129-1104
USA
Tel: (001) 617 242 3900
Fax: (001) 617 242 4195
Portable Ph meters

Oxfam-Delagua
Robens Centre for Public and
Environmental Health
University of Surrey
Guildford
Surrey GU2 5XH
United Kingdom
Tel: (0044) 1483 259203
Fax: (0044) 1483 503517
Portable water testing kits

Phillips Scientific (Philips Analytical)
York Street
Cambridge CB1 2PX
United Kingdom
Tel: (0044) 1223 358880
Fax: (0044) 1223 374266
Spectrophotometers

Potapak (Potalab) Ltd.
PO Box 154
3 Canal Walk
Toomer's Wharf
Newbury
Berkshire RG13 1XN
United Kingdom
Tel: (0044) 1635 30552
Fax: (0044) 1635 30844
Water testing kits

Primary Diagnostics Ltd.
Ash barn
Braunton
North Devonshire EX33 2EG
United Kingdom
Tel: (0044) 1271 815310
Fax: (0044) 1271 814997
E-mail: royrickman@AOL.com
Centrifuges (including mechanical models); microscopes; haemoglobinometer.

Prior Scientific Ltd.
Unit 4,
Wilbraham Road
Fulbourn
Cambridgeshire CB1 5ET
United Kingdom
Tel: (0044) 1223 881711
Fax: (0044) 1223 881710
Microscopes

Pbi international
Via novaria 89
Milano 20153
Italy
tel: +(39) 2701031
Fax: + (39) 2 40090010
Autoclaves

Priorclave Ltd.
129/131 Nathan Way
West Thamesmead Business Park
London SE28 0AB
United Kingdom
Tel: (0044) 181 316 6620
Fax: (0044) 181 855 0616
Autoclaves

R & L Enterprises Ltd.
Swinnow View
Bramley
Leeds
West Yorkshire LS13 4NA
United Kingdom
Tel: + (44) 1532 574208
Fax: (0044) 1532 560876
Clamps; burners; stands; clips cork borer sets

R & S Renewable Energy Systems BV
PO Box 45
5600 AA Eindhoven
The Netherlands
Tel: (0031) 40 520155
Fax: (0031) 40 550625
Solar energy equipent

Reactifs RAL
3 rue la Boetie
F-75008 Paris
France
Tel: (0033) 1 4742 7981
Fax: (0033) 1 4742 4757
Biological stains and dyes

Reagecon Ltd.
Shannon Free Zone
Shannon
County Clare
Ireland
Tel: (00353) 61 472622
Fax: (00353) 61 472642
pH meters, electrodes; safety containment stations (portable)

Record Townson Mercer Ltd.
Record House
Atlantic Street
Altrincham
Cheshire WA14 5DB
United Kingdom
Tel: (0044) 161 927 7596
Fax: (0044) 161 926 9750
Ovens; water baths; centrifuges, hot plates; incubator/ovens

RIF Industries
PO Box 204
Chester Hill
New South Wales 2162
Australia
Tel: (0061) 2 727 4455
Fax: (0061) 2 727 7447
Solar energy equipment

Russell pH Ltd.
Station Road
Auchtermuchty
Fife KY14 7DP
Scotland
United Kingdom
Tel: (0044) 1337 828871
Fax: (0044) 1337 828972
pH meters, electrodes and spare parts

S. Murray & Co. Ltd.
Holborn House
Old Woking
Surrey GU22 9LB
United Kingdom
Tel: (0044) 1483 740099
Fax: (0044) 1483 755111
Glassware

Sanyo Gallenkamp PLC
Riverside Way
Uxbridge
Middlesex UB8 2YF
United Kingdom
Tel: (0044) 1895 251100
Fax: (0044) 1895 256542
Incubators; ovens; centrifuges; water stills; water deionisers; refrigerators & freezers

Sartorius Ltd.
Longmead Business Centre
Bleinheim Road
Epsom
Surrey KT19 9QU
United Kingdom
Tel: (0044) 1372 745811
Fax: (0044) 1372 720799
Balances; filter paper; membranes; holders

Schott in the Laboratory
Hattenbergstrasse 10
D-55122 Mainz
Germany
Tel: (0049) 6131 66 4466
Fax: (0049) 6131 66 4016
Glassware

Sebia
23 rue Maximilien Robespierre
92130 Issy-les-Moulineaux
France
Tel: (0033) 1 4644 8630
Fax: (0033) 1 4644 2470
Electrophoresis chambers and power supply units; reagent kits for electrophoresis; densitometer

Sentinel Laboratories Ltd.
Mitchell House, The Mardens
Crawley
West Sussex RH11 OAQ
United Kingdom
Tel: (0044) 1293 526457
Fax: (0044) 1293 517870
Gloves

Siemens Solar GmbH
Buchenalle 3
D-5060 Bergisch-Gladbach
Germany
Tel: (0049) 2204 4060
Fax: (0049) 2204 40666
Solar energy equipment

Sigma Laborzentrifugen GmbH
Postbox 1713
D-37507 Osterode am Harz
Germany
Tel: (0049) 5522 5007 0
Fax: (0049) 5522 5007 12
Centrifuges

Solar Charge Pty Ltd.
115 Martin St
Brighton
Victoria 3186
Australia
Tel: (0061) 3 9596 1974
Fax: (0061) 3 9596 1389
Solar energy equipment

Solarex
630 Solarex Court
Frederick
Maryland 21701
USA
Tel: (001) 301 698 4200
Fax: (001) 301 698 4201
Solar energy equipment

Solenco GmbH
PO Box 100219
D-40766 Manheim
Germany
Tel: (0049) 2224 78806
Fax: (0049) 2224 79671
Solar energy equipment

Sollatek UK Ltd
4/5 Trident Industrial Estate
Blackthorne Road
Slough SL3 OAX
United Kingdom
Tel: (0044) 1753 682337
Fax: (0044) 1753 685306
Uninterruptible power supply units
voltage stabilizers

Sonnenschein GmbH
PO Box D-63652 Budingen
Thiergarten
D-63654 Budingen
Germany
Tel: (0049) 60 42 81 0
Fax: (0049) 60 42 81538
Solar energy equipment; lead acid
batteries (VRLA)

Sorvall Inc.
31 Pecks Lane
Newtown
Connecticut 06470-2337
USA
Tel: (001) 203 270 2203
Fax: (001) 203 270 2210
Centrifuges

Southern Precision Instrument
3419 East Commerce Street
San Antonio
Texas 78220
USA
Tel: (001) 210 212 5055
Fax: (001) 210 212 5062
Microscopes

Spectronic Instruments Inc.
820 Linden Ave
Rochester
New York 14625
USA
Tel: (001) 716 248 4000
Fax: (001) 716 248 4014
Spectrophotometers (Milton Roy)

Speed Fair Co. Ltd. (Motic)
GPO Box 5153
Hong Kong
Tel: (00852) 897 5828
Fax: (00852) 897 5990
Microscopes

Spintron
PO Box 539
Newport Beach
Sydney 2106
Australia
Tel: (0061) 2 973 1343
Fax: (0061) 2 973 1363
Centrifuges

Swift Instruments Inc.
PO Box 562
San Jose
California 95106-0562
USA
Tel: (001) 408 293 2380
Fax: (001) 408 292 7967
Microscopes

Techne (Cambridge) Ltd.
Duxford
Cambridgeshire CB2 4PZ
United Kingdom
Tel: (0044) 1223 832401
Fax: (0044) 1223 836838
Dry heat blocks; water baths

Technical & Optical Equipment Ltd.
Zenith House
69 Lawrence Road
Tottenham
London NI15 4TG
United Kingdom
Tel: (0044) 208 800 8088
Fax: (0044) 208 809 0556
Microscopes

Technical Research Associates Inc.
410 Chipeta Way
Suite 222
Salt Lake City
Utah 84108-1209
USA
Tel: (001) 801 582 8080
Fax: (001) 801 582 8182
Centrifuges

