

Medical Instrumentation in the Developing World

Robert Malkin, Editor

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Forward

The common phenomenon in most developing countries is the presence of lab equipment which is not usable or not used because it is not appropriate for the local needs, is improperly installed, or is defective at delivery. End users are often untrained in equipment usage or maintenance.

-adapted from the World Health Organization

Who is this Book For?

How do you test a defibrillator on a freshly killed pig? How can you use a piece of chicken to test an electrosurgery unit? How can you test the bili-lights before releasing them for use on infants when you have no photometer? These are the types of questions that an engineer working in a developing world hospital asks every day. The proper test equipment isn't available, and the hospital has a desperate need. You can neither release the equipment without testing, nor deny the clinical team the only piece of equipment that could help the patient. What should you do? This book provides answers: the kinds of practical testing and repairing suggestions that engineers can use when in a poorly equipped hospital, far from a clinical engineering department.

If you are an engineer who is soon to be going to the developing world, a technician from a developing country or simply a visitor to a third world country who wants to help with the tremendous lack of working medical technology, then this book is for you.

This book is primarily intended for engineers and technicians traveling to the developing world to work in a secondary, typically public, health care facility. While reading this book and taking this book with you cannot fully prepare you for the adventure of working in the developing world, it should help you know what to expect, technically.

What this Book Covers

The body of this work is divided into sections, each dealing with an individual piece of equipment. In 2003, Engineering World Health reported that 44% of the medical equipment problems found in the developing world are user error (only slightly higher than found in the United States). Therefore half of each section is devoted to explaining the clinical use of the equipment and its principle of operation. Taken together, the patient engineer should be able to figure out the operation of the device without the manual (as the manual is often missing in the developing world).

About 27% of the problems seen in the developing world were reported to be power supply related. Power supplies are not treated in this book as they are extensively covered in the companion lab manual.

Most of the remaining 25% of the equipment problems seen in the developing world are described in this book.

More importantly, perhaps, than describing the most likely problems, this book gives detailed information on how to test a piece of equipment to determine if it is working. This very important step in any repair is not often covered in field manuals and is very challenging in the developing world, where the proper test equipment is often lacking.

What this Book Does Not Cover

This book does not cover diagnostic imaging equipment. This specialty is less frequently seen in the developing world, but more to the point, requires specialized knowledge and equipment not typically available to the volunteer engineer spending a few weeks in a developing world hospital. If the problem is not user error, then the engineer is likely to be unable to fix the device.

This book also does not cover automated clinical laboratory equipment. This equipment is very poorly suited for the developing world as it requires expensive reagent packs and frequent maintenance. The maintenance and repair often requires knowledge and tools which are not likely to be available. In most cases, the volunteer engineer is better spending their time in some other part of the hospital.

How to Use this Book

The material in the introduction and at the end of the book might be useful to read before leaving. The sections on living and working in the developing world cover some critical points which might dramatically improve your enjoyment of the trip. The tool list should be used as a guide for packing your checked bags (you must assume that there will be no tools available in the developing world hospital). The section on troubleshooting is a good review of basic principles, if you feel rusty in that area.

It is probably not very helpful to read every section on each piece of equipment. This book is intended to be brought with you on your trip. When you encounter a piece of equipment, before beginning the diagnosis and repair, read the corresponding section of the book. Review the rules for trouble shooting if you haven't been in this situation in some time. Then begin your interviewing and diagnosis.

For most equipment, you must test it before returning it to the user. Yet, you are unlikely to have the proper test equipment. Each section describes a test that you can do, if you have the recommended tool set. Perform these tests as many times as needed to insure that the equipment is in good working order before returning it to use.

How this Book Was Created

This book has been written by the faculty and students of The Engineering World Summer Institute as well as other engineers who have worked in the developing world. Let us know if you think you have a chapter, section or correction to contribute. Perhaps there is a better way to test a device or a more thorough testing procedure. It is only through our combined efforts that books like this one can be made available to the people of the developing world and the volunteers who are helping them.

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1 Introduction to Developing World Medical Equipment

To deliver healthcare effectively, even the most basic hospital must have functioning technology [1], [2]. Yet, in a developing world hospital, as much as 60% of the equipment doesn't work [3]. Basic diagnostic tools, such as X-ray imaging [4], do not exist, do not function or lack the necessary infrastructure to be used in most of the world's public hospitals. Functioning clinical laboratory equipment often consists of nothing more than a hand-cranked centrifuge and a microscope with a broken light.

It is into this desolate equipment environment that the volunteer engineer finds himself injected. Succeeding certainly depends upon the technical knowledge and skills that the engineer brings with him. Knowledge of the political and economic landscape is certainly helpful in negotiating the delicacies of removing a piece of equipment for repair. However success also depends on an admission and an understanding of the role that engineering has played in causing such desolation.

Engineering has played a critical role in creating a situation where only a tiny fraction of the world's population can access what Americans consider routine medical technology. For example, X-ray imaging and microscopes have existed in the clinical setting for more than 100 years. Yet the modern designs for these basic tools typically operate for little more than six months once introduced into the developing world. It is, at least in part, the design of such equipment that has failed the majority of the world and design is the domain of biomedical engineering.

1.1 What Characterizes the Developing World

What is Human Development?

(adapted from: United Nations Development Program, 2003)

"The basic purpose of development is to enlarge people's choices. In principle, these choices can be infinite and can change over time. People often value achievements that do not show up at all, or not immediately, in income or growth figures: greater access to knowledge, better nutrition and health services, more secure livelihoods, security against crime and physical violence, satisfying leisure hours, political and cultural freedoms and sense of participation in community activities. The objective of development is to create an enabling environment for people to enjoy long, healthy and creative lives."

Mahbub ul Haq

Human development is about much more than the rise or fall of national incomes. It is about creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests. People are the real wealth of nations. Development is thus about expanding the choices people have to lead lives that they value. And it is thus about much more than economic growth, which is only a means —if a very important one —of enlarging people's choices.

Fundamental to enlarging these choices is building human capabilities —the range of things that people can do or be in life. The most basic capabilities for human development are to lead long and healthy lives, to be knowledgeable, to have access to the resources needed for a decent standard of living and to be able to participate in the life of the community. Without these, many choices are simply not available, and many opportunities in life remain inaccessible.

11 million children under age five die each year from preventable causes —equivalent to more than 30, 000 a day.

Around 1.2 billion people live on less than \$1 a day (1993), and 2.8 billion on less than \$2 a day.

34 million people living with HIV/AIDS (end of 2000)

163 million underweight children under age five (1998)

The Human Development Index

The Human Development Index (HDI) is a measure of the human development in a country. The index is calculated as a combination of many factors, including Life expectancy at birth (years), Adult literacy rate (% age 15 and above), Combined primary, secondary and tertiary gross enrolment ratio (%), GDP per capita, Life expectancy index, Education index and GDP index

What are the poorest countries in the world?

The bottom ten countries in the world are all African (Name/HDI):

Mali/51.5

Central African Republic/44.3

Chad/45.7

Guinea-Bissau/44.8

Ethiopia/43.9

Burkina Faso/46.7

Mozambique/39.3

Burundi/40.6

Niger/45.2

Sierra Leone/38.9

The top ten countries in the world are (Name/HDI):

Norway/78.5

Sweden/79.7

Canada/78.8

Belgium/78.4

Australia/78.9

United States/77.0

Iceland/79.2

Netherlands/78.1
 Japan/81.0
 Finland/77.6

1.2 Healthcare Technology in the Developing World

Conditions which have led to a low human development index vary from one country to the next. Military or one-party (person) rule can lead to low human development [5]. Lacking a commitment to international standards in human rights leads to torture and other treatment which can lower human development. Civil war has torn apart many of the nations at the bottom of the UN Human development index.

It is sometimes stated that there are inherent factors, such as climate or geography, in developing world regions which contribute to their condition. Climate may play a role in some diseases. However, in many developing nations, there is a thriving private sector for healthcare delivery. Despite the climate and other inherent conditions, the private system typically delivers excellent health care, rivaling that available in the developing world, at a price.

The relationship between the private sector and public sector is somewhat different in the developing world. In the US, the private sector serves the majority of the population through employer-offered insurance. Users pay a small co-pay. US citizens without insurance use the public hospitals, where treatment is often free. In the developing world, the private sector serves a very small percentage of the population (perhaps 3-4%). Users must pay the full fee for their services. The public hospitals and clinics treat the majority of the population. Users of the public system in the developing world must, typically, still pay a small co-pay. Therefore, unlike in the US but somewhat similar to Europe, healthcare for most citizens is delivered at a small cost in the public hospitals.

However, lacking technology, the standard of care can be quite low. An example technology might be illustrative. Diagnostic X-ray imaging is critical for quality health care delivery. Yet, it remains unavailable to most hospitals in the developing world. Engineering World Health recently completed a small survey of diagnostic X-ray imaging availability in some of the world's poorest countries [4]. As part of this report, EWH visited a total of eight hospitals in Sierra Leone (the poorest country in the world), Haiti (the poorest country in the western hemisphere), and Nicaragua (the second poorest country in the western hemisphere) [5]. The survey documents the mobile, stationary, working and non-working, diagnostic imaging, X-ray machines. Where the machines are broken, the cause of the removal from service was noted. The survey results are summarized in the table below.

Country	Hospital	Number of Portable X-ray Machines	Number of Stationary X-Ray Machines	Number of Beds
Sierra Leone	Connaught	1 (1)	1 (2)	500
	Good Shepard	0	0 (1)	30
	Bo	0	1 (2)	225
	Kissy	0	0 (1)	150
Haiti	Jacmel	0 (2)	1 (1)	250
	La Vallee	0	0	50
Nicaragua	La Mascota	0 (1)	0 (2)	250
	Leon	0 (1)	1 (2)	400

(Numbers in parentheses are the number of broken machines.)

Each hospital had at least one operating room and an intensive care. La Mascota and Leon Hospitals conduct thoracic surgeries. Yet, only one of the eight hospitals had a mobile X-ray machine, a tool typically considered essential for thoracic surgery and nearly essential in any intensive care unit. In several cases, the hospital had a portable machine, but it was broken, most often due to an expired X-ray tube. The stationary X-ray machines were also broken because spare parts are unavailable, principally the X-ray tube. Only approximately half of the hospitals had a working stationary X-ray machine. Even La Mascota, the largest pediatric hospital in Nicaragua (250 beds) had no working X-ray machine of any kind - stationary or mobile at the time of this survey. In short, one of the most common and perhaps essential medical tools remains largely unavailable in the developing world.

Problems with Solutions to Healthcare Technology

An engineer faced with a broken piece of equipment wants to fix it to help the people she sees around her. However, it is unavoidable to also try to imagine solutions to the larger problem of a general lack of equipment. Before selecting the solution to the problems the engineer sees, it is important to have a realistic view of what problems may be encountered by medical technology solutions.

Certainly, the ever spiraling cost of the latest developments in healthcare technology is one of the barriers to implementation for certain technologies. For example, a single MRI machine can cost US\$10,000,000, or about 0.5% of the entire economy of Sierra Leone (as opposed 0.0001% of the US economy) [11]. While it is not possible for Sierra Leone, a country of 5.6 million people, to purchase such equipment, the city of Memphis, Tennessee, with 1.2 million citizens, has more than five MRI machines. The University of Saskatchewan recently installed an MRI machine for dogs [12].

However, in many cases, capital cost is not the primary barrier to technology in the developing world. For example, many American firms stand ready to donate their used equipment, sometimes working, to needy hospitals. These well-meaning donations often result in disappointment and frustration to the recipients. Even after the equipment is donated, there are barriers to technology implementation.

The most serious problem is the lack of spare parts. Inevitably, equipment breaks. Spare parts may not be available because the parts may not be made anymore and indigenous personnel may not have the expertise to find alternatives. For newer equipment, the parts may be made, but may not be available in the developing world. Even when the parts are made and are available, the cost may be prohibitive. Even when available at a small cost, the hospital may lack the expertise or tools required to execute the repair.

Lack of tools is a severe problem in the developing world. Even screwdrivers and wrenches are sometimes unavailable to those responsible for servicing medical equipment. Slightly more advanced equipment such as voltmeters and oscilloscopes are rarely available in the world's poorest countries. Testing equipment that biomedical technicians consider essential in the United States, such as patient simulators, artificial lungs and defibrillator calibrators are nearly nonexistent in the third world.

After the lack of spare parts and tools, the next major barrier is the lack of service manuals. As every manufacturer provides service manuals with their equipment, the lack of service manuals is usually the result of donors sending equipment, but failing to donate the service and users manuals. Where the equipment is purchased, the manuals are lost, or in the case of service manuals, were never available in the native language.

Another lacking is reliable power and water [13]. Much of today's equipment assumes an existing infrastructure of at least water and electricity [14]. Sometimes distilled, deionized water must be available. In small quantities, specialized water is not an obstacle. However, continuous sources are not typically available. Power is rarely available on a continuous, reliable basis in developing world hospitals, and may not be available at all. There certainly are some measurements which inherently consume so much power, such as MRI, that without reliable electricity they must be considered impossible. However, many measurements do not require large amounts of energy. An ideal equipment design would tolerate very large fluctuations in the power grid voltage, including battery or manual operation backups for periods of power outage. However, most designs available today are intolerant to power line variation.

There are a few subtle problems worth mentioning. There is a considerable "brain drain" from the developing world. That is to say that modern medical equipment often requires highly skilled technicians to operate and maintain. However, once a technician or engineer becomes highly skilled, they are able to find higher paying jobs in the developed world. So, they leave. The result is that there are few highly skilled technicians in the developing world, despite the ever increasing need for specialized training to maintain medical equipment.

Even where there are adequately trained personnel, the environment (no tools, no spare parts, no manuals) can lead to frustration. Corruption in the government, perhaps extending to the public hospitals or centralized clinical engineering facilities can add to the frustration. Long standing frustration with one's job can lead to detachment from the environment. The detachment can decay to the point where no work is attempted, even when the job could be accomplished. So, it is sometimes the case that equipment remains broken, even when the tools, spare parts and expertise are available to repair the equipment.

The proliferation of disposable equipment, where reusable alternatives exist, is a difficult barrier for the developing world hospital to overcome. For example, there are few, if any, US hospitals using metallic, reusable, ECG electrodes today for routine monitoring, having replaced them with disposable, sponge-based, self adhesive pads. At first, this substitute appears to be less expensive, since there application is faster and they do not require cleaning and sterilizing between uses. However, the apparent cost savings are labor costs. In the developing world, labor costs are very low; the metallic ECG electrodes are actually a cheaper alternative for a developing world hospital. It is often this difference in the cost of labor which drives biomedical engineers to develop apparently cheaper equipment (automated systems, premixed calibration solutions packs, etc.) that is actually more expensive to operate in the developing world.

The use of servicing contracts for sophisticated equipment has become an obstacle incorporated into the equipment. In other words, the equipment is expressly designed to be serviced at regular intervals. In some cases the equipment will simply stop working if it is not serviced every six months. Such high levels of service are not realistic in the developing world. Equipment must operate with minimal service for many years. Where service is required, it must not require specialized training, tools (including a computer) or manuals. Particularly frustrating is equipment which requires knowledge (sometimes arbitrary knowledge, such as a secret code) which can only be acquired after completing the manufacturer's training course.

Non-Problems for Developing World Technology

Just as attempting to implement a solution to a problem which itself has inherent problems can stymie the best engineer, so can avoiding solutions based on preconceived, false notions of the barriers to technology implementation in the developing world.

A common misconception is that instruments must be simple. This is simply not true. The people in the developing world can be trained to operate any instrument that you could be trained to operate. In fact, there is often knowledge about the operation of medical instruments in the developing world which can no longer be found in the developed world.

Although it was mentioned above that the one-time cost of modern equipment is a barrier, in many cases the government can pool its resources to purchase a single piece of expensive equipment. However if this piece of equipment requires an extensive infrastructure to operate, such as specialized tools, frequent maintenance, or specially trained service personnel, then the country's prized investment is likely to work for the first few months and then stop. The result is frustration for the politician, doctors and patients. However, capital costs are not always a barrier.

1.3 Working Within a Community

Before selecting a solution to a problem, the engineer should consider who else is working in the area that might be able to help. In reality, the problem is so large, that only by such collaborations can we really make significant contributions to the people of the developing world.

Since the infrastructure support for modern medical equipment is lacking in the developing world, and since an educated population can deliver the necessary infrastructure, one solution to the problem is to deliver training to the local population. In this vein, many have set-up schools to train technicians. Project Hope, International Aid and many other organizations run training schools for clinical engineers in the developing world.

One solution to filling a technology gap is to export first world technology into the third world. There are many organizations that donate medical technology to the developing world and the UN and the World Bank may give loans or donations to poor countries to purchase medical equipment. In certain cases, this is the ideal solution to rebuilding a country. However, in other cases, this approach has led to only limited success. There are certainly thousands, if not millions, of pieces of donated equipment in the developing world. However, only a small percentage remains functional. Besides all the barriers to continued functionality already mentioned, donated equipment can also be ineffective because a cable or accessory can be forgotten, the equipment breaks in shipping, the hospital technical staff may not be prepared to properly install the equipment, or have the training to use the equipment.

Just as many organizations deliver doctors to the developing world, Engineering World Health and many other organizations send biomedical engineers to the developing world. When these engineers arrive, they deliver equipment, train the local population, deliver spare parts and install equipment. Frequent short term training sessions eventually lead to competence.

In the back of this book are several chapters listing organizations, web sites and books which contain a wealth of information about developing world medical technology.

Working Conditions for the Volunteer Engineers

One of the critical issues for selecting solutions to problems is understanding the specific working conditions faced by a developing world engineer. Knowing how to work in these conditions is equally important.

Working successfully in the developing world environment takes patience and a different mindset than we are used to. First of all, it is imperative to get to know the local staff and earn their trust. Take time when you first arrive to talk to the local employees, install all the working equipment, and repair the most highly valued equipment. This will garner respect and credibility from the locals. These people have been promised a lot but seen little, and distrust - of Americans in particular - is a natural defense for them. This distrust is not cruel or treacherous, but the locals no longer believe that anyone can really supply them with parts and help them fix machines that have been broken for years.

Once you earn the trust of the staff, you will be able to be successful and will enjoy your stay at a more relaxed pace. Staff will begin to bring you broken equipment and ask for help, or will provide you with lists of equipment they wish. You must become proficient at working to understand the problem as described by the locals and communicating with them what your solution will be. Many of the problems you will encounter will be rooted in communication and user error, not technical difficulties.

You must be extremely patient. The pace of work is very slow compared to what we are used to; a simple project may take days to complete. It is important to be meticulous on your paperwork to make sure you do not forget to finish something (perpetuating the myth that outsiders won't really come to their aid), and even more important to be persistent with the locals in getting their help or guidance. You must be willing to ask for help and assistance, because you cannot be successful trying to do everything your own way. Instead, learn to work within the natural framework of the hospital and adapt yourself to it.

There is no point in giving equipment if they are not confident in its use. We can observe, give suggestions, and try to improve, but if we overstep our bounds the locals will again become distrustful. If you observe a local procedure that you suspect to be incorrect, take the time to thoroughly ask questions about why the procedure is being followed. If, after thorough discussion with the local staff you determine the procedure should be changed, do not expect your suggestions to be followed immediately. Discuss the necessary changes with the department head, and then with the individual workers, and above all be patient and flexible. You must be confident in the fact that the work you are doing is enough, and that doing your work thoroughly and patiently is the best way to have a positive effect on the hospital and the people.

Living Conditions in the Developing World

Living in the developing world presents a wealth of personal problems which can become professional problems. Living conditions are often very sparse, and are always different than those to which you have become accustomed. There are a few basic tips that will help you survive, but culture shock is the largest problem you may face.

In terms of basic tips, try to avoid complaints and anything else that could lead to arguments or dissension with your hosts and department heads. You don't know the local customs. In many countries complaints and arguments are very poorly tolerated.

Do not go wandering off on your own without seeking local knowledge. There are dangers in the developing world that you may not be familiar with.

Do not leave valuables unattended or get into other situations that could invite theft. Fanny packs (or something similar to wear on your belt) are safer than purses. You definitely should

bring and wear a concealed waterproof pouch under your clothing for most of your money, your passport, and other identification.

Don't drink the tap water or brush your teeth with it. Use bottled water instead. Always carry waterless instant hand sanitizer (Purell or other brand) or Wash-n-Dry packets to clean your hands immediately before eating.

Use mosquito repellant with at least 30% DEET content to protect against both nuisance mosquitoes and those that carry dengue fever (somewhat similar to malaria). Sunscreen should be used if there is any chance of getting sunburned. Always carry a disinfectant with you, such as Polysporin or Neosporin, and use it anytime you cut your skin. Always check with a medical care professional when you have any questions about these or related matters.

Don't think that you are better or smarter than your hosts. You should try to respect their customs and seek to learn from them as they do from you and your group. Realize that some words and forms of non-verbal communication that may be friendly in our culture can have opposite meanings in others.

Culture Shock

The most serious problem you will face when living in the developing world is culture shock. It can be a very debilitating condition. Everyone experiences culture shock when they first visit a foreign country for an extended period. Culture shock is a type of psychological stress which affects those adjusting to new cultures or environments. This is not simply the shock of experiencing something new, but is an all-encompassing environmental change which may take weeks or even months to overcome.

As cultures operate and behave very differently from each other, people are shocked - or made temporarily uncomfortable - by the differences and apparent unpredictability they encounter, whether it be in the language, food or societal ceremonies of everyday life. One positive of this experience is the ability to better understand your own culture and society.

Culture shock is typically experienced in stages. Here's a summary of the first four stages of culture shock. As you are about to return home you may experience the fifth stage (a sadness and longing to stay), and finally, you may experience reverse culture shock when you return home. These last two stages don't cause problems in getting your work done in the developing world hospital.

Stage 1 Euphoria Homestay is adequate, the tourist sights are intriguing; the local people are courteous and helpful; we think a wonderful experience lies ahead.

Stage 2 Depression Everything different is a problem. Misunderstandings seem frequent. The gratitude we expected seems lacking. Health problems may develop. Work ethics are different and frustrating. We feel like giving up and going home.

Stage 3 Adaptation We begin to understand some of the behaviors and enough of the language to limit isolation. The situation seems less hopeless. We begin to laugh again.

Stage 4 Longing We accept the customs of the country, perhaps not enthusiastically, but we don't chafe. Basic work anxieties are gone. We begin to feel a longing for home, but not a strong need.

Culture shock typically strikes a few days or weeks after arrival when the newness of the location starts to wear off and you are no longer acting as a tourist but are starting to integrate with the local society. Recognizing the following symptoms of the first stage can help you understand yourself as well as to empathize with others.

The most common symptom is a feeling of uncontrollability and helplessness. This can be either a positive or negative experience depending on how you adapt to it, whether you grow and adapt or withdraw and lose confidence. The challenges of finding new places to eat, shop, and play can be taxing on anyone and you should try to relax and not push yourself in the initial weeks of living abroad. Culture shock is experienced at different rates. Don't let your better adjusted friends disagree or try to make you do something you aren't comfortable with.

You may notice difficulty sleeping, a disregard for day-to-day life, withdrawal from social contact, difficulties eating, weight loss, homesickness, extreme dislike for races or cultures other than your own, health problems, recurring sickness, socializing difficulties, obsessive worrying, fear, or depression.

The good news is that the symptoms will subside over time as adjustment takes place. There are many ways that you can combat culture shock. Don't be afraid to admit that you are uncomfortable or confused in a new situation. Feel free to express your frustration with understanding friends or your trip leader. Don't be surprised if normal activities are more difficult than those at home. Establish a routine as quickly as possible. Make your home stay comfortable. Learn the local rules of living in the new location. Learn as much of the local language as possible. Take advantage of new opportunities and activities. Try to attack problems right away; don't procrastinate. Stay in contact with friends at home (e-mail and telephone). Write down your experiences (keep a log book). Try to keep a sense of balance, humor and perspective. Ignore those who would force you to change or don't understand your experience. Understand that adjusting takes time, but is by no means impossible or traumatic.

1.4 When You Return

Culture shock will also accompany your return home, called reverse culture shock. You may find that your friends grow tired of hearing your stories before you grow tired of telling them. Eventually, you will readapt to your home culture.

Hopefully your first experience in the developing world will not be your last. The needs are tremendous and the group that could have the most impact on the state of health care in the developing world is engineers. You can still remain involved and be helpful, long after you return. You can educate, research new technologies, design new tools and develop entire strategies for the reliable, low-cost delivery of health care.

Very little is being done to design specialized equipment for the developing world. While engineers will focus on coping aids for the physically disabled, no similar effort is underway for the economically disabled. Engineering solutions for the developing world can be envisioned for x-ray, ultrasound, electrosurgery, clinical laboratory equipment, etc. Alternative designs avoid disposables, consider the low cost of labor, require little power, little service (or easily delivered service), require little specialized training for servicing, etc.

Finally, there is very little, if any money put into the research and development of technologies for the developing world. There are very notable exceptions, for example the detection and treatment of certain diseases, e.g., malaria, TB and AIDS, receive considerable attention. However, the funding of alternative technologies for diagnostic x-rays, neonatal incubation,

electrosurgery and many other common technologies is nearly non-existent. Engineers should be at the forefront of encouraging their governments to fund these types of technology development on an equal footing with one-disease oriented projects.

1.5 Conclusions

Before diving into the technical chapters it is worth considering what it means to “make a difference” or “have an effect” on the hospital and the people. The living conditions in developing world are so poor that the expectations are very low. Yet, on the whole, people are happy and are thankful for any help they receive. It is not your job, as a volunteer engineer, to refurbish the entire hospital in four weeks. If you put just a few pieces of equipment back into service, Make a few friends, and pledge to return, you will have made a huge impact on the healthcare in the developing world.

1.6 References

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2 Equipment Found in OR, ICU and ER

2.1 Working in the Operating Theatre and ICU

In the developing world, the biomedical engineer will often be called into an active room to do a quick repair or adjustment. You will need to know what procedures to follow. Procedures will vary from hospital to hospital but the core requirements are the same. Most OR suites are set up with 3 distinct areas, clean, dirty and sterile. In the hallways there will be a red line on the floor or wall and a door, which indicates the start of the sterile area. To enter this area you need the proper clothing, head and shoe covers and a mask. In the clean area proper clothing, head and shoe covers are needed. In the dirty area street clothes may be permitted but it is a good idea to be properly clothed, as you may have to cross into other areas.

2.1.1 Clothing

There are jump suits which you can wear over your clothes; however, these are hot and uncomfortable after about 30 minutes. In general, you should change into scrubs. In the developing world, these will be cotton coverings. In the same area will be boxes of masks, head and shoe covers. These will also be reusable cotton items in the developing world. Masks are disposable paper or reusable cotton. If disposable, the nose stay needs to be bent over the bridge of your nose to get a good fit. This is very important if you wear glasses as a bad fit on the mask will cause your glasses to fog over as you breathe. If you are assigned to the operating room you may want to have a special pair of shoes that is only worn in the OR. If you do that no shoe covers are required. If you go out of the OR to another area you must change out of the scrubs back into your street clothes. Generally, in the developing world, it is not reasonable to cover your scrubs and leave the OR for a later return.

2.1.2 Hands and Behavior

You don't have to wear gloves when you enter an operating room but you should touch nothing. A good procedure to follow is to cross your arms across your chest as you move about the room. Someone in the room will direct you to the problem and tell you if it is OK to touch the device or if it has to be removed to be serviced. Never assume that you can touch anything in an active OR room. If the room is not active, after a case there generally is no problem in touching

equipment. If the room is being set up for a case you should consider the room active and act accordingly. Be especially careful of anything blue, which is in the sterile field of the active room.

If you have to work on a device during a case you may have to wipe down the tools and test equipment with alcohol before proceeding. However, this precaution is rarely adhered to. Move slowly and watch where you step. Watch out for power cords on the floor and fluid spills. Stay away from the sterile field (blue things) unless specifically directed to it by the staff. Talk softly and directly to the person who asked you into the room. All body fluids and tissues are considered hazardous material.

Radiation exposure is possible from the x-rays that are taken in the OR and from radioactive implants that are put into a patient. Most x-ray devices are well collimated and there is very little scatter but it is still a good idea to be a minimum of 12 feet away from both the generator and the patient.

The greatest danger in the OR is the physician or nurses egos. The staff can be under great stress and become abrasive and obnoxious to the support staff (meaning you). In their minds they can do no wrong and every one else just contributes to their problems. If this starts it is time to leave the area until they cool down.

2.1.3 Working in ICU

As technology advanced in healthcare, in the 1950's, decisions were made to put the technology into confined areas instead of dispersing it throughout the hospital. This led to the creation of the first intensive care units. In larger hospitals, there may be a number of intensive care areas, cardiac (CCU), surgical (SICU), cardio/thoracic (CTU), medical (MICU), Neuro (NCU), neonatal (NICU), and respiratory (RICU). In some very large hospitals there may be an area just for patients with infectious diseases where they are quarantined from the general hospital population. In smaller hospitals these patients are often put into isolation rooms that are part of an existing ICU.

In the typical ICU setting the nurses and other staff are under considerable stress and may not always be friendly to the biomedical engineer. They need and expect their equipment to work and work the same way every time they use it.

In almost all cases, no special clothing is required and there is no need to avoid touching certain areas (there is no sterile field). However, if you are called in to work on active equipment, you must be extremely cautious. These patients are very ill and cannot typically tolerate any disturbance. If at all possible, remove the equipment from the floor before working on it. Be especially cautious with ventilators, which can cause serious injury when disconnected or connected prematurely.

In developing world ICU's, there may or may not be emergency power outlets. If there are, electrical outlets commonly might be divided into several circuits. Most outlets will be connected to emergency power sources, designated by their color, generally red but sometimes white. All outlets should have the circuit number on them so resetting the breaker is easy. In the developing world power outages are very common. However, it may or may not be common for the backup generator to function properly. In some hospitals, even those with an ICU, the backup power generator may be the only source of power.

Some outlets in the ICU are "dedicated lines" in that no other equipment can be plugged into that circuit, these are generally for monitors and computers. Unfortunately it is not unusual for

other outlets to be connected to the circuit making it non-dedicated in the developed world. In the developing world, dedicated lines are rarely respected.

In developed ICU's there will be a number of compressed gas outlets on the headwall in each ICU bed area. There will be one or more air outlets, one or more oxygen outlets, and possible a vacuum outlet. The pressure at these outlets should be 50 psi. The fittings to connect the hoses from the gases to the devices are specific to the gas so cross connections are not possible, exterior to the wall. However, far more common in the developing world are bottled gases. Most typically the only gas available is oxygen. In some hospitals, even this cannot be obtained, in which case an oxygen concentrator will be used.

If the ventilator being used requires compressed air and it is not present on the wall a compressor has to be used. Some ventilators have a built in compressor but most do not. The external compressor needs to be plugged into AC and may have a large enough current draw to limit what else can be on that circuit, a common source of an open circuit breaker.

The number of suction (vacuum) outlets on the headwall varies with the type of intensive care unit. In a surgical or cardio-thoracic unit suction is needed for airway, gastric and possibly wound and chest tube suction. In a coronary care unit possibly an airway or gastric suction would be used. The vacuum and flow requirements are the same as in the operating room. Suction regulators are generally installed on each active outlet. The regulators may have a selector for either constant or intermittent suction and an off position. The constant setting is used for airway, gastric and chest tube applications. The intermittent selection is used for wound suction. However, far more common in the developing world are stand alone suction machines, often called "Gomco's" whether manufactured by Gomco or not. There is a chapter on these machines later in this book.

Most intensive care areas are positive pressure environments. That is, the air pressure inside the unit is higher than the pressure outside of the unit, which helps prevent microorganisms from entering the ICU area. This is accomplished with the air handling system of the hospital that also filters the incoming air. The air handling system can either use outside air or recirculate some or all of the air through a set of filters called hepa filters. Some intensive care units may have isolation rooms. In this room the air pressure is negative to the adjacent area, which prevents anything from the inside of the room getting outside of the room. There is a second set of doors that separate the rooms with the outside room being positive pressure. It is fairly common in the developing world to see ICU's designed with these types of air handling in mind, even though the doors are left open or no air handling was ever installed.

Isolation rooms are used when patients are infectious to others. If you have to enter such a room you must follow the posted signs for gowns, gloves and masks for your own protection. The sign may say "reverse precautions" which means you can become infected by the patient. "Precautions" means you can infect the patient. Generally, you will not be able to enter, leave or work in one of these areas without help. The clothing and handling restrictions vary from patient to patient and hospital to hospital.

2.1.4 Sections of Every Chapter

The following chapters describe all of the equipment that you are most likely to find in an ICU. About 44% (according to a recent report by EWH) of the errors that you will encounter are user errors. As the manual is often missing in developing world hospitals, you must often deduce the operation of the machine from an understanding what the piece of equipment is supposed to do

and how it is supposed to do it. Therefore, the first section of each chapter describes the clinical use of the piece of equipment and its principles of operation.

About 27% (according to recent report by EWH) of the problems encountered in developing world equipment relate to power supply. This includes broken fuses, cords which don't match the outlets (donations are coming from all over the world); devices rated for 110 V in a 220 V environment, and occasionally more sophisticated problems. However, the power supply is the focus of the laboratory manual which accompanies this book. Therefore, these issues are not treated here.

After eliminating user error and power supply problems, there remain a certain number of problems which are commonly seen in a given piece of equipment. These are treated in the second section of each chapter.

According to the annual performance reports of Engineering World Health, about 54% of the equipment currently unused in the developing world can be placed back in service. While most of that success comes from user error and power supply related problems, 26% of the equipment that exhibits other problems (not user error or power supply) is also fixed by engineers who have studied this text. Therefore, the information contained in this manual and the accompanying lab manual is sufficient more than half the time.

Finally, when you have completed your repair, you need to test the equipment before returning it to the floor for use. As each piece of equipment is used by many different staff members, it is the sole responsibility of the engineer working on the equipment to insure that it is in good working order. Unfortunately, you will frequently not have the testing equipment required to properly test a piece of equipment. Therefore, the third section of each chapter gives guidelines on how to conduct the most critical testing in the desolate technical environment of the developing world hospital. Enough testing can and should be completed after every repair to confidently release a piece of equipment for use.

2.2 Ventilators

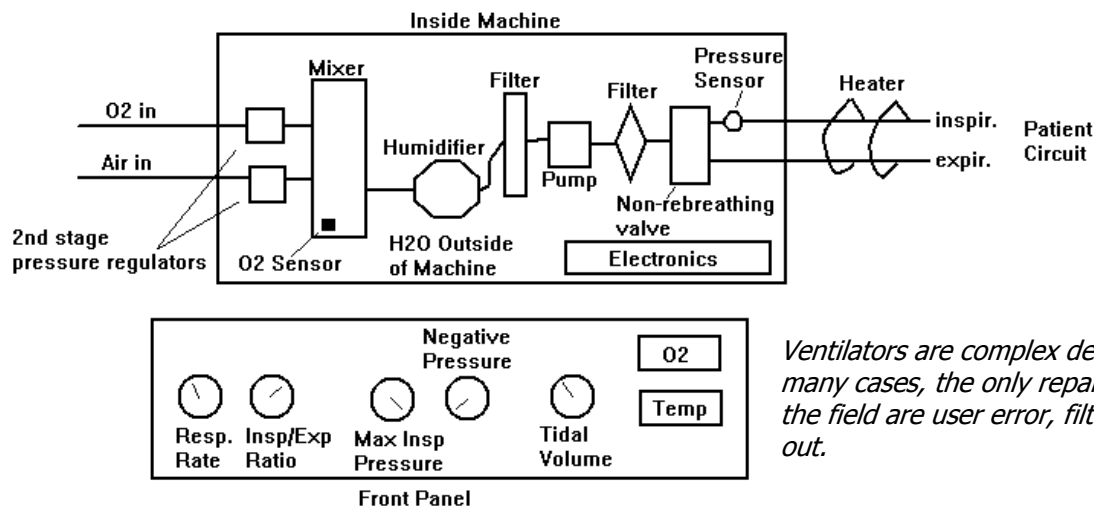
2.2.1 Clinical Use and Principles of Operation

Many patients in an intensive care and the operating room require the mechanical ventilation of their lungs. All thoracic surgery patients, for example, require mechanical ventilation. Some patients simply need assistance breathing, when a patient is recovering from certain illnesses and operations for example. In any case, ventilators can take over the major effort of respiration for the patient.

Some people use the term ventilator and respirator interchangeable. They are not the same. A respirator is a device that supplies or filters air in a harsh environment. The patient is breathing on their own when they use a respirator. In most cases, without the ventilator, the patient could not breathe, or would have great difficulty breathing.

Basic Elements of a Ventilator

A ventilator may include a pump which creates pressured air for delivery to the patient. However, in most cases, compressed gases are connected to the machine. The compressed gas is at a very high pressure, so a pressure regulator is typically connected to the bottle or the ventilator or both (see bottled gases chapter for more details). There are generally moisture traps and particulate filters in line with the incoming gases. The figure below details most of the common components and controls. However, there is considerable variation between manufacturers.



Ventilators are complex devices. In many cases, the only repairs possible in the field are user error, filters and rain out.

Some ventilators can accept air, oxygen or a combination of both. Some will measure the concentration of oxygen delivered to the patient, sounding an alarm if it becomes too high or low.

Very old ventilators will deliver the pressurized gas directly to the patient. However, this is very rare, even in the developing world. More common is for the ventilator to measure the volume

(usually derived from measured flow) and pressure of the delivered gases. A computer then controls the timing and pressure for the next cycle.

All ventilators must insure that the patient does not re-breathe his own, untreated expired gases, as they will eventually become excessively concentrated in carbon dioxide. So, in most cases, the simple volume limited ventilator contains a "non-rebreathing" valve that opens to allow fresh gas into the cylinder, closes during inflation and opens to allow expiration of the gases from the lungs into the room or a waste collection canister. In most modern ventilators, the non-rebreathing valve is in the tubing set (or circuit), in which case it is disposable.

The non-rebreathing valve may have a separate tube connected to the ventilator to force the valve open and closed. Or, the non-rebreathing valve may operate on the pressure of the inspiratory gas. In either case, it operates as a one-way valve that allows air to flow from the inspiratory tube to the patient, but when the patient is expiring gas, blocks the inspiratory tube, allowing the expired gas to pass through a separate expiratory tube.

Most ventilators will include humidification. Bottled gases delivered from cylinders are too dry for the human body to moisturize comfortably. Sterile water should be used for humidification, but often isn't in the developing world. The water is heated and the vapor drawn into the gas flow to the patient. In some cases, ultrasound is used to nebulize the water.

Most ventilators have an arm that the patient circuit tubing is attached to. This takes the weight off of the tubing where it connects to the patient. Most of the tubing fittings are also specific sizes to make misconnection harder. On adult machines the patient connector at the machine is 22 mm and the patient end of the tubing has a 15 mm connector. These connections are often missing or manipulated in the developing world to allow for the use of mismatched tubing.

Some ventilators have the ability to heat the tubing or the delivered air or both. This can prevent "rain-out" of the vapor in the gases being delivered to the patient. On some older systems you still may find water traps where the "rain-out" collects in the tubing.

Modes of Ventilation

There are many different types or modes of ventilation. Most ventilators can switch between several modes, but not all. The selection of the ventilator is ideally dependent on the patient's condition, but is often dictated by availability in the developing world. In fact, ventilation is so critical that availability of the appropriate ventilator or ventilator mode often dictates what procedures can and cannot be conducted in a given hospital.

There are three basic modes of ventilation, volume limited, pressure limited and timed cycle. Timed cycle is a combination of the other two basic modes. Jet ventilation is a fundamentally different mode of ventilation, but it is rarely seen in the developing world.

In the volume limited mode a preset volume of gas is delivered to the patient regardless of the pressure reached in the lungs or the time required to complete the inflation. This is a simple system where a gas is drawn into a cylinder and then forced out of the cylinder and into the lungs. It is rarely used by itself in humans because of the lack of pressure sensitivity.

In a simple volume limited ventilator, the cylinder is adjusted for the volume of gas desired. The motor is rate adjustable, generally between 5 and 50 breaths per minute (respiration rate). The drive mechanism is a cam that creates a rapid inflation of the lungs and allows for a longer period of time for the deflation of the lungs.

In the pressure limited mode a pressure limit is set where gas will flow into the lungs until that pressure is reached, regardless of the volume of gas delivered. This is a simple system where pressurized gas is passed through a pressure regulator to the desired pressure, then a valve that allows the gas to enter the patient. It is rarely used by itself in humans because of the lack of volume sensitivity.

The simplest device typically used on humans is the timed cycle ventilator. This is the most common mode because it combines both the volume and pressure limited methods of operation.

In the timed cycle mode the physician sets the respiration rate, the tidal volume (the volume of gas to be delivered), the upper pressure limit, and the inspiratory/expiratory ratio. If the pressure limit is not exceeded, then the device will deliver the desired volume of air, more or less evenly during the entire inspiratory time. The inspiratory time is the total respiration time (one over the respiration rate) times the inspiratory/expiratory ratio. For example, at a tidal volume of 1 liter, a respiration rate of 20 breaths per minute (3 seconds per breath), and an inspiratory/expiratory ratio of 0.5 (inspiratory half as long as expiratory), the total inspiratory time would be 1.0 seconds. One liter of gas would be delivered in one second.

If the pressure limit was exceeded, then an alarm will flash. Gas is still delivered to the patient when the pressure limit alarm is indicated. However, the pressure is not allowed to exceed the specified limit. Therefore the tidal volume desired has probably not been reached.

The Jet-Frequency mode is a newer ventilation mode. It is rarely seen in the developing world. This mode is mostly used on neonates. There is no inspiratory/expiratory ratio and no pressure limits to be set. The basic principle is a constant series of small volume pulses of gas is supplied to the patient.

Ventilation Control

There are several modes for controlling the ventilator. The basic modes are controlled and assisted. However, again, the combination of the two is the most common in practice.

The simplest mode is the controlled ventilation mode. In this mode the patient makes no effort to initiate respiratory effort. The ventilator delivers a set volume of gas at a set rate for as long as needed. Some units have a "sigh" level where every so many breaths or minutes the machine automatically provides the patient with a greater volume of gas.

In the assisted mode of ventilation, the patient will trigger the flow of gas by starting to inhale. When the patient reaches a preset withdrawn volume or a preset negative pressure, the ventilator will start the flow of gas into the lungs. The assisted mode is typically used while the patient is being weaned from the ventilator.

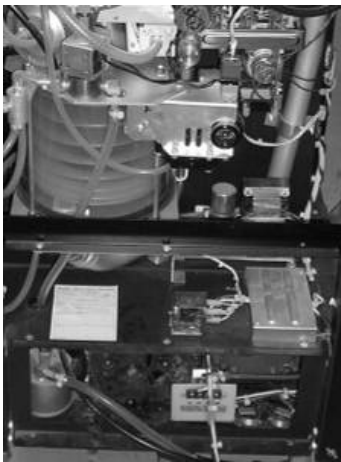
The most common mode is a combination of the controlled and assisted modes. At first, the patient is on a completely controlled ventilation mode. As the patient starts to recover they will make efforts to breathe on their own. This is called "fighting the ventilator" and is an important clinical milestone in the recovery of a patient. Once that milestone is reached, the staff will switch the ventilator to the assist mode, and begin to wean the patient from the ventilator.

Weaning is accomplished by slowly increasing the amount of negative pressure or withdrawn volume required to trigger the flow of gas. This weaning process can take from hours to months depending upon the patient's condition. If the patient fails to initiate a respiratory effort in a certain number of seconds the machine will automatically switch back to controlled ventilation mode, breathing for the patient until another respiratory effort is made by the patient.

2.2.2 Common Problems

Ventilators are one of a small group of life support devices that if it fails death will occur unless there is intervention by staff and a replacement device available. In addition, the lungs are a very delicate tissue which can be easily destroyed by a poorly calibrated ventilator. With that knowledge it is paramount that the ventilators are kept in top working condition.

However, the dangers posed by a lack of ventilation combined with the dangers posed by a poorly calibrated ventilator places the developing world engineer in a very difficult position. On the one hand, without specific training on the ventilator at hand, you may endanger the patient by working on the device. On the other hand, with no substitute ventilator available, you will surely jeopardize the patient if you do not work on the device.



The inside of the Bennett ventilator illustrates the complexity of the device. Fortunately, the required repairs are typically simple. If they are not, repair in the field may not be possible.

Fortunately, ventilators are very reliable devices. The most common problems are user error, the power supply, filtration and the tubing. The most common problem with user error is that the controls are not standardized between manufacturers and the manuals were either not supplied with the donation or were supplied in a language that the hospital staff does not speak.

If the problem is related to the power supply to the ventilator or a simple mechanical problem (such as the wheels, lid or tubing arm) repair is straightforward.

The most common problem with the tubing is that disposable tubing is being reused. The non-rebreathing valve may break or the tubing may leak. Leaks can be fixed with epoxy or a silicon sealant in most cases. The non-rebreathing valve cannot be repaired in general. However, it may be possible to adapt the non-rebreathing valve from one leaking circuit to be used on another circuit that doesn't leak, but has a non-rebreathing problem.

If the problem is not one of the problems described above, it is probably better not to attempt to fix the ventilator without specialized training. However, your decision should be made in careful consultation with the physicians. Discuss what the risks are to the patient if you do not work on the machine and what the risks are to the patient if you work on the machine, and it accidentally over pressurizes or under-ventilates the patient. Ultimately the decision is the physician's and you must follow his instructions.

2.2.3 Suggested Minimal Testing

If your repair has been a simple mechanical fix or the power supply. Then you can release the machine to the floor for use with only simple testing. The simple testing should consist of measuring the breathing rate (it should be within a few breaths per minute of the setting over the entire range) and measuring the inspiratory/expiratory ratio (it should be within approximately 20% of the set ratio). Test the pressure limit by partially occluding the connection to the patient with your hand. The pressure limit light should flash.

If the ventilator is likely to be used in an intensive care unit, then it will likely be used to wean patients. In this case, check that the assisted mode is working. After conducting the simple tests, you can connect the ventilator to yourself. Do this by gently placing the patient tube in your mouth (being sure that you can easily remove it if there is a problem). In the assisted mode, as long as you are breathing, the device will deliver gas only when you inhale. Then, remove the tube from your mouth. The device should take over in a controlled breathing fashion. Place the tube back in your mouth and breathe normally and the device should automatically return to assisted mode.

If your repair has been on the breathing circuit, then you only need to test the tubing and the non-rebreathing valve. The tubing should be leak free (occlude one end and blow hard into the other end with the tube submerged in water. There should be no bubbles. The non-rebreathing valve is a one-way valve. If it does not have a connection to the ventilator, then you can check it by simply blowing into the patient connection end and making sure that the air goes down the expiratory tube. Then suck from the patient end and make sure the air is coming in from the inspiratory tubing. If the non-rebreathing valve has a connection to the ventilator, then you will have to operate the ventilator. Check that the gas is flowing down the correct tubing by occluding the other tubing by squeezing the appropriate tubing and making sure that there is no change in the ability to deliver or collect air.

If your repair has been anything more than power supply, tubing or mechanical, then you must complete more tests. Be sure to discuss your limited ability to test the machine with the physician and the potential dangers to his patients before conducting any repairs beyond the power supply, tubing or simple mechanical repairs. However, if you and the physician determine that you must attempt a repair; complete at least two more tests before releasing the ventilator: the pressure limit and the delivered volume. Both the volume and pressure are typically tested with dedicated equipment you will likely not have. However, they can be approximated.

The pressure limit is adequately tested by connecting the patient tubing to a u-shaped bend of tubing filled with water. The ventilator should push the far end of the column of water the height of the pressure setting, and then indicate a pressure limit alarm. For example, if the pressure limit is set to 25 cm of water, then the top of the column of water away from the ventilator should be 25 cm of water higher than the top of the column of water near to the ventilator. Test several settings of the pressure limit. Discuss the accuracy of the limit test with the physician.

The volume can be approximated by connecting a balloon to the patient tubing. You must calibrate the balloon to volume before you begin. The easiest way to do this is to fill the balloon with a known volume of water. Make two marks on the balloon a fixed distance apart, indicating the volume next to the mark. Repeat this procedure for several volumes. Now, when the balloon expands to the indicated volume, the marks should be your set distance apart. To use your calibrated balloon, clamp off the balloon at the end of the inspiratory cycle. Test several settings of the volume and discuss the accuracy of the test with the physician.

2.3 Oxygen Concentrators

2.3.1 Clinical Use and Principles of Operation

Oxygen is a widely prescribed medication in both the hospital and home setting. Hypoxia, or an inadequate amount of oxygen, is the main physiological state requiring this medical technology and is present in a number of life-threatening conditions. These include chronic obstructive pulmonary disease (COPD), which refers to the restriction, inflammation, or infection of bronchioles or alveoli whereby oxygen supply or transfer to the blood is limited. Cardiovascular insufficiency also causes hypoxia when an irregular rhythm, decreased flow, or inefficient transport prevents adequate oxygen delivery to peripheral tissues.

In addition to these medical conditions, a reliable source of oxygen is essential wherever anesthetics are administered, both to supplement the inspired gas mixture and also for resuscitation, though other machines such as ventilators may be selectively used.

Oxygen has traditionally been supplied in cylinders in the developing world. However, cylinders are both bulky and expensive. In isolated areas transportation of cylinders is difficult and may be unreliable. For these reasons, The World Health Organization recommends oxygen concentrators as a better long-term investment for smaller, remote hospitals in the developing world.

Engineering Details

Ambient air contains 78% N, 21% O₂ and 1% trace gases. An oxygen concentrator works by separating and removing the nitrogen from the ambient air, leaving nearly pure (95%) oxygen. At high flow rates the oxygen concentration may drop.

Most machines now operate using pressure swing adsorption (PSA). Ambient air is compressed and passed through a synthetic aluminum silicate (zeolite). Zeolite acts as a molecular sieve by binding to nitrogen, but only at high pressures. The zeolite is designed with a porous configuration to maximize surface area.

The high pressure, concentrated, oxygen is stored in a tank. A pressure regulator is used to step down the pressure to the desired range.

After the zeolite is saturated with nitrogen, the valve leading to the oxygen tank is closed and the pressure is decreased in the zeolite tank. As the pressure drops the zeolite releases nitrogen which is vented into the air. A small quantity of enriched oxygen is then passed backwards through the zeolite canister to completely purge the zeolite of nitrogen. Since the patient probably needs a continuous supply of oxygen, a typical concentrator will have two zeolite canisters. One is concentrating oxygen while the other is being purged.

An oxygen concentrator is easy to operate with only a power switch and a flow meter. An alarm sounds if the pressure in the compression chamber falls below 20 psi. Some models include a built-in device called an OCSI (oxygen concentration status indicator) that measures the oxygen concentration just before the outlet. An alarm would sound if the concentration is low in these devices. Some machines automatically shut down if the concentration of oxygen falls below 70%.

2.3.2 Common Problems

Concentrators do malfunction occasionally, and their repair can require considerable expertise; worn parts on the compressor and valves may need replacement. Assuming that all other parts function optimally, the machine is only limited by the life of the zeolite crystals, which is expected to be at least 20,000 hours.

The primary complaints are low oxygen concentrations and decreased gas flows. Since this machine is so widely used and has few options on the interface, user error is unlikely. A clogged filter may be the cause. The filter is located between the air source and the zeolite containers. Some models may have multiple filters. A dirty filter can lead to a decreased oxygen concentration and/or a decreased flow rate.

If the flow to the patient is insufficient, the tubing and connectors should be checked for leaks. Remember that part of the oxygen-providing pathway from the zeolite canisters can be inside of the machine.

If the motor or compressor is not functioning properly, air in the zeolite canisters will not be pressurized enough to remove an adequate amount of nitrogen from the air. It is necessary in this case to check any seals/gaskets associated with these systems. Inside the chambers, 20psi is the standard pressure.

The valves at the inlet and outlet of the zeolite canisters must be tight and timed correctly. During pressurization, the inlet valve should be opened and the outlet valve should be closed. During filtering, which normally takes 8 to 20 seconds, both valves should be closed as nitrogen binds to the zeolite. During release of oxygen-concentrated air to the patient, only the outlet valve should be opened. Remember that in the regeneration stage a small amount of oxygen is released back into the canister to expel leftover nitrogen. Most models have valves that are coordinated between chambers. However, check the timing of valve opening and closing. Canisters will be in different stages of the pressure swing cycle so that while one canister is filtering, the other is regenerating.

2.3.3 Suggested Minimal Testing

It is important that this machine achieve oxygen concentrations near 90% or above and provide gas flows in the manufacturer's range, keeping in mind that for high flow rates (around 5 liters/minute) oxygen concentration will be lower. In addition, it is not safe to trust flow meters and oxygen concentration indicators on the machine when releasing an oxygen concentrator to the floor. These variables need to be checked using a separate oxygen analyzer and flow meter, respectively. It is not typically difficult to determine the flow rate in the developing world, as there is an abundance of flow meters. However, measuring oxygen concentration can be challenging. If you are unable to locate an oxygen concentration meter, discuss the problem with the physician before releasing the device to the floor without an oxygen concentration test. The measurement must be performed 10 minutes after switching the concentrator on to give the machine time to build up the concentration of oxygen.

2.4 Fluid pumps

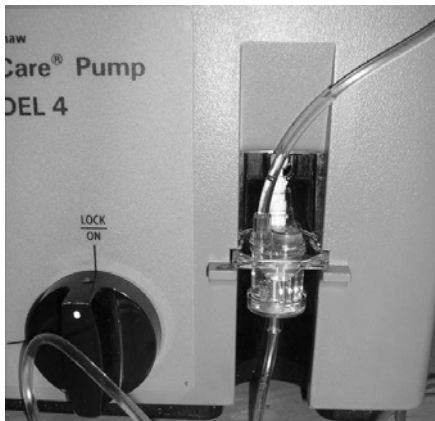
2.4.1 Clinical Use and Principles of Operation

It is not unusual for a patient in an ICU setting to have 6 or more fluid pumps connected to veins, arteries or the esophagus. These pumps can supply basic fluids and electrolytes, nutritional support, antibiotics or pain medications. Some pumps can have up to 4 separate channels infusing fluid at the same time.

The positive pressure generated by the various manufacturers' pumps can widely vary. All pumps should be able to overcome arterial pressures of a patient (150-200 mmHg). Most pumps have a pressure limit of 500 mmHg (10 psig). If the limit is reached, an occlusion alarm should sound. In some pumps, the user can lower the pressure limits. Pumps with lowered pressure limits are often labeled as pediatric.

On many pumps the output pressure also has a low limit. If the pressure in the fluid line is below the lower limit, an alarm should indicate a possible loss of connection to the patient or artery (an infiltration alarm, when the catheter is no longer in the blood vessel but infusing fluid into the surrounding tissue).

All fluid pumps work on one of three principles, volume displacement, roller peristaltic or linear peristaltic. A volume displacement pump requires a dedicated (meaning applicable to only one type of pump) IV administration set, available only from the manufacturer. The dedicated equipment includes a small cassette which acts as the pumping chamber. An IV bag or other source is hung some distance above the pump. These pumps are relatively rare in the developing world because the supply of the dedicated IV sets is not regular.



This volume displacement pump requires a dedicated cassette (cylinder on right hand side). Because these cassettes are not readily available, this type of pump is often non-functional in the developing world.

In the linear peristaltic pump, instead of a cassette containing the pumping chamber, the pump "milks" the fluid through the tubing of the IV line. This may require special, usually silastic, tubing. The basic operation is to occlude the pump with a roller, then advance the roller – or finger – forcing fluid through the tube. The tubing and fingers are typically linearly arranged. Since this tubing is a known diameter the volume infused by a peristaltic pump can be calculated as the area of the tubing times the distance that the fingers travel.



This linear peristaltic pump uses fingers (next to the large black arrow) that "milk" the fluid along and through the tubing. In general specialized tubing is required, making this type of pump less popular in the developing world.

A major difference with a peristaltic pump is that it has a free flow prevention device. This is a mechanical system to clamp off the tubing when the door is opened so the patient does not get a bolus (large single dose) infusion.

A roller peristaltic pump is a peristaltic pump where the fingers are rollers, typically arranged in a circle. Very few of this type of a pump are used for the administration of IV fluids. Most roller peristaltic pumps are used as feeding pumps and as pumps in heart-lung machines.

A syringe pump is used when fluid to the patient has to be limited or a very precise amount of a drug is to be administered. A syringe is loaded into the machine and a stepper motor advances the plunger to administer fluid to the patient. These pumps can be battery or line operated. Most units will require the programming of the pump, via the control panel keypad, for syringe size, (10 to 60 cc), flow rate and delivered volumes.

2.4.2 Common Problems

User error is common with pumps. While only the clinical staff should program the pump, the technician must know the programming procedure so they can troubleshoot or calibrate the units. Therefore, if you have the opportunity, try to use the pumps in the ICU when they are not connected to a patient.

Many of the pumps available in the developing world are the type which are distributed for free or at low cost in the developed world, but require the purchase of a specific tubing set. The pumps are donated under the incorrect assumption that they can be used in the developing world. Since these tubing sets are expensive, they are generally not available in the developing world. In most cases, you will not be able to adapt these pumps.

Some of the most common problems with syringe pumps are the clutch slipping which causes under infusion of the drug, broken latches so the syringe does not fit securely onto the pump and bad batteries. User abuse is very common as the pumps are dropped on a regular basis.

With roller pumps, the rollers may need adjustment. If the roller is too close to the tube, it causes high friction, low flow rates and premature wear of the tube and motor. The tube may march through the system as well. If the roller is too loose, there will be insufficient occlusion to move the required volume of liquid. Flow rates may drop as well, despite rapid motion of the rollers.

2.4.3 Suggested Minimal Testing

Pumps should be tested for their delivered volume with time, or flow rate. This is easily accomplished with a graduated cylinder and a stop watch. If the flow rate is set to 10 milliliters per minute, then you should measure 10 milliliters in a minute (or 100 milliliters in 10 minutes) emptying into the graduated cylinder or measuring cup.

The occlusion (or high pressure) limit should be tested. The ideal test uses a manometer. However, an adequate test is to connect the pump to a tube strung up the wall. The pump should push water up the wall to the level of the pressure limit, then stop and sound an alarm. For example, if the pressure limit is set to 200 mmHg, then the column of water should ascend 260 cm (20 cm of Hg is equivalent in pressure to 260 cm of water). In the worst case, simply clamp off the tube and make sure the alarm sounds.

If the pump includes an infiltration alarm, then it can be tested by letting water from the pump exit the tubing from the pump at different heights. Typically the infiltration alarm will sound when the water exits the tubing a few centimeters above the pump. If the water must exit the pump at the level of the pump or below, then the alarm is not working.

If the pump has batteries, it is usually sufficient to simply test that the device runs on the batteries for a few minutes. A more thorough test is described in the battery section of this book

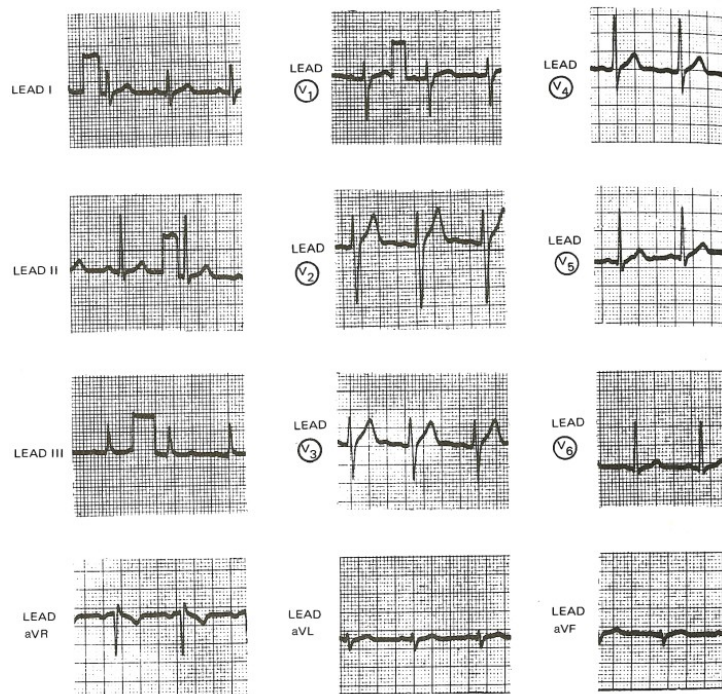
Finally, if the pump has a free flow prevention device, then insure that the removal of the tubing does not allow free flow of the liquid into the patient.

2.5 Electrocardiographs

2.5.1 Clinical Use and Principles of Operation

An ECG amplifier, (EKG is a German term that is widely used), is an amplifier with from three to ten inputs combined to show from one to twelve traces (leads) of cardiac electrical activity. Each input amplifies the signal from two or more electrodes placed on the skin.

If the ECG is being used to monitor a patient's condition, then usually three to five wires are connected to the patient and a low resolution ECG waveform and the heart rate are continuously displayed and observed by the physician. Monitoring devices will include alarms for significant changes in rhythm or waveform. If the ECG is being used as a diagnostic tool, then typically six to ten wires are connected to the patient and one or two cardiac cycles are displayed, or printed, in high resolution.



This image shows typical ECG images from all the most common leads. The square pulse is 1 mV in height. Most developing world systems only display leads I, II and III, with some adding aVR, aVL and aVF.

Most ECG machines in the developing world are of the monitoring type. For these, three or four patient cable leads are directly connected to the patient's extremities: right leg (RL – not always used), right arm (RA), left leg (LL), and left arm (LA). If the machine is reasonably modern, it will have a color code marked on the leads. However, the color code is different in Europe, and developing world hospitals often have a mixture of European and American donations. So, the color code is of little value. A fifth connection marked "C" is often present, but rarely used and may be left unconnected in most cases. A switch on the front will change the display to monitor the difference between different electrode pairs: I, II, III, aVR, aVL, aVF, and V. The table below shows the active electrodes for each switch setting. The RL lead, if present, is always active, as it is used as a ground, either driven or passive, to reduce noise. If the RL lead is not present, then one of the unused leads is being used as the reference.

SWITCH SETTING	ELECTRODES USED
Lead I	LA, RA
Lead II	LL, RA
Lead III	LL, LA
Lead aVr	RA, LA, LL
Lead aV1	RA, LA, LL
Lead aVf	RA, LA, LL
Lead V	C, RA, LA, LL (rarely used)

The terminology can get confusing between inputs, which have wires which are called leads by the engineer, and inputs, corresponding to clinically significant features, which are also called leads by the clinical staff. Using the term clinically, there are limb leads and modified limb leads. Limb leads have the electrodes placed on the limbs, typically wrists and just above the ankles. Modified limb leads have the electrodes placed on the shoulders and just above the patient's waist. Limb leads are used only for monitoring. For diagnostic purposes, there are 12-lead ECG machines, with electrodes connected at specific spots across the chest, in addition to the modified limb leads. In addition to the six leads already mentioned (Leads I, II, III, aVR, aVL and aVF) the 12-lead machine will display V1, V2, V3, V4, V5 and V6, a total of 12 leads.

To operate, the machine should first be switched on. Then, the device should be connected to the patient via the appropriate series of electrodes. After a few seconds, the device should begin to record the ECG. In some cases, a start button must be pushed. Some of the 12-lead ECG's require a series of user inputs to record the patient's name, gender and other factors.

All inputs are isolated from the power supply of the amplifier by an isolation transformer. This prevents any power supply fault from putting voltage on the electrodes and potentially giving an electrical shock to the patient. Also each input has a diode, resistor or spark gap circuit that will short any high voltage/high current pulses to ground so the amplifier is not damaged by, for example, defibrillation. The input impedance of an ECG amplifier is typically 100 megaohms.

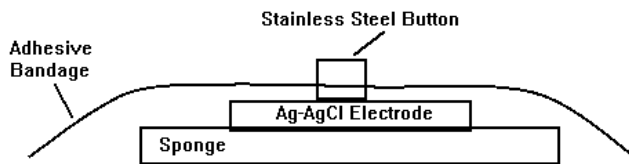
Amplifiers, both those used for monitoring and diagnostics, have a switching mechanism that selects the waveform (lead) to be displayed. The switch may be rotary, pushbutton or flat panel. On some recorders there is an automatic button which switches the output through all leads depending upon the mode. On some units there is a calibrate position on the switch which, when selected, displays a 1 mV signal. The 1 mV calibration signal is used to confirm the gain of the amplifier and is a good way to do a quick check to see if the amplifier is properly functioning. If the output shows the 1 mV signal the amplifier is working.

The standard gain of an ECG amplifier is about 1,000 cm/V, meaning that a 1 mV signal on the body surface creates a 1 cm deflection of the display device. However, some amplifiers have an automatic gain control and some may have switches with settings like 0.25 (gain of 250), 0.5 (gain of 500), 1.0 (gain of 1,000 Standard) 3.0 (gain of 3,000) and 5.0 (gain of 5,000). As with any amplifier, saturation can become a problem, even at the lowest gain setting. This is common when the patient is small, a neonate or a thin, athletic adult. A distorted waveform, usually with some peaks or valleys or, in the worst case, a flat line at the top or bottom of the display will result. There also can be a voltage offset caused by the electrodes placed on the patient. This offset voltage can move the base line up or down and can cause temporary saturation of the amplifier.

ECG amplifiers have two frequency responses that are selectable, monitor and diagnostic. The monitor frequency response for long-term observation of the patient's ECG, as in intensive care, is 0.5 to 35 Hz. Many of the monitors in the developing world do not observe modern standardization of the frequency ranges. Therefore, the monitoring frequency range may range

as high as 50 Hz. The diagnostic frequency response is from 0.1 to 100 Hz, or up to 150 Hz, with or without a notch filter to remove 50 or 60 Hz power line noise.

There are many different types of electrodes used to connect the patient to the monitor. These electrodes range from short to long-term use. Monitoring electrodes are single use items with a central column of conductive material surrounded by a plastic foam or paper tape disc or square to hold the conductive column in place. At the top of the conductive column is a snap that the lead wire is attached to, that goes to the patient cable that goes to the amplifier (figure 2.6.2). These electrodes cost between \$0.05 and \$0.11 each. They cannot be cleaned or otherwise reused. As these electrodes age, the conductive column will dry out, rendering the electrode useless.



Disposable ECG electrodes look something like large buttons. However, they are often reused in the developing world, making them a constant source of problems.

There are non-disposable alternatives for monitoring. The most common is the plate electrode that is held on to the patient with a rubber belt. Between the electrode and the patient's skin a conductive gel is placed to assure good electrical contact. However, this gel is not critical. A saline soaked gauze, or even a few drops of water, may improve the recording quality. If plate electrodes are in use they should be checked and cleaned on every inspection.

For diagnostic ECG recordings, the most common electrodes are multiuse. The "Welch cup" is the most common of these. This is a cup-shaped, silver-coated electrode with a suction bulb on the top. Corrosion is a common problem as is the lack of suction as the suction bulb ages. It is not unusual to find the suction bulb full of conductive gel and fungus has been known to grow in the bulbs.

There are two general methods of displaying the ECG waveforms, electronically or on paper. The most common form of electronic display is on a screen or CRT. The size of the display and the type of phosphor used in the manufacture of the CRT can enter into the quality of the waveform. The presentation of the ECG trace can be in the same format as a paper/chart presentation with the newest data closest to the left edge of the display, often called a moving or solid trace display. Some manufactures use an ERASE BAR presentation, sometimes called a stationary trace. In this presentation the waveform is stationary and a blank space, or bar, moves across the CRT with the newest data being to the left of the space/bar.

The other common method of waveform presentation is on paper. The size and shape of the paper varies between manufacturers. There are four general types of paper used for waveform presentation, ink, clay, wax and chemical/thermal. Each has specific benefits and problems.

Ink paper has a shiny surface, with grid lines pre-printed. They can be single sheet or continuous strip, roll or z-fold, or a continuous strip that can do a single sheet. In most cases there are many channels of waveform presented with one or more ECG lead configurations per channel. The marking of the leads is done with alpha characters or dots and dashes. If the stylus is not properly maintained there can be blotching or smudging on the waveforms. Wax paper is for hot stylus recordings. It is rare. Thermal paper is the most common paper. It comes in rolls and z-folds. Its distinguishing feature, in most cases, is the lack of grid lines. Thermal paper looks like, and essential is, thermal fax paper. The chart speeds on most

recorders and electronic displays are 25 and 50 mm/sec. Some may have additional speeds. When the chart speed is 25 mm/sec each mm on the horizontal axis is 0.04 seconds.

2.5.2 Common Problems

By far the most common call to engineering is simple user error. ECG's are common donations in the developing world, but the manuals are not. Even when the manuals are delivered with the machines, they are often in a language that the staff does not speak. Even when the staff can read the manual, they often don't. Modern ECG recorders can present a myriad of buttons and controls and can be quite confusing. For all of these reasons, if the machine turns on, the first thing to suspect is user error in the operation of the machine.

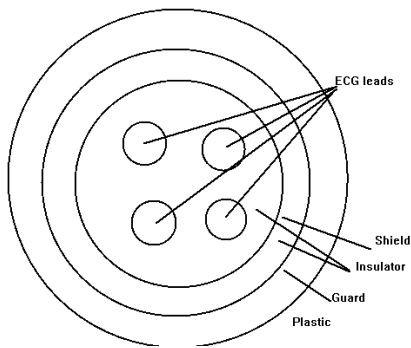
A common problem in older machines is getting the correct rate. The heart-rate meter may not have an automatic gain control. In these cases, the user may not realize that they have to adjust the gain for the rate to read correctly.

User error can extend beyond the operation of the machine. Though the positioning of the electrodes is the doctor or nurse's job, when done poorly, it can result in a call to engineering. The most typical symptom is a saturated ECG or an ECG distorted by power line noise. A few points to remember for electrode placement are: 1) electrodes should not be placed on scar tissue, 2) electrodes should not be placed over a lot of body hair, 3) electrodes placed closer than 2 inches from each other may not record a clear signal, and 4) if more than one device requires that electrodes be placed on the patient they may interfere with each other. Switching to different leads, repositioning electrodes and shaving the skin may resolve these problems.

After the electrode the weakest link in an ECG system is the lead wires. The patient cable should last for many years. However, abusive use can lead to wire breakage. Before rejecting a lead wire, try a different wire from another machine to confirm that this is the cause. Lead wires often look to be in poor condition because of tape residue on the cable. This residue can be removed using alcohol or other solvents.