The Tintometer Ltd.
Waterloo Road
Salisbury
Wiltshire SP1 2JY
United Kingdom
Tel: (0044) 1722 327242
Fax: (0044) 1722 412322
Lovibond comparator for colorimetric analysis

Thermolyne
PO Box 797
Dubuque
Iowa 52004-0797
USA
Tel: (001) 319 589 0538
Fax: (001) 319 589 0530,
319 556 0695
Dry heat blocks

Trace Engineering
5916 195th St. N.E
Arlington
Washington 98223
USA
Tel: (001) 360 435 8826
Fax: (001) 360 435 2229
Solar energy equipment; inverters

Tuttnauer USA Co. Ltd.
33 Comac Loop
Equi-Park
Ronkonkoma
New York 11779
USA
Tel: (001) 516 737 4850
Fax: (001) 516 737 0720
Autoclaves

USF Permutit Ltd.
Harforde Court
John Tate Road
Hertford SG13 7NW
United Kingdom
Tel: (0044) 1992 823300
Fax: (0044) 1992 501528
Water deionizers

UVS Ultra Violet Pty Ltd.
8-10 Keith Campbell Court
Souresby
Victoria 3179
Australia
Tel: (0061) 3 9764 1444
Fax: (0061) 3 9764 1700
Microbiological safety cabinets

Vogel GmbH & Co KG
Marburgerstrasse 81
PO Box 101047
D-35396 Giessen
Germany
Tel: (0049) 641 932310
Fax: (0049) 641 39221
Electrophoresis chamber

Vulcon Technologies
718 Main Street
Grandview
Missouri 64030
USA
Tel: (001) 816-966 1212
Fax: (001) 816-066-8879
Centrifuges (including microhaematocrit)

Walden Precision Apparatus
The Old Station
Linton
Cambridgeshire CB1 6NW
United Kingdom
Tel: (0044) 1223 892688
Fax: (0044) 1223 894118
Water baths; pH meters; colorimeters; spectrophotometers.

Welsh Water Marketing
Cambrian Way
Brecon Wales LD3 7HP
United Kingdom
Tel: (0044) 874 3181
Fax: (0044) 874 4167
Portable water testing kits

WESCO Western Scientific Co. Inc.
1577 Colorado Boulevard
Los Angeles
California 90041
USA
Tel: (001) 213 257 0832
Fax: (001) 213 257 0982
Microscopes

Wifug (Eltex of Sweden Ltd)
Lane Close Mills
Bartle Lane
Great Horton
Bradford
West Yorkshire BD7 4QQ
United Kingdom
Tel: (0044) 1274 571071
Fax: (0044) 1274 501209
Centrifuges

3M United Kingdom PLC
3M House
PO Box 1
Market Place
Bracknell
Berkshire RG12 1JU
United Kingdom
Tel: (0044) 1344 858000
Fax: (0044) 1344 858278
Respiratory protection

WTB Binder Labortechnik GmbH
PO Box 102
D-78502 Tuttlingen
Germany
Tel: (0049) 7461 17920
Fax: (0049) 7461 179210
Incubators

Annex 6
Laboratory equipment supply

Non-profit and low profit suppliers of second-hand and reconditioned equipment

Germany

Technologie Transfer Marburg in die Dritte Welt e. V., Siegener strasse 33, D-35094 Lahntal-Gossfelden, Germany
Tel: (0049) 6423 9288 0 Fax: (0049) 6423 9288 88

Technologie Transfer Marburg (TTM) activities include developing, constructing and supplying certain technical equipment, appropriate and suited to conditions in most developing countries. TTM supplies reconditioned as well as new laboratory equipment, both at low cost. Examples of reconditioned equipment are photometers, incubators, autoclaves, centrifuges, haematocrit centrifuges and balances. Used equipment is supplied against reimbursement of the reconditioning costs.

TTM has developed a portable laboratory for use in developing countries and emergency/disaster situations, e.g. refugee camps. The composition depends on the type and number of laboratory tests which the user intends to carry out. The portable laboratory is transported in multipurpose aluminium containers. On site, these containers serve as lockable cupboards with storage drawers.

TTM supplies spare parts and consumables. TTM can supply solar energy systems of between 12 V and 40 V with batteries as well as systems of 220 V.

United States of America

International Aid Inc., 17011 West Hickory, Spring Lake, Michigan 49456-9712, USA
Tel: (001) 616 846 7490 Fax: (001) 616 846 3842

International Aid Inc. is a non-profit relief and development organization. It works with mission organizations and hospitals primarily in developing countries.

REAP International, a division of International Aid Inc., specializes in the refurbishing of technical medical equipment. Used laboratory equipment it has includes centrifuges, incubators and spectrophotometers. A catalogue of medical equipment, medical supplies, medical books and medications is available upon request.

A remote laboratory kit includes a low-cost battery operated microhaematocrit centrifuge, a colorimeter, a urine concentrator and a binocular microscope.

Worldwide Lab Improvement Inc., 10046 Schumann, Portage, Michigan 49024, USA
Tel: (001) 616 323 8407 Fax: (001) 616 323 2030 E-mail: wwlab@aol.com

Worldwide Lab Improvement Inc. (WLI) is a Christian, charitable, non-profit-making corporation specializing in equipping medical laboratory facilities in mission hospital and clinics in developing countries. WLI offers new or refurbished equipment and provides training in the operation of equipment.

Pacific, Asia, Eastern Europe, Caribeean and Africa

Medical Aid Abroad, PO Box 26336, Auckland 1003, New Zealand
Tel: (0064) 9 262 1855 Fax: (0064) 9 307 2863

Medical Aid Abroad (MAA) is a non-profit voluntary organization seeking to assist health work in developing countries through supplying surplus medical supplies and equipment as well as providing backup support when appropriate. MAA receives surplus drugs and equipment from hospitals, pharmaceutical companies, medical and dental practices. Upon receipt of an order from a requesting agency, items are packaged for delivery.

MAA is recognized by the Ministry of Health, and supported by the New Zealand Medical and Dental Associations, the Red Cross and others.

Freight expenses are generally the responsibility of the requesting agency or their sponsoring body.

Canada

Lab Equip Ltd., 330 Esna Park Dr. # 32, Markham, Ontario L3R 1H3, Canada
Tel: (001) 905 4755880 Fax: (001) 905 4751231

Lab Equip Ltd. is a supplier of reconditioned and surplus laboratory instrumentation. An information service, Labequip Info-Tech, answers questions about equipment being considered and where to obtain equipment or parts etc. Catalogues are supplied on request.

General Scientific Instrument Services Inc., 1764 Oxford Street East, Unit E7,
London, Ontario N5V 3R6, Canada
Tel: (001) 519 659 2275 Fax: (001) 519 659 6444

The services of General Scientific Services Inc. (GSIS) include the sale of used equipment, parts and repairs.

United Kingdom

Science Exchange Service, Rutherford House, 43 Terrace Road, Walton-on-Thames, Surrey, KT12 2SP, United Kingdom
Tel: (0044) 1932 246688 Fax: (0044) 1932 246680

The Science Exchange Service is a company that both buys and sells utilized scientific equipment. The equipment is fully serviced second-hand scientific equipment and as such is exported throughout the world. Catalogues are available on request.

Non-profit and low profit suppliers of new scientific and laboratory equipment

Germany

Begeca, P.O. Box 287, D-52003 Aachen, Germany
Tel: (0049) 241 477 9 824 Fax: (0049) 241 477 9840

The assistance provided by Begeca includes the procurement of hospital and laboratory equipment, spare parts, HIV testing material and providing technical advice. The logistics department can arrange insurance and the transport of goods by sea or air.