If the lead wire is at fault, replacement is the preferred option. However, lead wires can be repaired in some cases. To find the faulty wire, for each position on the patient selector switch, wiggle the patient cord at its end, in the middle where the five leads fan out, and at the machine plug end. A break will be evidenced by a violent deflection on the display. If the break is in the last, typically quite thin, part of the lead, this can be cut and soldered in the standard fashion, as the last dozen inches are typically unshielded wire. If there is a shield, be sure to reconnect it as well.

The most common problem is in the connection to the main cord, or the connection to the machine. This wire contains potentially two or three layers before the conductor. If the violent deflections occur when the patient cable is wiggled at its plug end, and this occurs with several lead sets, then the socket is broken. As replacement sockets are nearly impossible to find in the developing world, you must consider rebuilding the socket (a time consuming, and often unrewarding venture), or consider permanently soldering the lead set to the machine, if the hospital desperately needs that ECG.



ECG cables are multi-conductor, complicated structures That frequently break in the developing world.

The remaining problems are described by their symptoms because they are so common and are often caused by user error, lead placement or lead wires.

Wandering baseline is noticed by the technician as the line between cardiac cycles bounces around or jumps. This is most often caused by attempting to use a monitor in diagnostic mode or by electrode placement or quality.

An intermittent trace results when the signal saturates, then returns and saturates again. These problems are almost always caused by the electrodes or lead wires. Loose patient connections can also be the cause. These same problems can cause a weak ECG (as well as a user setting an inappropriate gain).

You can verify that a problem is caused by AC interference (ECG contaminated with 60 Hz or 50 Hz) by removing the machine from the operating room or ICU to see if this solves the problem. If not, insure that the device has been set correctly for the local power line frequency. The numbers of donations from different parts of the world, and the poor engineering support that accompanies some donations leads to some devices being left in 50 Hz mode while being operated in a 60 Hz environment, and vice versa. Also, check to see if the patient is cold or nervous. If so, muscle tremors could be causing the interference. Another cause can be the patient or nurse touching any metal or nearby wall during monitoring.

When no trace shows up at all, the most typical cause is user error. There may be brightness settings, or an off position. Bad electrodes and lead wires do not typically cause the trace to disappear. Power supply problems should also be suspected.

If the trace does not appear, and the device is a printing ECG, you may be experiencing problems with the printer. With the heated stylus, the pressure of the stylus on the paper can affect the width of the trace and its frequency response. If too much heat is used the trace will also be widened. If too little is applied, then no trace will appear.

With an ink system the stylus is longer and touches a flat surface. The ink is carried via small bore tubing from a central supply to the stylus. These tubes sometimes become blocked and can be cleaned by removing and flushing them with alcohol. This is a messy process and care should be taken to protect clothing. The tips of the stylus, (pens), may also pick up lint and bits of paper that will widen the trace. These should be cleaned using a lint free cloth or paper. The tip may wear in an uneven manner and require re-flattening, commonly referred to as lapping. This is done using a very fine piece of emery paper and lightly running the tip over the paper. One favorite way of doing this is to put the emery cloth under the tip, hold it in place while moving the position control so the stylus moves across the emery cloth. Only 2 to 3 swings across the cloth are generally needed to flatten the tip.

Ink cartridge systems have a specifically shaped "felt tip marker" instead of a heated stylus or ink reservoir. These systems have the potential of drying out and not making full traces. The system is used for both stationary paper, (x-y plotter) and continuous roll paper. Spare cartridges should be with the unit as they can be replaced easily by the user. With age the writing tip may widen and should be replaced. If a replacement cartridge is not available, it can be refilled. However, some trial and error will be required to find an ink that will work. If the tip is damaged, the tip from some felt tip pens may be fixed in its place, but again trial and error will be required.

2.5.3 Suggested Minimal Testing

For most monitoring ECG's, it is sufficient to simply connect the ECG to yourself and record an accurate ECG and heart rate. If the heart rate matches your own (as measured with a watch while feeling the artery in your neck), and the ECG looks like a normal ECG, then the device is probably working. You should check the heart rate alarms to make sure that they sound when they are set either lower than your own heart rate (upper rate alarm) or higher than your own heart rate (lower rate alarm).

If the ECG is to be used in the OR, then there is a chance that it will be used for direct heart contact. Even a small current running through the lead wires can cause death (via ventricular fibrillation) in these situations. Unfortunately, without a specialized device, it is not possible to properly check for leakage currents.

If you are in a hospital where an ECG must be used in the operating room and the appropriate test device is not available, there is an adequate partial test. Be sure to discuss the limitations of your testing with the physician before returning the device for use. An adequate substitute is to only test for large leakage currents to ground. This is the most common danger to the patient. To accomplish this test, place a resistor of about 1000 ohms between each patient connection and ground, one at a time, in succession. Measure the voltage drop across the resistor. Calculate the current flowing in each lead to ground (voltage drop divided by the resistance you used). The currents should be below 50 microamps (measured voltages below 50 millivolts rms).

You can also test the metal case of any piece of equipment using the same technique. However, for pieces of equipment which are not directly touching the heart, 500 microamps of current may flow. Items which can be tested with this technique include the heating system, air-conditioning, plumbing, the oxygen and suction terminal board, nurse-call and TV controls, the bed stand, and any monitoring or other equipment attached to the patient.

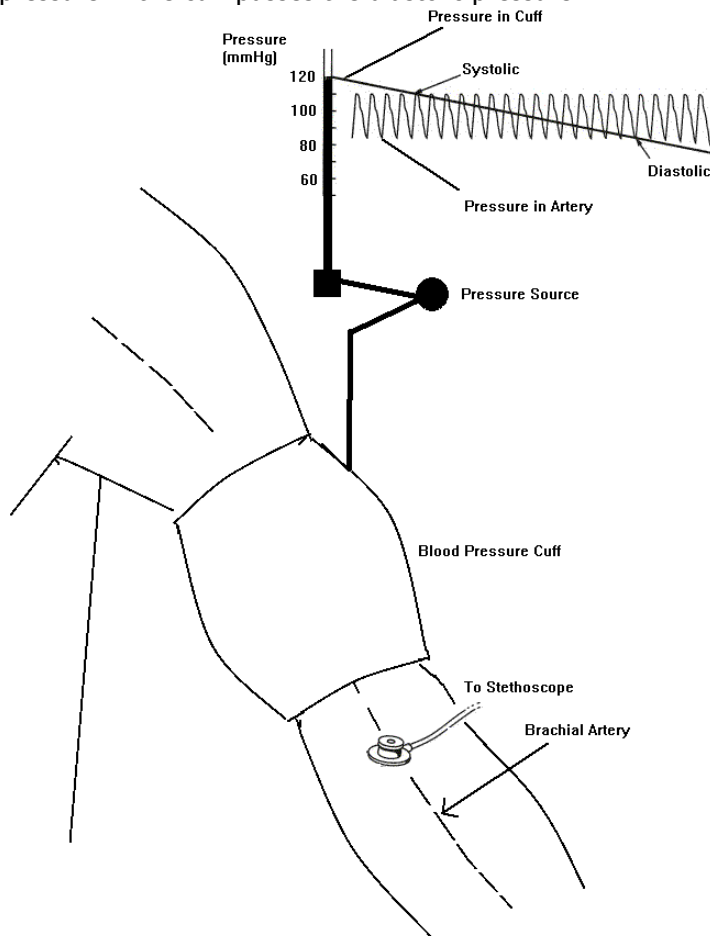
It is a good practice to clean the electrodes before release back to the floor. Also, check for any loose or broken lead wires. If the machine has a battery, check that it is in good condition and that the charger is working properly.

2.6 Blood Pressure Machines

2.6.1 Clinical Use and Principles of Operation

Blood pressure machines are one of the primary diagnostic tools used by health care workers. Sphygmomanometers are used for determining the patient's resting blood pressure, one of the preliminary tests that health care workers may perform. A diagnosis of high or low blood pressure can be indicative of other, more serious diseases. There are three main types of blood pressure machines: mercury, aneroid, and electronic.

The measurement of blood pressure has been common for over a century and is often misunderstood. The non-invasive measurement of blood pressure is accomplished by occluding an artery in the upper arm with an inflatable cuff that is connected to a mercury manometer. A stethoscope is used to listen for the Korotkoff's sounds as the blood flows. The first sound is heard as the pressure in the cuff passes the systolic pressure. The last sound is heard as the pressure in the cuff passes the diastolic pressure.



A traditional blood pressure measurement is made by occluding the brachial artery with a cuff. As the cuff is deflated, the technician can hear, at first, nothing, as no blood flows in the artery, then a sound as the pressure in the cuff is just below the systolic (maximum) pressure. When the cuff pressure just descends below the diastolic (minimum) pressure, the sound goes away because the flow returns to laminar flow.

The ideal pressure is 120 mmHg systolic and 80 mmHg diastolic. Systolic pressures above 150 mmHg or diastolic pressures above 100 mmHg are of clinical concern. The difference between the systolic and diastolic pressures is called the pulse pressure. This generally runs between 40

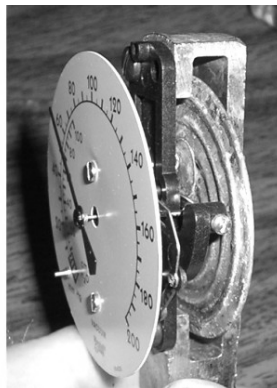
and 50 mmHg. An estimated mean pressure can be obtained by adding one third of the pulse pressure to the diastolic pressure. The mean pressure shouldn't drop below about 80 mmHg.

To measure the pressure in the cuff, a mercury manometer is often used. A plastic or glass column with graduations from 0 to 300 mm is connected to the cuff via latex or rubber tubing. The tube is filled with mercury. The pressure reading is the height of the mercury column. To get accurate readings the tube must be exactly vertical. At the top of the tube, under the cap is a calf skin diaphragm that allows air to move in both directions. If this diaphragm is dirty the mercury in the column will not move smoothly, either up or down. Mercury manometers are no longer used in The United States. However, they are quite common in the developing world.



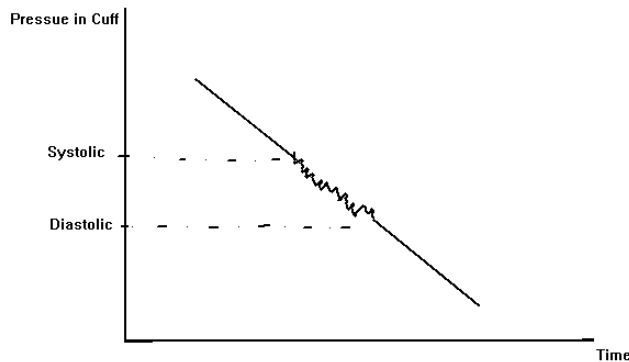
In this photo, the cover for the mercury reservoir has been removed (right). The mercury has oxidized leaving a fine powder that should be removed before refilling the reservoir.

Another manometer used for blood pressure readings is the aneroid manometer. This is a bellows based system that has a dial calibrated in the range of 0 to 300 mmHg. At the resting point of the needle on the dial is a rectangular box. If the needle is in that box the manometer is calibrated and can be used.



An aneroid manometer uses a calibrated dial. Notice that when the dial is at zero, there is a small rectangle where the needle should rest. This manometer is also calibrated in inches of water.

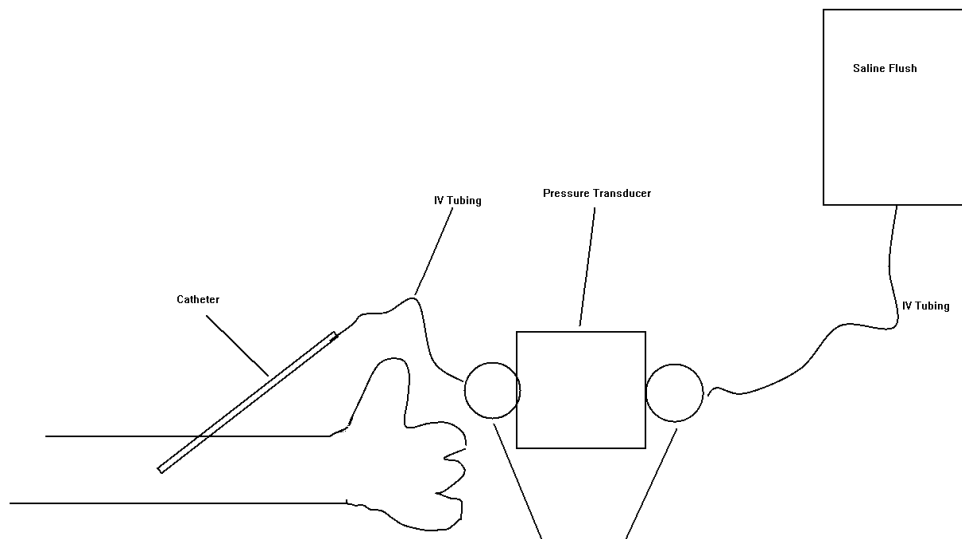
Non-invasive blood pressure machines (NIBP) are devices that automatically and electronically measure blood pressure. In these system electronics replaces a human in the inflation/deflation of the cuff. In most modern devices, the detection of the pulsation, not the listening for Korotkoff sounds, drives the detection of the maximum and minimum pressure. The results are displayed in digital format on separate displays or on a screen. The units can be programmed to take blood pressures on a set cycle, 1, 5, 15, 30 minutes, trend the data and often sound alarms if the results are outside of preset limits.



Automatic non-invasive blood pressure (NIBP) machines typically measure the presence of small oscillations in the pressure to determine the systolic and diastolic pressures. Some older machines may use a sensor to detect the Korotkoff sounds.

Older NIBP's may use two tubes to inflate the blood pressure cuff. Some devices have a transducer in the cuff to detect the sounds.

A completely different approach to measuring blood pressure is to invasively introduce a catheter into an artery. This is most common in surgery and intensive care units. The blood pressure device is connected to the catheter via a rigid wall plastic tube filled with a saline solution. The tube is connected to a transducer, which may be connected to bag of saline or "flush." Figure 2.7.3 illustrates the set up. The transducer is hung at the level of the heart. The output from the transducer is amplified and displayed as numbers, waveform or both. Since the skin has been breached the patients first line of defense for both infection and electrical shock have been bypassed. Extreme care must be taken to assure the safety of the patient.



An invasive blood pressure measurement typically involves piercing the skin of the arm or leg. The pressure transducer should always be at the level of the patient's heart. The flush bag is held a foot or more above the patient.

2.6.2 Common Problems

Non-invasive, manual blood pressure machines are extremely reliable. They are also inexpensive. Even in the developing world, they are often replaced rather than repaired. However, there are a few common problems.

Leaks in the tubing are common and can often be repaired with epoxy or silastic. To check for leaks, inflate the cuff to 250 mmHg and allow it to stand. The pressure should slowly decrease at a rate not exceeding 5 mmHg per minute. If there is a leak, you can find it by rubbing soapy water over the tubing and looking for bubbles.

User errors related to calibration are somewhat common. The cuff must be at the level of the heart and the manometer must read zero before the cuff is inflated. Check the cleanliness of the mercury. After a time, mercuric oxide will form and is distinguishable by a black powder. The mercury, the mercury reservoir, and tube will all need to be cleaned. Keep in mind that mercury is toxic and care should be used to not release any into the ground or building. Check the leather seal and washer located at the top of the upright tube. Pump the pumping bulb: as soon as the pumping is stopped, the mercury should stop rising. If it continues to rise, the leather seal and washer will have to be further investigated and perhaps replaced.

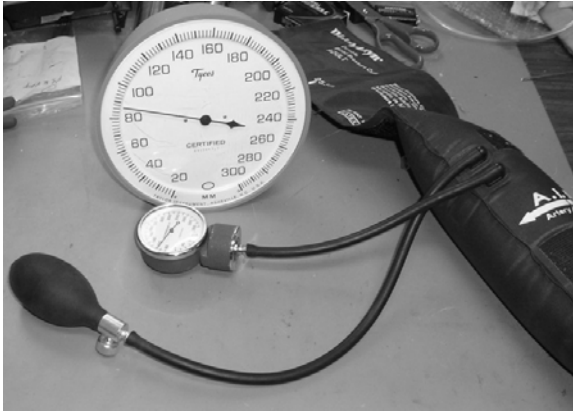
For automatic NIBP's the most common problem is the use of the incorrect cuff. If the correct cuff is being used, and if the transducer is located in the cuff itself, it may be possible to access the transducer with some difficulty. However, repair often requires specialized knowledge, as the manufacturer's designs vary considerably.

For invasive blood pressure measurements, there are many possible problems. The most common is reusing non-reusable transducers. The single use disposable transducers are now the standard of care in the United States. While there are non-disposable alternatives, they are rarely used. The transducer is commonly mounted on an IV pole next to the patient's bed. It should be at the same level as the patient. There is a 2.5 mmHg error for every inch that the transducer is above or below the level correct level.

During the set-up process the invasive catheter transducer is vented to air, zeroed and all the air removed from the line, usually using the flush solution. The technician may, or may not correctly complete each of these steps, leaving air bubbles in the line or leaving the transducer improperly zeroed. Also check that the transducer is at the level of the heart.

2.6.3 Suggested Minimal Testing

The most critical element to calibrate is the pressure measurement. A simple pressure standard can be made by creating a column of water in a tube. Taping a tube to the wall and filling it with water up to a height of 271 cm, for example, creates a pressure standard of 200 mmHg (the density of mercury is 13.55 times that of water). Before releasing the blood pressure machine, check several pressure levels (200 mmHg, 100 mmHg and 50 mmHg – or 271 cm H₂O, 136 cm H₂O and 68 cm H₂O, respectively). The manometer should be accurate to within 1-3 mmHg.



A manometer can be tested against a known good manometer, against a mercury manometer, or against a simple column of water in an IV tube (100 mmHg of pressure is exerted by a column of water 135 cm high).

If the pressure is consistently too high or too low, you will need to adjust the zero by removing or adding mercury or twisting the manometer face (if aneroid). Electronic blood pressure devices will have a zero setting which should never need to be adjusted, if the device is properly zeroed before each use. There is a gain setting for electronic devices that occasionally needs to be adjusted.

If the blood pressure machine is intended for manual use, you should also check the device for convenience of use. When inflated with the valve closed, the pressure should not drop appreciably in ten seconds. When the valve is open, the pressure should drop slowly and linearly. Consult with the physician or nurse about the leak and drop rates to be sure that the device will be convenient for them to use.

If a mercury manometer has been used for many years, mercuric oxide may form in the tube and will appear as a black powder. The mercury, tube, and reservoir will all have to be cleaned if the nurse objects to its presence. Keep in mind that mercury is toxic and should not be touched or the vapors excessively inhaled. To remove the mercuric oxide, take off the reservoir cap and remove the mercury using a needle and syringe. Filter the mercury through filter paper into a clean container. Repeat several times until all the solid oxide is removed. Take the tube and reservoir outside and use an air line to blow out any particulate matter. Replace the clean mercury into the reservoir and top off the reservoir with new mercury up to the '0' mark. Replace the reservoir cap.

Automatic, non-invasive blood pressure machines (NIBP's) are more difficult to calibrate than the others because the need to detect the Kortokoff sounds to function. If you do not have a phantom arm, then the best approach is to use your own arm. Borrow a stethoscope and measure your own BP. If you are not confident that you can use a sphygmomanometer accurately, then ask someone else to measure your BP. Repeat the measurement five times. Then connect yourself to the NIBP and measure your blood pressure five times. The average diastolic and systolic pressures from the two systems should match to within 3 mmHg.

2.7 Pulse Oximeter

2.7.1 Clinical Use and Principles of Operation

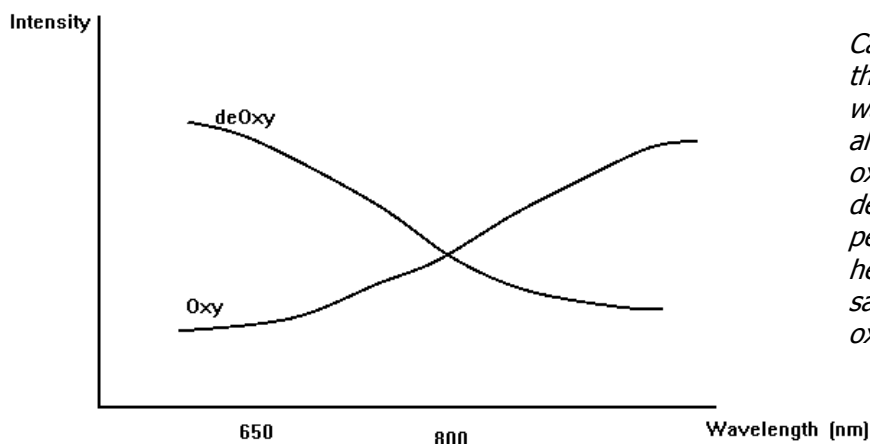
Oximetry is a non-invasive method of measuring the oxygen saturation of the hemoglobin in the blood. The percentage of the hemoglobin that is saturated with four oxygen molecules is a good indicator of the oxygen carrying capacity of the blood. In a healthy human, nearly 100% of the hemoglobin is saturated all of the time in the arteries.



Most pulse oximeters display both the heart rate and the SpO2 – the oxygen saturation.

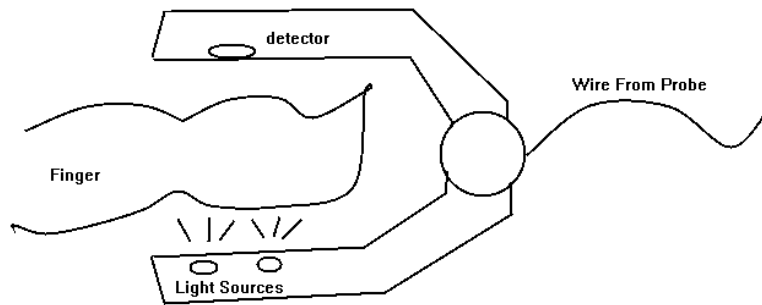
Modern oximetry is conducted with a pulse oximeter. The pulse oximeter uses the plethysmographic pulse from the artery to improve the measurement. Therefore, in addition to the oxygen saturation of the hemoglobin, the device also can report the heart rate and the plethysmograph, though the latter is less common.

The pulse oximeter uses two frequencies of light impinging on the tissue. One of the two frequencies (or wavelengths) is sensitive to only the volume change (plethysmogram) and one which is sensitive to both the plethysmogram and the oxygen saturation. Figure 2.8.1 shows that at about 805 nm, the intensity of the light from the tissue does not depend on whether it is oxygenated or deoxygenated. Whereas, at 655 nm, there is a large difference in the amount of light reflected from the tissue. By carefully analyzing both signals, the device can deduce the oxygen saturation of the blood hemoglobin, usually simply reported as a percent (SpO2).



Careful analysis of the light from two wavelengths allows the pulse oximeter to determine the percentage of hemoglobin saturated with oxygen.

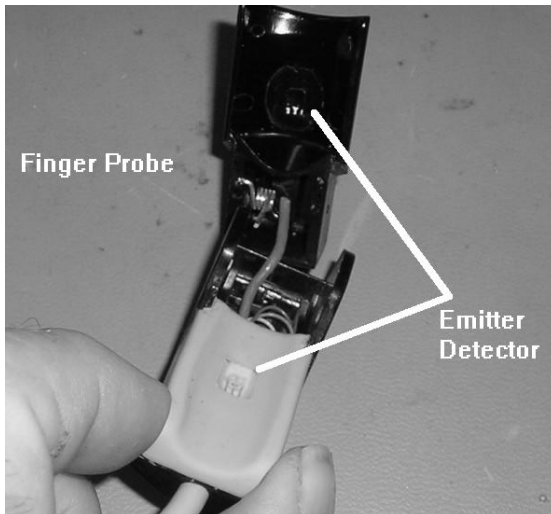
The probe, which contains both the light source and the light sensitive sensor, can be placed on a finger, ear lobe, toe or forehead depending upon its design. Some probes are single use while others are multi-use. Multi-use probes are preferred in the developing world. However, disposable probes are often reused.



The most common pulse ox probe contains two light sources (about 650 and 800 nm) and one detector that is multiplexed.

2.7.2 Common Problems

The most common problems with the pulse oximeter are related to the probe. The constant reuse of disposable probes eventually results in lead breakage. These can often be repaired, if only a single wire is broken. The second common problem is a missing probe. Unfortunately, it is not possible to substitute incompatible probes, as the wiring, and even the approach to producing and sensing the two wavelengths differ between manufacturers.



The most common probe for a pulse oximeter is the finger probe. Broken wires, springs and plastic cases are common problems that can be fixed in the field.

There are a few areas of user error which are common. Sensor placement is the most common. The sensor should be positioned to avoid letting ambient light enter the tissue or the sensor. Some nail polish will block light transmission. If the patient is cold the blood vessels may constrict making detection of blood flow difficult.

Beyond probe problems, typical power supply problems and user error (which is rare with this device), there is very little that can be done to repair a broken pulse oximeter.

2.7.3 Suggested Minimal Testing

A pulse oximeter can be easily tested on yourself. Your heart rate should be accurately reflected (to within 1 bpm) on the display as compared to a standard stop-watch/neck-artery technique. Also, check the alarms to assure that when your heart rate is outside of the set range, the alarms sound.

2.8 Defibrillators

2.8.1 Clinical Use and Principles of Operation

A defibrillator is used to reverse fibrillation of the heart, restoring the heart's normally coordinated contractions. The uncoordinated contractions of the heart can take place in the atrial, or upper, chamber of the heart as well as in the heart's ventricular, or lower, chamber. Atrial fibrillation (AF) is relatively common and can be well tolerated by the patient. Ventricular fibrillation (VF) causes the heart to stop pumping blood immediately, and is therefore fatal if not treated within minutes. Death from VF is often called a massive heart attack and is the most common cause of death.

The defibrillator works by delivering a brief, very strong, electrical shock across the chest. The typical pulse is 10 ms and as much as 3000 V. Energies ranging from 300 to 360 J are used during external ventricular defibrillation. While treatment of ventricular fibrillation is the most common use in the developing world, most hospital defibrillators can also treat ventricular tachycardia, where the heart beats too quickly, but in a coordinated fashion. Energies for treatment of ventricular tachycardia are typically below 200 J.

There are several different types of defibrillators. The most common in the developing world is the manual defibrillator. The most common in the developed world is the automated external defibrillators. The implantable defibrillator and the home defibrillator are very rare in the developing world.



The manual defibrillator is commonly found in the developing world. The unit on the left includes an ECG monitor. The device delivers a potentially lethal shock and should be worked on with great care.

The manual defibrillator is a box about 1.5 cubic feet in size, weighing around ten pounds. Cables connect two large metal paddles, which are used to apply the electric shock to the patient. ECG leads can also be connected from the device to the patient. However, most can monitor the ECG through the defibrillation paddles as well. When the ECG connections are used, the ECG can be manipulated in many of the same ways as a bedside monitor.

Defibrillator paddles come in several types: external adult, external pediatric, internal (there are several sizes, all used when the chest is open) and disposable or adhesive electrodes. The external adult and pediatric defibrillators require a conductive gel to be added between the patient and the paddle. The gel is used to assure conduction between the paddles and the chest wall.

The defibrillator works by charging a capacitor, then discharging part of the stored energy in the capacitor through the patient. Older defibrillators discharged through an LCR circuit to the

patient. In these devices, the pulse can be as high as 7,500 volts. These discharge circuits have a characteristic waveform to the discharge current called an Edmark waveform. Edmark waveform devices are still very common in the developing world. Because the Edmark waveform can cause severe damage, even death, everyone should stand clear of the patient during the delivery of the discharge of the capacitor. More modern defibrillators discharge the capacitor through a transistor network to deliver a more effective, biphasic, waveform. The biphasic waveform is less likely to cause damage, but the risk still exists.

All defibrillators have a battery back-up system. This way you can bring the defibrillator to the patient, instead of bringing the patient to the defibrillator, which could add minutes to the time until VF is treated. Batteries are often the reason that defibrillators are heavy. Unfortunately, they are also, often, the cause of their failure in the developing world.

2.8.2 Common Problems

Defibrillators are highly reliable devices which require relatively little maintenance if properly stored and used. The most common problem in the developing world is the batteries. Batteries should be replaced every 24 months, or less, to assure proper operation of the defibrillator. However, this is almost never done in the developing world. Refer to the battery chapter for instructions on replacing and testing batteries.

If the batteries cannot be replaced, some defibrillators will not work. However, some will function on mains power alone. If the defibrillator is destined for the OR, the need for batteries is minimal. If the unit is destined for the ER, and won't operate without batteries, it is better to send it back with a very long extension cord, rather than deny ER their only defibrillator. For EMT's a defibrillator without functioning batteries has no value.

Some defibrillators will contain a synchronizer for atrial defibrillation. This is rarely used in the developing world, but can cause problems if the user unwittingly engages the synchronizer. For ventricular fibrillation, the synchronizer plays no role and should be switched off. If this feature is broken, the synchronizer should be bypassed or its sensitivity increased to trigger the discharge.

2.8.3 Suggested Minimal Testing

There are a few maintenance issues that you should take care of before releasing the defibrillator to the floor. The gel will sometimes build up on the paddles and have to be cleaned. Alcohol will soften the gel and make removal easy.

The external paddles should be inspected for pit marks; these could cause high current density and leave burns on the chest. The marks can be removed using emery sand paper. Internal paddles should be inspected to be sure that there are no breaks in the insulation around the conductive part of the paddle. If breaks are present, attempt to repair them with epoxy or a dip plastic. Tape will not withstand OR.

You should test the defibrillator before returning it to the floor. If the defibrillator is not defibrillating, the patient may die. However, the defibrillator should never be discharged by putting the two paddles or electrodes together and pushing the discharge switch. At a minimum this will damage the paddles and potentially the unit.

Ideally, you should discharge the defibrillator through a defibrillator tester. However, these are rare in the developing world. Some defibrillators have an internal test load that you can use. Engineering World Health has recently begun distributing limited-function defibrillator testers free-of-charge. You can contact them to obtain one. However, in most cases, you will have no tester and no internal test load.

If you find yourself without any testing equipment, you can try defibrillating through a large piece of meat. While either chicken (or better turkey), pork or beef will work, you can often purchase a freshly killed pig at very low cost in the developing world. Be sure to place the paddles on opposite sides of the animal, at least six inches between the closest approaches of the paddles. Also, be sure you are wearing gloves and no one else is touching the animal. Gel is required between the paddles and animal, but be sure the gelled areas of the skin are no closer than six inches. A freshly killed pig will jump several inches when a defibrillation pulse is properly applied. Large edemic (red) areas will quickly develop where the paddles were applied. The pig is safe to eat after this procedure, after you remove the gel.

In the absence of freshly killed pig, the next best choice is a large piece of dead meat. You need something large enough that the defibrillation paddles are never less than six inches apart at their closest approach. Of course, the dead meat won't jump. However, after ten 360 J shocks, you should begin to see burn marks on the meat, typically outlining the electrode placement.

2.9 *Fetal Monitor and Fetal Doppler*

2.9.1 Clinical Use and Principles of Operation

Fetal monitors document two major functions: 1) the heart rate of the fetus, and 2) the contractions of the mother. A normal fetal heart rate is between 110 to 160 beats a minute. The sound of the beat is usually strong and regular. It is normal to have some changes in the fetal heart rate during labor, but drastic changes in heart rate before or after a contraction may indicate that the fetus is in distress. A fetus with large changes in heart rate may need to be removed from the womb immediately, by Caesarean section.

Fetal monitoring during labor, when it is most commonly applied, has been controversial since its inception. Some claim that fetal monitoring offers a monitoring tool that can reduce fetal mortality and morbidity. Others blame the technology for the large increases in Caesarean sections and the attendant maternal morbidity.

Currently, there are three widely used methods of monitoring the fetal heart rate: Doppler, Surface Electrodes, and a Scalp Electrode.

Surface electrodes are applied directly to the mother's body, typically with adhesive silver-silver chloride electrodes. The surface electrode technique operates identically to a typical electrocardiogram, but with much more complex signal processing to reduce the probability of mistaking a maternal heart beat for a fetal heart beat. The surface electrode approach to measuring the fetal heart rate has the advantages of being not invasive, being applicable at any time during pregnancy, and are very low cost. However, they are subject to artifacts from the maternal heart beat, don't work well with certain fetal positions and can't resolve multiple fetal pregnancies.

For the Doppler technique, a doctor, nurse, or technician applies ultrasound gel to the end of a flat transducer and moves it across the abdomen until a good reflection is found from the heart. The Doppler technique is the most common as it is less prone to artifacts than the surface electrodes and it is equally easy to apply. However, the transducer and accompanying electronics are expensive, may require repositioning during labor, and don't resolve multiple fetal pregnancies well.

The fetal Doppler probe is also used by itself to detect the fetal heart beat. As a hand-held device it can be used from about the end of the first trimester to delivery. The probe produces ultrasonic pressure waves at about 2.5 MHz and hand-held unit produces a sound with heart beat. A typically hand held device has no display or chart. The doctor must time or count the heart beats to determine the fetal heart rate.

The principle of operation of the Doppler probe is the Doppler Effect. If waves of a given frequency are transmitted to a stationary reflector, the reflected waves are of the same frequency as those transmitted. If the reflector is moving towards the transmitter-receiver, the reflected frequency will be higher than the transmitted frequency. In this case, the waves are bounced off the fetal heart. The occurrence of a frequency shift is taken as the presence of a heart beat by the machine.

Scalp electrodes are applied directly on the fetus' head and operate in a manner identical to a standard electrocardiogram. This approach is used only with high-risk patients, if labor is going

very slowly or if the external fetal monitor is not detecting the fetal heart rate. The amniotic sac must be broken to apply the electrode. The scalp electrode gives accurate fetal electrocardiograms. However, it is invasive, opens the amniotic sac for infection, and cannot be easily applied to multiple fetal pregnancies.

The contractions are measured with a strain gage transducer (usually called TOCO) either mounted externally or with a belt around the abdomen.

The fetal heart rate is displayed digitally on many units and in graphic form on a chart. Typical fetal heart rates are in the range of 110 to 160 beats per minute. During contractions the heart rate will decrease and revert to previous levels after the end of the contraction. If there is a delay in the heart rate returning to its previous level it can indicate that there is fetal distress.

2.9.2 Common Problems

User errors are common with fetal monitoring. Incorrect connections of the transducers and incorrect loading of the paper, or the loading of the wrong paper are the most common of these problems. Power supply problems, typically dead batteries, are common with the hand held fetal Doppler devices. Be sure that gel is being used between the ultrasonic transducer and the patient.

The Doppler probe is the most sensitive part of both the handheld and bedside devices. When it breaks no output is heard, even when a stethoscope or fetoscope indicate the presence of a fetal heart beat. You can quickly check the probe operation by gently tapping the probe surface about once per second. If this is not detected, there is certainly a probe problem.

The probe consists of the transducer assembly, the cable, and a multi-pin fixable connector. The cable contains between 5 and 80 separate conductors. The most frequent malfunction occurs as a result of a break in one or more of the cable conductors. Such malfunctions are usually the result of mishandling of the cable or of soaking it with gel. The probe is expensive and typically cannot be replaced in the developing world.