The Netherlands

International Dispensary Association, P.O. Box 3098, 1003 AB Amsterdam, The Netherlands
Tel: (0031) 20 4033051 Fax: (0031) 20 4031854

The International Dispensary Association (IDA) was set up in 1972 to support health care in developing countries on a non-commercial basis by supplying high quality medicines, laboratory equipment, and medical supplies at the lowest possible price. Its publications include *Medical laboratories; methods and materials* (French edition available), *Electricity from sunshine* and various systems/price indications. The booklet *Medical laboratories; methods and materials* includes tests, materials and technical specifications of laboratory equipment. Leaflets on sterilizers, boilers and pressure cookers are available. A *Price indicator* outlining medicines and equipment is available on request.

United Kingdom

British Laboratoryware Association Ltd. (BLWA)

The Association of the Laboratory Supply Industry, Guild House, 30/32 Worple Road, London, SW19 4EF, United Kingdom
Tel: (0044) 20 8946 2548 Fax: (0044) 20 8879 1219

The British Laboratory Ware Association represents the laboratory supply industry of the United Kingdom. It produces a members newsletter, provides a free information and enquiry service to potential customers and gives training courses and seminars. BLWA compiles a membership directory which lists over 150 UK-based companies; a short profile outlining key products of each company is included.

ECHO International Health Services Limited, Ullswater Crescent, Coulsdon, Surrey, CR5 2HR, United Kingdom
Tel: (0044) 20 8660 2220 Fax: (0044) 20 8668 0751
E-mail: echo.intnlhealth@ofl.btx 400.co.u k

ECHO International Health Services Limited is a self-financing registered charity offering a comprehensive medical supply service for the relief of sickness abroad, regardless of race, caste or creed. ECHO supplies low-cost medicines and medical, surgical and hospital laboratory equipment to government, charity and mission health care programmes in developing countries worldwide. Supplies include generic pharmaceuticals, new and expertly reconditioned medical equipment, specialized medical kits, HIV testing kits and solar powered equipment. Publications available from ECHO include *Selecting medical supplies for basic health care.* The price guide *Medical equipment, instruments and consumables* includes laboratory equipment and consumables.

Developing Health Technology, Gordon-Keeble GP Head Office, Bridge House, Worlington Road, Barton Mills, IP28 7DX, United Kingdom
Tel. (0044) 1638 510055 Fax: (0044) 1638 515599

The policy and philosophy of Developing Health Technology (formerly trading as Solmedia Tropical Laboratory Supplies) is to provide laboratory equipment to developing countries at the lowest feasible price. Price list available on request.

International Laboratory Buyer's Guide, Enquiry Processing Service, PO Box 440 Amersham, Buckinghamshire, HP6 6TL, United Kingdom

This buyer's guide includes:

- Product listings: alphabetic listing of equipment e.g. centrifuges, chemicals, flasks
- Manufacturers' directory: alphabetic listing of manufacturers referred to under the product listings. There are over 2000 worldwide manufacturers listed. It also produces a short guide to dealers listed by countries.

Tropical Health Technology, 14 Bevills Close, Doddington, March, Cambridgeshire, PE15 OTT, United Kingdom
Tel: (0044) 1354 740825 Fax: (0044) 1354 740013
E-mail: thtbooks@tht.ndirect.co.uk

Tropical Health Technology (THT) supplies a microscope especially produced for tropical medicine. THT also supplies medical publications (see Annex 8).

United States of America

Hands to Clinical Laboratories of Third World Countries Inc., National Coordinator, 179 Broadway, Patterson, NJ 07505, USA
Tel: (001) 201 881 3972 Fax: (001) 201 279 7511

Hands to Clinical Laboratories of Third World Countries Inc. (HCL) is a voluntary, non-profit organization which arranges the exchange of new or used laboratory equipment, supplies, text books, manuals, journals, slides, tapes and charts to laboratories in developing countries. Examples of support which HCL can provide are training of laboratory personnel, short-term consultants, and the "Adopt-a-Laboratory" programme.

ECRI, 5200 Butler Pike, Plymouth Meeting, Pennsylvania 19462-1298, USA
Tel: (001) 610 825 6000 Fax: (001) 610 834 1275 E-mail: ecri@hslc.org

ECRI is a non-profit agency. Its services include technical assistance programmes, databases and publications. Databases contain reports of medical device evaluations, problems and hazards, cost studies and technology assessments from worldwide sources. ECRI assists in equipment acquisition, negotiation, and evaluation of "best buy" alternatives through life-cycle cost analysis. ECRI's *Healthcare product comparison system* provides information to make brand-name, model-specific comparisons of laboratory equipment. The *Health devices source-book* published by ECRI is an annually published directory of medical product manufacturers, servicers and distributors in North America.

United Nations Children's Fund (UNICEF)

Supply Division, UNICEF Plads, Freeport, DK-2100 Copenhagen 0, Denmark
Tel: (0045) 3527 3527 Fax: (0045) 3526 9421 E-mail: afortin@unicef.dk

The United Nations Children's Fund warehouse in Copenhagen includes laboratory equipment and consumables. Laboratory emergency modules and kits are not supplied. Supplies are sent out to UNICEF projects, or on behalf of nongovernmental organizations or governments.

World Health Organization (WHO)

Chief, Supply Services, Avenue Appia, 1211 Geneva 27, Switzerland
Tel: (0041) 22 791 2111 or (0041) 22 791 2811 (direct to Procurement Services)
Fax: (0041) 22 791 4196
Internet: http://www.who.int

The major part of the supplies of the World Health Organization is procured by Procurement Services (PRS), Geneva, Switzerland. The Chief of Supplies is assisted by purchasing officers in sub-units: Drugs and Biologicals (DBP), Environmental (ESP), Hospital and Teaching (HTP), Laboratory (LSP), General, which includes Administrative and Building materials (GSE), Computer and Office furniture and equipment (GSL).

PRS takes procurement action and issues the necessary purchase orders to suppliers. PRS has its own shipping unit (SHP) which takes care of air and surface shipments as well as all the documentation.

Purchases may be made locally by supply officers in the WHO regional offices, country representatives (WRs) or project staff, depending upon availability of supply sources within their areas.

Note: There are many commercial suppliers of laboratory equipment. These may be located through your local telephone directory.

Annex 7
Information and materials

The following are among the many useful sources of information and materials.

The Association for Appropriate Technologies, Gansheidestrasse 43, D-70184 Stuttgart, Germany
Tel: (0049) 711 21095 0 Fax: (0049) 711 21095 55

The Association for Appropriate Technologies (FAKT) is a non-profit-making German organization with a consultancy service operating in the field of hospital technology, rural energy supply, water supply and sanitation, food processing and vocational training. It operates a resource centre on all aspects of hospital equipment management and appropriate medical equipment. FAKT assists partners in developing countries in the building of medical equipment maintenance programmes, evaluations, training programmes and workshops.

ATOL, Blijde Inkomststraat 9, B-3000 Leuven, Belgium
Tel: (0032) 1622 4517 Fax: (0032) 1622 2256

ATOL is a Belgian nongovernmental organization for development cooperation. Its fields of specialization are the promotion of appropriate technology, the development of small industries and institutional support. It has a specialized library, provides a question and answer service and can supply a list of publications.

Bath Institute of Medical Engineering Limited, Head of Engineering, The Wolfson Centre, Royal United Hospital, Combe Park, Bath, BA1 3NG, United Kingdom
Tel:(0044) 1225 824103 Fax: (0044) 1225 824111 E-mail: bime@bath.ac.uk

The Bath Institute of Medical Engineering is a design and development charity in the field of medical engineering that is part of the University of Bath and based at the Royal United Hospital in Bath. The institute takes requests for medical devices, mostly from healthcare professionals, and develops prototypes to the point when they can be shown to be truly effective, e.g. work is being done on a low-cost haemoglobinmeter. It also arranges exploitation though various manufacturers and has its own production and marketing facility for manufacturing and selling small batches of successful designs.

Brace Research Institute, Publication Department, Faculty of Engineering, PO Box 900, MacDonald College of McGill University, Ste. Anne de Bellevue, Quebec H9X 3V9, Canada
Tel: (001) 514 398 7833 Fax: (001) 514 398 7767

The research of Brace Research Institute includes simple desalination systems, solar water purification, solar motors, wind-electric transmission systems, windmills and biogas technology. Leaflets serving as a technical guide are available in English, French and Spanish.

The Centre for Alternative Technology, Machynlleth, Powys, SY20 9AZ, Wales, United Kingdom
Tel: (0044) 1654 702400 Fax: (0044) 171 242 0041 E-mail: cat@gn.apc.org

The centre publishes a large range of how-to books and leaflets, for example, *Off the grid: managing independent renewable electricity systems, It's a breeze! A guide to choosing windpower* and *Save energy, save money: a guide to energy conservation in the home.* They have extensive resources sections and provide names and addresses and renewable energy suppliers.

German Agency for Technical Cooperation, Post Box 5180, D-65726, Eschborn, Germany
Tel: (0049) 6196 79 1215 Fax: (0049) 6196 79 7104

German Agency for Technical Cooperation (GTZ) is an organization with the authority to implement technical-aid programmes in developing countries on behalf of the German government. Activities of GTZ include technical management and maintenance systems.

HAMLO, Secretariaat, Wilhelminapark 52, 3581NM Utrecht, The Netherlands
Tel: (0031) 30 523792

The assistance that HAMLO gives includes advice about procedures, literature and acquiring equipment and supplies. HAMLO will supply notes on how to make a low-cost incubator.

Healthcare through Appropriate and Reliable Technology Consultancy, Agro Business Park 52, 6708 PW Wageningen, The Netherlands
Tel: (0031) 317 479778 Fax: (0031) 317 479778
E-mail: 01463.3454@compuserve.com

Healthcare through Appropriate and Reliable Technology (HEART) Consultancy can offer advice in equipment management. Its main activity is sterilization in health institutions in remote areas. Services offered by HEART Consultancy include field visits for feasibility studies/assessments of projects related to equipment in health care; assistance with the selection and procurement of equipment; setting up training

programmes and maintenance programmes; compiling of training materials; and field visits for installation, repair and maintenance of equipment.

Healthlink Worldwide, Farringdon Point, 29-35 Farringdon Road, London, EC1M 3JB, United Kingdom
Tel: (0044) 20 7242 0606 Fax: (0044) 20 7242 0041 E-mail: info@healthlink.org.uk

Healthlink Worldwide (formerly AHRTAG) works to improve the health of poor and vulnerable communities by strengthening the provision, use and impact of information. Healthlink Worldwide does this by: communicating about health issues, promoting the development of good policy and practice, providing training in information management and dissemination, and supporting sustainable partner activities.

IAMLT, Adolf Fredriks Kyrkogata 11, S-11137 Stockholm, Sweden
Tel: (0046) 810 3031Fax: (0046) 810 9061
Internet: www.iamlt.se

The International Association of Medical Laboratory Technologists (IAMLT) is an independent, nongovernmental association of societies in 40 countries. As a representative body, IAMLT works with international organizations to promote medical laboratory technology all over the world. IAMLT is the worldwide voice of the medical laboratory technology profession. As a federation, IAMLT encourages national societies of medical laboratory technologists to prescribe the minimum standards of training and to raise the standards of training. IAMLT is a valuable resource for the individual society seeking greater involvement in medical laboratory technology related to government policy-making and planning. As a means of communication, the IAMLT enables medical laboratory technologists from diverse backgrounds to share learning experience, explore medical laboratory technology issues, and exchange information of clinical and general interest to all technologists.

IAMLT acts as a nongovernmental agency in official relationship with the UN and the World Health Organization (WHO). In this context IAMLT is represented at meetings of the Executive Board of WHO, the World Health Assembly as well as the meetings of Regional Committees. IAMLT is collaborating with WHO on issues related to laboratory services, such as quality assurance, education for laboratory personnel and professional standards.

Medical Technology International is the official publication of IAMLT. It is published twice a year and obtainable free from your own organization. IAMLT provides members in developing countries with assistance through information and liaison with members in developing countries and has been developing a network to connect those who need to solve special problems with the ones willing and able to assist. Congresses are held every other year and highlight the activities of IAMLT. The Congress includes extensive

workshops, scientific sessions, symposia, a WHO-round table discussion, a Book Donation Project, an educational session organized by the Council, the meeting of the General Assembly of Delegates and a major exhibit of products by industries.

Indian Renewable Energy Development Agency Limited (IREDA), Indian Habitat Centre Complex, Lodi Road, New Delhi 110-003, India
Phone: (0091) 11 4601366 Fax: (0091) 11 4602855
E-mail: gen@ireda1.globemail.com

IREDA supports the promotion, development and financing of renewable energy in India. Publications available from IREDA include a booklet entitled *Guidelines for loan assistance* and *IREDA News.*

Médecins sans Frontières Logistique, 14 avenue de l'Argonne, Merignac, Bordeaux 33700, France
Tel: (0033) 56137373 Fax: (0033) 56137374
E-mail: standard@bordeaux.msg.org
office@paris.msf.org
Intenet: http://www.msf.org

Médecins sans Frontières (MSF) Logistique is a private, non-profit-making, procurement and logistic organization whose objective is to provide professional medical and non-medical logistic support to humanitarian organizations. MSF is active in providing emergency laboratory kits (made up of modules relevant to the particular need) in disaster/emergency situations MSF Logistique has a permanent stock of medical and logistic items and kits including emergency laboratory kits. It has produced a booklet *Medical kits and modules.*

Medical Research Council, Health Technology Research Group, PO Box 19070, Tygerberg 7505, Republic of South Africa
Tel: (0027) 21 938 0413 Fax: (0027) 21 938 0385
E-mail: pheimann@eagle.mrc.ac.za or vitalink@eagle.mrc.ac.za

The Health Technology Research Group (HTRG) of the Medical Research Council makes less difficult the processes for decision-makers to examine and report the properties of technologies used in healthcare, such as safety, efficacy, feasibility, cost-effectiveness and social, economic and ethical consequences. HTRG facilitates the research, development, transfer and utilization of appropriate technologies.

The Medical Mission Institute Wurzburg, Appropriate Technology Teaching Laboratory, Hermann-Schell-Str. 7, D-97074 Wurzburg, Germany
Tel: (0049) 931 8048 515 Fax: (0049) 931 8048 520

The Appropriate Technology Department of the Medical Mission Institute trains volunteers in medical technology and offers professional education to local staff from

developing countries as well as to missionaries. The activities in developing countries of the Appropriate Technology Department include advice and training, information and educational material on appropriate medical equipment; a hands-on approach to laboratory equipment and testing methods, sterilization, hygiene, solar energy, water provision and waste disposal.

Program for Appropriate Technology in Health, 4 Nickerson Street, Seattle WA 98109, USA
Tel: 206 285 3500 Fax:(001) 206 285 6619

Program for Appropriate Technology in Health (PATH) is a non-profit-making, nongovernmental organization. PATH works with private sector and university collaborators to develop and introduce low-cost diagnostic technologies for infectious diseases. It has developed the following.

- Tuberculosis dipstick: a rapid, easy-to-read low-cost screening test for tuberculosis.
- Syphilis diagnostic system: a simplified specimen preparation method and mechanical rotator.
- HIV dipstick: a rapid, easy-to-read low-cost screening test for HIV-1 and HIV-2.
- Hepatitis B dipstick test: a low-cost method for detection of hepatitis B surface antigen (HBsAg) to be used in parallel with the PATH HIV dipstick test.
- Faecal leukocyte diagnostic test: a simple agglutination method to detect inflammatory diarrhoea.
- Indicator for detection of *Neisseria gonorrhoeae.*
- Cholera diagnostic test: agglutination method.
- Field culture method for *Neisseria gonorrhoeae.*

Project Hope, Health Sciences Education Centre, Milliwood, Virginia 22646, USA
Tel: (001) 703 837 2100 Fax:(001) 703 837 1813

Activities of Project Hope include emergency relief, technical support, appropriate technology, laboratory equipment, primary health care and treatment of parasitic diseases.