Fortunately, the cable can often be mended. The face of the probe is usually an acoustic lens. It must be handled with care. Do not drop the probe, and avoid scratching the face with sharp objects. Keep the probe assembly clean of oil and gel. Always clean the probe and cable with a tissue or damp cloth, after finishing work.

The surface electrode problems are similar or identical to those discussed in the chapter on electrocardiograms. Poor electrode function will result in no fetal heart beat being reported. Check that the patient electrode connections are clean and in good condition. Check that the leads to the patient are in good condition, that the conductor is not broken, and that there is not a short circuit to the shielding that surrounds the other connectors.

The last most common problem is with the paper. The paper is often installed wrong or the wrong paper is used with the device. Check that the digital heart beat and the paper trace are giving the same reading when you tap the transducer, or apply the electrodes to yourself. The chart recorders themselves are identical to those used for electrocardiograms. Check that chapter for ideas on what could be wrong with a chart recorder.

2.9.3 Suggested Minimal Testing

All of the transducers designed to measure the fetal heart rate can be used to measure your own heart rate. For surface electrodes, you may have to attach one set of electrodes to yourself (as the mother) and one set of electrodes to a friend (as the fetus) in order to satisfy any alarm conditions before operating the machine. The Doppler probe should work when placed on your chest, with the proper gel, near your heart. Check for the accuracy of both the digital display and the paper trace by comparing their output with a measure of your own heart rate from a watch. The two should be within 1 or 2 beats per minute of the correct rate.

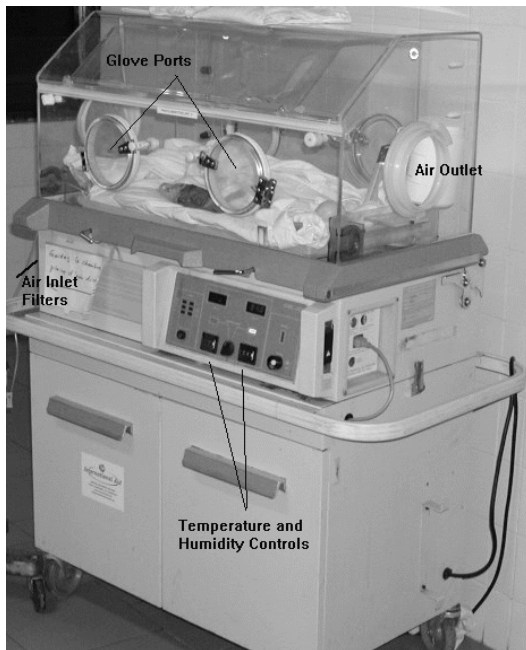
For the contraction monitor, stretch the belt, or very gently press on the transducer at a rate of about one gentle push every minute. Use a watch to verify the time between applications. The monitor should reflect your application pressure (approximately) and rate (accurately – about 10%).

If both contraction rate and fetal heart rate are reported accurately, then the device is ready to release to the floor.

2.10 Infant Incubator

2.10.1 Clinical Use and Principles of Operation

A baby incubator is an isolation chamber that helps regulate the temperature of an infant and can provide air which is enriched in humidity or oxygen. The basic machine has a place for the baby to lie and is surrounded by a clear plastic box. A heating element lies below the baby. There is always a control for the heater, and generally a feedback mechanism to regulate temperature within a degree of a set point. Most incubators in the developing world have latex gloves built into the chamber that allow for manipulation of the baby without entering the isolated environment (see figure).



An infant incubator provides a warm, moist and sometimes sterile environment for a newborn. In the developing world, as shown in this incubator in Togo, the ports are left open and the filters are missing, leaving the environment warm and moist, but not sterile. The infant sits on a platform covering a water holding tank and fans.

In some older units the temperature is controlled by a rheostat and must be manually adjusted as conditions change. The temperature is displayed via panel displays, digitally in newer units, with an analog meter in older units and with a thermometer in the oldest units. Most units have a small fan to move the air past the heater and into the infant chamber. All but the oldest of the units will have alarm settings for over and under temperatures in the incubator. There also is a default high temperature cutoff that prevents the incubator from heating above 40 degrees C.

In some units there is a reservoir of water that the air moves over to increase the humidity in the infant chamber. This is often supplemented by other sources of humidity. To reduce the water loss of an infant in an incubator literature suggests that the relative humidity in the incubator be between 60 and 90%.

All the access doors should have positive latches on them so that they stay closed. The hoods will have one or more cable/tubing entry ports that allow for monitoring cables, IV lines, suction tubing, etc. to enter the infant chamber without going through an access door.

2.10.2 Common Problems

If the chamber is not heating, it may be the heating element. The heating element is typically a special (nicrome) wire. The wire cannot be repaired, typically, but it is common and a replacement can often be found in a large city. The only requirements for replacing the heating element with a new one are that the power and resistance of the new element be equal to the old.

Particles can build up inside the humidification chamber. The humidification chamber should be rinsed out and dried after every use. If necessary, it is acceptable to use diluted bleach to cleanse the chamber.

If the heater control is a rheostat the knob should be checked to make sure that it is not loose and turning on the shaft. The markings on the control are only approximate. A dead spot in the rheostat may cause it to change the temperature drastically with only a small change in position. Try cleaning the dust out of the rheostat. If that does not work, the rheostat will have to be replaced.

If the air flow has dropped, check the fan filter. The frequency of replacement depends on the environment and usage. The fan also assists in the removal of carbon dioxide from the chamber, which should be kept below 500 ppm.

If the temperature is not maintained in the chamber, there may be a large leak or opening. Check the seals around the doors. Also check for an external heat source, sunlight or phototherapy (bili) lights. They can affect the warming characteristics of the incubator.

If the fan is getting noisy, try lubricating the motor or tightening any loose bolts. If the fan is noisy, it can effect the long term hearing of the infant. The path for the movement of air must be kept clear to assure that the temperature is stable and even across the infant in all positions.

In some units there is an inner wall in the infant chamber that directs the flow of the heated air around the infant. These inner walls are held in place with plastic standoff posts and may loosen up with use. These should be inspected to assure that they are properly fastened in place.

2.10.3 Suggested Minimal Testing

When deciding whether to release an infant incubator back to the floor, the temperature should function between 34 and 40 degrees Celsius and should be accurate to within 0.5 degrees at all possible settings. Be sure the temperature cannot exceed 40 degrees Celsius.

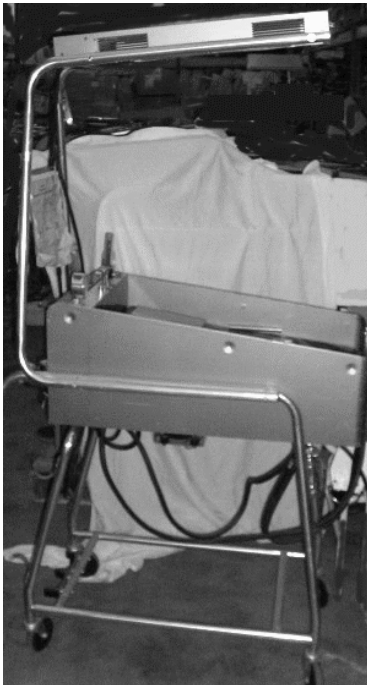
The fan should not be excessively noise (below 65 db). Assuming you don't have a sound meter with you, try to estimate the noise of the fan with your own ear placed where the baby's will be. It should be so quiet that you could comfortably hear all the conversations in the room around you.

The humidifier chamber should be clean and dry when returned.

2.11 Infant Warmer

2.11.1 Clinical Use and Principles of Operation

The infant warmer is an open device for keeping a baby warm. True infant warmers use resistance or radiant (infrared energy) heating elements, not heat lamps, which can burn. Warmers are often used for the patients that require the most care, as it is easier to work on the infant on a warmer instead of an incubator which is a closed system. On the other hand, as they are open, warmers do not offer the environmental protection of an incubator from air borne particles, pathogens or humidity variations.



Infant warmers like this one are not common in the developing world. Many of the hospital's rooms are always at 37 degrees Celsius or higher without the need for heating. In this unit, the baby is placed on the platform in the middle of the image. The warming elements are near the top of the image.

In the resistance element, long rods are placed approximately 1 meter above the level of the infant, reflecting heat downwards. There is an open grille that covers the rods. When energized the rods glow red. Some old versions may use open coils, which can give inconsistent heat distribution over the infant.

With radiant warmers the heating elements are not visible as they are imbedded in the cover material or behind the cover. The elements are focused over the infant providing for a consistent distribution of heat. It is difficult to judge if the unit is working by sight, but if it is working you can feel the heat.

In more sophisticated warming units, a thermistor is placed over the liver of the infant, (the largest internal organ, closest to the skin, with good blood flow), and is connected to the control module. The output of the heaters varies around the set point, similar to an incubator, as the infant's temperature varies. In the developing world, these thermistor probes are often lost, broken or forgotten when donated. Therefore, most units are operating in manual mode (constant output from heaters). This mode is more dangerous as the baby can be overheated.

Many infant warmers will have exam lights and bili-lights (see the next chapter) built into the warming hoods. These exam lights can vary from simple incandescent light bulbs, to mini-spot lights to reflector type (Halogen) lamps. Bili-lights can range from fluorescent tubes to reflector type lamps with special filters to pass only the proper wavelength of light.

2.11.2 Common Problems

There are very few problems with user error and power supply in infant warmers, as they are generally simple devices. However, the probe, as already mentioned, is a frequent problem. The technology in the probe is simple; typically just a thermistor. However, determining the exact type and resistance of thermistor requires data from the manufacturer. If this data can be obtained, then a replacement probe can be manufactured from a standard thermistor and the proper connector. However, without the manufacturer's data, it can be impossible to construct the probe.

A possible solution to a missing thermistor probe is to place a known, fixed resistor in its place, essentially forcing the device to operate in manual mode. A potentiometer can be used to determine the value of resistance that is required to force the lights to come on.

Thermocouple probes are sometimes used on warming units, in which case a resistance will not substitute for the probe. A voltage source might work, however. Using a potentiometer, a battery and a fixed resistor, a voltage divider can sometimes be created and adjusted until the warming unit comes on. Since the device is now in manual mode, care should be used to insure that the patient's temperature is carefully monitored.

The warming units burn out from time to time. Finding replacements can be difficult in the developing world. Some units use quartz elements and some use resistive elements. Both are common in the developing world, but finding an exact match for the quartz element is very difficult. In some cases, you can find a specialist that can adapt or replace the heating element in a resistive warming unit.

2.11.3 Suggested Minimal Testing

If you have defeated the temperature sensing function, then you must be careful to explain the risk of overheating to the nursing staff. Fixing an alternative temperature sensing device to the warming unit with an alarm is an excellent option, if it is available.

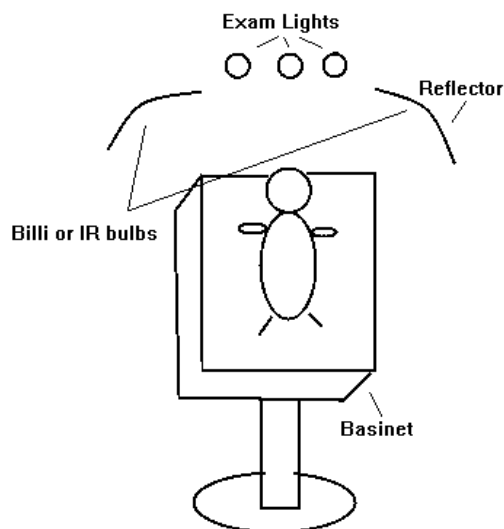
Besides concerns with the manual mode, the only other necessary test is the ability of the device to warm. The temperature on a blanket placed where the baby will go should be uniform across the field. In most cases, you can simply mark dead spots and warn the staff. In some cases, you can adjust the reflectors to better distribute the heat. The temperature should not rise about 40 degrees Celsius. However, if you have left the device in manual mode, it may exceed this value. Be especially careful to explain the risks of using such a device with a physician. In some cases, if there are no other infant warmers, it may still be preferable to release the device which overheats as compared to having no warmer at all. However, in most cases, if the temperature exceeds 40 degrees anywhere on the blanket or in the patient area, then you will need to adjust the heating system to provide less heat, or abandon the unit.

2.12 Phototherapy lights

2.12.1 Clinical Use and Principles of Operation

The build up of bilirubin in an infant's blood, caused by decreased liver functions, can cause long term damage to the child. Bilirubin buildup causes the patients' coloring to range from yellow to orange to red depending upon the level of bilirubin in the system. By exposing the patient to light with wavelengths between 425 and 475 nm, the bilirubin is broken down, and then eventually excreted from the body.

The phototherapy unit, or bili-lights, as they are more commonly called, is simply a strong source of light in the correct wavelength. The baby sits in a basinet below the lights for 20 minutes or more, depending on what the physician prescribes (see figure). The light is strong enough that it can damage the retina. So, the patients' eyes must be protected from the light when using the bili-light.



Phototherapy lights are common in the developing world. However, the bulbs are often broken or ineffective. Exam lights are often included as well as heating (IR) lamps.

2.12.2 Common Problems

The most common problem is a broken or missing light bulb. There is little else that can go wrong. There are many substitute light sources. The use of Florissant brand tubes or Daylight blue bulbs is quite common. The "Gro-Lux" light, also used by indoor gardeners was the most common form of treatment. Unfortunately the Gro-Lux tubes degrade and have to be replaced after about 200 hours of use to keep the light in the proper wavelength range. The same light spectrum is used in a PUMA unit to treat certain skin disorders in adults. The light bulbs in tanning beds are also in the correct wavelength range.

2.12.3 Suggested Minimal Testing

If the light turns on and is still in the correct wavelength range, then the unit can be used. To verify that the light is in the correct range, you need a light meter and a filter. A photographer's light meter can be used if the proper filter is at hand. If you have time, you can check the light source by leaving your arm exposed to the light for 30 minutes. The next day, that part of your skin should be tan, but not burned.

If you have replaced the light bulb, or have built a phototherapy unit from light bulbs that you purchased (gro-lux or tanning bed lights, for example), then you must be sure that the lights are not too intense for the patient. Again the ideal test is a light meter and a proper filter. However, you can use the arm-tanning test mentioned above. Start with 5 minutes to be sure that you do not get burned. Test longer and longer intervals until you can withstand 30 minutes without burning, but receiving a significant tan. Explain your testing to the staff so that they know that it is safe for up to 30 minutes, but that you haven't tested it for longer exposures.

If the light is working and you have a meter, you can also check that the intensity is consistent over the entire surface of the patient.

2.13 Respiration Rate Meter or Apnea Monitor

2.13.1 Clinical Use and Principles of Operation

Apnea is defined as the cessation of respiratory air flow. The air may have ceased to flow because the patient has stopped trying to breathe (central or diaphragmatic apnea) or because the airway is blocked (obstructive apnea). The two types of apnea are clinically treated quite differently. Obstructive apnea is typically caused by choking on food or another object. Episodes of central apnea are somewhat common in children and often disappear as the child develops. However, in severe cases, neonates and babies can be kept on apnea monitors for up to one year. When Sudden Infant Death Syndrome (SIDS) is feared, the physician may prescribe continuous apnea monitoring.

An apnea monitor is a device used to monitor a patient's respiration rhythm and often cardiac activity and oxygen saturation. Most monitors will attempt to distinguish between central and obstructive apnea, sounding an alarm if either is prolonged. Most monitors run on both batteries and line power.



This stand-alone apnea monitor would be unusual to find in the developing world. Most apnea monitors are respiration rate meters incorporated into a vital signs monitor.

Transthoracic Electrical Impedance

The most popular type of apnea monitoring is based on transthoracic electrical impedance. To use this device, electrodes are placed in the 5th intercostal space on each side of the neonate. A signal of 55kHz at 2 to 3 mV is injected into the electrodes and the impedance of the chest is measured. As the chest expands during inspiration, the impedance increases. During expiration, the impedance decreases. Simultaneously, the impedance electrodes are used to monitor the ECG.

It is possible for the monitor to read a false positive (presence of breathing when there is none) because it can be fooled by muscle movement. False negatives can occur if the chest motion is slight or in the presence of excessive electrical noise. Despite the popularity of this monitor, it is not effective at distinguishing between obstructive and central apnea.

Pneumatic Abdominal Sensor

Unlike the transthoracic apnea monitor, the abdominal monitor measures the motion of the abdomen. However, the impedance of the abdomen does not tend to change, as the cavity is not filled with air. Therefore, the abdominal sensor operates by detecting the increased circumference of the abdomen, typically with a linear variable displacement transducer (LVDT) or other displacement transducer.

Thermistors and Pressure Sensors

Neither the thoracic nor the abdominal apnea monitor can distinguish between central and obstructive apnea. Currently, only the thermistor and proximal airway pressure sensing apnea monitors can make this distinction. Neither is likely to be found in the developing world. A thermistor monitor measures the temperature of the air entering or exiting the nostrils. A proximal airway pressure sensor measures the change in pressure at the mouth and nose.

2.13.2 Common Problems

The most frequent source of error is caused by false alarms. The worst case is when an apnea monitor fails to alarm during apnea because it senses artifact and interprets it as respiration (false negative). Artifacts include vibration from equipment, interference from the ECG, and patient movement. Electrical impedance monitors are the most prone to this type of error.

A false positive (when the alarm sounds unnecessarily) is often caused by infant movement that loosens an electrode or sensor. Also, a false positive alarm may sound when the child is breathing normally but too shallowly for the monitor to detect.

For any false alarms first consider user error. The alarm limits may be set inappropriately. They can be confusing to program, and may need to be changed as the patient matures. Never change a limit without consulting with the physician.

The next most likely cause of false alarms is the electrodes. The electrodes may not be placed correctly (across the chest). Or, the sensor is in a belt, the belt may be too loose. Ask a nurse to help with tightening the belt, as an excessively tight belt can lead to complications.

If the electrodes are placed correctly, they may be dirty or old. Try rinsing them in isopropyl alcohol, then water. Electrode belts can be gently cleaned with soap and water. Be careful to rinse off all soap residue and hang to dry before applying to the patient's skin. Also, check to see if the skin is dirty. The child may have lotion or powder on the skin under the electrodes. You can clean the child's skin with soap and water. In some cases, electrode paste can be used, and may improve the measurements.

2.13.3 Suggested Minimal Testing

Apnea monitors are easily tested on yourself. Hold your breath to trigger an alarm. If the alarm doesn't sound when you are breathing normally and does sound when you hold your breath, the apnea monitor is ready to release to the floor. If the machine is a respiration rate meter, check to see that the rate matches what you measure when you count breaths with a watch. If the apnea monitor includes ECG, be sure to check your heart rate against the machine's rate. The rates should be very close (within 5 beats per minute).

2.14 Electrosurgery machines

2.14.1 Clinical Use and Principles of Operation

Electrosurgery is an alternative approach to cutting a patient. Typically, it is used as an alternative to a scalpel. Electrosurgery can cut like a scalpel, but can also coagulate the blood in small vessels so the surgical field is dry, meaning bloodless. Electrosurgery allows the surgeons to work faster as they do not have to hand tie off every vessel they cut. The patient recovers better as there is less blood loss and there is more rapid healing.



Electrosurgery machines come in many sizes and shapes. The front panel of this device is typical of many more modern machines.

Electrosurgery is accomplished by converting high frequency electrical current into heat, caused by the tissue resistance to the passage of electrical current. As current must pass through the body, at least two electrical connections must be made between the patient and the machine. The power needed is up to 400 watts. If the waveform is damped it will coagulate blood and stop bleeding (coag setting). If the waveform is undamped the tissue is ablated leaving a void or cut or incision (cut setting). In all electrosurgery procedures there is the smell of burning flesh and smoke.

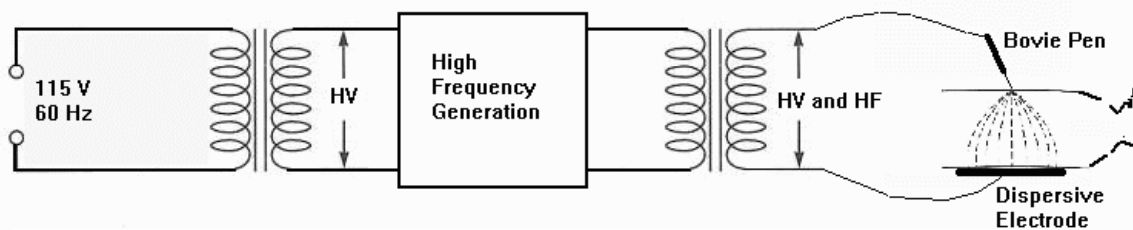
There are four common techniques used in electrosurgery: electrodesiccation, electrofulguration, electrosection and electrocoagulation. For electrodesiccation, a highly or moderately damped waveform is supplied to the contact point, active electrode, a ball, needle or blade which is placed on the tissue before energizing and produces coagulation around the site. For electrofulguration, the same waveform is used but the active electrode is held 1 to 2 mm above the tissue and when energized sparks spray the area drying it out and leaving some burning of cell edges. For electrosection, an undamped modulated or slightly damped waveform is applied to the active electrode, which is placed on the tissue surface creating an incision. For electrocoagulation, a damped sine wave is delivered to the patient to stop bleeding without doing any additional cutting.

All electrosurgery techniques require two connections to the patient, usually referred to as the active electrode (or pen, or bovie pen) and the reference electrode (or dispersive or ground electrode). For monopolar electrosurgery, the reference electrode is placed under the patient and the active electrode is held in the surgeon's hand.

For bipolar electrosurgery, the reference and active electrodes are both held by the surgeon in one combined pen. Bipolar is most commonly used with small vessels and for precise tissue destruction. The bi-polar function may not be on all electrosurgical generators. If it is contained in the same unit as the monopolar, it will have separate connections and possibly separate controls from the mono-polar functions.

Activation of the electrosurgery is done by the surgeon using either a hand switch on the bovie pen or by stepping on a foot switch. Both have two contacts one labeled CUT for electrosection and the other COAG for electrodesiccation or electrofulguration.

The generating unit itself is often called a Bovie. It is generally a solid state device that can produce 300 to 3000 kilo Hertz. Most machines produce 25-200 Watts. Conceptually, the Bovie breaks up the 60 or 50 Hz from the wall into many shorter pulses, then uses a transformer to generate the high voltage required (see figure).



Most electrosurgery machines use a two stage process to change the wall power to high voltage (HV), then to high frequency and high voltage (HV and HF). Many convert to high frequency, then to high voltage. The Bovie pen (or ESU pen) is held on the patient by the physician. In modern ESU machines, the dispersive electrode must touch the patient to prevent an alarm.

The dispersive electrode can be a metal plate covered with a conductive gel or saline soaked cloths. However, many are now using single use dispersive electrodes. Single use devices are often pre-gelled, conductive adhesive pads that include multiple connections to the machine. The multiple connections are used to allow the device to constantly check for a good contact between the patient and the dispersive electrode. Poor contact with the dispersive electrode is the most common cause of unintentional patient burns.

Sparks are a common occurrence when electrosurgery is in use. When oxygen is being administered to the patient, it may leak, creating an atmosphere where fires can quickly ignite. The drapes covering the patients should be flame retardant but will burn under the right conditions. Special care is required when doing neck or mouth surgery to avoid a flash fire.

2.14.2 Common Problems

A number of problems can occur during electrosurgery. Although the majority of these accidents are not instrumentation-based but caused by carelessness and extremely poor communication, on occasion the equipment can be faulty.

The most common avoidable problems involve the dispersive electrode. The first problem is poor contact of the dispersive electrode. The dispersive electrode should always be placed on an area of the body that has good blood flow and not subject to high weight concentration. The side of the thigh is a very common location, under the buttocks is not a good location as it generally is a high weight bearing point.

The second problem is no contact with the dispersive electrode. In older machines, the lack of contact may not be detected by the generator itself. The effect can be patient burns where the current finds an alternative path to ground. In newer machines, the generator has two connections to the dispersive electrode. When connected to the patient, a small current is passed between the two halves of the dispersive electrodes. When not properly connected to the

patient, the current cannot pass and an alarm will sound. Make sure that both halves of the dispersive electrode are in contact with the patient or testing surface.

If the tip is dirty, there can be little, or no, current passing through the patient. The bovie pens are not intended to be reused. However, they are often reused in the developing world. In addition to problems with dirty tips, the wires become broken with reuse. They are simple wires which can be re-soldered for repairs. If the wire break is in the pen, the pen can be taken apart, the wires reconnected and the pen glued together.

If the physician wishes a different tip for a monopolar electrosurgery unit, it is sufficient to connect any metal tip to the existing tip. Insure that the connection is electrically and mechanically sound to the existing tip and pen.

The reuse of disposable pens leads to frequent broken wires. There is nothing special about these wires. They can be rewired using standard techniques.

2.14.3 Suggested Minimal Testing

An electrosurgery unit can be checked and calibrated easily and efficiently through the use of an electrosurgery tester. However, such a tester is often not available in the developing world.

You can not test the device by performing the operation on a resistor in most cases. Although 400 ohms would work, only a resistor with a very large power rating will survive the procedure. Such large power resistors are generally not available in the developing world. In most cases, a bar of soap or a fresh piece of citrus fruit (like an orange) can be used to do your initial testing. Be sure that both sides of the dispersive electrode are touching to prevent an alarm.

In many cases, you will want a final test on meat. A reasonable final test is to cut a raw piece of chicken, pork or beef. Be sure that the indifferent electrode is touching the meat before testing. Both sides of a split dispersive electrode must touch the meat to avoid an alarm! It is best to conduct the final test with the physician present. In this way, you can not only assure that the device is minimally operating, but you can also be sure that it is operating in a manner that satisfies the physician.

For more modern units, insure that the dispersive electrode alarm is working by disconnecting half of the electrode from the meat, or pulling the dispersive electrode out of the machine.

2.15 Suction Machines

2.15.1 Clinical Use and Principles of Operation

A suction pump can have hundreds of uses in the medical setting, all of which relate to removing fluids and substances from the body. Suction pumps can be used for removing ingested toxins (a stomach pump), unwanted fats (liposuction), mucosal secretions from the esophagus, blood from the surgical field, and many other applications.

Suction applies negative pressure, which is any pressure less than atmospheric pressure (760 mmHg, 100kPa or 14.7 psi), to allow for the movement of fluids or substances. The suction developed by the machine will be measured as a pressure. The common units of pressure are millimeters of mercury (mm Hg) or pascals (Pa or kPa), inches or centimeters of water (inH₂O), or pounds per square inch (psi). To convert between pressures:

$$1 \text{ mmHg} = 0.133 \text{ kPa} = 1.36 \text{ cmH}_2\text{O} = 0.535 \text{ inH}_2\text{O} = 0.193 \text{ psi}$$

The essential elements of a suction machine are the source of suction, the tubing, the collection canister or bottle and if present, a manometer to measure the amount of suction. For the source of suction, there are two types of suction machines most commonly found in the developing world: electric pumps and foot-operated suction. The electrical suction is often called a "Gomco" after one of the more popular brands. A thermally driven suction machine is occasionally seen as well.



This is a typical simple suction machine. The collection jar and seal are missing. The float valve and trap are shown near the bottom left (arrow).

No matter what the source of suction, the vacuum is pulled through a collection bottle. A water trap may also be present, to prevent liquid from entering the vacuum source.

The most common suction machine will use electric motor to drive a single piston. As the piston descends, it produces a vacuum through one of two one-way valves, often reed valves, typically at the top of the piston. As the piston moves up air is forced out of the piston chamber through the second valve.

Pump

Each suction machine is a bit different, but the basic components are nearly the same. The exhaust is rarely filtered in the developing world, and the inlet filter's absence is often the cause of failure.

With a foot-operated suction, manual labor acts to drive the piston. The valve assembly is identical. On the return stroke of the piston, as the foot is removed from the top of the pedal, the piston will return to its original setting, via a spring, and suction is created with a series of valves directing the flow of fluid and air flow.

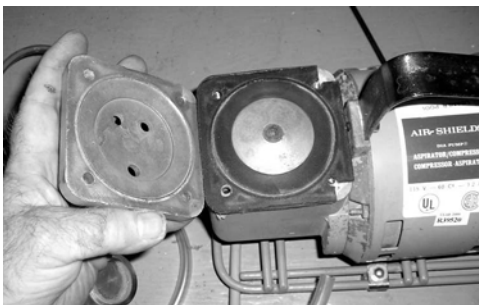
In all cases, the suction level can either be totally adjustable or has low, medium and high settings. The high settings are used for airway and gastric suctioning. The medium setting for chest tubes and the low setting for wound suction.

The thermally driven units are sometimes called thermionic units. They operate on the principle of air movement caused by heating and cooling. A coil in the unit heats up for approximately 45 seconds at which point the power to the coil is shut off and it cools rapidly. This cooling creates a suction airflow and pulls fluid from the wound site.

2.15.2 Common Problems

The most common problems with suction machines are clogs, leaks and the motor.

Material from the collection bottle can migrate into the suction machine. This can be very damaging to the machine, possibly permanently damaging the suction machine. To avoid this, machines should be operated with some sort of filter or valve before the suction machine. However, the filter and valve present problems because they can get clogged.



If the device is operated without a filter, the suction pump can be damaged. Remove the head, as shown, to see if it can be cleaned and repaired.

A shutoff float is sometimes provided to shutoff the suction before the collection bottle overflows into the motor. The float volume must be on the pump side, not the patient side, of the collection bottle. If a multicanister setup is used, only the last canister before the connection to the suction source must have a float valve. The other canisters, closer to the patient will have the floats removed. Sometimes, someone on the operating room will remove the shutoff float

from the last suction canister as well. If fluid does get into the suction machine, it will need to be completely disassembled, cleaned and reassembled.

On some Gomco machines, bacterial filters are used in input or output of the machine. These should be replaced after each patient, but in the developing world they are not. If the unit is used without the filter, it will eventually need to be rebuilt. However, this may be a short term solution. For a more long term solution, the filter may be replaced by any filter 3 micron size. The hose barb-hose barb PTFE filters can often be found for under US\$1 each. Hose barb adapters (to convert the NIPT connection on the Gomco to a hose barb) are available to allow the use of hose-barb/hose-barb filters.

Air leaks are probably the most common problem. A leak will cause the flow and pressure to cease or be reduced. The first place to look for air leaks is in the collection bottle lid, particularly with disposable canisters. The tubing can be replaced with any compatible tubing. If the leak is near one end, the tubing can be cut and used as shortened tubing. To find the leak, rub the top with soapy water while blowing through the cleaned-off tube (close off the distal end). Bubble will form where there is a leak.

The collection bottle often breaks. The collection bottle is not special. Any glass or rigid plastic bottle can be used as a substitute. The alternative must be air tight and have two connections of the proper size to fit the collection set. The seal between the collection bottle and its cap can be improved with a small amount of petroleum jelly, or replaced with rubber, or even leather, cut to the proper size and shape.

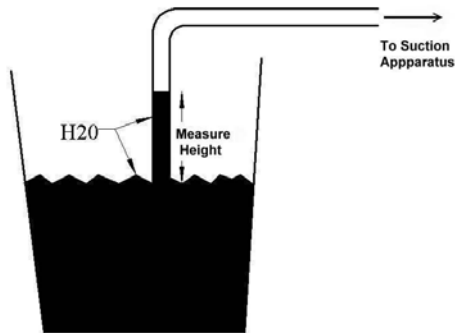
Noise is a frequent complaint from electrical pumps. Try placing a pad under the machine to reduce the vibration noise between the suction machine and the floor.

The pistons are generally driven with an induction motor. An induction motor is used as it is the easiest, most cost effective motor to drive a medical device. There are no gears or chains. Check the section on the centrifuge (later in this book) for more information on electrical motor repair and testing.

2.15.3 Suggested Minimal Testing

The pump is connected to the piston through a bearing. To clean bearings without dismounting, hot light oil at 180-200° F may be flushed through the housing while the shaft is slowly rotated. Light transformer oils, spindle oils or automotive flushing oils are suitable for cleaning bearings, but oils heavier than light motor oils, such as SAE 10, are not as effective. To lubricate the pumps, first, thoroughly clean the grease fitting and outside of the bearing housing. Next remove the drain plug and inject clean, new grease to forcing out the old grease. Start and run the pump for a short time to eject any excess grease, which should later be wiped off surfaces, and then replace the drain plug.

Most suction apparatuses cannot be calibrated, per se. However, the accuracy of the pressure gauge can be checked as can the ability of the suction machine to pull a vacuum in the desired range. To check the pressure, place water in a bucket. Turn on the vacuum and draw the water as high as it will go, typically between three and five feet. Record the height in inches or millimeters and calculate the actual pressure in mmHg as the $(\text{Height of Water (in inches)} * 25.4 \text{ (mm/in)}) / 13.6 \text{ (mmH}_2\text{O/mmHg)}$. This can be compared to the pressure shown on the gage and compared with the physicians intended use.



To check the pressure, place water in a bucket. Turn on the vacuum and draw the water as high as it will go.

As collection sets (tubes and suction tips) are frequently reused in the developing world, they often become clogged and leaky. Before releasing a suction machine for use, if you suspect that a collection set will be reused, try to perform your equipment checks using the intended collection set.

The filters often become clogged, and are not often replaced because the correct filter requires a threaded NIPT male end for some models. However, with an NIPT to hose-barb adapter, you can use the very cheapest filters, which have hose barb on both ends.

2.16 Theatre Lamps and Other Lights

2.16.1 Clinical Use and Principles of Operation

All lights in all parts of the hospital operate on the same principals. However, the operating theatre has the most variety of lights.

Operating rooms in the developing world have several separate lighting sources. The first is the general room lighting found in the ceiling. This is used during the set up of the rooms, cleaning and as background lighting for the staff who are not working in the sterile field.

The second source of light is the overhead operating room lights. These can be large reflectors with one or more bulbs in them, mounted on a counter balanced arm that can be positioned over the site of the operation. These units have a sterile positioning handle that is often adjusted over the period of the operation. Many of the problems associated with these lights are mechanical in that they do not stay in the position selected and the counter weights have to be adjusted. A secondary problem is that one or more of the lights will burn out giving dark spots in the surgical field. These lights have control boxes on or in the wall where the intensity control is found along with the on off controls. This control box usually contains an SCR control board, or transformer that powers the lights at some voltage under 115 volts.



A typical OR in Africa showing two principal lighting sources: The overhead light and the window. Against the far wall is an X-ray viewing light source.

In some rooms there may be a portable operating room light. These are large reflector lights that roll from room to room. They simply plug in to a 115 pr 220 volt outlet and are positioned as needed by the surgeons.

The third source of light is the "personal head light" that a surgeon will wear. This is a lens that focuses light transmitted to it by a fiber optic cable from a remote light source. This light source may have a multitude of bulbs in it that can be switched into use via a knob on the top of the

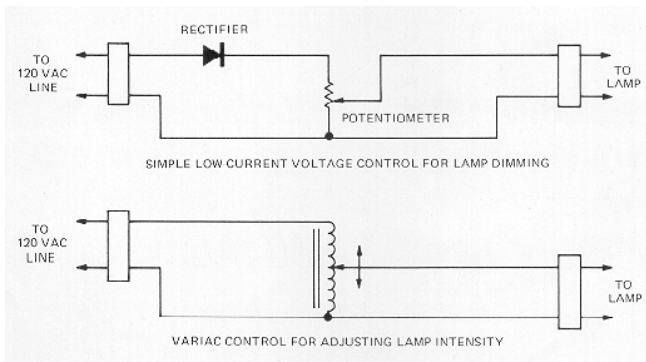
unit, or by moving the fiber optic cable from one side to another and turning on that light. These units are often the personal property of the surgeon.