Royal Tropical Institute (KIT), Department of Tropical Medicine, Mauritskade 13, 1092 AD Amsterdam, The Netherlands
Tel: (0031) 20 5688 711 Fax: (0031) 20 5688 444

Support provided by the health care and disease control department includes technical training and control of communicable diseases (tuberculosis, leprosy and malaria). Projects include a course in serological diagnostic techniques at the University of Zimbabwe. This course provides Africans in Africa with training in theory and practice of laboratory techniques.

Teaching Aids at Low Cost, PO Box 49, St Albans, Hertfordshire, AL1 4AX, United Kingdom

Teaching Aids at Low Cost (TALC) supplies slide sets (helminths, protozoa, microscopic diagnosis of tropical diseases and schistosomiasis), books and manuals.

The Wellcome Centre for Medical Science, Information Centre, 183 Euston Road, London NWI 2BE, United Kingdom
Tel: (0044) 171 611 8586/888 Fax: (0044) 171 611 8545
E-mail: infoserv@wellcome.ac.uk

The institute provides support services for health care professionals, teachers, medical researchers and the general public. Departments: communication and education, information service, medical photography library, medical film and video library and the unit for Policy Research in Science and Medicine (PRISM) and Tropical Medicine Resource.

World Health Organization, 20 Avenue Appia, CH-1211 Geneva, Switzerland
Tel: (004122) 791 2111 Fax: (004122) 791 0746

World Health Organization Regional Office for Africa, PO Box BE 773, Harare, Zimbabwe
Tel: (00263) 470 3580/470 3684 Fax: (00263) 407 7265062
E-mail: regafro@whoafr.org

World Health Organization Regional Office for the Americas/Pan American Health Organization, 525, 23rd Street, N.W., Washington, DC, 20037, U.S.A.
Tel: (001 202) 974 3000; Fax: (001 202) 974 3663
E-mail: postmaster@PAHO.org

World Health Organization Regional Office for the Eastern Mediterranean, PO Box 1517, Alexandria 21563, Egypt
Tel: (0020) 3 4830090/6/7 Fax: (0020) 3 4838916
E-mail: emro@who.sci.eg

World Health Organization Regional Office for Europe, 8, Scherfigsvej, DK-2100 Copenhagen 0, Denmark
Tel: (0045) 3917 1717 Fax: (0045) 3917 1818
E-mail: postmaster@who.dk

World Health Organization Regional Office for South-East Asia, World Health House, Indraprastha Estate, Mahatma Gandhi Road, New Delhi 110002, India
Tel: (0091) 11331 7804 Fax: (0091) 11331 8607
E-mail: postmaster@whosea.org

World Health Organization Regional Office for the Western Pacific, PO Box 2932, 1099 Manila, Philippines
Tel: (00632) 528 8001; Fax: (00632) 521 1036
E-mail: Postmaster@who.org.ph

Ziken International (Consultants) Ltd., Carlton House, 11 Marlborough Place, Brighton, East Sussex, BN1 1UB, United Kingdom
Tel: (0044) 273 608311 Fax: (0044) 273 609040

Ziken International is an international health sector planning and management consultancy organization with a strong medical equipment programme. The medical equipment programme concentrates on the development of coherent management systems for the procurement, management and maintenance of medical equipment, including laboratory equipment, at hospitals and health centres in the developing world.

Annex 8
Publications by post

Books

German Agency for Technical Cooperation, Post Box 5180, D-65726 Eschborn, Germany
Tel. (0049) 6196 79 1215 Fax: (0049) 6196 79 7104

German appropriate technology exchange (GATE) is a quarterly newsletter published by the German Agency for Technical Cooperation (GTZ).

Healthlink Worldwide, Farringdon Point, 29–35 Farringdon Road, London, EC1M 3JB, United Kingdom
Tel. (0044) 171 242 0606 Fax: (0044) 171 242 0041
E-mail info@healthlink.org.uk

Healthlink Worldwide (formerly AHRTAG) publishes a range of free and low-cost newsletters, resource lists, briefing papers and manuals. Details are included in the publication list, available free on request. Books are available from the address above. Titles include: *How to look after a refrigerator, How to choose and make a cold box, Practical guidelines for preventing infections transmitted by blood or air in health-care settings, Laboratory investigation of diarrhoeal disease in primary health care, Free international newsletters* (describes over 130 newsletters and magazines on health-related issues available free in developing countries and 20 recommended newsletters and journals available on subscription).

Intermediate Technology Publications Ltd., 103–105 Southampton Row, London, WC1B 4HH, United Kingdom
Tel: (0044) 207 436 9761 Fax (0044) 207 436 2013

Intermediate Technology Publications Ltd. specializes in the provision of books on appropriate technologies and development issues. Subjects include energy, health and nutrition, water and sanitation, development and technology. Some titles are available in French and Spanish. A catalogue is available on request.

International Dispensary Association, PO Box 3098, 1003 AB Amsterdam, The Netherlands
Tel. (0031) 20 4033051 Fax: (0031) 20 4031854

Oxfam Publications, 274 Banbury Road, Oxford, OX2 7DZ, United Kingdom
Tel: (0044) 1865 311311 Fax: (0044) 1865 312600

The Oxfam Publishing Catalogue includes technical titles (emergency water supply manuals pack), practical handbooks, health and health care titles, videos and journals. There is a separate catalogue available on educational materials.

Tropical Health Technology, 14 Bevills Close, Doddington, March, Cambridgeshire, PE15 OTT, United Kingdom
Tel: (0044) 1354 740825 Fax: (0044) 1354 740013
E-mail: thtbooks@tht.ndirect.co.uk

Tropical Health Technology supplies medical publications, laboratory training and bench manuals written specifically for developing countries, slide sets and bench aids. Books are sold at a reduced price for health workers in developing countries. The bench aid series consists of eight fold-out brochures showing colour microscope plates with text to diagnose parasitic and bacterial infections, urinary tract diseases, anaemia, and white blood cell disorders. Book titles include *District laboratory practice in tropical countries, Part 1, 1998, AIDS in the tropics—colour atlas, Tropical medicine and parasitology—colour atlas, Lecture notes on tropical medicine, 1995.*

Voluntary Service Overseas Books, 317 Putney Bridge Road, London, SW15 2PN, United Kingdom
Tel: (0044) 207 780 2266 Fax: (0044) 207 780 1326

VSO book titles include water supplies, agriculture, introducing technology, hospital equipment and using technical skills in community development. A catalogue is available on request.

World Health Organization, Distribution and Sales, 1211 Geneva 27, Switzerland
Tel: (0041) 22 791 247 Fax: (0041) 22 788 0401
Internet: http://www.who.int

The publications department of the World Health Organization (WHO) will supply a leaflet *Laboratories* giving a summary of books and bench aids for the diagnosis of malaria. Periodically WHO produces a catalogue of new publications. WHO books are sold at 30% less than the listed price to anyone ordering from developing countries.

WHO Regional Office for the Eastern Mediterranean, Distribution and Sales, PO Box 1517, Alexandria 21563, Egypt
Tel: (0020) 3 4879240, 3 4870090/6/7 Fax: (0020) 3 4838916

A number of publications of regional interest are published by the Regional Office for the Eastern Mediterranean (EMRO). These include laboratory standards handbooks,

Basics of quality assurance for intermediate and peripheral laboratories, Health laboratory facilities in emergency and disaster situations.

Update newsletters for laboratory products

Clinical Laboratory International, c/o Elsevier Librico N.V./PEPCO, B.P. 214, B-1210 Brussels 21, Belgium

LabMedica International, Circulation Department, 8 Cannon Road, Wilton, Connecticut 06897, USA

Annex 9
Glossary of terms and abbreviations

Alternating current (AC) The form of electrical current supplied by a generating system such as community mains supplies, or diesel or petrol-driven generating sets. This reverses its direction of flow at 50 or 60 times per second (Hertz). The supply system may be 1 or 3 phase, or sometimes 2 phase. The phase wires are "live", and the neutral wire is usually earthed or grounded at the point of supply and/or switchboard. There may be a 2 wire system (phase and neutral) or a 3 wire system (phase, neutral and earth/ground).