Some lights will utilize cooler light systems by filtering out infrared portions of the light. The different mirrors and reflective surfaces on the inside of the light will allow for maximum light transfer to the operating area. Also, the lights may have a plastic coating and thermal guard on the outside housing to ensure a cooler surface when adjusting the light.



A surgeon's headlamp

For overhead lights, the distance from the lower edge of the light to the operating table should be approximately one meter. Initial positioning is accomplished by using the rail on the lamp housing to move it into place. The surgeon has the option of adjusting the light using the center hand grip, which is provided with a replaceable, sterilized sleeve.



Older theatre lamps used simple circuits, such as those shown here to vary the intensity of the light. Similar circuits are used for 220 volts.

Most operating lamps work directly from the outlet power through a switch. However, some lights may provide dimming circuits. Older dimmers found in the developing world often work with a rectifier or a variable transformer (variac) gradually varying the voltage applied to the lamp and therefore the intensity of the light delivered. Some dimmers operate using solid-state electronics (SCR's). These are rarely seen in the developing world and are typically impossible to repair.

Some operating room lights use fluorescent bulbs. Fluorescent bulbs generally operate through a transformer and use a starting circuit (sometimes called a ballast). In some cases, the bulb is heated before the starter is engaged. The heat causes both a change in the internal tube pressure and an increased electronic flow between the electrodes. A high voltage (25,000 V) spike from the starter establishes an arc in the atmosphere between the electrodes. After the initial spike, the bulb will operate at a low current and temperature,

2.16.2 Common Problems

Take special precautions when working with medical lights. The highest intensity lights can cause blindness if you look directly into the light. For the same reason, the light should not be used if the cover glass or filter system is damaged or destroyed. In placing the light to begin work, your eyes should be greater than two feet or approximately sixty centimeters away from the source.

The lamps can be xenon, quartz-halogen, mercury-vapor or metal halide. These bulb types are not interchangeable because of the voltage supplying the bulb, the connector for the bulb and the heat generated by the bulb. The bulbs have a life expectancy of about 250 hours and need to be monitored for replacement. When replacing bulbs care must be taken to avoid touching the reflector part of the bulb as that can affect the brightness at the surgical site. Also, avoid touching the bulb itself. Your fingerprints can cause excessive heating of the glass, dramatically shortening the life of the bulb. If the glass of the bulb has been touched, clean the fingerprints off with alcohol.

It can be very difficult to find replacement light bulbs in the developing world and impossible to ship replacements into the country. While it may be possible to wire a replacement socket for a more readily available bulb, the engineer must be sure to consider size, voltage, temperature and materials. It may be more prudent to start with a readily available bulb and socket and design a completely new fixture.

2.16.3 Suggested Minimal Testing

There is no calibration needed for operating room lights. If the light turns on, changes intensity (if equipped) and stays in place after adjustment, it is ready to use.

2.17 Anesthesia Machines

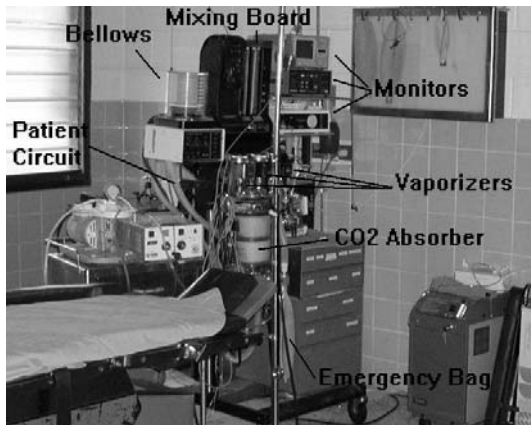
2.17.1 Clinical Use and Principles of Operation

Anesthesia is defined as the loss of feeling or sensation. During most surgical procedures, some form of anesthesia is used. There are at least four different types of anesthesia that are encountered in the developing world.

General anesthesia is a state of unconsciousness, with an absence of pain sensation over the entire body, produced by anesthetic agents, often with muscle relaxants. General anesthesia is administered by inhalation, intravenously, intramuscularly, rectally or via the stomach. Local anesthesia is where a specific area is "numbed" such as in a dentist's office. The patient is awake and may feel some limited pain. Saddle block anesthesia is where the patient is conscious and the area of the body that would touch a saddle is affected. This is accomplished by injecting an anesthetic agent low in the dural sac and is common for childbirth. Spinal anesthesia is where an anesthetic agent is injected beneath the membrane of the spinal cord. There is no sensation below that point until the agent wears off.

General Anesthesia unit, inhalation

The anesthesia machine, sometimes called a Boyle machine, works by mixing selected concentrations of gases and drugs that the patient inhales. Consciousness is regained relatively quickly after the procedure terminates.



This anesthesia machine in Togo shows all the basic components. There is little difference between this unit and the most modern units seen in the US.

Anesthesia machines are generally large, on wheels, and contain one or more vaporizers, flow tubes, attachments for compressed gas cylinders, a ventilator, ports for obtaining compressed gases from wall connections, a carbon dioxide absorber other gas traps (or scrubbers) and various monitoring devices either built in or attached to the unit. These machines can cost over \$60,000.00 to purchase and require regular maintenance. Some of the maintenance requires specialized testing equipment that may not be available in a developing world hospital, including devices for the measurement of the concentration of gases, flow rates and pressures. Additional training is typical in western hospitals before attempting any calibration or repair of the gas delivery system. However, in the developing world, repair, calibration and maintenance are often done by whomever is available.

The flow of gases can be traced from the source to the patient. Typically, compressed gases such as air, oxygen, and nitrous oxide are supplied from gas cylinders or from wall outlets. By passing through a pressure regulator, gas in a cylinder is reduced from thousands of psi to a typical delivery pressure between 20 and 50 psi (regulators and cylinders are covered elsewhere in this book). From the regulator, gas in the line will often pass through an O₂ failure detector. Next the gases enter the mixing board which contains rotameters for measuring gas flow. From there, the gases move through vaporizers where a volatile agent such as halothane will be added to the mixture. Delivery of the final gaseous product to the patient is achieved with a series of tubes, valves and a mask that is referred to as the anesthesia circuit.

Vaporizers

Vaporizers are used to convert a liquid anesthetic agent into a vapor. Because they are designed to function under continuous pressure and flow environment, they are sometimes called plenum vaporizers. As air enters the vaporizer, it is directed into either the vaporizing chambers or a bypass chamber. The anesthesiologist will control the bypass valve to allow more or less of the incoming gases to flow through the vaporizing chamber usually via a large knob on the side of the vaporizer. The liquid anesthetic agent resides in the lower part of the unit. As the gas moves across the top of the liquid, the anesthetic agent vaporizes and is carried by the gas towards the outlet, where it is blended with the gas that had bypassed the chamber.



Two vaporizers (for two different anesthetics) sit to the right of the mixing board and a large manometer.

Since vapor pressure is affected by temperature, a warm environment would normally encourage more of the anesthetic agent to vaporize and a cold environment less. Furthermore, the process of vaporization itself removes heat from the vaporizer and the anesthetic agent. In order to compensate for temperature effects, a bi-metallic valve is added to the by-pass system. The bi-metallic valve physically distorts to adjust for temperature changes. It is possible to compensate for temperature variations by warming the fluid to a fixed temperature, but this approach is less common.

The vaporizer should be maintained level as operation out of level can affect the calibration. Also, when working with a vaporizer, care should be exercised not to tip vaporizer as this can cause a hazardous spill. Should a spill occur, water can be used to clean up the anesthetic agent and doors should be opened to clear the vapors. Vaporizers should generally be calibrated every six months; however, in the developing world this is rarely undertaken. Vaporizers are very reliable, but if the vaporizer does break, it must be sent back to the factory or other qualified repair service. There is little a field engineer can do to repair a broken vaporizer.

Rotameters

A mixing board on the anesthesia machine will allow the anesthetist to mix oxygen, anesthetic gases and the patients expired air to the desired ratios for delivery to the patient. The ratio of the fresh gasses is continuously measured by their flow rates. A typical mixing board will contain several rotameters for measuring gas flow. Rotameters are made from either glass or plastic tubes containing a metal or ceramic ball that serves as a float. The walls of the rotameters are slightly "V" shaped so that as the ball rises, more of the gas is diverted around the ball lowering the force upwards on the ball. When the force of gravity is just balanced by the force upwards of the gas, the ball will stop moving. As the flow rate increases, the ball moves up and as the flow rate decreases, the ball moves down. However, as the ball moves up, the force of the gas on the ball drops because more of the gas is diverted around the ball. Thus, the height of the ball can be used to determine the flow rate of the gas in the rotameter.



A small mixing board with only two rotameters. In some anesthesia machines there can be four or five rotameters.

Rotameters are calibrated in cubic centimeters (cc) or milliliters (ml) of gas per minute. The amount of each gas entering the mixing board is controlled by needle valves at the base of each rotameter.

Gas Handling

Anesthesia gases are supplied from tanks that are mounted on the anesthesia cart or from a central source in the hospital. In the latter case, there will be wall mounts in the room with specialized fittings so that hoses are not misconnected. As a safety feature, gas tanks may have what is called a pin index connection that allows only specific yokes to be connected to the tank. The tank is attached to a yoke that has pins sticking out that match the holes in the neck of the tank. During every inspection of the anesthesia unit, the pins on each yoke should be verified that they are present and in the correct positions for the designated tank. However, in the developing world as donations may come from many sources, the pin indexes may be missing, tampered with or ignored. A backup to the pin index is the color-coding of the paint on the tanks. In the US, oxygen tanks are painted green (blue in some other countries) while nitrous oxide tanks are blue and air tanks are yellow. Similarly, the connection hoses for the centralized gas system should be color coded to match the gas tank. Europe has a different color-coding scheme, and in the developing world, there may be no system to the color of the tanks or hoses.

Faced with unmarked tanks, connectors and hoses, the engineer should first thoroughly discuss the system, and label it, before attempting service.

The modern anesthesia machine will contain a purge button which serves as a bypass button, bypassing the mixing board, vaporizers and rotameters. This button allows for 100% oxygen to flow to the patient connection. It is used before a surgical case begins to clear out any residual gases from the patient connection. Additionally, it is used to provide a quick burst of oxygen to the waking patient (and reduce the level of anesthesia to the patient) as the case terminates.

Since the expired gases of the patient contain anesthetic agents, they must not be allowed to enter the operating room. In addition to potentially placing the operating staff under the anesthetics effects, certain agents are flammable, and chronic exposure can cause high fevers and severe liver damage. To remove this danger, anesthesia machines will contain a scavenger (or scrubber or trap) before venting the expired gas into the room. In the developing world, the activated carbon may no be changed –or even available – forcing the staff to vent the expired gas outside.

In the expired air is to be rebreathed - that is returned to the patient - then a CO₂ absorber is used. A CO₂ absorber contains a soda-lime filter that strips the expired gases of CO₂.



This scavenging system shows the CO₂ absorbing material (white material in glass container behind cage in lower left). Two valves are shown under the glass domes in the middle right.

Self-inflating bags or bellows are purely mechanical devices that allow the anesthetist to measure the patient's ventilation. By its movement in a calibrated chamber, a bellows indicates the volume of air that the patient is breathing. The bellows will rise when the patient exhales and will fall when the patient inhales.

The bellows may be connected to a ventilator that controls the patient's ventilation. The ventilator forces air into the patient's lungs at a prescribed rate and volume. Ventilators are covered elsewhere in this text. When intermittent ventilation is required, the doctor can use a bag (emergency bag), or reservoir bag. The bag allows the doctor to manually push air into the patient's lungs. This bag is also used to give the anesthetist a sense of the patient's lung compliance and resistance, which can be used to indicate that more or less anesthetic agents are needed or that the physiology of the lungs is changing.

The Circuit

The circuit contains tubing and valves required for the operation of the anesthesia machine. Both the bellows and self-inflating bag are filled through a non-return valve that ensures that the proper gases are always delivered to the patient. The circuit will also contain a non-rebreathing expiratory valve at the patient end that diverts inspired and expired gases through two different pathways. Often, these non-rebreathing valves are part of the circuit. The circuit includes the connection to the patient, the mask, endotracheal tube and other components.

While considered a disposable item, in the developing world, the circuit may not be replaced after every patient. Even in the developed world, there may be connections to and from the absorber

that, while part of the circuit, are not replaced with each use. If the circuit is to be reused, after patient use, it is best to hang the tubing vertically to dry in a storage area.

Monitoring

The anesthesia machine may also have a monitor for the patient's ECG, invasive or non-invasive blood pressure, and pulse oximetry. More details about these monitors are available in their respective chapters.

Drawover Anesthesia

A drawover anesthesia system provides anesthesia without necessitating a supply of compressed gases. Drawover anesthesia systems have the added advantages of being (1) inexpensive to purchase, (2) easy to maintain, and (3) compact and portable. In using a drawover system, atmospheric air serves as the primary carrier gas and is drawn through the vaporizer by the patient's inspiratory effort. Whether a patient is being artificially ventilated or breathing spontaneously, the patient will draw air through the vaporizer. Therefore the vaporizer must have a low resistance to the intermittent gas flow. Once in the vaporizer, the atmospheric air mixes with the anesthetic agent which is typically ether or halothane. The patient now inhales this air via a non-rebreathing valve. Low-flow oxygen, such as from an oxygen concentrator, may be added to the drawover system by using a T-connector.

General Anesthesia, Injectables

Injectable anesthetics are cheaper and therefore more common in the developing world than in the US. They are more dangerous as an overdose cannot be as easily reversed. These agents are combined with muscle relaxants and should be used only for short-term procedures. Ketamine is a very common general anesthetic agent, and lidocaine is a popular local anesthetic. No additional equipment is required to use these agents.

2.17.2 Common Problems

As with other pieces of medical equipment, power supply and user error problems account for most of the problems in anesthesia machines. Injectable anesthetics are not generally referred to the technician when there is a problem. Drawover machines have fewer problems than other anesthesia machines, but all machines suffer from leaks and sticky valves.

Leaks

Tubes tend to deteriorate in hot and humid environments. Also, reusing disposable materials tends to favor deterioration. An expiration-side leak occurring before the scavenger is most critical to check, but also the easiest because anesthetic gases have a distinctive smell which is easily detected. If a leak occurs in the OR, doors to the room should be opened to allow air to flow through the room (consult with the staff before doing so). Moreover, a second danger with gas leaks is that some anesthetic gases are flammable. Halothane and ether are two explosive anesthetic gases.

The tubing most often develops leaks in between the corrugations. You can check for leaks by placing the tubing in a bucket of water, blocking one end, blowing in the other, and looking for

bubbles to escape. Repair tubing leaks with epoxy or a silicon sealant. However, this is a temporary repair. It is better to replace the tubing. In some cases, the tubing can be shortened to remove the leaking section. Consult with the anesthetist before shortening a section of the circuit.

Other problems

The monitoring devices are covered in other sections of this book.

The needle valves controlling the flow into the rotameters can be sticky or blocked. Also, the floats in a rotameter can be stuck. Rotameters and needle valves can be dismounted and flushed alcohol. Make sure they are completely dry before using again. When taking apart multiple rotameters, floats and needle valves, be sure to put them back together in a set. The float from one gas may not work in the glass tube from another. One simple solution is to disassemble only one rotameter at a time.

If there are valves which appear to be sticky in the circuit, the circuit needs to be replaced. Other sticky valves may be cleaned with water and dried thoroughly before reuse.

If the problem is in the ventilator, CO₂ absorber or vaporizer, and the problem is not a leak, the problem is typically very difficult to repair in the field. It is generally necessary to replace the entire subunit with one from another anesthesia machine.

2.17.3 Suggested Minimal Testing

If the device has been removed from the operating room due a problem that you have now fixed, you should test it before returning it to use. However, most often you will not have the equipment required to test the function of a vaporizer, CO₂ absorber or ventilator. As the surgical schedules may be severely affected or even halted until the anesthesia machine is working, it may not be in the hospitals patient population's best interests to wait until you have the proper testing equipment to release the anesthesia machine for use. If a repair resulted in a replacement of the vaporizer, absorber or ventilator, you will need to consult with the anesthetist on what testing will be required before use.

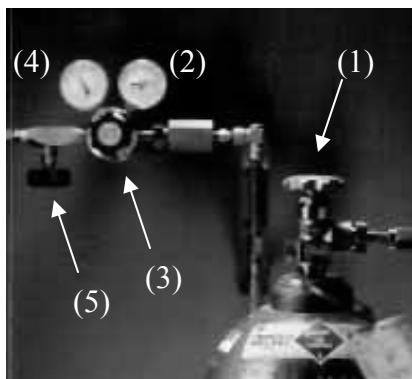
If the repair required the fixing of a leak, it is sufficient to retest the tubing to insure that the leak is repaired.

If the repair involved the rotameters, they should be checked before use, even if the problem was just a sticky valve or float. A simple way to check flow rates is to flow the gas into a calibrated balloon for 60 seconds. The volume can be approximated by connecting a balloon to the patient tubing. You must calibrate the balloon to volume before you begin. The easiest way to do this is to fill the balloon with a known volume of water. Make two marks on the balloon a fixed distance apart, indicating the volume next to the mark. Repeat this procedure for several volumes. Now, when the balloon expands to the indicated volume, the marks should be your set distance apart.

2.18 Bottled Gases

2.18.1 Clinical Use and Principles of Operation

The clinical use of bottled (pressurized) gases can range from anesthesia machines to spectroscopy. The most common bottled gas in the developing world is oxygen. However, anesthesia gases, dry air and carbon dioxide are all seen occasionally. Bottles of high pressure gas can be explosive and flammable. Therefore, handling the bottles must be done with care.



The components of a bottled gas. (1) The main cylinder valve, (2) The cylinder pressure gauge, (3) the pressure regulator and pressure regulator valve, (4) The gas outlet pressure gauge and (5) the gas outlet flow control valve.

A bottled gas has a few components: the cylinder, the main cylinder valve, the cylinder pressure gauge (the gauge closest to the cylinder), a pressure regulator for reducing the pressure, the gas outlet pressure gauge and typically a gas outlet flow control valve. The pressure regulator usually has an adjustment control. This control may have a large knob, or it may require a crescent wrench to adjust the outlet pressure. The entire assembly is often referred to as the regulator.

When not in use, gas cylinders should have a cap that screws onto the top of the cylinder to protect the gas cylinder valve from being cracked off, should the cylinder be dropped. This cap should always be used when the gas cylinder is being transported.

In the United States, oxygen cylinders are green, with a specific hose fitting, and feature a main cylinder valve with a reverse thread (counterclockwise to tighten). However, most of these standards are different around the world, and are not followed in the developing world. Even in one hospital, oxygen tanks may be of different colors and have different types of regulators. Oxygen bottles are sometimes seen in a small size which uses a different pressure regulator. However, these are rare in the developing world.

2.18.2 Common Problems

The most common problem in the developing world is a missing or broken regulator, followed by a hosing set which does not match the standards of the regulator. Mismatched hosing sets need to be adapted with whatever parts and tools are available. This type of patching can only be accomplished after the pressure regulator (on the low pressure side). Clearly label the outlet of the hose after adaptation, in the local language, if possible.

If the regulator is broken, it may be impossible to repair. The pressure gauges for both high and low pressure readings are removable, by simply unscrewing them. Replacements can often be

found in the developing world. Use a Teflon pipe thread tape when replacing the gages, if at all possible, as it will seal much better than the metal-to-metal seal required without the tape. The outlet flow control valve is not typically very important, and can be replaced with any valve which can be made to fit into the system. If the pressure regulator is broken, there is little that can be done. This piece cannot be repaired.

If you must move a cylinder in order to repair it, or the regulator, place the cap on the cylinder before beginning. Moving a gas cylinder is dangerous and difficult. Always ask for help. Before moving the cylinder, check the cap again to insure that it is secure. The best way to move a cylinder is to slowly roll it on its bottom, with the cylinder tilted a few degrees. Highly experienced staff may move cylinders at high speed this way with seeming ease. However, if you are not very experienced at moving cylinders, you can easily lose control of the cylinder. Have a friend stabilize the cylinder while you tilt it and roll it. Check the cap frequently while moving the cylinder.

If you must work on the cylinder, do not empty it entirely (by leaving the cylinder valve open). This may allow ambient air to enter the cylinder and cause moisture to build up in the cylinder. The moisture can ruin the cylinder and contaminate the next filling.

Pipes and tubing leaks, while not exactly a problem of the cylinder, are common. Rub some soapy water over the pipe to check for bubbles and locate the leak. Try to cut out the leaky section of tubing and shorten the tube, if the leak is near the beginning or end of a long run. Otherwise, epoxy can serve as a temporary fix for a leaky pipe.

When you are placing the cylinder back on line, do not simply connect the regulator and open the cylinder valve. This can place unnecessary stress on the pressure regulator, can introduce contamination, and can stress the downstream system. The typical reconnection sequence is to first "crack" the main cylinder valve. Cracking the valve means quickly opening and closing the cylinder valve a very small amount to briefly allow the passage of a very small amount of gas. The gas will be high pressure and velocity. So, stay clear of the gas stream. This cracking clears debris in the valve outlet. Next connect the regulator to the system. Now crack the main cylinder valve again. This will pressure the regulator, but not stress it excessively. Finally, open the cylinder valve again to begin using the system.

Beyond that which has already been discussed for gas cylinder care and maintenance, further attention must be paid to the specific gas used. Oxygen has already been discussed. Carbon dioxide is a nonflammable gas. However, take care to ensure proper ventilation when using carbon dioxide as any leaks may be hazardous. A concentration of CO₂ as low as 10% can cause unconsciousness.

Nitrous Oxide is sometimes used for anesthesia, though its use is rare in the developing world. Any cylinders containing such a mixture must be stored above 10° C or the nitrous oxide will separate out. Warm and shake any such mixture before use. When mixed with oxygen, nitrous oxide can be explosive.

Butane, Propane and Acetylene are highly flammable gases which are not used in medicine. However, they are often seen at the hospital. Butane and propane are liquids under high pressure and are used for cooking and heating, including clinical laboratory heating. Acetylene is mostly used for cutting metal with a flame torch. However, it is rarely used for atomic absorption spectroscopy, a procedure which is already rare in the developing world. Acetylene will ignite explosively in air.

2.18.3 Suggested Minimal Testing

Gas cylinders are intrinsically simple devices that need very little calibration. The only apparatus that should be checked are the pressure gauges and the piping. Pressure gauges can be checked by attaching a second gauge (that is known to be accurate) in series with the first and assuring that both gauges give the same reading. If this is not possible, the outlet gas may be connected directly to a mercury manometer which will allow pressure checks at relatively low pressures, ranging from 0 – 300 mmHg typically (up to 40 kPa). Leaks may be checked by passing dilute soapy water over piping connections and looking for bubble formations. If the outlet gas is at the correct pressure and there are no leaks, the cylinder is ready for use.

2.19 Batteries

2.19.1 Clinical Use and Principles of Operation

While not a medical device in itself, the battery, like the generator, is often the source of problems in developing world hospital equipment. The battery comes in a wide variety of forms and can be used to provide electrical energy and portability to all types of clinical devices, from surgical lighting to high drain clinical devices (e.g., x-ray machine). The underlying purpose of the battery remains the same, to simply convert stored chemical energy into electrical energy which can be readily used by a given device.



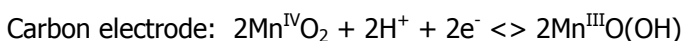
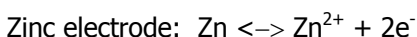
Batteries come in many shapes and sizes. These rechargeable (secondary) cells are lead acid (bottom right) and nickel-cadmium.

There are two main classes of batteries, primary (single use) and secondary batteries (rechargeable). Primary batteries are becoming more common as the number of hand held medical devices grows. Primary batteries, or dry batteries, are typically alkali-manganese (alkaline), lithium, or carbon-zinc. Each of these chemical combinations is called a battery chemistry or a battery technology. Secondary systems include nickel-cadmium, nickel-metal hydride and lead acid batteries. These secondary systems are used with instruments that require greater amounts of electrical energy and particularly when recharging is a viable option.

Besides being described by their technology, batteries are described by their voltage and their capacity. The battery voltage is determined largely by their chemistry. For example, all alkaline batteries are 1.5 volts or can be put together to get multiples of 1.5 volts. The battery capacity is largely determined by the physical size of the battery. Unfortunately, the battery capacity is not rated in Joules or Coulombs, which would make most engineering or chemical sense, but in Amp-hours (Ah). One Amp-hour is the equivalent of 3600 Coulombs of charge.

A battery cell consists of four principle parts: an anode, a cathode, an electrolyte that provides the mechanism for charge flow between the anode and cathode (a *gel* in modern primary systems), and a porous insulator which electrically isolates the cathode from the anode.

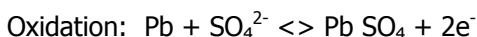
The carbon-zinc battery serves as a useful example. The case is made of zinc metal, serving as one electrode and a carbon rod coated with manganese oxide (MnO_2) serves as the other. The electrolyte solution is ammonium chloride (NH_4Cl). The following reactions take place:



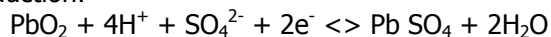
The zinc electrode is oxidized, giving off two electrons into the solution. The manganese is reduced at the carbon electrode by the presence of the two electrons and the hydrogen ions provided by the ammonium chloride solution. This chemical reaction stimulates the electron flow once the circuit is complete. The electrons will continue to flow until the battery is completely

discharged, i.e., the chemical reaction can no longer take place if either electrode is entirely oxidized or reduced.

Secondary systems differ from primary systems in that the chemical reactions are *reversible*. When you supply the appropriate electric energy to the terminals you recharge the battery. The lead battery can serve as an example. The lead-acid battery is a liquid-system battery and comes in two main forms, sealed and unsealed. Narrow gratings of lead or lead oxide (PbO₂) serve as the electrodes. The liquid solution is 20-30% sulfuric acid, serving as the electrolytic charge carrier. The oxidation and reduction equations are:



Reduction:



Unlike the primary cell and its chemical reactions, both reactions in the secondary cell are reversible, allowing the lead battery to be recharged.

2.19.2 Common Problems

The most common problem with batteries in the developing world is that the batteries in the machine have stopped working and an exact replacement cannot be found. The problem can be essentially divided into two parts: (1) determining that the batteries are, in fact, beyond their useful life, and (2) devising a substitute battery from batteries which are available. Determining whether a battery is beyond its useful life depends on the technology (or chemistry, NiCd, Pb-Acid, etc.). So, battery life will be covered for each individual technology below. The second most common problem in the developing world is that the charger has been lost or broken, and you cannot find an exact match for that charger in the market. Charging is also technology specific and will be covered below.

Substituting Batteries

Devising a substitute battery is a topic which cuts across all of the technologies. The easiest problem is when you can find batteries of the appropriate technology, but not the appropriate capacity or voltage. If different voltages or capacities are desired connect the batteries in series to obtain more voltage, or in parallel to obtain more capacity (see example below). It is very rare that such combinations cannot be directly substituted for the cells that have been removed.

Example Pack Substitution

Assume you make a pack of 12, 600 mAh, 1.2 V, NiCd cells connected 4x3 (three sets of 4 batteries in series, the three sets in parallel).

The four cells in series provide

$$1.2 \text{ V} \times 4 = 4.8 \text{ V}$$

The three sets in parallel provide

$$600 \text{ mAh} \times 3 = 1800 \text{ mAh}$$

Therefore, you have created one, 4.8 V, 1800 mAh battery pack.

To charge your pack, use

Trickle charge: $1800/100 = 18 \text{ mA}$ for a few days

Max charge: for NiCd $C=1800 \text{ mA}$ (1.8 A)

It is also common that you can find the batteries of the correct technology and the correct voltage and capacity (either by combination or alone), but the connection type is wrong. For example, the batteries that you have use solder tabs, but you need button connections. In these cases, simply solder wires to the circuit board and wires to the battery. When soldering onto a battery with button connections, use coarse sandpaper to rough up the surface. Then cover it with a large amount of solder – holding the soldering iron on the battery for as short a period as possible. Finally, melt the solder on the battery while holding the wire on top. You may still need to tape the wire on the side of the battery to avoid any physical strain on this relatively weak combination.

A more difficult problem is when you cannot find the correct technology, but must find a substitute battery. First you must typically match the voltage to within 0.7 volts. That is to say that the voltage of the replacement cell must match the original cell, or must be higher than the original cell. If the replacement cell is less than 0.7 volts higher than the original, you can probably use the substitute without modification for voltage. If the difference is larger than 0.7 volts, then use a diode in series with the battery to drop the replacement battery to within 0.7 volts of the original.

The capacity of the replacement cell is the most difficult item to match because capacity affects both the charge within the battery and the maximum amount of current that the battery can provide. The maximum amount of current that the cell can provide is sometimes specified as the cell's internal impedance. Unfortunately, changing battery technology, even when identical capacities are selected, changes the internal impedance of the cell. Therefore, if the battery was selected by the designer purely based on its capacity (hand held devices without motors are often in this category), then a substitute technology will probably work as the impedance is not critical. In many situations, the medical staff will accept a shorter time between replacement cells (or recharging), so a lower or higher capacity substitute technology can be used, as long as the voltage criterion is met.

However, if the battery size was selected by the designer to meet a maximum current specification (x-ray, defibrillation, and many motor driven devices are in this category), then a change in battery technology, and therefore in internal impedance, could render the device useless. If you know the internal impedance of the cells you are removing (it can often be found on the manufacturer's web site, if you have internet access), then you can simply select a cell of lower internal impedance from a substitute technology. However, more typically, you will not have internet access. In this case, if you can find a working model of the device, you may be able to measure the maximum current drain and select a substitute battery capacity based on its ability to deliver that maximum current.

If there are not working examples of the equipment, you may have to resort to trial and error. As a starting point, for all primary and secondary cells (except lead-acid selected for current drain) you can probably switch battery technologies if the replacement cell has twice the capacity of the original cell. For lead-acid selected for current drain (such as x-ray and some motor applications), you will need a far higher factor of capacity to substitute technologies. Lead-acid batteries are available in the larger cities of the developing world. So, substitution of technologies in this case is not recommended.

In summary, the first step is to match the voltage of the replacement cell. The second is to select a capacity either based on the longevity of the device between replacement (or recharging), or on the ability to deliver the needed current.

When changing technologies, if the original battery was a primary cell, it should be replaced with a primary cell. They are cheaper to replace and will last longer before needing replacement. If you replace them with a secondary cell, then the hospital will have to find a replacement secondary cell at greater expense in just a few years.

However, if the original cell was a secondary cell, replacement with a primary cell is possible. In general, primary cells of the same capacity and voltage will have lower impedances and can be used as direct substitutes. If the charger is internal, however, primary cells cannot be substituted except in an emergency (a defibrillator that won't discharge without cells, for example), because charging primary cells can destroy the equipment and the cells.

If the original cell was a secondary cell and the replacement technology was a secondary cell, then you must be concerned with charging your replacement cells. It is generally impossible to find a battery which will both operate the device and will achieve the same performance charging as the original technology. If the difference is simply that longer charging times are needed, this can be explained to the staff. However, if the charger delivers excessive charge, then the cells and device may be damaged. You will have to also replace the charger, when you replace the secondary cells. Select the charger based on the replacement technology, as described below.

Substituting Chargers

A more and more common problem in the developing world is that the charger for a battery operated device is missing or broken. Most chargers are wall transformers with female coaxial connectors at one end. When replacing a broken charger, you need only match the input voltage (typically 110 or 240 V), the output voltage, the output type (AC or DC) and the output current capacity. Any physical characteristics of the charger are irrelevant, including the connector, since you can simply snip off the connector from the broken charger and solder it to your replacement, being careful to match the original polarity for DC chargers. There is nothing magical about wall transformers. You should feel free to substitute any power supply, including a variable, bench-top power supply, as long as it meets the specifications stated earlier.

If you do not have the original charger and the device is marked, then the original problem is only more complex in the sense that you do not have the connector. It is often acceptable to open the device and wire in a new connector (if you can find a male and female in the market). If you cannot find any connectors, simply bring out clearly marked bare wires (with alligator clips on the charger). There is little danger to the staff or device for any charging voltages below 24 volts.

If the device is not marked and the original charger is lost and you do not have the manual - a very common occurrence in the developing world - then a substitute must be divined. If you have made a substitute secondary battery, then you will also have to provide a replacement charger. In either case, you will have to determine the correct charging voltage and current based on the battery voltage, capacity and technology. Each secondary technology must be considered separately. The most common encountered in medical devices in the developing world are NiCd and Lead-Acid.

NiCd (Nickel Cadmium)

NiCd (pronounced Nye-Cad) batteries are less reliable in hotter climates because of an increased rate of self discharge. They are also less efficient at recharging at higher temperatures. A NiCd battery has a potential difference of 1.25 V which drops to 1.0 V when completely discharged.

To determine whether a NiCd cell is beyond its useful life, first measure the potential. If it is below 1.0 volts, the cells are probably not salvageable. Next, attempt to charge the cells (as described below). If the potential across a single cell does not increase to 1.25 volts, the cells are probably beyond their useful life. If the cells measure well open circuit, and can be charged, they may still have lost most of their capacity. Measure the voltage before and after a brief load of 10 times the recharging current of the battery (by placing a resistor across the cell of the correct size to obtain the required current for five seconds). Fully charged, properly operating

cells will show only a slight difference, whereas older batteries will give a reading of less than 1.0 V after this brief load.

In some cases, apparently destroyed NiCd cells can be rejuvenated by erasing their “memory.” This can be accomplished by fully discharging the cells at their charging capacity for one day. Then charge them at one-tenth of their charging capacity for 12 hours. Then, finally, complete a full charge of the cells.

NiCd batteries can be charged safely for essentially an infinite amount of time at 0.1 times their capacity (called 0.1C charging). In other words, if the cell is a 1000 mAh cell, then the cell can be charged at 100 mA for as long as you like. These are DC currents measured with the positive of the charger connected to the positive of the battery (or battery pack) and the negative connected to the negative of the pack. It will take 10 hours or more to completely charge a fully discharged cell. Charging at 0.1C is called trickle charging. Medical devices can be left on trickle charge for their entire non-use time. For faster charging, the NiCd can be safely charged up to 1.0C. In other words, a 2000 mAh cell can be charged at a maximum of 2000 mA. The cell will get very hot when charged at this rate, hot enough to burn. Be sure there is adequate ventilation to dissipate this heat or the cell will be destroyed. NiCd cells cannot be charged more than one hour when charged at 1.0C or they will be destroyed.

Lead-Acid

Lead Acid batteries have a voltage of 2.1 volts. However, they are typically sold and used in packages which include 3 or 6 in series, yielding 6.3 volts or 12.6 volts. The voltage does not change appreciably during discharge, perhaps 0.3 volts for a 12.6 volt battery when it is charged to 50% of capacity. A lead battery should be recharged by the time it has a residual capacity of about 30%. Any further discharging considerably shortens the life of the battery.

Take extreme care when working with lead acid batteries as hydrogen gas may build up if proper venting has failed. The build up of hydrogen can cause the battery to explode. As you are dealing with a high capacity battery, care must be taken to avoid shorting the terminals. Remove all jewelry before working on the batteries. A single 12.7 volt lead-acid battery is sufficiently strong to destroy a finger if the a ring were to short the terminals. Keep the outside of the battery clean and free from damp and grease to avoid discharge between the terminals.

There are two main types of lead batteries, sealed and unsealed. A color indicator on the top of the sealed lead battery can tell you if it is necessary to recharge the battery. If no color indicator is available, it is easiest to perform a load test. A 100% charged 12V battery typically measures around 12.7V with a voltmeter, with only a 0.3V drop for a 50% charged battery. It is easiest to identify an exhausted battery by measuring the voltage before and after heavy use – the higher the difference in voltage the more depleted the battery.

The most reliable method to determine the battery capacity of an unsealed lead acid battery is to measure the density of (sulfuric acid) H_2SO_4 . This can be done using a hydrometer. Hydrometers are available in auto parts stores in the developing world. The density of the sulfuric acid should be 1.23 kg/liter in tropical countries. If you do not have a hydrometer, you can typically get an auto parts store to measure your batteries for you. If you have a hydrometer, follow the directions on with the hydrometer. If no specific density measurement is possible, perform a load test as described above.

If the electrolyte level appears low or the acid level is too high, add water. Use only distilled water. If distilled is unavailable, bottled water or freshly collected rainwater may substitute in an emergency. If necessary make your own distilled water by cooling steam and collecting the condensate. Do not use tap water unless there is no alternative. If acid must be added, it can be purchased at auto parts stores.

When recharging lead acid batteries in tropical environments, the charging voltage should stay between 11.2 and 13.9 V. Limit the recharging current to less than one tenth of the capacity ($<0.1\text{ C}$). For example, limit the charging to 10 A for a battery rated at 100 Ah and 5 A for a battery rated at 50 Ah.

2.19.3 Suggested Minimal Testing

If the battery is operating and a proper charger is available, it is ready for release. There are no additional testing procedures required.

3 Equipment Found in the Clinical laboratory

The most equipment-intense areas of the hospital are the operating room, intensive care unit and the clinical laboratory. Even in the developing world, where the clinical laboratories are often the weakest departments in the hospital, there is a significant amount of equipment concentrated in this area. Because this equipment does not directly contact the patient, it is treated somewhat differently from equipment in the other areas. Therefore, it is separated into a separate section in this book.

Because of high capital costs and changing technology, many of the larger devices in the developed world are not owned by the hospitals but leased or obtained on "reagent rental" basis in the US. Reagent rental means that the equipment is essentially free, but the hospital pays for the reagents used to conduct the tests. This economic model has made the use of the most modern clinical laboratory equipment impossible in the developing world. They simply can't support the purchase of the reagents. Therefore, there are enormous differences between a clinical laboratory in the US and in the developing world.

While some of the automated equipment found in the US will be seen in the developing world, it will often be sitting idly in the corner. Efforts to fix it may be futile as the reagents may be missing. This section only covers the most common equipment that will be routinely used in a developing world clinical laboratory.

In most clinical labs, you will see old outdated equipment, which if used properly will yield excellent results. However, they may be incorrectly used or broken. There is a higher rate of user error associated with clinical laboratory equipment, where the procedures are more intense, than in other areas of the hospitals. You are often spending more of your time, as an engineer, determining whether the problem is related to the procedure being followed or the equipment.

3.1.1 Sections found in this part of the book.

Unlike the equipment described in the first section of this book, you will rarely need to calibrate a piece of clinical laboratory equipment by yourself. In most cases, a given piece of equipment will have only one technician who knows how to use it - or who regularly uses it - in a given hospital. Therefore, you can, and should, share responsibility with that person to determine what is wrong with the equipment and to determine if the equipment is working adequately after your repair. You won't need to know how to calibrate the equipment in many cases because the technician assigned to use that piece of equipment should know how to determine if the equipment is working properly and should be able to recalibrate that piece of equipment.

Therefore, for clinical laboratory repairs, it is essential to first develop a relationship with the user of the equipment. Conduct an extensive interview with the technician assigned to that piece of equipment to determine the problem. Then sit with them again when you are ready to determine if the problem has been adequately fixed.

So, in this section of the book, there are few descriptions of the testing required before releasing for use. This is not that testing is not required, but rather the testing should be performed with the technician. An experienced lab technician is well versed in calibrating their own equipment.

3.2 Balances

3.2.1 Use and Principles of Operation

Balances are accurate and precise instruments used to measure the weight or mass of a substance or material. The ability to measure material as large as 50kg and as small as 10 μ g makes them quite common.

There are two main categories of balances, mechanical and electromagnetic. Mechanical balances tend to be the simpler of the two. They generally consist of springs or lever arms, and use either a known force or mass to determine the unknown measurement.

Electromagnetic balances are a little more complex, but generally more user friendly. They are often based on measuring the current needed to levitate the pan and mass. A wire is attached to the weighing pan. The wire is placed between two poles of a permanent magnet. When a substance is placed in the pan, the wire is displaced and additional current is required to return the wire to its original resting state. This difference in current is measured internally and used to determine the mass of the substance in the pan.

3.2.2 Common Problems

Internal problems with an electromagnetic balance cannot usually be repaired by the field engineer in the developing world. Mechanical balances are very reliable and rarely need major repairs. Therefore, the most likely problems to occupy the engineer working in the developing world are minor in nature.

The most common problems associated with an electromagnetic balance are the result of environmental factors and user error. The primary environmental factors leading to poor results from the balance are temperature, static electricity, vibration, out of level (tilted), and wind. If the readings are inaccurate or erratic, any one of these can be the cause. Shielding the balance from vibration, static electricity and air currents are easily accomplished and may solve the problem. Leveling the scale is also easily accomplished. Controlling the temperature, on the other hand, may be problematic. If you find that the balance operates correctly at night or in the early morning, but not at mid day, you may have to restrict its use to periods when the room temperature is stable and low.

The most common problem with mechanical balances is environmental factors and maintenance. The movements of the mechanical balance must be free of dirt and other residue. If a mechanical balance is yielding erratic readings, clean and oil all moving parts before attempting any other diagnosis or repair.

3.2.3 Suggested Testing

Balances are so reliable, that the technician may not know how to perform a calibration. However, a crude calibration is very straightforward. First, place a clean container in the center of the weighing pan. If the balance has a case, close the door. Zero the balance by pushing the TARE button (a long rectangular bar, a twist of a dial, or, if the TARE is absent, jot down the reading of the balance with the container). Place a known volume of water on the scale. In most cases, the most accurate way to add the desired amount of water is to use a syringe. Now read the balance. (If there was no TARE, subtract your original measurement). Compare the reading to the actual weight of the water (water weighs one gram per milliliter). The precision of the balance will probably exceed the precision of your water volume measurement, so repeat the measurement four or five times.

3.3 Centrifuges and Electrical Motors

3.3.1 Use and Principles of Operation

If a liquid contains particles, the particles will eventually sink to the bottom under the force of gravity. A centrifuge more rapidly separates particles from liquid by rotating a liquid to simulate a higher force of gravity. Either a liquid/liquid or a liquid/solid mixture can be separated with the substance of higher density migrating towards the outer part of the centrifuge. Centrifuges vary in size, in speed of the rotation, how long they will run, temperature and angles of rotation of the samples.



A small, table-top, electric centrifuge is common in the developing world. However, smaller clinics may have only a hand-cranked centrifuge.

A centrifuge consists of a base and an inner spinning cylinder in which the substance to be separated is placed. Some centrifuges have timers that automatically turn off after a set period of time and some also have high precision speed regulators to control the speed with which the centrifuge spins. Centrifuges can be used to prepare a substance for analysis or to analyze the particle content. There are two types of preparative centrifuges: mechanical and electrical. Of the analytical centrifuges, the only one used in medicine is the microhematocrit, used for separating plasma from the blood suspension.



With the lid of this centrifuge tipped back, you can see the four tubes where the specimen or dummy tubes would be placed. When the rotor turns, the tubes will tip out at an angle. The small round dot just beyond the white interior (center bottom) is an interlock that prevents the unit from spinning if the lid is open.

The simplest centrifuges have a single speed motor, a mechanical timer and a rotor that holds the samples at a preset angle of 20 to 40 degrees. For user safety, the lid of the centrifuge should have an interlock on it so that the unit will not spin with the lid in the up position.

A simple rotor is made from metal with 4, 6 or 8 holes drilled into it at an angle where the samples are placed. Balancing the rotor is very important. If the user has only a few samples to be spun down they may have to use "dummy tubes" to properly balance the load. Since the motor shaft is attached to the rotor, uneven loads can cause motor damage and uneven speeds. Another type of rotor has sample carriers that are vertical at rest but when spun move out to 20 to 40 degrees.

The simplest centrifuges have a single speed ranging from 2,500 to 10,000 RPM. Low speed centrifuges have RPM rates up to 12,000 RPM, high speed units go up to 35,000 RPM and the ultrahigh speed can reach 125,000 RPM. The simplest variable speed centrifuges will have a rheostat speed control, which may be non-linear. Most of the newer variable speed centrifuges have built in tachometers that provide the users with a speed indication. More sophisticated speed control systems can involve SCR's, stepper motors and servo systems.

Most high speed and all ultrahigh speed units are refrigerated because the friction caused by the air on the samples will dry them out and change the results.

Centrifuges have a timer that is either electronic or mechanical built into the controls. Depending upon the centrifuge, the time can be set from seconds to days. If no time is selected the centrifuge will probably not run. Also, the centrifuge may have a time delay on the start where it will not start to spin for several seconds after the RPM rate and timer are set and the start button pushed.

3.3.2 Common Problems

Any part of the centrifuge may cause a problem. However, not every part of the centrifuge can or should be repaired. After eliminating the timer, rotor and most of the rest of the machine, the only repairable part of the centrifuge which needs much further explanation is the motor.

If the timer is at fault, often the only practical solution in the field is to bypass the timer (so the centrifuge always turns when switched on), and instruct the staff to use manual timing. As personnel are generally plentiful in the developing world hospital, this solution is typically well accepted by the staff, especially if they have been attempting to operate without any centrifuge at all.

If the rotor is cracked or bent, it should not be repaired. There are tremendous forces developed in a centrifuge. If the rotor is weakened or off balance by being bent, the machine could be destroyed and the staff injured in the process.

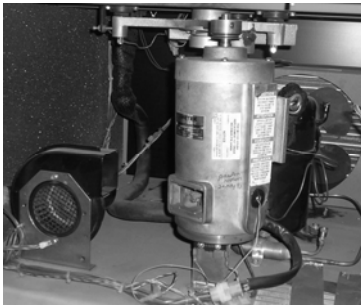
Mechanical centrifuges typically only need lubricating and cleaning to return them to use. If a piece is broken, it often cannot be repaired.

All centrifuges produced after 1990 are required to have an interlock system that does not allow the rotor to spin unless the cover is closed. Some of these interlock systems are very simple; a solenoid that pushes a rod through a hole in the cover latch is common. Others are more complicated and may involve several solenoids, flexible cables and a clock. The clock can be tied to the RPM indicator and will not release the solenoids until a set time has elapsed after the speed drops to zero. These timed units may give the appearance of failure because the operator

cannot immediately open the lid. Check the manual, if available, to confirm both the delay and if that delay is adjustable.

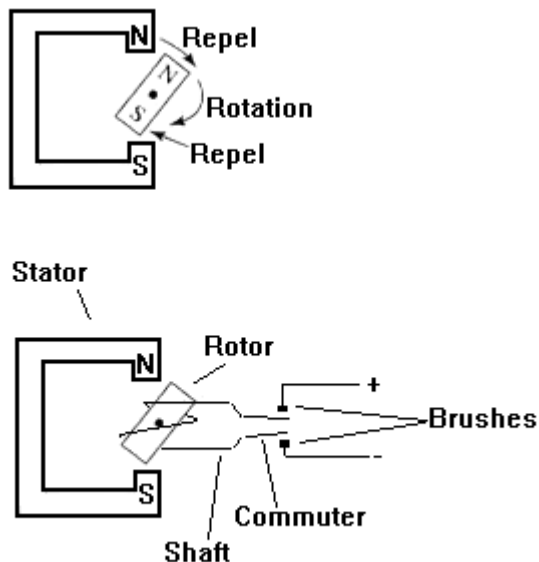
There is always a temptation to defeat a broken interlock system. This should only be done for clinical laboratory departments that have no alternative centrifuge and then only after careful consultation with the technician who will be using the machine. Affix a picture on top of the machine showing a damaged finger and an open lid so that all future users will know about this danger.

3.3.3 Motors



The inside of a simple centrifuge is nothing more than a motor and a few switches. This more sophisticated centrifuge includes two fans (additional motors) and a small bit of electronics (not shown).

The heart of the centrifuge is the motor. Almost all variable speed electrical motors in the developing world work on the same principle, whether they are in a centrifuge or any other piece of equipment (fixed speed motors, such as pumps and compressors are often of the induction type, not discussed here). The motor works by passing electrical current through electro-magnets attached to a rotating shaft. Stationary, permanent magnets attract or repel the electro-magnets depending on the orientation of the magnetic fields. The fields' orientations are switched such that the electro-magnets are progressively attracted to the permanent magnets around the circle, bringing the shaft of the motor around with them.



If a magnet is placed within another magnet, it can be made to rotate around a shaft by aligning the magnets to repel each other. If the polarity of the rotating magnet is then switched, the shaft and magnet will continue to rotate, and the device will be a motor. In order to switch the polarity, brushes contact commutators, the brushes and commutator forming switches. As the shaft rotates, the brushes contact different commutator parts, alternating the polarity of the rotating magnet.

In general, the engineer in the field will not be called upon to rebuild an electrical motor. Almost every major city in the developing world has a shop that can accomplish this task. However, most motors use carbon brushes to make electrical contact with the electro-magnets on the

rotating part of the motor. These brushes wear down over time and need to be replaced. The brushes can be replaced by the field engineer.

Brushes should only be replaced with brushes of the same size. Do not use undersize brushes as they may wear unevenly and score the shaft of the motor. Brushes are held against the shaft via spring pressure, if the spring weakens, breaks or is missing the motor may not spin. If the caps holding the brushes in place become loose or cracked, that can also cause the brushes to lose contact and the motor will not run at all or will not run consistently.

Brushes that are installed properly and with the correct tension make the brushes wear evenly and have a bright almost shiny look on the contact end. If the brushes are defective or not making good contact the contact face of the brush will be dull and not smooth. Both brushes should be removed from the unit and compared when troubleshooting.

The shaft is held in the center of the permanent magnets by bearings. These are not often the cause of the problem, but in certain cases they can cause noise as the shaft rattles instead of being held in place. Bearings can be removed and replaced. Most developing world cities have motor repair shops which can replace or repair the bearings.

Besides the brushes and the motor bearings, many motor systems, including centrifuges, will have braking systems. If the rotor of a centrifuge, for example, was left to stop on its own, it could take a long period of time for the rotor to drop from 100,000 RPM to zero. To cut the time most units have a brake. The brake is not a mechanical device, as on your car. In some systems, the brake is a resistor that is temporarily placed across the motor. The motor is essentially operating as generator, with the mechanical energy coming from the spinning rotor and the electrical energy dumping into the resistance.

Motors are sometimes used in a 50 Hz country, despite being designed for 60 Hz use. In general, this causes few problems in centrifuges. In other applications, it can cause overheating. If possible lower the voltage about 10% on these motors to reduce heating.

In more sophisticated systems, the brake reverses the electrical field in the electro-magnets to make them attempt to spin the rotor in the opposite direction. The operator has to energize the switch and should only hold the switch in the reverse or stop position for a few seconds at a time.

3.3.4 Suggested Testing

The centrifuge creates tremendous forces inside the vessel when in use. If the rotor were to break or become dislodged, it could damage the machine or injure the user. Therefore, you should perform some safety testing before releasing the device for use.

First, check that the lid cannot be opened when the rotor is turning. Never release a centrifuge which can be opened while the rotor is turning without a thorough discussion of the dangers with the staff. If this is the only centrifuge that the hospital has at its disposal, you may have to release the device for use without a safety interlock.

Second, you should insure that the device can spin up to speed and brake without excessive noise. Be sure to balance the rotor (with equal amounts of water-filled vials on each side) before turning it on. Check the rotor for cracks or bends before starting the centrifuge. Particular attention has to be paid to centrifuges that have rotors that can be changed out. The users have been known to not fully tighten down the knob securing the rotor to the motor shaft causing severe damage to the device and lab when the rotor broke loose while spinning.

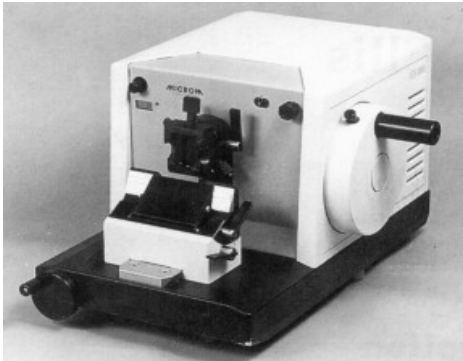
The ideal test for a centrifuge is a tachometer used to verify the rpm. However, you can make an approximate measurement of the centrifuges speed without one. Under light from a fluorescent bulb that runs on 60 Hz. current, the gage shown below will give you an accurate reading when you are running at one of the speeds on the gage. The "flashing" of the fluorescent bulb at 120 Hz will cause one of the bands to appear to stop moving at the RPM indicated by that band. The gage will not work with an incandescent light bulb.

To use the gage, photocopy it, cut it out, and place it on the spindle. You may need to cover it in clear packing tape to make it stiffer. Spin up the centrifuge until one of the bands has stopped, mark that spot on the speed control knob. Count the bands from the inside to note which band has stopped. You can increase the speed and find the next time that this same band stops. This speed corresponds to twice the marked RPM. Likewise, you can find speeds which are three, four or more times what is marked by counting the number of times the bands stop as you increase the RPM's. To determine the RPM, stop the centrifuge, read the band, and multiply by the number of times it stopped as you were increasing the rotation. You'll need to try this a few times before getting consistent results.

3.4 Microtomes

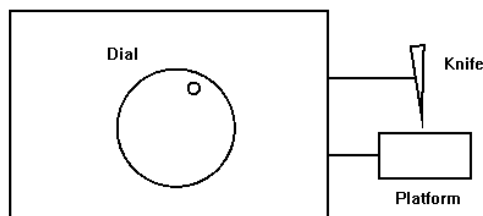
3.4.1 Use and Principles of Operation

Histology is the study of tissue, restricted in the developing world to using visible light and a microscope, magnifying lens or the naked eye. In order to better examine the tissue sample from the patient, it is first cut (or sectioned) in to thin slices, typically 1- 10 microns (micrometers) thick. The tissue is so thinly cut, that it is translucent. The instrument that cuts the tissue into these thin sections is the microtome.



Most larger developing world hospitals will have a small, manual microtome like this one.

A small hospital in the developing world might have a hand operated microtome. Larger hospitals in the developing world will have either a rotary unit or a cryostat microtome for doing frozen sections. No matter what type of microtome is being used, the specimen is prepared, often in paraffin, and then clamped into the microtome. The tissue is then advanced on the feed pawl until its edge is in the cutting zone. The knife is moved by turning a flywheel (or by advancing it by hand). As the knife descends a specimen slice is made. In an automatic microtome, as the knife ascends the specimen is drawn back so the knife edge does not touch the specimen.



A manual microtome slices a thin piece of tissue off of the preparation with a knife. The platform holds the tissue. The dial advances the tissue a few micrometers.

There are additional types of microtomes such as the sledge microtome (for hand cutting large pieces), the freezing microtome (with a cutting stage that freezes the tissue) and the ultramicrotome (which cuts very fine sections), but these are rarely seen in the developing world.

3.4.2 Common Problems

The most typically problem with a microtome is the knife. Many modern microtomes use disposable knives. These are inconvenient in the developing world due to the expense. The disposable knives are often reused for that reason. Durable knives are a better option, as long as they are sharpened periodically. Knife sharpening is typically available in the developing world, but may not be used.

The knife angle can cause problems. The clearance angle is the angle between the knife edge bevel and the block, typically between 2 and 4 degrees for paraffin sections, and between 5 and 7 degrees for resin or frozen sections, being most effective. If the cutting angle is too great it can cause compression in the cut section. If the cutting angle is too fine, the edge of the knife can vibrate causing chatter in the section. These angles can be adjusted and sections cut until the technician is satisfied with the results.

The machine needs to be well maintained to operate correctly. It should be cleaned after each use. You can use a very light oil to prevent corrosion and improve the operation of the mechanism. The knife should be removed after each use. A dust cover should cover the machine's cutting surfaces after each use. If you don't see evidence that these procedures are in place, thoroughly clean the machine and attempt the sectioning again.

On cryostat machines, you can also suspect the cooling elements. There is a defogging mechanism that allows the user to see the section inside the cold chamber. This may become clogged or otherwise broken.

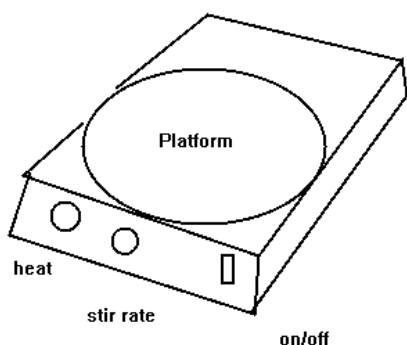
Finally, you should suspect user error. The preparation of the tissue and the handling of the tissue after sectioning can greatly affect the results. The hardness of the embedding compound being one of the primary factors affecting tissue sectioning. Embedding compounds range from gelatin (50 to 200 microns), simply freezing the tissue (5 to 20 microns), paraffin (1 to 15 micron), paraffin/wax/resin mixtures (0.5 to 2 microns and pure resin (0.05 to 1 microns). You may encounter any of these preparations in the developing world, and you may encounter a technician using the wrong embedding material for the thickness of section desired.

3.5 Water Baths, Stir And Hot Plates

3.5.1 Use and Principles of Operation

As the name suggests, a water bath is simply a device which maintains the water at a set temperature to bathe an object. A water bath is normally used to control the temperature of bottles and flasks containing enzymes, medicine, or blood, as well as many other substances. They can be used in both clinical or research settings depending on the needs of the user. In a clinical setting, the water bath is commonly used to bring a colder specimen to body temperature, such as blood or an organ for transplant. Likewise, a refrigerated water bath can cool a specimen to at or below freezing if necessary.

Water baths can be used at several different temperatures, and depending on the manufacturer, can either have set points, often 37 °C, or the user can set the water bath temperature. Depending on the device and specifications, the temperature can be maintained within a very narrow range, with some as accurate as plus or minus a tenth of a degree Celsius. Other models may fluctuate as much as a degree or two.



The most basic water baths are "open" systems, either hotplates or stirring hot plates. The stir system adds a spinning magnet under the platform (activating a second magnet dropped into the jar on top). Without a temperature control, The operator must monitor and adjust the temperature by hand.

There are four common types of water baths: standard, stirrer, refrigerated, and shaker. The first is the standard water bath with very few electronic components, and it is the simplest of the water baths. These are called hot plates. There is no feedback with this type of device (open control). In other words, the device does not adjust the amount of delivered heat dependent on the sensed temperature. This type of water bath will usually have an analog dial to crudely set the desired temperature (actually the delivered heat).

Another type of water bath is the stirrer, also known as a circulating water bath. The stirring water bath includes a rotating magnet below the hot surface. A magnet dropped in the liquid rotates with the magnet under the platform, stirring the fluid in the beaker. The stirring action allows for water to heat up faster and more evenly.

The refrigerated water bath is used to cool substances more slowly than just placing in a refrigerator. It is relatively rare in the developing world.

The shaker or orbital water bath, is the most recent advance in water bath technology. It provides means for shaking the solution without the need to drop a magnet in the solution. Shaker water baths usually have a control for temperature as well as shaker speed, stroke length, and occasionally a timer for mixing. They are also rare in the developing world.

3.5.2 Common Problems

The more complex the model, the more components that can go wrong and cause the machine to either not work or work incorrectly. However, the basic components of a water bath are the heating element and the motor (if it is a stirring or shaking bath). For more details on motors, see the chapter on centrifuges. The heating element is typically a Nicrome wire, which can often be removed and replaced in the developing world.

User error is fairly common with water baths, because the level and temperature alarms can be confusing. Be sure that the device is full and level before attempting to use.

The only device required to calibrate a water bath is a thermometer, and perhaps a watch. If you wish to test the device just to be sure it works, make sure the bath is full and level before turning it on. If it warms up and moves, it is ready for final testing. Discuss the most critical aspects of operation with the technician who uses the device and test those aspects of the device to his or her specifications.

3.6 Microscopes

3.6.1 Use and Principles of Operation

In histology, pathology, hematology and other sections of the clinical laboratories the microscope is a critical device. Even the smallest and poorest equipped developing world hospitals will have a microscope. While these units rarely fail they do require cleaning and lubrication on a regular basis.

There are many types of microscopes. However, the only one regularly encountered in the developing world is the compound light microscope. A compound light microscope can have a maximum magnification on the order of 2000. However, typical clinical strengths range only up to 1000 X (100X objective and a 10X eyepiece).

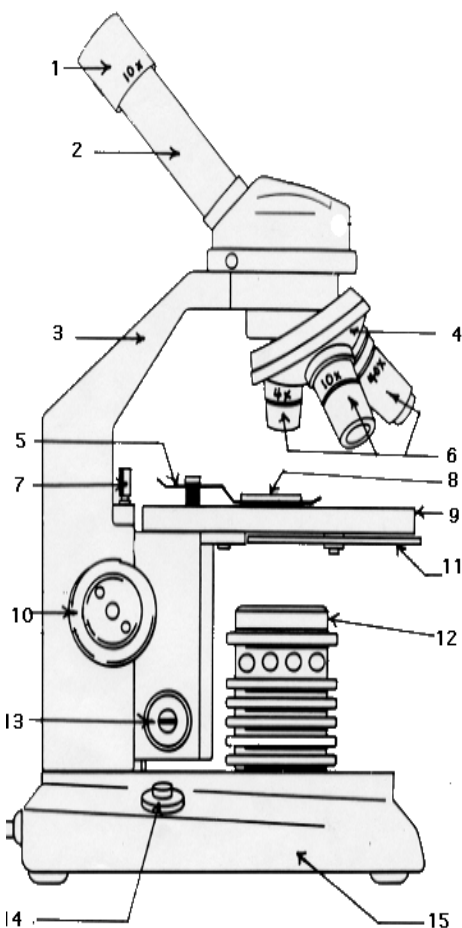


Figure 2: General layout of standard compound light microscope, labeled by part. (1) eyepiece, (2) body tube, (3) arm, (4) nose piece, (5) stage clips, (6) objectives, (7) stage stops, (8) aperture, (9) stage, (10) coarse adjustment knob, (11) diaphragm, (12) light source, (13) fine adjustment knob, (14) power switch, and (15) base.

Compound microscopes have a light source, either external or built in, that is used to bottom light the slide-mounted specimen. It may be a direct light beam or focused via a mirror. On some units there is a diaphragm that will control the size of the light beam impinging on the specimen. There may be an intensity control on the light source as well. There also may be a filter between the light and the specimen that removes certain wavelengths of light from the spectrum or polarizes the light.

The general layout of a compound light microscope is shown in the figure at the left. It consists of fifteen main components.

The most critical components are the objectives (6), the adjustment knobs (10), the light source (12) – often located in the base (15) and the eyepiece (1). The objective lens of a microscope is small and spherical, which means it has a small focal length, to bring the object into focus at a shorter distance. The image is then magnified by a second lens, called the ocular lens or eyepiece.

Normally, in a clinical compound microscope, the three objectives will be four times (4X), ten times (10X), and forty times (40X) magnification. Sometimes a 100X objective is present, but it will require oil between the objective and the tissue, not air. The objectives are interchangeable within one microscope and sometimes between microscopes of the same manufacturer. They are often not interchangeable between manufacturers. The eyepiece is usually fixed at some magnification, usually ten times (10X).

The thickness of the cover glass of the specimen can also affect the ability to focus the image, and the correct cover-glass thickness is sometimes written on the side of the objective lens.

3.6.2 Common Problems

The most common problem with microscopes is dirty or broken objectives. Unfortunately, the objectives cannot be repaired and are very expensive to replace. It can be cheaper to replace the entire microscope than to replace one objective.

The optics can be cleaned with an alcohol dampened lint free cloth. It is a good idea to blow off any dust with canned air before cleaning. Be very careful not to scratch the optics as they are coated with very precise, thin coatings to correct for color aberrations. The coatings can be significantly softer than the lens itself.

The light source is the next most common source of problems. Bulbs should only be replaced only with the same bulb. If the bulb is different it may have differing light output, filament voltages, heat or light spectrums that could affect the reading of the specimen. See the chapter on lighting for more information.

If mechanical positioning adjustments do not operate smoothly it is an indication that either too much or too little lubricant has been used. Clean off any excess lubricant, especially if it has dried and is clumping. Use a soft cloth dampened with alcohol for the cleaning. Do not use any solvents that may leave a residue. Also be careful not to leave lint on any surface.

When the microscope is used in hot, humid rooms, as is often the case in the developing world, a serious concern is fungus growing on the microscope, especially on the surfaces of the lens, and the grooves of the screws. To help prevent moisture and fungus from destroying the microscope, store it under air-tight cover with a dish filled with blue silica to desiccate the air under the cover. Once the silica turns red, it will have lost its capacity to absorb moisture from the air, and it will need to be regenerated using by heating it in a hot air oven or over a fire. If silica is not available, put an air tight plastic bag over the microscope and place a small pile of dry rice in the bag with the microscope. Replace the rice every week or so.

When a repair is completed, you may wish to insure that the microscope is working to some extent. The precise operation of a microscope takes skill and practice. However, a rudimentary knowledge of a microscope's operation is sufficient to determine that it is working at all. Always carry a microscope by the arm with one hand, and the base with the other. The microscope should be placed on a level table. Before using the microscope, turn the coarse adjustment knob to raise the body tube to its highest level and revolve the nosepiece until the low-power objective lens clicks into place. Then adjust the diaphragm and mirrors while looking through the eyepiece until a bright white circle of light is seen. Next place the slide specimen on the stage and center it over the opening in the stage, using the stage clips to hold the slide in place. Looking at the stage from the side, carefully turn the coarse adjustment knob to lower the body tube until it almost touches the slide. While looking through the eyepiece, very slowly turn the coarse adjustment knob until the specimen comes into focus. However, caution should be used in this step, as the objective should not touch the slide. Once the specimen is almost in focus, use the fine adjustment knob until the specimen is seen in a sharp view. When you are ready for a more detailed test, consult with the technician in charge of using the device.

3.7 Autoclaves

3.7.1 Use and Principles of Operation

An autoclave is a device used to sterilize medical instruments and equipment. It uses steam and pressure in the absence of air to assure sterile conditions. The small, table-top autoclave uses heat to boil water into steam. The steam continues heating and the pressure continues to increase. Bacteria can not survive in these conditions. However, not all viruses and spores are killed. Exposing materials to a single heat cycle is somewhat effective, but sterilizing them 3 times over a period of 3 days will kill most vegetative spores.



Inside and outside of a small, electric autoclave.

Most hospitals have electric, steam autoclaves, but you will also find an autoclave like the "All American" distributed by UNICEF. It uses an open fire as its source of heat.



The small open fire autoclave is still common in the developing world.

An autoclave is a fairly simple instrument to operate but could be dangerous if operated improperly. It is important to wait until the chamber is completely depressurized before opening! If it is opened under pressure, large quantities of steam could escape causing severe burns! Most modern hospitals have automated autoclaves. These devices go through the steps of operation without intervention. If the machine is not going through its steps correctly, there is little that can be done to change the sequence of steps.

Manual machines, such as the All American, must be operated correctly to insure sterilization. The automated machines follow the same steps, though automatically.

Start by making sure that the water reservoir is filled to proper level with distilled water or filtered rain water. Well water will, in time, leave a scaly deposit on the instruments and autoclave. An indicator strip should be used with each pack being sterilized. However, in the developing world, this practice is not followed. Place the instruments into the chamber and close lid securely. Open the air outlet valve. Automated machines may use several cycles of vacuum to remove the air. The manual machines depend on the steam to push the air out of the chamber.

Now, the machine is ready to begin its cycle. Turn on or light the heating element. During this part of the cycle, the manual machine is evacuating the air. Therefore, it is important to wait until there is a steady stream of steam exiting from the autoclave. If the air release valve is

spitting and sputtering, it should remain open. Air left in the chamber will lead to cold spots, and poor sterilization.

When the air is completely evacuated from the machine, either by vacuum in the automated machines or by steam in the manual machines, the air outlet valve must be closed. The steam pressure will begin to rise. At this point, it is sufficient to monitor the temperature and time to insure sterilization. Do not open the chamber or valves, as the pressure of the escaping steam can be dangerous.

The sterilization cycle and sometimes the cool-down cycle can be timed. The proper time and temperature is shown below for unwrapped surgical instruments. Allow 30 minutes more at the holding temperature and pressure if the instruments are wrapped.

Sterilizing Temperature (C)	Appropriate pressure (kPa)	Appropriate Pressure (psi)	Minimum holding time (min)	Overall time (min)
115	75	11	30	50
122	115	17	15	40
128	150	22	10	30
136	225	33	3	20

After the specified holding time, the sterilization cycle is complete. Turn the heating element off completely. Now the cool-down cycle begins. The progress of cool-down can be followed by time, temperature, or simply by dropping water on the outside of the vessel. If it boils off, the vessel is still too hot. When cool down is complete, the chamber can be opened. If a sterilization tape was used, check to see that it is completely black.

3.7.2 Common Problems

There are a number of different types of problems you may encounter. However, the manual autoclave is a very reliable instrument. It rarely fails when properly operated and maintained.

The most common problem in the developing world is a build up of a scale due to the use of non-distilled water in the sterilization cycle. The scale can usually be scraped off the machine and simply thrown away. On manual machines, the scale may cause the air release valve and the over-pressure relief valve to be clogged. Both of these systems are difficult to scrape clean. If they can be removed from the machine and forced or left open, then simply soaking them for several days in pure distilled water should dissolve any deposits. It may be best to run a few dozen cycles with distilled water, where the air release valve is intentionally left open (steam will escape through the valve the entire cycle). This will help to dissolve any remaining the scale. If the relief valve cannot be opened and cleaned, it is best to replace this component.

Automated machines with scale build up may also see clogs in the vacuum lines and associated valves. If the machine is still operable, the best procedure may be to remove any visible build up, then run many cycles with pure distilled water until the remaining scale dissolves. If the valves have become blocked, remove them all and clean them all (not just the clogged one). If only one is clogged, it is certain that the others are close.