Alternating voltage, nominal The AC system voltage at consumer level is usually 110 V (American practice) or 220 V (European practice); it is sometimes 230 V or 240 V (British practice). In a 3 phase system, the voltage will usually be 380 V–415 V between phases, and 220 V–240 V phase to neutral.

Ampere, amp The unit of measurement of electrical current. A milli-ampere is one thousandth of an amp.

Ampere-hour (Ah), milli-ampere-hour (mAh) Normally used to define the capacity of a cell or battery. It is the constant current which can be drawn for a specified time in hours, usually stated at the 5, 10 or 20 hour rate, e.g. Ah (5), Ah (10), Ah (20).

Battery A set of similar electrical cells connected in series (one after the other), and sometimes also in parallel (side by side), to give the required voltage and capacity. It may be called a **battery bank** where several separate batteries (mono-blocks) are connected together.

Battery capacity Usually given in ampere-hours at a stated hourly rate, e.g. Ah (20), and is the amount of steady current which can be drawn for a given time (hours) to a given cut-off end voltage below which the battery or the load equipment may be damaged. **Available battery capacity** is the capacity available under specific operating conditions of discharge rate, temperature, initial state of charge, age and cut-off voltage. The battery capacity may be given in **watts per cell** or **battery** for a given time and cut-off voltage.

Battery charger A device, either electronic (static) or mechanical (direct current diesel or petrol generating set), which provides direct current at the correct voltage for recharging secondary batteries. It is important that the voltage and capacity match the batteries to be charged, e.g. between 13.6 V and 14.5 V for a nominal 12 V battery, to avoid damage (see battery manufacturer's data). Solar panels, wind generators or. vehicle alternators (usually

battery manufacturer's data). Solar panels, wind generators or. vehicle alternators (usually rated 12 V, sometimes 24 V) can also be used for charging batteries. A battery charger should include the means of regulating the output voltage, and sometimes also current, to avoid charging the battery excessively and causing damage.

Battery draw-off or **discharge** Batteries for motorcycles, cars and trucks are designed to give very high currents for a short time for engine starting and recharging during vehicle running. These will only run for a limited number of complete discharge–recharge cycles before failing. Batteries for supplying energy in discharge–recharge cycles are specially made, and are called **deep cycle, traction,** or **solar** types, and will give hundreds of cycles before losing capacity permanently.

Blocking diode An electronic device which prevents the backward flow of direct current into a solar panel or other equipment from a battery. This would discharge the battery and might damage the panel or equipment.

C-rate A shorthand way of saying the charge or discharge current in a battery, related to the battery capacity in ampere-hours, e.g. current of 0.5 times C would be 10 amperes for a 20 Ah battery.

Cell A basic electrochemical device consisting of metal plates in an electrolyte (acid or alkali) in a plastic or metal container, designed for storage of electrical energy. Cells can be built up to make batteries. The term cell is also used for the basic unit in a photovoltaic panel.

Charge controller This is usually wired between the battery and the source of charging current and sometimes also the load on the battery, to control the rate of charge, the maximum voltage, and sometimes the minimum voltage on discharge, to avoid damaging the battery or other equipment.

Charge rate Normally expressed as a fraction of the C-rate, or in amperes, and is the rate at which current is supplied to a cell or battery for recharging.

Charger See battery charger.

CIF Cost, insurance and freight; the total cost of the goods at the point of destination.

Consignee The person, government agency or institution to whom the goods will be addressed or delivered.

Converter A device which converts alternating current to direct current or direct current to alternating current at a differing voltage, usually electronically but sometimes mechanically (rotary converter). Commonly used as direct current/direct current converter between 12 V and 24 V.

Current The rate of flow of electricity in a circuit and is measured in amperes, symbol A. The current may be **alternating current** or **direct current.**

Cycle A single discharge and recharge cycle of a cell or battery.

Cycle life The number of cycles a cell or battery will provide before failure, at a given depth of discharge in each cycle. The lower the depth of discharge in each cycle, the more cycles can be provided.

Direct current (DC) Current which flows in the same direction all the time, into the load or other device. Photovoltaic panels and batteries are examples of direct current devices.

Deep discharge This is discharging a battery to near its minimum end voltage, usually more than 80% of its stated capacity for the actual rate of discharge.

Deep discharge cycle Discharge–recharge cycle in which the battery is nearly completely discharged.

Depth of discharge (DOD) Usually expressed as a percentage, which is the energy removed from a battery during discharge as a percentage of the rated energy capacity. Note that at high rates of discharge, only a limited percentage of capacity is available.

Direct current nominal voltage Direct current systems are usually 12 V (as in motor vehicles), 24 V (as in trucks and some boats), or 48 V (as in telecommunications systems). In uninterruptible power supplies the direct current voltage can be as high as 400 V. Solar powered systems are usually 12 V or 24 V systems. Direct current systems are usually 2 wire systems, positive and negative according to the battery terminals and one (usually the negative, but check this) may be earthed (grounded).

Discharge The function of removing energy from a cell or battery.

Earthing or grounding The practice of connecting one wire of an electrical system to a rod or pipe driven into the earth or submerged in water, and connecting **all** exposed metal in a site together to the same earth or ground terminal, for safety. This is usually done in permanently wired systems. In isolated, temporary or portable systems, it may be safer **not** to earth the electrical supply and exposed metal. In an earthed system, there will be earth wires, usually colour coded green or yellow/green. Expert advice should be sought for the safest system.

Energy Measured in watt-hours (Wh) or kilowatt-hours or (kWh or units). A 25 watt lamp run for 1 hour consumes 25 Wh of energy. It is important not to confuse power with energy, as power (mW, W or kW) is the rate of use of energy.

FOB Free on board; the cost of goods at the country of origin.

Frequency Alternating current voltages and currents reverse direction and back again at a frequency 50 or 60 times per second, measured in Hertz (cycles per second or Hz). In a less than fully reliable mains system, or in an isolated alternating current system such as a local generator, the frequency can vary by several cycles per second. Even if voltages are similar, devices such as clocks, timers and motors may not work correctly at a frequency other than that for which they are designed and rated.

Grid The common word used for the mains electricity supply network of transmission lines, transformers, substations, etc.

Insulation The amount of sunlight striking a given area (power, watts) and in a given time (energy, watt-hours). This is usually stated for an area of 1 square meter lying horizontally. Standard sunshine conditions are defined as 1000 watts per square meter onto a surface inclined directly to the sun. For any other inclination, or for cloudy or other conditions, or time other than noon, or other than summer season, the amount of sunlight (insulation) will be less. Insulation may be stated as watts or kW per square metre per day onto a horizontal surface, and insulation tables or maps usually use this measure. Alternatively, the measure may be in kilojoules (kJ) and 3.6 kJ equals 1 kW. Suppliers of solar panels can provide calculations for specific sites for the performance of their panels.

Inverter A device that converts direct current to alternating current.

Inverter input Greater than the output, due to internal losses (heat generated). Inverter input (watts) equals output × 100/inverter efficiency.

Kilowatt (kW) 1000 watts.

Kilowatt hour (kWh) 1000 watt–hours. Sometimes called a unit of electricity for metering and sale of electricity.

Line conditioner An electronic device connected between the supply and a load which filters out high voltage spikes or surges which might damage equipment. The surges may be due to lightning, welding or switching of heavy loads on the system. Line conditioners are designed for various performance standards and load power, and expert advice is recommended.

Load Any device or equipment which is using power.

Mono-block A word used to describe several cells, usually 3 or 6, housed in the same casing and connected in series (see battery).

Negative The "return" wire or connection in a direct current system, usually colour coded black or blue.

Neutral The "return" wire or connection (other than the phase) or the centre wire or connection in 2 or 3 phase electrical systems, usually colour coded black or blue.

Peak watts or watts-peak (Wp) The power output of a solar module (panel) is expressed in watts-peak (Wp). This is the approximate amount of power a new photovoltaic device will produce at noon on a clear day at the equator (insulation 1000 watts per square meter) when the cell is faced directly into the sun.

Phase The "live" connections in an alternating current system are called phases. There may be 1, 2 or 3 phases. In a single phase system, the phase is usually colour coded red or brown. In a multiphase system, colour codes are usually red, yellow and blue.

In a 3 phase system, the "phase rotation" (red-yellow-blue, or red-blue-yellow) is important and, if wrong, motors may run backwards or uninterruptible power supplies may not work at all. Get expert advice.

PFI The cost of packing, freight and insurance of the goods ordered or to be ordered.

Photovoltaic (PV) Pertaining to the direct conversion of light energy into electricity.

Photovoltaic array An interconnected system of photovoltaic modules or panels that functions as a single electricity producing unit. The modules (panels) are assembled on a mounting frame and either connected electrically together in parallel (to get increased output amperes) or sometimes in series (to get increased volts). The array may be adjustable for different angles to the sun at different times and seasons.

Photovoltaic cell A basic device that converts light directly into electricity. Also called a solar cell, if used for conversion of sunlight. All photovoltaic or solar cells produce direct current. An individual cell generates a voltage of about half a volt. If shaded and part of an array, a cell can become a load on the others and heat up. Typical cells are between 12% and 14% efficient in converting light energy.

Photovoltaic module (panel) A number of photovoltaic cells mounted and connected together in a weatherproof panel suitable for handling, shipping and assembling into an array or using as a single panel. Usually panels have 36 cells, and are rated for about 17 V–21 V output in full sun, and are rated in watts-peak. Get manufacturer's advice concerning connection of panels into an array which may require blocking diodes.

Power Measured in watts (W or kW) and is a measure of the rate at which electricity or other energy is used. Power is calculated as the voltage multiplied by the current amperes, 1 V × 1 A = 1 W (1 volt multiplied by 1 ampere equals 1 watt of power). This is true for both alternating current and direct current, provided the alternating current is "in phase" (see power factor). Note that one horsepower (HP) is equal to 746 watts in electric motors.

Power factor In an alternating current circuit, the current may not be exactly "in phase" or coincident with the voltage, due to the effects in the circuit from motors, capacitors (condensers), electronic power supplies, fluorescent lights, etc. This is measured by the power factor expressed as a decimal always less than 1, e.g. 0.8, or a percentage always less than 100%, e.g. 80%. In an alternating current circuit with such effects, the real power is equal to the apparent power multiplied by the power factor (see volt-amperes).

Primary cell or **battery** A cell or battery designed for single discharge only, then disposal.

Rating The performance figures for the device or equipment as stated in the manufacturer's information, and/or on a nameplate, such as voltage, amperes, power

watts, speed rpm, horsepower, efficiency, etc. Note that the actual performance may be different and, if critical to sizing of power supplies, should be measured.

Rectifier A device, usually electronic, which converts alternating current to direct current, usually at a lower voltage. Can refer to a complete assembly in a box or cabinet, or the basic essential electronic device(s) used within. A rectifier, fitted with a suitable regulator and filter on the output circuit, can be used as a battery charger.

Regulator A device, usually electronic, placed between an unregulated source of power, e.g. a rectifier, rotary generator, wind generator or solar panel, and a load requiring a more precisely controlled supply. Common examples are voltage and current regulators on vehicle engine alternators and those used between a solar array and a battery bank. They may be alternating current or direct current depending on the circumstances.

Sag A short-term decrease in voltage levels; also known as a brownout.

Secondary cell or **battery** A cell or battery that is capable of being recharged repeatedly.

Solar Pertaining to the sun and sunlight (see photovoltaic).

Spike An instantaneous, dramatic increase in voltage; also referred to as an impulse.

Surge A short-term increase in voltage.

Transformer An alternating current device which converts power at one voltage to another, e.g. 220 V alternating current to 110 V alternating current or vice versa. A transformer is also used to isolate a local circuit from an earthed mains supply, for safety, without changing the voltage.

Uninterruptible power supply (UPS) A device consisting of a rectifier/battery charger, a battery bank and an inverter, usually all in the same cabinet, to provide reliable power to an essential load, e.g. a computer, to avoid interruptions due to loss of supply or major variations of voltage, or frequency. Smaller uninterruptible power supplies may still give a break in supply of less than one second while they change over to batteries (check the manufacturer's data carefully).

Volt (V) The unit of potential difference or pressure (voltage) in an alternating current or direct current electrical supply.

Volt ampere (VA) The unit of apparent power used by a device, equal to the voltage multiplied by the amperes. Uninterruptible power supplies are usually rated in volt amperes or kilovolt amperes. Apparent power multiplied by the power factor equals the real power (W or kW).

Watt, wattage (W) The amount of real power an electrical device will generate, consume or transmit. This is usually shown on the manufacturer's nameplate or label on the rear or base of the equipment.

Watt-hour (Wh) The measure of quantity of electrical energy (electricity), e.g. a 100 W device consumes 100 Wh in one hour.

Annex 10
Useful references and recommended reading

A solar solution to clean water, *ReNew,* Issue 65, Oct–Dec 1998.

Allen P. *Wired up to the sun–an introduction to photovoltaic power.* The Centre for Alternative Technology, 2nd edition, 1997. Obtainable from Centre for Alternative Technology, Machynlleth, Powys, SY20 9AZ Wales.

Bartram J, Johns WL. Water supply in primary health care: experiences of Amazon Indian communities. *Waterlines*, 1988, 7(1):

Block DL, *Solar desalination of water.* FSEC-RR-14-89, February 1989, Florida Solar Energy Center, 1679 Clearlake Rd., Cocoa, FL 32922-5703, USA.

Bloom, G. The right equipment in working order, *World health forum*, 1989, 10(1):3–10.

Britten AFH, Ala FA, El-Nageh M. *Blood transfusion: a basic text.* Alexandria, World Health Organization Regional Office for the Eastern Mediterranean, 1994 (Eastern Mediterranean Series, No. 7).

Build your own solar stills. *Soft technology,* 1994, 48:41-42.

Cheesbrough M. *Criteria for choice of laboratory equipment for developing countries–improving communication between manufacturers and user.* Paper presented at the workshop on health laboratories in developing countries, organized by the Associazione Italiana "Amici di Raoul Follereau", co-sponsored by the World Health Organization, Santa Margherita Ligure, Genoa, Italy, 5–9 October 1988.

Equipping district laboratories, In: Cheesbrough M. *District laboratory practice in tropical countries*, Part 1, March, United Kingdom, Tropical Health Technology, 1998: 96–177.

Collins CH, Johns WL. Home-made microbiological safety cabinets in the tuberculosis laboratory: a hazard warning, *Biomedical scientist,* May 1998: 296–297.

Derrick A, Francis C, Bokalders V. *Solar photovoltaic products, a guide for development workers.* Southampton, Intermediate Technology Publications Ltd., 1989.

El-Nageh M, Heuck C, eds. *Health laboratory facilities in emergency and disaster situations.* Alexandria, World Health Organization, Regional Office for the Eastern Mediterranean, 1994 (Eastern Mediterranean Series, No. 6).

Function, use and maintenance of routine microscopes, No. K41-010e, Technical manual for maintenance work and teaching purposes prepared by the Zeiss company: available from Health Technology and Pharmaceuticals, World Health Organization, 1211 Geneva 27, Switzerland.

Guidelines for country situation analysis on management, maintenance and repair of health care equipment, Geneva, WHO, 1988 (unpublished document WHO/SHS/NHP/88.3).

Guidelines on equipment donations. *Contact,* October 1994: 11–14.

Halbwachs H. Maintenance as part of the district health system. *GATE* (German Agency for Technical Cooperation), 1994, 13–21.

Halbwachs H. *The Madagascar experience and maintenance of health care equipment–principles and policies in the district hospital,* Workshop report. Cameroon, 1992 (unpublished document WHO/IMT/GTZ).