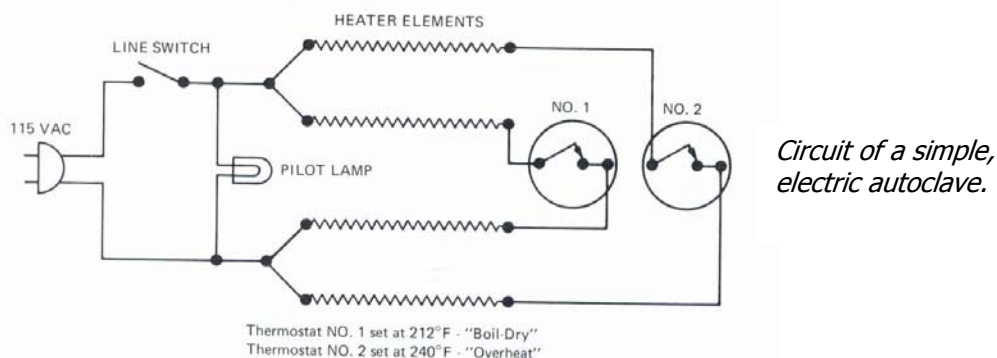
The second most common problem for autoclaves in the developing world is clogging of filters due to the use of dirty water, such as non-filtered rain water. This primarily plagues the automated autoclaves which often have inlet filters between the water storage and the main vessel. Some of these filters can be removed and back-flushed (run water backwards through the filter) to clean and restore them. Be sure to clean the tank of any particles that have settled to the bottom. In other cases, the filter must be replaced.

If you hear a hissing noise, then there is a leak in the pressure vessel or valve. Try to isolate the problem by looking for steam escaping and by using your ear. If the problem is a valve, it will probably be necessary to replace the valve. If the problem is the vessel, it is impossible to fix and the autoclave should be discarded. The seal on the vessel is also a common source of leaks. Check to see that there are no obstructions (dirt, or scale build up) along the seal. In some cases, the seal can be reground, but often, replacing the seal is required.

Some machines use a plastic or rubber seal. For these machines, run your fingernail into the seal. It should be pliable. If the seal is hard, or worse cracked, then it must be replaced. In larger cities, you may be able to find an automobile repair shop that can cut you a replacement gasket. Silicone sealant can be used to seal cracks in door gaskets until a replacement gasket can be located and installed.

If the seals are working and there are no leaks or clogs, the manual autoclave should work. The automatic autoclave may still not reach the proper temperature. The cause may be the thermostat or the heating element. In the most sophisticated autoclaves, the controller can be suspected.

If there is no heat generated, it could be the heating element or the thermostats. The typical heating element consists of two coils of nickel-chrome resistance wire, each of which has approximately 14 ohms of resistance. If the resistance across a coil is significantly higher, it is probably broken. These heaters are paralleled and the combination is placed in series with the on/off switch and one or both of the thermostats. Nicrome wire is common and can usually be found in the developing world. Match the resistance and length as closely as possible.



There are often two thermostats. One is a boil-dry safety thermostat connected in series with one of the elements and set to open at 212 degrees F. This will reduce the violence of boiling once 212 is reached. The second thermostat, often called the overheat relay, is set to turn off the electricity going to the nicrome elements when the temperature is excessive, usually meaning that the water has boiled away. Both thermostats for this instrument are usually of the bimetallic-switch type. They rarely degrade themselves, but the device which holds them in place is often deteriorates.

3.7.3 Suggested Testing

Autoclaves are like centrifuges in that there is a safety issue associated with their use. The device can injure the operator or leave the equipment undetectably contaminated. Therefore, some testing should be performed before releasing the device for use.

Before releasing an autoclave back to the floor, check the gaskets and check for scaling. You can prevent future clogging by removing any scale or dirt now. If the gasket for the vessel breaks, it

may leak steam, which can be dangerous. If the autoclave has an interlock that prevents opening during a cycle, check this again for safety.

If possible, check the temperature inside the vessel during sterilization. Most US hospital users put test strips with each sterilization pack. These strips verify that the temperature reached the required level for the required time and that humidity was present. However, in the developing world, these test strips are rarely used. It is nevertheless, possible to test the autoclave.

A complete test of an autoclave includes a Bowie-Dick test (to see that all the air was being removed) and either a temperature or a pressure test to see if the temperature and pressure reached the needed levels (since $PV=nRT$, and the chamber is only filled with steam, it is not necessary to measure both temperature and pressure). The time of the sterilization cycle can be measured with a watch. The Bowie-Dick test for air removal can be approximated by placing a standard Time-Temperature test strip on a sheet of paper in the center of a stack of 100% cotton towels and placed in a metal dressing can. The dressing can is placed in a warmed pre-vac sterilizer and a short cycle is run using the tape on the cotton towels as a check. If there is any air left in the sterilizer chamber, then it would be trapped in the towels. Because the air would not allow the steam to touch the tape, the color change would not be uniform around the strip. In order to pass the test, the entire tape must change colors, not just the edges. This procedure will test both the temperature and the air removal process.

If test strips are not available, then it is not possible to reliably test the autoclave for both air removal and temperature/pressure. You will have to settle for a pressure measurement. At the present time, there is no reusable alternative to the test strips readily available in the developing world.

Check the safety valve on the vessel. If it is dirty or corroded, attempt to replace it. If you cannot replace it, it is possible to test the safety valve by bypassing the overheat limit switch. This should only be attempted by experienced technicians wearing proper safety gear. Furthermore, you can only test the safety valve on autoclaves with working pressure gages. The safety valve is factory set to open at 30 psi. To test this valve, short out the thermostat with a clip lead, operate the autoclave as in starting a normal cycle. Be ready to pull the plug from the wall very quickly, should the safety valve fail and the pressure rise above 31 psi. If the safety valve fails to operate at this upper limit, it must be replaced. If you cannot find a replacement, discuss the danger with the administration. Although not having a safety valve is a severe danger to the operator, not having an autoclave is a severe danger to the patients.

3.8 Laboratory Incubators

3.8.1 Use and Principles of Operation

Laboratory incubators are devices that maintain controlled environmental conditions. These conditions include, but are not limited to, proper oxygenation, humidity and temperature. They are generally designed to cultivate cell and bacterial cultures.

Laboratory incubators come in various sizes and levels of technology. All are designed to maintain set temperatures and conditions within the chambers. Some may have internal AC outlets so other devices can be used inside of the incubator. Most will have fans to move air from the heating elements around the cultures (specimens) and out a vent. Much of the air is recirculated within the chamber and not vented. The doors have to seal tightly and should only be opened on a strict as-needed basis. Every time the door is opened it will take several minutes for the temperature and humidity to stabilize. A difference of 1° C can cause culture growth to slow or stop, which affects the clinical results.

In all incubators, a temperature sensor compares the temperature inside the chamber to a set temperature on the front panel. If the temperature is too low, the heat will come on to warm the chamber. The fan may come on with the heat or operate continuously.

Incubators can vary greatly in size ranging anywhere from 2' to 6' tall and 1.5' to 5' wide. They generally have stainless steel interiors/exterior and hinged glass doors. They include controls and displays of the chamber temperature, as well as temperature fail safes to protect the contents in the unlikely event of a temperature change. Incubators have various numbers of shelves and are equipped with fluorescent lamps.

3.8.2 Common Problems

There generally are one or more lights in the incubator not only for visibility but to promote the growth in the cultures. If the light needs to be replaced you must use an exact replacement and not just one that fits. The emitted light spectrum is very important for the proper functioning of the incubator.

Filters on the air system have to be cleaned on a regular basis. It is not a good idea to remove and clean the filter while cultures are in the incubator. Also any moisture traps should be cleaned at the same time.

The most common problems with an incubator are the fan, the heating element and the controller. The controller cannot generally be repaired if broken. The fan is a motor and is subject to all of the problems and repairs described in the centrifuge section of the book. The heating element is generally a nicrome wire which can be removed and replaced with a new wire in the developing world.

The only critical testing that you can do without the help of the technician is the measurement of temperature. The incubator should maintain a constant temperature, typically to within one degree Celsius. You can also check that the over-temperature alarm works at the correct setting and that all dials read correctly. More detailed testing should be conducted in cooperation with the technician using the incubator.

After assuring that the incubator is properly working, it may be necessary to disinfect the unit. Discuss this with the technician. The disinfection procedure begins by removing the porous material from the incubator. This includes the filters and fabrics, including the bedding. Place a bowl with 250 ml of formaldehyde solution (formalin) in the incubator. Turn on the incubator to 20°C and leave it to heat, with the fan circulating, for at least 1.5 hours. After this time, replace the bowl with 200 g/l of ammonia solution for another 1.5 hours. (The ammonia functions to remove the smell of formalin.) When time is up remove the ammonia solution and wipe out the machine. (If after cleaning there is still some residual smell of formalin, leave the incubator running until the smell has disappeared.)

3.9 Water Purifiers

3.9.1 Use and Principles of Operation

In the hospital setting it is crucial to have pure water. In many cases, the success of the laboratory depends on the quality of the water available. In the intensive care, much of the medicine delivered to patients may be mixed with water or water and salt before delivery. Even the washing of patients and the preparation of food may require water which has been purified at the hospital to some level in the developing world.

Purification is a general term used to describe the process of removing impurities from water. It can range from simple filtration to complicated multistage processing, the complexity depending on the source of the water and its eventual use. The impurities to be removed can range from parasites, bacteria, and viruses to organic compounds and ions, roughly in order of the size and difficulty of the problem. As varied as are the uses of water in a hospital, so are the requirements for the purity of water needed. Requirements can range from essentially zero tolerable contamination (for parasites) to relative indifference (for ions). Likewise, the cost of purification can range from just a few pennies a gallon to far more.

Some components are found in every purification system no matter what method of purification is being used. These components include the inlet, outlet, vent, filter, and drains. The inlet is simply where the water enters the system and the process of cleaning begins. The drains allow excess impurities to be stored or disposed of. Vents allow gas, mostly air, to exit the system. Finally, once the water has been filtered, it leaves the system through the outlet.

There are at least eight common methods of purification in developing world hospitals: 1) Distillation, 2) Ion Exchange, 3) Carbon Adsorption, 4) Filtration, 5) Ultrafiltration, 6) Reverse Osmosis, 7) Electrodeionization and 8) Ultraviolet (UV) Radiation.

Distillation

Distillation is the oldest method of water purification. The process involves heating water in a still to its boiling point and condensing the resulting steam to water again. The removal of the contaminants depends on how well the still is designed. If boiling is too vigorous, "bumping" can take place, where liquid water shoots out of the boiler directly into the condenser. Any organic compounds with boiling points lower than 100 °C cannot be removed. In fact, they can become concentrated in the process.



Stills do not need to be sophisticated. Here, a simple pot is held over a fire and covered by a large bowl of water. Three rocks hold the pot in place. The long tube allows for condensation. The condensate falls into the collection vessel in the bottom right corner.

Distillation is a robust and simple technique that has the advantage of removing a broad range of contaminants. Unfortunately, it requires careful maintenance to insure purity. Also, distillation consumes a large amount of energy and water, neither of which are in great supply in the developing world.

Ion Exchange

Ion-exchange purification is a rapid and reversible process in which impurity ions present in the water are replaced by ions released by an ion-exchange resin beads. The impurity ions are taken up by the beads, which are then periodically regenerated. The two most common ion-exchange methods are softening and deionization.

Softening is used primarily as a pretreatment method to reduce water hardness prior to reverse osmosis processing. The softeners contain beads that exchange two sodium ions for every calcium or magnesium ion removed from the "softened" water.

Deionization beads exchange either hydrogen ions for cations or hydroxyl ions for anions. The cation exchange resins will exchange a hydrogen ion for any cations they encounter. Similarly, the anion exchange resins will exchange a hydroxyl ion for any anions they encounter. The hydrogen ion from the cation exchanger unites with the hydroxyl ion of the anion exchanger to form pure water. The resin containing the charged contaminants must then be regenerated once it has exchanged all its hydrogen and/or hydroxyl ions in the water, the impurities being shunted to the drain.

Deionization removes some dissolved inorganics and most ions. It requires a relatively inexpensive initial capital investment. However, it cannot be used to remove particles, pyrogens or bacteria. In fact, deionization beds can release resin particles into the water and serve as a culture medium for bacteria growth.

Carbon Adsorption

As mentioned above, ion-exchange resins remove soluble anions and cations from raw water, but some nonionic, organic molecules can coat the resin. Such a coating will decrease the life of the resin and diminish its capacity. To remove nonionic, organic molecules and protect the ion-exchange resin, carbon filters are often placed upstream (before the ion-exchange filter).

In addition to nonionic, organic molecules, carbon also removes free chlorine and protects other purification media in the system that may be sensitive to oxidants.

The adsorption process in a carbon filter is controlled by the diameter of the pores in the carbon filter and by the diffusion rate of organic molecules through the pores. The rate of adsorption is a function of the molecular weight and the molecular size of the organics.

Carbon filters remove dissolved organics and chlorine effectively and have relatively long life. However, they can release carbon particles into the water.

Filtration

Filtration removes particles from the water based on their size. There are three types of microporous filtration approaches: 1) depth, 2) screen, and 3) surface. Each approach serves a different purpose.

Depth filters are matted fibers or materials compressed to form a matrix that retains particles by random adsorption or entrapment. Depth filters are usually used as prefilters because they are

economical and can remove nearly all (perhaps 98%) of the suspended solids, protecting downstream elements from fouling or clogging.

Screen filters are single layer, uniform structures which retain all particles larger than a precisely controlled pore size. The particles are retained on one surface of the screen filter.

Surface filters are made from multiple layers of media. When fluid passes through the filter, particles larger than the specified size are retained, accumulating primarily on the surface of the filter. Surface filters are very efficient, removing almost all of the suspended solids (perhaps 99.99%). Surface filters may be used as either prefilters or clarifying filters.

Since the pore size can be specified below the size of bacteria and parasites, surface filters can be used as a partial sterilization process. Filtration requires almost no maintenance, but filters must be replaced occasionally because the flow rate drops as the retained particles clog the filter. Filtration will not remove dissolved inorganics, pyrogens, colloids or viruses. They can be expensive to replace and cannot be reused.

Ultrafiltration

Ultrafiltration is a process like screen filtration but pore sizes lie in the range 0.001-0.02 μm (100 to 10 times smaller than typical screen or surface filters). Most of the ultrafiltration membranes used in water purification have a hollow fiber configuration, and are non-biodegradable.

Ultrafilters are capable of removing 1) particulates, 2) micro-organisms, including all parasites and bacteria and some viruses, 3) inorganic colloids and 4) large organic molecules including pyrogens. Smaller molecules, such as solvents and ionized contaminants pass through the filtrate. Ultrafilters can be used either for pre-treatment or 'polishing' duties in water purification systems.

Ultrafiltration produces the highest quality of water for the least amount of energy and it can be regenerated. However, it will not remove dissolved inorganics, such as calcium, sodium and chloride.

Reverse Osmosis

Reverse osmosis is the most economical method of removing 90% to 99% of all contaminants. Reverse osmosis is a process like filtration and ultrafiltration, but the pore structure of reverse osmosis membranes is even finer than ultrafiltration. Reverse osmosis membranes are capable of rejecting 1) practically all particles, 2) bacteria, 3) viruses, and 4) any organics greater than 300 Daltons in molecular weight.

In order to understand the process of reverse osmosis, it is helpful to understand the process of osmosis in general. Osmosis occurs when solutions with two different concentrations are separated by a semi-permeable membrane. Osmotic pressure drives pure water to dilute the more concentrated solution. The pressure exists until enough water flows that the two solutions are equally concentrated. In water purification systems, the process is driven in reverse. Hydraulic pressure is applied to the concentrated solution to oppose the osmotic pressure. Pure water is driven from the concentrated solution and collected on the other side of the membrane.

Reverse osmosis rejects nearly all of the strongly ionized ions and most of the weakly ionized ions like sodium. Reverse osmosis membranes are very restrictive and therefore yield very slow flow rates so storage tanks are required to produce an adequate volume in a reasonable amount of time. Reverse osmosis can be the most economical and efficient method for purifying tap water.

Electrodeionization

This new technology is a combination of electrodialysis and ion exchange. The process consists of a number of "cells" sandwiched between two electrodes. Each cell consists of a polypropylene frame onto which are bonded a cation-permeable membrane on one side, and an anion-permeable membrane on the other. The space in the center of the cell, between the ion-selective membranes, is filled with a thin bed of ion exchange resins. The cells are separated from one another by a screen separator.

The source water entering the module is split into three parts. A small percentage flows over the electrodes, 65-75% of the source water passes through the resin beds in the cell, and the remainder passes along the screen separator between the cells. The ion-exchange resins capture dissolved ions in the source water at the top of the cell. The potential on the electrodes pulls the ions out of the resin beds. The ions travel towards the electrodes until they reach the adjacent ion-selective membrane, which is of the opposite charge. The ions remain in the space between the cells until they are flushed out of the system to the drain.

Electrodeionization effectively deionizes water. The ion exchange resins are continuously regenerated by the electric current in the unit increasing the time between maintenance calls for the purifier. The result is a deionization approach that is relatively inexpensive to operate. However, electrodeionization requires prefiltration to prevent clogging of the cells.

Ultraviolet (UV) Radiation

Ultraviolet radiation is beginning to be a widely used method for the sterilization of water in the developing world. In most systems, mercury, low-pressure lamps generate 254 nm of ultraviolet light. Exposure to intense UV light of this wavelength destroys the DNA and other proteins in the bacteria, parasites and viruses, rendering the water sterile.

Some lamps generate both 185 nm and 254 nm UV light. This combination of wavelengths is capable of photo-oxidation of additional organic compounds.

The UV technique can kill micro-organisms and, in some cases, photo-oxidize organic compounds into smaller fragments. However, the organisms are not removed from the water. Therefore, particles or clumps of microorganisms can cause shadowing, which may affect the efficiency of disinfection by the ultra-violet light. Water with significant amounts of color and organic compounds will also reduce the intensity of the light and therefore its efficiency.

3.9.2 Common Problems

Water purifiers can be complicated, multi-stage machines. In many cases you will not be able to affect a repair without specialized tools. However, there are a few common problems which can be diagnosed and repaired in the field.

One of the most common problems is clogged filters, typically indicated by a low flow rate. Some filters can be cleaned by backflushing them (running water from the following stage through them backwards – discarding the results). Don't use upstream water for this purpose. However, if possible, the filters should be replaced.

Leaks are also common. Check all tubing, glass, and reservoirs for cracks or leaks. If the leak is in the inlet to the systems, it can be repaired with epoxy or a silicone sealant. Once the water enters the system, the solvents from glues and adhesives can contaminate the water. Replace the tubing or component rather than repairing it.

When the deionizer fails, the electrical conductivity of the water will increase. When this happens, check the resin bed and see if the beads need to be replaced or regenerated.

Older systems can accumulate deposits which are not being removed in the drains. If deposits are found, scrape them from the system and flush those components with the purest water available.

3.9.3 Suggested Testing

Most users will not know how to determine if the water purifier is working. Furthermore, unlike other clinical laboratory equipment, there is not typically one person using the water. Therefore, the burden is upon the engineer to test the water purifier. Unfortunately, in the developing world, the necessary testing equipment may be unavailable, leaving the engineer few options.

If flow rate was the reason for the initial call, then this can be easily checked with a measuring cup or graduated cylinder and a watch. However, after any work, the purifier should be checked for the purity of the water exiting the system. This can be done by measuring the protein content in a spectrophotometer and the ion content by measuring the conductivity. Sterility can be insured by culturing. However, all or some of these measurements may not be possible in a developing world hospital. Despite the fact that this testing should be performed by the engineer, you may have no choice but to resort to a discussion with the laboratory personnel as your best alternative to testing. They should be able to indicate what the problem was that initiated the call for repair in the first place, and therefore, they should be able to determine if the problem has been fixed.

3.10 Clinical Laboratory Ovens

3.10.1 Use and Principles of Operation

Ovens in laboratories are used to dry samples and for evaporating, dehydrating or sterilizing. On a limited basis some are used as a dry incubator. In many cases, precise temperature control is required.

Clinical ovens may be bench, cabinet, or walk-in size. However, bench top are the most common in the developing world. All ovens will include a heat source, a well insulated container (usually including a door with tight sealing gaskets), and a thermostat/thermometer. More advanced ovens may include timers/alarms, fans to circulate air inside the oven to achieve uniform heating, shelving units or racks, humidity control options, or air filtration. The heating mechanism may be electric, natural gas, propane, oil, radiofrequency or microwave, but the electric heater is the most common in the developing world.

Operation is simple. Place the sample in the oven (or empty it if you are testing it). Shut the door. Set the desired temperature. The oven may have a timing feature or timing may have to be completed manually. After the heating cycle, allow the oven to cool before opening it.

If the oven is being used for sterilization, the following table should be used. Sterilization timing should not begin until the oven has reached the required temperature.

Temperature (°C)	Time (min)
160	180
170	120
180	30

3.10.2 Common Problems

The power supply and heating element are the most likely sources of problems. The electrical heating element is of a typical construction and material and can probably be replaced in the developing world, as long as the resistance and max power (nichrome wire) are matched.

If the oven is not reaching the desired temperature, you should suspect the door gasket, fan or sensing device. If the door gasket does not seal air tight, try cleaning the seal with soap and water. Rinse well before testing again. It may be possible to find a material to seal an oven door in the developing world, if the seal must be replaced.

If there is a fan, and it is not turning, and the problem is not the power supply, the fan motor can be replaced with any motor of a similar size (see the centrifuge and motor chapter for more suggestions).

The temperature sensing device may be part of the temperature feedback mechanism. An exact match is often necessary. You may be able to defeat the temperature sensor with a short circuit or open circuit, leaving the oven in the on position at all times. The user would be required to carefully monitor the temperature. Install a switch in the main power line so that they can cycle the heater as needed. This is clearly not an ideal solution, but is better than having no oven at all.

If the oven is reaching the desired temperature and holding that temperature, then the device is working. In some cases, the user may complain about highly non-uniform heating. In many cases, this will be caused by a broken fan. In this case, attempt to measure the temperature in several parts of the chamber. Discuss the degree of uniformity required to satisfy the user's needs. In the developing world, they may have to survive with little uniformity, but at least a functioning oven.

Temperature accuracy varies tremendously with the oven's application. Larger error can be acceptable if the oven is used for drying glass, but accuracy may be crucial if biological fluids are being warmed in the oven. The same is true with the fan. An operating fan may not be critical depending on the oven's use. Discuss these issues with the user before returning the oven.

4 Related Topics

4.1 Electrical Safety

Electrical safety testing is one of the most common procedures done by a biomedical engineer in a hospital. Every patient related device must be tested for electrical safety before it is initially put into use. All electrical/electronic devices have a current leakage ranging from a few micro amps to 500 mA. Various agencies have set current limits for electrical leakage currents in medical devices. Not all agencies have the same limits. The National Fire Protection Agency, NFPA, AAMI, (Association for the Advancement of Medical Instrumentation), or IEC/ISO, (International Electrical Commission) are some of the many agencies setting safe current limits for electrically operated medical devices.

In the late 1960's there were several publications stating that up to 10,000 people per year were electrocuted in hospitals because of defective electronic equipment that was applied to patients. In various studies it has been shown that as little as 30 micro amps applied directly to a portion of the heart during a critical part of the cardiac cycle can cause an arrhythmia, an abnormal beat. If this abnormal beat triggers additional abnormal beats a potential for a lethal arrhythmia is present.

The most common solution for leakage currents in devices after about 1970 is to isolate the patient from the device. This was done by using isolation transformers, light emitting diodes or electromagnetic links between the patient connections and the device.

Without a safety analyzer, it is not possible to do a complete safety test. Nevertheless, a reasonable substitute for the most common danger is described in the chapter on ECG's. This section describes which other devices should be considered for safety testing.

Equipment found throughout the hospital or clinic that is not directly connected to patients includes both medical and non-medical devices. In general, these devices do not need to be tested at all or should only be tested once.

Devices which are not patient connected, but are in the vicinity of the patient (x-ray equipment, for example) should be ground tested after every major repair. One technique that is commonly used is to select one ground point in the area and measure the resistance to ground of all exposed surfaces to that point. The problem with this method is that one lead wire may have to be as long as 20 feet to reach all surfaces in that area. A variation of this technique is to select a

point, such as the x-ray table as the ground and measure everything in the “patient vicinity” to that ground point. With either technique the ground resistance should not exceed 0.5 ohms. A key point to remember in performing this type of ground resistance testing is to select your starting point and document it so that the test can be repeated. A small dab of nail polish next to the ground point is one method of documenting the ground point location.

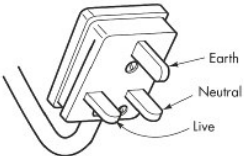
Patient connected devices used for diagnostic purposes amplify and process signals detected in the body by electrodes. The signals travel over the lead wires and patient cables to the device where they are amplified, processed and displayed. The key point is that it detects a signal and has wires between the patient and the device. This category of equipment contains such devices as EKG, EEG, EMG recorders and patient monitors. For all of these devices, testing should be completed after every repair as described in the section on ECG’s.

Patient connected devices used for therapeutic purposes deliver energy, fluids or gases to a patient. The delivery can last for a few milliseconds, as with a defibrillator, to years for a ventilator or IV pump. In the case of an IV pump the fluids are contained in a non-conductive plastic so any electrical contact requires that there be a hole in the tubing. On ventilators the tubing is non-conductive, as are most of the gas mixtures that would be administered. Because energy is delivered to the patient it is not required to test the lead isolation while the unit is delivering that energy. In fact, testing the device while it is in operation could be dangerous. The same testing procedures as that described in the ECG chapter is performed after every repair, but leakage is only tested with the device plugged in and the power off.

4.1.1 Electrical Outlets

The primary source of electrical danger is the power outlet itself. These should be tested once per year. However, in the developing world, many of the outlets are wired incorrectly. Therefore, as with other work, this effort has to be prioritized against repairing broken equipment.

United Kingdom



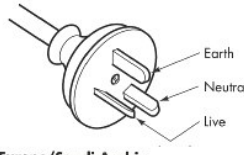
Green/Yellow

Light Blue

Brown

13 Amp/250 V ac

Australia/New Zealand



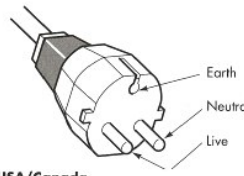
Green/Yellow

Light Blue or Black

Light Brown or Red

15 Amp/250 V ac

Europe/Saudi Arabia



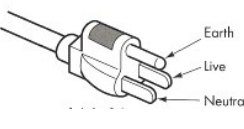
Green/Yellow

Light Blue

Brown

16 Amp/250 V ac

USA/Canada



Green/Yellow or Green

Brown or Black

Light Blue or White

15 Amp/125 V ac

Almost all developing world countries follow one of the standards to the left. In many cases, the outlets will be wired incorrectly. The voltages may not match the voltages given here, or the intended voltages. Often the power fluctuates (often including periods of zero volts). There are many variations in these plugs.

Incorrectly wired outlets are a danger. Each outlet has only one wire carrying power (called hot or live). The other is neutral and the third is ground (or earth). The fuse for a piece of equipment is placed between the power source and the load in the one "hot" line. If the electrical outlet is wired backwards, then the fuse is in the neutral wire, not the power line. Should the device find an alternative path to return current to ground, then the power line will not be fused. This type of fault can be deadly to the attendant or the patient.

The wiring of the outlet can be tested with a two-pin neon bulb tester available at any hardware store. Inserting the pins in the right and left spade jacks (of a US plug, or the two round pins of a European plug) will illuminate the lamp. Note the voltage registered on the lamp. In some hospitals in the developing world, plugs used for the 120V standard will be wired for 220V and vice versa. Be sure to mark the voltage on the wall next to the outlet if you find an outlet mismatched to the standard.

Inserting one pin into the large spade jack (of the US standard plug) and touching the other pin to any grounded surface to be tested should not light the lamp. Only the small spade jack is "hot," and should light the lamp against ground. This simple preliminary test is true for all three-wire wall outlets and most European two-wire outlets, with the exception of those which are wired through an isolation transformer.

Isolation transformers have their primary windings connected to the main power line but the secondary windings are not connected to any system ground. They are rarely used in the developing world, but are required in some parts of US hospitals. When an isolation transformer is used, the neon bulb tester will light only between the two spade plugs and not against ground for either plug.

The use of such a neon bulb polarity tester indicates the voltage, but not the quality of the wiring. A lamp with a high-wattage incandescent bulb from 60 to 100 watts (W) connected between the plugs or between the small spade plug and ground should light. This is usually an adequate test of the quality of the wiring.

4.1.2 60 Hz versus 50 Hz

It is common for an engineer to encounter a device designed for 60 Hz that was donated years before. If the power system in the hospital runs at 50 Hz, the engineer is faced with the question: Is it still safe to use that device? Will it work at all? The answer is ... it depends.

It is also common that the power system will be at 220V when the device is designed for 110V. However, a transformer can be used to adapt the voltage. This still leaves the question of frequency unaddressed.

Devices Without a Motor

If the medical device does not have a motor in it, then the only concern is the power supply. After about 1980, most medical equipment was designed with switching power supplies. These supplies can handle either 50 Hz or 60 Hz without the need for conversion. You can usually tell these supplies because they will be labeled 50/60 Hz.

If the medical equipment is older, then the power supply may be of a traditional design. Some of these machines will use multi-tap transformers. If this is the case, then there should be a switch or jumper on the primary side of the transformer (the side where the power comes in) that can be moved to adapt the equipment. Occasionally, the jumper will be on the secondary side (where the power goes to the electronics in the equipment).

If the transformer is not of the multi-tap variety, then there is no certain way to tell if the equipment will work when switching between frequencies. Switching from 60 Hz to 50 Hz will cause about 17% more current to flow through the primary side of the transformer (because the impedance will have been reduced from $2\pi 60L$ to $2\pi 50L$, where L is in inductance of the transformer). This additional current will cause the transformer primary to heat up more than originally anticipated. Therefore, if the transformer is not of the multi-tap variety, it will typically be sufficient to account for any voltage difference, and then to provide more cooling to the device (an extra heat sink, more cooling vents, leaving the cover off, etc.).

Devices With a Motor

If the device uses only a small motor or runs on batteries most of the time, then the motor is probably a DC motor. These motors are typically the size of one's thumb or smaller. Small, DC motors are voltage sensitive only, and are, therefore, unaffected by the frequency change.

If the device uses a larger motor, the size of a fist or larger, then the motor is probably an AC motor and it is made for a specific frequency. Switching frequencies will have several effects. First, when switching from 60 Hz to 50 Hz, the motor will run slower; at 5/6 of the original rpm. Likewise, when switching from 50 to 60 Hz, the motor will run too fast; 6/5 of the desired rpm. Second, when going from 60 Hz to 50 Hz, the current increases by 17% in the windings. This causes additional heating which is compounded by the fact that the drop in rpm's will decrease the mechanical cooling. Going from 50 Hz to 60 Hz does not cause such heating problems. Finally, depending on the type of motor, the horsepower or the torque may be affected by a change in frequency. All of these changes can affect the operation of a medical device.

The increase or decrease in speed can not be corrected. If this change is critical to the operation of the device, then it must be abandoned.

When running a 60Hz motor at 50Hz, the biggest concern is the second problem: heat buildup. To avoid destroying the motor, the engineer could provide additional cooling (leaving the top off, increasing the fan size, etc.). Another way to avoid heat buildup is to use a transformer to reduce the voltage into the windings by 17%, reducing the current back to its original value. However, reducing the voltage may reduce the available power.

The most challenging problem is the third problem: the change in horsepower or torque. Horsepower is a function of frequency and torque $P = \tau N$, where P is the power from the motor, τ is the torque, and N is the rpm of the motor. The frequency is inversely proportional to the torque. So, as the frequency goes from 60 Hz to 50 Hz, the torque goes up, increasing the power output of the motor. When going from 50 Hz to 60 Hz, the torque drops, dropping the power out.

Most motors found in medical equipment have varying torque and horsepower. Machines that fall into this category include fans, blowers, centrifugal pumps, mixers and agitators. When going from 60Hz to 50Hz, the power output of the motor increases and since the motor is required to deliver more output at faster speeds, torque and horsepower increase. In addition to

the risk of increased heating, already mentioned, the increased torque strains the motor and accelerates the rate of burn out.

Conversely, when running a 50Hz motor at 60Hz, the primary concern is the decrease in available torque. If the available torque falls below what is necessary to start the motor, it could fail to start and burn out.

General Guidelines

It may be impossible to predict the precise outcome of changing the frequency of operation of a medical device. However, the discussion above can be used to sort medical equipment into a few categories.

Electrical Medical devices without Transformers

Examples: infant warmers, autoclaves, incubators, clinical ovens

Some older medical devices do not use any electronics and may not have any transformers. In general these devices are not sensitive to frequency and can be used once the voltage has been adapted.

Electronic Medical devices With Transformers but Without Motors

Examples: electrocardiographs, invasive blood pressure machines, pulse oximeters, defibrillators, fetal monitors, fetal Doppler, balances, lights (all types), electrosurgery units,

For these devices, first check to see if it is marked 50/60Hz compatible. If it is, then use the device without modification. If it is not rated for both frequencies, check to see if the transformer is multi-tap. If it is, change the wiring to use the correct tap. If the transformer is not multi-tap, then attempt to run the device with the cover off and check the temperature frequently. If the transformer is not heating up excessively, then use the device as is. If it is heating up, provide extra cooling.

Medical Devices with Pumps

Examples: Suction, anesthesia machines, water purifiers.

When switching from 60 Hz to 50 Hz, devices with pumps will most likely overheat. If the heat cannot be dissipated, the motor will burn out. Attempting to provide additional cooling may prolong the life of the device. When switching from 50 Hz to 60 Hz, attempt to use the device with caution. If the device does not start, the motor will quickly burn out. If the device consistently starts, then it should be possible to use the device without a problem.

Motorized devices without Pumps,

Examples: centrifuges, microtomes, water baths,

These devices will operate at different speeds when switching between frequencies. The change in frequency may alter the clinical utility of the device. Be sure to discuss this with the staff before adapting the voltage for use. In addition, when switching from 60Hz to 50Hz, the devices will most likely overheat. If the heat cannot be dissipated, the motor will burn out. Attempting to provide additional cooling may prolong the life of the device.

4.2 Troubleshooting Medical Equipment

Troubleshooting medical equipment requires patience, persistence and a willingness to ask a lot of questions. The most common error in troubleshooting is to rush down the wrong path, perhaps because of a misunderstanding or misdirection from the staff. A willingness to sit back and take a fresh look at the problem is essential. A structured approach helps avoid the most common errors. This section presents one possible structured approach to troubleshooting.

Before You Start

Consider safety first. Know the hazards that are associated with the device be it electrical, mechanical, chemical, gas or bacterial. As a minimum, refamiliarize yourself with the equipment's principles of operation and clinical use, as described in this book. If you are unsure about a hazard, consult someone else before beginning.

User error accounts for a large fraction of the broken equipment in the developing world, according to a recent report by Engineering World Health. Make sure you know how the device should work before you begin. If you can find the manual, read it.

Here are seven steps that you should follow, once you are convinced that you are ready to proceed.

No matter what the problem, begin by assessing the piece of equipment. It is absolutely essential that you not skip the assessment steps. Hours of your time can be spent repairing a problem which never existed in the first place. EWH reports that most of the problems you will encounter are related to user error. Another quarter are related to power supply issues. You should always consider these two possibilities before all else. Of the remaining problems, the most likely to be solved are those related to the presence or absence of the proper inputs and outputs. In other words, the problem is related to some other piece of equipment, which itself has either a user error or power supply problem.