Hankins M. *Small solar electric systems for Africa.* (Planning guide towards installation of small PV systems for those with no previous experience.) Commonwealth Science Council, London and ACROTEC, revised edition, 1995. Obtainable from Energy Alternatives Africa Ltd, PO Box 76406, Nairobi, Kenya.

Hench CC, Hill PG, eds, *Production of basic diagnostic laboratory reagents,* Alexandria, World Health Organization, Regional Office for the Eastern Mediterranean, 1995 (Eastern Mediterranean Series, No. 11).

Huys JFMM. *Sterilization of medical supplies by steam. Volume I. General theory,* 1996. *Volume II. Operating and management of steam sterilizers,* 1996. *Volume III: Manual for technicians of steam sterilizers,* 1997. Utrecht, HEART Consultancy.

International Association of Medical Laboratory Technologists. Curriculum for a course in health and safety for medical laboratory workers, supplement to *Medicine technology international,* 1992:1. Available from IAMLT, Adolf Fredriks Kyrkogata 11, S-111 37 Stockholm, Sweden.

Inverter buying guide. *Soft technology,* 1994, 49:65-73. Published by the Alternative Technology Association, 274 Flinders Lane, Melbourne 3000, Australia.

IT power news. International magazine of IT Power, The Warren, Bramshill Road, Eversley, Hants, RG27 OPR, UK

Johns WL. *Establishing a refugee camp laboratory,* London, Save the Children (UK), 1987.

Johns WL. Respiratory protection when working with *M. tuberculosis, Medicine technology international,* 1997, 1:4.

Laboratory equipment preventive maintenance programme, In: *Principles of management of health laboratories.* Alexandria, World Health Organization, 1993. (Eastern Mediterranean Series, No. 3.)

Lee P. *Get it right: a guide to maintenance, safety precautions and hygiene of medical equipment.* Coulsdon, UK, ECHO International Health Services Ltd, 1995.

Maintenance (equipment) for Health Systems–4th GTZ Workshop, Senegal, 1993, GTZ. Available from German Agency for Technical Cooperation (GTZ), Post Box 5180, D-65726 Eschborn, Germany.

McCluney WR *Solar distillation of water.* FSEC-EN-3-80, February 1984, Florida Solar Energy Center, 1679 Clearlake Rd., Cocoa, FL 32922–5703, USA.

McNelis B, Derrick A, Starr M. *Solar-powered electricity: survey of photovoltaic power in developing countries.* Southampton, Intermediate Technology Publications Ltd., 1988.

PATH. Major equipment for peripheral laboratories. *Health technology directions,* 1991, 11:1. Available from Program for Appropriate Technology in Health (PATH), 4 Nickerson Street, Seattle, WA 98109–1697, USA.

PATH. Small equipment and supplies for peripheral laboratories. *Health technology directions,* 1992, 12:1. Available from Program for Appropriate Technology in Health (PATH), 4 Nickerson Street, Seattle, WA 98109–1697, USA.

Payne D. Use and limitations of light microscopy for diagnosing malaria at the primary health care level. *Bulletin of the World Health Organization,* 1988, 66: 621–626.

Philip D. *Guidelines for equipment selection. Getting what you want and wanting what you get.* Proceedings of the 17th Congress of the International Association of Medical Laboratory Technologists Congress, Stockholm, 3-8 August 1986.

UNDP/IAPSO, *Power generators for development assistance.* Catalogue of the InterAgency Procurement Services Office (IAPSO) of the United Nations Development Programme (UNDP). Topics covered include selecting a power generator. Research and Development, IAPSO, Midtermolen 3, PO Box 2530, DK-2100, Copenhagen, Denmark.

Principles of management of health laboratories. Alexandria, World Health Organization, Regional Office for the Eastern Mediterranean, 1993. (Eastern Mediterranean Series, No. 3.)

Roberts, S. *Solar electricity, a practical guide to designing and installing small photovoltaic systems.* Cambridge, Cambridge University Press, 1991.

Safety in health-care laboratories, World Health Organization, Geneva, 1997. (Unpublished document no. WHO/LAB/97.1. Available from Health Technology and Pharmaceuticals, WHO, 1211 Geneva 27, Switzerland.)

Sharma KB, ed. *Health laboratory services in support of primary health care in developing countries.* Delhi, World Health Organization, Regional Office for South-East Asia, 1994 (South-East Asia Series, No. 24).

Skeet M, Fear D. *Care and safe use of hospital equipment.* London, VSO Books, 1995.

Smit Sibinga CT. *Blood transfusion and blood components.* Alexandria, World Health Organization, Regional Office for the Eastern Mediterranean, 1995 (Eastern Mediterranean Series, No. 12).

Solar today. Magazine of the American Solar Energy Society, 2400 Central Ave., Boulder, CO 80301, USA. Tel: (001) 303 443 3130, Fax: (001) 303 443 3212, E-mail: beckych@csn.net, Internet http://www.engr.wisc.edu/centers/sel/ases/ases2.htm/

Stone L. Clean water from the sun (solar distillation). *Home power*, 1993, 36: 62–4.

The power guide International catalogue of small-scale energy equipment (includes suppliers in developing countries). Intermediate Technology Publications, 1994. Obtainable from Intermediate Technology Publications Ltd, 103/105 Southhampton Row, London WC1B 4HA.

World directory of renewable energy suppliers, published annually by James and James Science Publishers Ltd., Waterside House, 47 Kentish Town Road, London NW1 8NZ, UK

WHO Global Programme for Vaccines and Immunization (GPV) has issued a large number of publications, including on cold chain equipment maintenance, solar energy, temperature monitoring, EPI technical series booklets; technician's handbooks for compression refrigerators, installation handbook for photovoltaic refrigerators, user's handbook for photovoltaic refrigerators, maintenance and repair series. Details of all titles are given in the GPV Catalogue available from WHO, Global Programme for Vaccines and Immunization. Single copies of most items are provided free of charge. Ask for material in Arabic, Portuguese, Swahili, French and Spanish. World Health Organization, Global Programme for Vaccines and Immunization, 1211 Geneva 27, Switzerland. Fax: (0041) 22 791 4192/93.

World Health Organization, United Nations Children's Fund, *Product information sheets*, 1993/1994. (WHO/UNICEF Technical Series. Available from: Global Programme for Vaccines and Immunization, World Health Organization, 1211 Geneva 27, Switzerland.)

World Health Organization, *Laboratory biosafety manual*, 2nd ed., Geneva, World Health Organization, 1993.

World Health Organization, *Maintenance and repair of laboratory, diagnostic imaging, and hospital equipment.* 1994, Geneva, World Health Organization, 1994.

Yaron G, Irving TF, Jansson, S. *Solar energy for rural communities: the case of Nambia.* Southampton, Intermediate Technology Publications Ltd., 1994.

Other recommended sources of information on solar panels and systems are in the publications of: International Solar Energy Society, Wiesentalstr. 50, D-79115, Freiburg, Germany. Tel: (0049) 761 459 060 Fax: (0049) 761 459 0699 E-mail hg@ises.org, www http://www.ises.org/

Index

Selection of basic laboratory equipment for laboratories with limited resources

This book provides a framework within which laboratory workers in developing countries can choose equipment and consumables. The book is addressed to two groups of people with different degrees of technical expertise and responsibilities. The first group is the laboratory staff working in developing countries. The second group is the staff involved in laboratory supplies procurement, such as hospital administrators, central stores officers and laboratory supplies procurement officers. The steps in buying equipment, procurement from suppliers, consumer problems, equipment receipt and maintenance, buying second hand laboratory equipment, minor equipment and consumables are all covered. The need for reliable laboratory power supplies, such as batteries and solar energy, is discussed comprehensively in a section covering energy requirements. Quick reference buyer's guides, forms for assessment of quotations and equipment data specification sheets provide easy reference to buying information and make the buying process easier.

ISBN 92-9021-245-4

Price:US$9.50