Look at the device

If at all possible, remove the equipment from the patient floor to a quiet, clean bench where you can work without interruption. Look at the device and all the information that may be around it. Are there any notes from the users? Is there a description of the problem or is it just labeled "broken"? Is there a name of the person who found the problem? Is there an error log on the device? Is there evidence of a drop, spill, smoke, heat or other damage?

If there is evidence of a spill it must be considered hazardous and cleaned by someone trained to handle hazardous spills. Spills, even non-hazardous ones are usually conductive and can cause shorts in the device circuitry. Some solutions are very thick and can act as glue that will overload motors on a pump. Always follow the Universal Precaution Procedures against infectious agents.

Next look at any connectors, power cords, input or output cables to be sure that they are in the correct positions and secure. Check the positions of all switches and controls to be sure that they are correctly positioned and working. Before moving any switch or cable, take a digital photo of the control panel. That way you will be able to go back to the device's original settings.

Assuming that there are no signs of mechanical damage to the device, do a "self-test" or "calibration" on the device. This may also give you the "error log" on the device, which must be reviewed and problems noted.

Look at the manual (if you can find it), the device history (if it exists), and the service manual (if you can find it) to be sure that you have covered what needs to be done to operate the device properly and to determine if the problem has occurred in the past. If it is a repeat problem, try to determine how it was repaired before. If you can get the service manual, review it briefly to see if there is a system test or additional self tests that might help.

Listen to the User

Interview the user. In most cases, the user is not the person who gave you the equipment. So, ask questions until you find the user of the device. You want to talk directly to the user of the device. Many problems arise from misunderstanding between the user and the person who gave you the equipment.

Carefully listen to the user's complaint about device. Find out what they see as the problem as. What has changed with the outputs or process? Is it still within normal ranges or not? Has the speed of the process changed? Has the use of consumables increased?

It is common for a user or an operator to not know all the functions of a device. To avoid looking foolish they will give bad answers to questions outside of their knowledge. Also, it is common for a user to not tell you a piece of information which is critical to diagnosing the problem. The opposite is also true. Sometimes the user says they know exactly what the problem is, when in fact they are merely guessing. You must act as a detective, listening to everything, but rejecting and accepting facts as you piece together a hypothesis concerning the problem with the equipment.

Suspect User Error

Always suspect user error. If you have followed the first steps, then you have not, as yet, opened the device. Verify again that the device is, in fact, malfunctioning. Nearly half of the time, the device is operating correctly; the person is simply using it incorrectly. Follow the recommended testing described here.

If the device is operating as you expect, then the problem is user error. But what type? Attempt to determine if the problem is language, incorrect programming or settings or a misunderstanding of what the equipment is capable of doing.

If the problem is a misunderstanding of the equipment's abilities, perhaps you can suggest an alternative. If the problem is programming, or settings, see if you can permanently program or fix the devices function. Consider taping over switches or labeling the correct setting.

If the problem requires a sequence of steps to resolve; or it is a language problem. Consider creating a "cheat sheet" that can be attached to the machine. This is a simple explanation of the device's operation (or the specific operation that is causing the problem). Write short, direct sentences that describe how to accomplish the task. These should be accompanied by drawings wherever possible. A digital camera and the internet café can be used to create a sequence of "how-to" photos. Often the photos tell the story better than the words. The cheat sheet must be written in the local language. Be sure to try out the sheet with the nurse or doctor before attaching it to the device. Have them attempt the operation using the sheet – and without your intervention. If you have to say anything while they attempt the operation, then the cheat sheet

needs revision. You cannot rely on the fact that this particular nurse or doctor will always be at the hospital to train the rest of the staff. Nurses leave and doctors are often too busy to return to a piece of equipment.

Suspect Power Supply

You may feel that you are ready to open the device. There is one more area to test, before opening the device: the power supply.

Does the device power up at all? The signs that a device is powered up include indicator lamps, the screen is lit, hearing a fan or motor running (though not always, they may have a separate supply), pressure/flow indicators not on zero, a warming of the device. On pneumatic, hydraulic or vacuum powered units do you hear or see leaks?

First, check for the obvious. Is it plugged in, (both ends of the power cord)? Is the outlet "live"? Is the power cord good (try another one)? Is there a second power switch on the unit? Is the fuse good (less than one ohm)? Is the breaker open (push the reset). Are the batteries of the proper type, installed correctly and charged?

On some devices there is a voltage compensation switch. Check that to be sure it is in the correct setting (110 or 220 V). Also some devices have a 50/60 Hertz switch that needs to be in the correct setting (see the separate section on frequency adjustments).

After checking the obvious, recheck the device. If it still won't power up, or it powers up, but won't operate correctly, you will need to remove the covers.

Now that the cover is off, be very careful. In most modern equipment there is more than one power supply in an instrument. There are often ± 5 , ± 12 or 15 volt power supplies for the logic circuits, 60 to 120 volts for motors and certain displays, plus high voltage power supplies, up to 150,000 KV. You will need to check each of them to see if they are producing the expected voltages.

Never work alone on a device with the cover off and the power on. Double check that you are wearing no jewelry. Latex or rubber gloves offer some protection from high voltages. Place your probe leads with care to avoid shorting out two lines. Proceed slowly.

Once the cover is off, carefully look for dust buildup over fans or vent holes, fluid spills, loose hardware, or worse, floating hardware cleaning and correcting as you proceed. Make sure all the chassis components are secure. Look for signs of heat, smoke or burned components.

Look at any fluids carefully. In very old equipment, if they are oil based it may be an indication that a capacitor or transformer is leaking or failed. Generally if this has happened there will also be signs of heat damage around the failed component.

Next, move on to the circuit boards. Are they properly seated? Is there dust or spills on them? Are there signs of heat buildup? Are the components secure on the boards? Correct problems as you find them. You might look over the solder connections on the boards to be sure that there are no "cold" joints from previous repairs. You might also want to clean the connectors with a pencil eraser (the white kind is best). Take note of any prior repairs: They are clues to current problems.

Power Supply or User Error some where Else

If you have ruled out user error and power supply, and the problem is not one of the common errors listed in this manual, then there are only two other categories of error that are worth your time investigating: input and output errors.

Input errors can cause an otherwise operating device to appear to have failed. Find out where the input comes from? Is it a cable, electrode, probe, tissue sample, liquid sample? What, if anything, has changed on the input? If the device tests blood or tissue samples are they properly prepared? Are the samples being presented correctly?

If the device works on your bench, but not on the patient, there still may be a device problem, but more likely it is an input problem. As dumb as it may seem, is the patient alive? Has the patient's condition changed? Is there more movement, (shaking, shivering, thrashing around in the bed)? Did an electrode or other sensor fall off? Are the lead wires and cable good?

The output of a device is its final product. In many cases it is a delivered energy, a graph or a display. In some cases it may be more than one. If the device appears to be working, but the display is faulty, try to do everything you can to devise an alternative display. Working equipment in the developing world is too precious to abandon due to display errors.

In older equipment, you can sometimes find a voltage which is proportional to the desired output. If this is the case, consider displaying this voltage on a multimeter and giving the user a table to convert from volts to the desired units. Perhaps a display from another device, perhaps even an unrelated device, can be used. Perhaps the user can live with less resolution or precision, making a substitute display possible. Be as creative as possible before abandoning the device due to display errors.

4.3 Recommended Minimum Tool Sets

If you are about to leave for a trip to the developing world to work on medical equipment, unless you know otherwise, you must assume that the hospital you are going to will have no tools for you to use. In fact, there may be a handful of scattered tools of low quality. However, you should not depend on these to accomplish the work you will want to see done.

Recent changes in the security regulations in airports have forced engineers to carry their tools in checked luggage instead of carry-on luggage. The only significant problem this imposes is the increased likelihood that your tools won't arrive when you do. Fortunately, you can often purchase adequate tools in the developing world. However, the prices will be no less than those that you pay at home. You can also buy inferior tools at lower prices in most of the larger developing world cities.

As a minimum tool set, you should plan on bringing the following: electrical tape, super glue, epoxy (30-minute, two part), sandpaper (1 sheet, med), black marker, scissors (shears), batteries (4-AA, 1-9v), knife, hex wrench set (Allen wrenches), crescent wrench, tape measure, multi-meter, small tube or roll of solder, a solder sucker and/or desoldering wick, a soldering iron, wire cutters, wire strippers, screwdrivers (#1 and #2 phillips and small, medium flat head), jewel screwdrivers, needle nose pliers, a working flashlight, balloons (to test air volumes), small plastic cup measure, latex gloves, and outlet adapters for your target country.

If you have the room, consider adding the following tools to your bag: WD-40 (small can), Ziploc bags (10 to hold parts while you work), batteries (4-AAA), fuses (250 v, 0.5, 1.0 and 1.5 a glass tube type), AC outlet analyzer/tester (to quickly test for 110 or 220 v), AC-to-DC universal adapter, extension cords, hemostats and forceps (small clamps and tweezers), and wire crimp/fasteners.

4.4 Definitions of Some Common Medical Equipment

It is relatively easy to find definitions of medical equipment and terminology on-line. Many of the on-line dictionaries are sufficient, e.g. www.websters.com. There are also many on-line biomedical engineering bibliographies, e.g., www.msdistributors.com/biomed/meh/index.htm and som.finders.edu.au/FUSA/BME/FBEHomePage.htm. However, you may find what you need by just looking up the piece of equipment on Google. This section only covers the most commonly found pieces of equipment.

Anesthesia machine or Boyle's Machine - Sometimes referred to as the anesthetic trolley (boyle's machine or gas machine), this normally refers to a trolley on which are mounted gas cylinders and/or pipelines for various gases used in anesthesia, together with the various valves, controls and ancillary equipment used by the anesthetist. The trolley usually includes some basic monitoring such as ECG and pulse ox. On the trolleys, the gases can be dispensed and mixed. These usually include oxygen, nitrous oxide and carbon dioxide, and sometimes medical air, cyclopropane and anesthetic vapors such as halothane, ether, etc.

Autoclave - an apparatus in which special conditions (such as high or low pressure or temperature) can be established for a variety of applications; *especially*: an apparatus (as for sterilizing) using superheated steam under high pressure

Aspirators - an apparatus for producing suction or moving or collecting materials by suction; *especially*: a hollow tubular instrument connected with a partial vacuum and used to remove fluid or tissue or foreign bodies from the body

Analyzer, hematology (cbc, complete blood count) - A device used as a blood cell counter, especially red and white blood cells.

Ambu bag - Part of the ambu resuscitator, the ambu bag is used for providing emergency artificial respiration for resuscitation. The bag remains inflated in its resting state and when squeezed closes the expiratory port and inflates the patient's lungs. When the bag is released it automatically re-inflates with fresh air and the patients expired air passes out to atmosphere via the expiratory valve.

Chemistry Analyzer (electrolytes) - A device used to measure the amount of electrolytes, especially potassium, sodium and chloride in blood.

Bili-light – see light source

Blood gas analyzer - A device used to measure the amount of oxygen and carbon dioxide in the blood.

Bronchoscopes - a tubular illuminated instrument used for inspecting or passing instruments into the bronchi

Blood warmer - During blood transfusion it is desirable to pre-heat the blood to the body temperature. The most common device for this is a temperature-controlled water bath. The temperature of the bath is normally maintained slightly above body temperature to allow for any cooling in the feed tube to the patient. The device consists of a bath with a heating element, a stirrer (usually) to ensure even distribution of temperature, and electronic circuitry to control the temperature and to provide an over-temperature limit in the event of system failure or low water level.

Centrifuge, hematocrit, urine - a machine using centrifugal force for separating substances of different densities, for removing moisture, or for simulating gravitational effects

Compressor, air - A device used to deliver air to another machine at a higher than atmospheric pressure. A device used to fill bottles of gases.

Complete Blood Count (CBC or Coulter Counter) – a hematology analyzer for determining the number of cells of different types in a sample of blood.

Concentrator, oxygen - A device used to deliver oxygen at a higher concentration than atmospheric. May or may not compress the air and deliver it at a higher pressure.

Crash Cart - A trolley used in emergency (patient crash) situations. It contains the most vital supplies and administration equipment needed to treat the most common causes of sudden medical emergencies (crashes). Often used for cardiac arrest. Typical equipment includes a laryngoscope, cardiac monitor and defibrillator.

Cast saw (stryker saw, bone saw) - Hand saws looking very like carpenters' saws are sometimes used for working on large bones. However, there are power saws available which fall into electric and pneumatic types. The electric types usually have a blade which vibrates. The advantage of having a vibrating rather than a rotating blade is that, if the vibrations are small, cutting will only occur in hard materials (e.g. Bone) but will not occur in soft materials. Compressed air powered saws are more common particularly for orthopedic surgery. They often come as a kit consisting of an air-operated motor and foot-operated speed control, and a set of fittings for sawing, drilling, screwing and pinning. They are intended to work from nitrogen or air at 7 bar pressure, which may be provided by pipeline or from cylinders.

Cardiotacograph - This is essentially a device for recording the uterine contractions during labor. However, the term is normally applied to an instrument which also records the fetal heart rate on a beat-to-beat basis to monitor the progress of labor and in particular the well-being of the fetus. Uterine contractions are sometimes monitored using a tocodynamometer lightly strapped on to the mother's abdomen, which consists of a central plunger coupled to a force transducer and outer guard ring so that the plunger is pressed during the uterine contractions. This provides a qualitative indication of the strength and occurrence of contractions and this is compared with the fetal heart rates which result. Sometimes an internal transducer is used once the fetal membranes have been ruptured and a recording catheter can be introduced into the uterus. The recording catheter can be a fluid-filled tube connected to an external pressure transducer or it may have a miniature pressure transducer built into the tip of the catheter.

Cryostat - an apparatus for maintaining a constant low temperature especially below 0°C

Cautery pens - a device used to cauterize, meaning to sear or burn. Pens are connected to electrocautery machines.

Cauterizers (electrosurgery units) - An instrument that applies electric current to destroy tissue. See cautery pens

Dialysis machines - An instrument that removes certain elements from the blood based on the difference in their rate of diffusion through a semi-permeable membrane. See dialyzer.

Defibrillators - an electronic device that applies an electric shock to restore the rhythm of a fibrillating heart

Dialyzer, hemodialysis, peritoneal - Haemodialysers (sometimes called artificial kidneys) take blood from the body and pass it along one side of the dialyzing membrane so that unwanted small molecules may diffuse into a special dialyzing fluid passing along the other side. Small molecules which need not be removed are included in the dialysate so that there is equal diffusion of these molecules in each direction. The peritoneum is a double membrane enveloping most of the organs in the abdomen, and renal dialysis may be achieved by pumping a special dialyzing fluid into the cavity between the two membranes and allowing time for the diffusion to occur before withdrawing it. This technique is called peritoneal dialysis which may be a hospital procedure operated by sets of pumps, valves and timers, or may be used at the patient's home without special apparatus but using a collapsible bag from which the fluid is delivered and then returned after the process is complete.

Diathermy -See cauterizers, electrosurgery units

Doppler, non-fetal, fetal - Information about the motion of blood in the larger vessels may be obtained from the Doppler shifted reflections received by a transducer outside the body. This is most commonly used to assess the quality of flow from an audible signal produced from the Doppler shifted components or by processing of these signals to indicate the flow pattern or flow

rate. Images can also be produced by combining the information derived from these Doppler signals with B-scan images. This is particularly useful since a diseased artery will have turbulent flow. The color display can provide unequivocal evidence of arterial disease and identify the site of any constriction or dilatation. Such techniques are used by vascular surgeons in special clinics and they offer the potential of avoiding dangerous and painful X-ray contrast procedures.

Electrocautery unit, diathermy (ESU) - See cauterizers.

Endoscopes - an instrument for visualizing the interior of a hollow organ (as the rectum or urethra)

EKG or ECG units - A unit that records the moment-to-moment electromotive forces of the heart as projected onto various sites of the body's surface, delineated as a scalar function of time. Major types are 12-lead (primarily diagnostic) and 3-lead (primarily monitoring).

I.V. devices/equipment - Any of the many pieces of equipment used to gain intravenous access.

Gomco – a slang term for aspirator

Glucometer - A device for measuring the amount of glucose in the blood

Gurney & mattress -a bed-like platform which can be used to move a patient within the hospital

Gastroscope - an instrument for viewing the interior of the stomach

Heart Lung Machine – see pump, heart-lung

Hematocrit- an instrument for determining usually by centrifugation the relative amounts of plasma and corpuscles in blood, also refers to the ratio of the volume of packed red blood cells to the volume of whole blood.

Incubator, lab - a clinical laboratory device used to keep specimens and samples warm. Typically used to grow cultures from samples taken from patients. The cultures can then be examined to determine what bacteria are found in the patient.

Incubator, neonatal - an apparatus with a chamber used to provide controlled environmental conditions, especially for the cultivation of microorganisms or the care and protection of premature or sick babies

Laryngoscope - an instrument for examining the interior of the larynx

Light handles for surgery - The sterilizable part of the overhead light in an operating theater. The handle allows the doctor to adjust the light without breaking sterility.

Laparoscope - a fiber-optic instrument inserted through an incision in the abdominal wall and used to examine visually the interior of the peritoneal cavity

Laser unit - A device that produces a laser beam that can be used for cutting or coagulating tissue with great precision.

Light source (Bili-lights, phototherapy) – Bili-lights are used to treat patients with a surfeit of bilirubin, a common condition in newborns. Also, see lamp

Microscopes - an optical instrument consisting of a lens or combination of lenses for making enlarged images of minute objects

Manometers - an instrument (as a pressure gauge) for measuring the pressure of gases and vapors

Microtome - an instrument for cutting sections (as of organic tissues) for microscopic examination

Microwave - A device for heating tissues. It uses electromagnetic radiation to heat.

Monitor, cardiac, ICU, fetal, neonatal, temperature, maternal, patient

Equipment which sits alongside the patient to measure vital signs (heart rate, blood pressure and temperature) or other critical patient parameters. Fetal monitor is attached to mother, but monitors fetus.

Nebulizers - a device which reduces a liquid to a fine spray before allowing the patient to breathe it in. Used to deliver medicine and water to a patient.

Non-Invasive Blood pressure (NIBP or sphygmomanometer) - An instrument to measure arterial blood pressure. Consists of an inflatable cuff that goes around the arm about an inch above the elbow, with tubing that connects the cuff to the measuring device.

Oximeter, pulse - a non-invasive device which measures the percentage of hemoglobin saturated with oxygen. The device can also measure heart rate. Most are optical.

Oxygen tent (with regulator) - a container which can be placed over a patient to increase the percentage of oxygen in the air that the patient naturally breathes.

Otoscope unit - an instrument for use in viewing the ear drum and exterior/middle ear.

Ophthalmoscope - an instrument for use in viewing the interior of the eye and especially the retina

Oxygen regulator, flow meter - A device for measuring and regulating the flow of oxygen from a cylinder of compressed oxygen.

Pulse oximeters (pulse ox) - see oximeter pulse

Pump, heart – lung - a large device used to bypass the heart and lungs during open heart surgery. Also called a heart-lung machine or perfusion device.

Phaco emulsifier - an ultrasonic device for emulsifying (liquefying) the lens of the eye. Used for cataract surgery.

Prostratron, laser unit - a device for delivering high energy laser pulses to the prostate

Photometer - an instrument for measuring luminous intensity, luminous flux, illumination, or brightness

Pacemakers & supplies - Device used to artificially pace the heart when the natural pacemaker fails.

Respirator Masks - Methods for delivering concentrated oxygen to patient who is naturally breathing

Resuscitators - an apparatus used to restore respiration (as to a partially asphyxiated person)

Scale (balance, weighing, child, infant, adult) - an instrument or machine for weighing a patient

Speculum, vaginal, ear - Hand held tools or implements used by health professionals for the performance of surgical tasks. Typically inserted into a cavity to open up the passage for inspection. Typical varieties include vaginal and ear specula.

Sphygmomanometer - a non-invasive instrument for measuring blood pressure and especially arterial blood pressure

Stethoscope, adult, amplified, fetal (fetoscope), pediatric - an instrument used to detect and study sounds produced in the body

Sleep apnea monitor - a device for monitoring the breathing of the patient during sleep. Device alarms when the patient stops breathing.

Spirometer - an instrument for measuring the air entering and leaving the lungs. Advanced instruments can measure flow rates, tidal volume and breathing rate.

Sigmoidoscopes - a long, hollow tubular instrument passed through the anus for inspection, diagnosis, treatment, and photography especially of the sigmoid colon.

Slit lamp - a device used during eye exams.

Sterilizer, desktop, gas, steam, large/small – see autoclave.

Stryker Saw - see cast saw

Suction machine, continuous / aspirator, desktop, high pressure, surgical - see aspirator

Surgical microscopes - a light microscope typically having x-y or x-y-z remote motion control

Traction machine - a device used to apply tension to some joint (s) of the body.

Ultrasound (Doppler, diagnostic, therapeutic, cardiac, abdominal, ob/gyn) - A large device for the diagnostic or therapeutic use of pressure waves and especially a technique involving the formation of a two-dimensional image used for the examination and measurement of internal body structures and the detection of bodily abnormalities -- called also sonography, echograph, echocardiograph.

Ventilator / respirator - a device for introducing fresh air or expelling foul or stagnant air. Can also be used to maintain positive pressure to inflate the lungs, or to assist a patient who is otherwise breathing spontaneously.

Vital sign monitors - see monitors

Warmer, infant - device for giving out heat to a moderate or adequate degree for an infant.

Washer, ultrasonic - a water bath which can excite the water with high frequency pressure pulses. Can effectively remove particles from instruments. Often used as a prelude to sterilization.

Wound suction (Hemovac) - See aspirator

4.5 *Spanish-English Dictionary for a BME*

There is currently no Spanish/English dictionary of biomedical engineering available. This section covers many of the words you are likely to encounter. However, if you don't find the dictionary in this section sufficient, consider one of these:

Diccionario enciclopédico de términos técnicos: inglés-español / español-inglés.

Collazo, Javier L.S. McGraw-Hill, 1980. ISBN 0-07-079172-4 (English Binding) / 0-07-079162-7 (Spanish binding). 2217 pp.

Diccionario Técnico Inglés-Español / Español-Inglés. Beigbeder, Federico. Madrid: Ediciones Díaz de Santos, 1996. ISBN 84-7978-221-8. 1253 pp.

Diccionario Técnico Español-Inglés. Malgorn, Guy. Madrid: Editorial Paraninfo, 1991. ISBN 84-283-1354-7. 569 pp.

ENGLISH	SPANISH	ESPAÑOL	INGLES
A	A	A	A
abatement	disminución	abandonar	quit
abbreviated dialing	marcación abreviada	abandono (s)	quit
abend	(v) terminar anormalmente - (s) terminación anormal	abortar (v)	abort
abort	(v) abortar - (s) interrupción	acabar (el tiempo asignado)	timeout
A C dump	corte de energía	acceder (v)	access
A C input	entrada de CA	accesar (v)	access
A C line	línea de corriente alterna	acceso (s)	access
A C outlet	salida de CA	acceso aleatorio	random access
access	(v) acceder, acceder - (s) acceso	acceso denegado	denied access
ack	ver acknowledgement	accesorio	attachment
acknowledge	ver acknowledgement	Accionador	actuator
acknowledgement	(v) confirmar, reconocer - (s) confirmación, reconocimiento	aceite	oil
acronym	acrónimo, sigla	ácido de batería (m)	battery acid
actuator	Accionador, actuador	acondicionador de aire	air conditioner
admittance	entrada, admitancia	acrónimo	acronym
ageing fault	avería por envejecimiento, fallo por envejecimiento	activador	trigger
aging failure	avería por envejecimiento, fallo por envejecimiento	activar (un programa)	start
air circulation vents	tomas de aire	actualización (s)	upgrade
air compressor	compresor de aire	actualización (s)	update
air conditioner	acondicionador de aire	actualizar (v)	update
air cooling	enfriamiento por aire	actualizar (v)	upgrade
air duct	ducto de aire	adjuntar	attach
air exhaust	descarga de aire	administración	m anagement
air inlet	admisión de aire - toma de aire	administrador	manager
air intake	toma de aire	admisión de aire	air inlet
air leak	fuga de aire	admittancia	admittance
alarm	alarma	afilarse	sharpen
alert	(v) alertar, avisar (s) alerta, aviso	aflojar	loosen
alias	alias, seudónimo	agotar	timeout, deplete
alignment	alineación, alineamiento	agrupación (s)	cluster
allen wrench	llave inglesa, llave Allen	agrupamiento	batching
allocation	asignación	agrupar (v)	cluster
ammeter	amperímetro	agua de la llave	tap water
amperes	amperios	agua purificada	purified water
analog	análogo, analógico	aislación	insulation
analog to digital converter	convertidor analógico-digital	aislamiento	insulation, isolation
ancillary equipment	equipo de apoyo, equipo auxiliar	aislante termoretráctil	heat shrink
anesthesia machine	máquina de anestesia	aislante termoretráctil	heat shrink
announcement	anuncio, locución, mensaje	Autoclave	autoclave
anode	ánodo	ajustable	tunable, settable
anomaly	anomalía	ajustar	tune
answering machine	contestador telefónico contestadora telefónica	Al mismo tiempo	at the same time
antifase	ver antiphase	alambrado	wire, wiring
antiphase	oposición de fase - contrafase	alambre	wire
apparatus	aparato	alambre armado	armor wire
append	añadir	alarma	alarm
appendix	apéndice, anexo	alarma crítica	critical alarm
applique	la appliqué	alarma mayor	major alarm
area	área, zona	alarma menor	minor alarm
armor wire	alambre armado	alarma muy urgente	critical alarm
armored cable	cable blindado	alarma no urgente	minor alarm
assemble	ensamblar	alarma óptica	visual alarm
assembler	ensamblador	alarma secundaria	minor alarm
assembling	Ensamblaje	alarma urgente	major alarm
assembly	Ensamblaje	alarma visual	visual alarm
assembly stand	soporte de ensamblado	alcance	coverage
asymmetric	Asimétrico	alcohol de fricción	rubbing alcohol
asynchronous	Asincrónico, asíncrono	alcohol isopropílico	isopropyl alcohol
asynchronous interface	Interfaz asíncrona	aleatorización	scrambling
at the same time	Al mismo tiempo, simultáneamente	aleatorizador	scrambler
ATM	cajero automático	alerta	alert
attach	adjuntar - asociar	alertar	alert
attached equipment	equipo asociado	aleta de ventilador	fan blade
attachment	Dispositivo, accesorio	alias	alias
attempt	intento, tentativa	alicate	plier, wire cutter
authenticate	Autenticar	alimentación de CC	DC power
autoboot	arranque automático	alimentación para servicios auxiliares	utility power
autoclave	Autoclave	alineación	alignment
autodiagnostic	Autodiagnóstico	alineamiento	alignment
automate	Automatizar	almacenamiento	storage
automatic data processing	procesamiento automático de datos	almacenar	save
automatic dial modem	módem de marcación automática	alta tecnología	hi tech
automatic distributor	distribuidor automático	alta tensión	high voltage
autopump	recarga automática	altavoz	speaker, loudspeaker
autotransformer	autotransformador	alteración	corruption, disturbance
avoid	Evitar	alterar	disturb
		alto voltaje	high voltage
		altoparlante	speaker
		ambiente	environment
		ambiente esterilizado	sterilized environment
		amperímetro	ammeter
		amperios	amperes
		amplificador de potencia	power amplifier
		añadir	append
		analizador bioquímico	biochemical analyzer
		analógico	analog
		análogo	analog
		ancho de banda	bandwidth
		anexo	appendix
		anfitrión	host
		anillo	ring
		ánodo	anode
		anomalía	anomaly
		antenas rectilíneas	linear antennas
		antiparras	goggles
		anuncio	announcement
		apagar	turn off, shutdown (equipo)
		aparato	apparatus
		apéndice	appendix
		apertura	opening
		apoyo	support
		apretar	squeeze, tighten
		archivo	log
		archivo de anotaciones	logfile
		archivo de registro	logging file
		archivo histórico	logfile
		archivo reutilizable	scratch file
		área	area
		área reutilizable	scratch area
		armario	cabinet
		armazón	rack, framework, frame
		arrancar (v)	boot

arranque	startup, boot
arranque automático	autoboot
arranque en frío	cold start
arranque general	big boot
arrastrar	drag
arreglar	fix(to repair), repair
asegurarse	make sure
asignación	allocation
Asimétrico	asymmetric
Asincrónico	asynchronous
asíncrono	asynchronous
asistencia técnica	technical assistance
asociar	attach, link
aspa de ventilador	fan blade
aspirador general	general aspirator
aspirador para cirugía	surgery aspirator
atenuación	loss
atenuador de luz	dimmer
atornillador	screw driver
aumentar	increase
Autenticar	authenticate
autocomprobación	self check
Auto diagnóstico	autodiagnostic, self diagnostic
Automatizar	automate
autónomo	standalone
autotransformador	autotransformer
autoverificación	self check
avería	fault, trouble
avería por envejecimiento	ageing fault, aging failure
avisar (v)	alert
aviso (s)	alert

B	
backpanel	panel posterior
backup	respaldo, seguridad
backup copy	copía de respaldo, copia de seguridad
backup drive	unidad de reserva
bacteriologic chamber	cámara bacteriológica
bacteriologic incubator	incubador bacteriológico
balanced circuit	circuito balanceado, circuito equilibrado
banana plug	enchufe tipo banana
band pass filter	filtro pasa banda
bandwidth	ancho de banda
bar chart	gráfico de barras
bar code	código de barras
bar graph	gráfico de barras
baseband	banda base
basic	básico
batching	agrupamiento
battery	Batería, pila
battery acid	ácido de batería (m)
battery rack	banco de baterías
bay	bastidor, compartimiento
bay frame	bastidor
beacon	baliza
bearer	portadora
benchmark	Benchmark, punto de referencia, prueba de desempeño
bent	doblado
bias	(v) polarizar - (s) polarización
bias current	corriente de polarización
big boot	inicialización general, arranque general
billi light (phototherapy lamp)	lámpara de fototerapia
billirubin meter	bilirubinómetro
bin	depósito
biochemical analyzer	analizador bioquímico
biomonitor	biomonitor
bleach	cloro
blockage	bloqueo
board	Placa, tarjeta
boiler	caldera
boot	(v) inicializar, arrancar - (s) inicialización, arranque
boot up, boot-up	(v) rebootear - (s) rebooteo
both way, bothway	bidireccional
branch	(v) derivar, bifurcar - (s) derivación, bifurcación
break down time	tiempo de reparación
broke (torn)	quebrar
broken	roto, quebrado
broken (but can be fixed)	dañado
broken connection	conexión interrumpida
brushes (motor)	cabones (m)
bubbles	burbujas (f)
bucket	valde (m)
built-in	incorporado, integrado, interno
bulb	ampolleta, bombilla
burst	ráfagas
button	botón
buzzer	timbre, zumbador
by default	por defecto
bypass	(v) desviar, pasar de lado/por alto - (s) desvío, derivación

C	
cabinet	gabinete, armario
cable	cable
cable cutter	pelacables, cortador de cable
cable manhole	caja de empalme, cámara de empalme
cable pair	cable par, par de cables
cable shield	blindaje de cable - manguito de cable
cable tray	conducto de cable, bandeja de cables
cable vault	caja de empalme de cables
cable wiring	conexión de cables
cabling	cableado, tendido de cables
calibrate	calibrar
cancel	cancelar
capacitance	capacitancia
capacitor	condensador
card	tarjeta
cardiac monitor	monitor cardíaco
carriage return	retorno de carro Return
cartridge	cartucho
case (surrounding equipment)	estuche (m)
cassette	cassette, casete
cathode	cátodo
cathode ray tube (CTR)	tubo de rayos catódicos
cause (v)	causar
cause, source of problem	causa
CD	CD, compact disc, disco compacto

B	
bajar (programas de datos)	download
bajo voltaje	undervoltage
baliza	beacon
banco de baterías	battery rack
banda ancha	wideband
banda base	baseband
bandeja de cables	cable tray
barra de alimentación	power bus
base de datos	database
básico	basic
bastidor	bay frame, frame, rack, bay, shelf
bastidor de montaje	mounting frame
Batería	battery
batería de plomo	lead acid battery
batería de plomo sellada	sealed lead acid battery
batería solar	solar battery
batidor industrial	industrial mixer
Benchmark	benchmark
bidireccional	both way, bothway
bifurcación (s)	fork, branch
bifurcar (v)	fork, branch
bilirubinómetro	billirubin meter
biomonitor	biomonitor
bitácora	history
blindaje de cable	cable shield
bloquear (v)	lockout
bloqueo	lockout, blockage, lock
bobina térmica	heat coil
bobinado	winding
bocina	speaker
bomba central	central pump
bomba contra incendios	fire pump
bomba de agua	water pump
bomba de infusión	infusion pump
bomba de vacío	vacuum pump
bombillo	light bulb
boquilla	tip of a probe
borrar	delete
botón	button
botón de reinicialización	reset button
botón de reseteo	reset button
bucle de conductores	leadloop
burbujas (f)	bubbles
buscas	hunt
búsqueda	hunting

C	
caber	fit(inside)
cabeza impresora	printhead
cabezal térmico	thermal head
cable	cable
cable a tierra	ground cable
cable blindado	armored cable
cable blindado	shielded cable
cable coaxial	coaxial cable
cable de alimentación	power cable
cable de fibra óptica	optical fiber cable
cable de puente	jumper cable
cable par	cable pair
cable plano	ribbon cable
cable trenzado	stranded cable
cableado	wiring
cableado	cabling
cabones (m)	brushes (motor)
cadena	string
caída	crash
caída de alimentación	power loss
caída de tensión	voltage drop
caída de voltaje	voltage drop
caja	housing
caja de conexiones	junction box
caja de contacto	receptacle

CD Drive	lector de CD	caja de empalme	splice box
cell	celda	caja de empalme	junction box
centigrade	centígrados	caja de empalme	cable manhole
central pump	bomba central	caja de empalme de cables	cable vault
centrifuge	centrífuga	caja de juntura	junction box
chamber	cámara	cajero automático	ATM
charge (battery)	cargar	calcular	compute
Check (out or test)	chequear, comprobar, verificar	caldera	boiler
check list, checklist	lista de comprobaciones, lista de control	calibrar	calibrate
chip	chip, circuito integrado	calibre	gauge
circuit	circuito	cámara	chamber
circuit board	tarjeta de circuitos	cámara bacteriológica	bacteriologic chamber
circuitry	circuitería	cámara de empalme	cable manhole
clad	revestir	cámara subterránea	manhole
cladding	revestimiento	cambiar el tamaño	resize
clamp	abrazadera, grapa, pinza	campo de excitación	excitation field
click	oprimir, hacer clic	canal	conduct
clipboard	portapapeles	canal de servicio	order wire
clockwise	Como las manecillas del reloj	canalización	ductwork
clothes dryer	secadora de ropa	cancelar	cancel, quit
cluster	(V) agrupar - (s) agrupación	capa transversal dieléctrica	dielectric crossply
coagulation meter	coagulómetro	capacitancia	capacitance
coaxial cable	cable coaxial	característica	setting, feature
code	(V) codificar - (s) código	carcasa	cover
codirectional	codireccional	carga desequilibrada	unbalanced load
cold start	arranque en frío	cargar	upload, charge (battery)
collect	colectar, recolectar	carpeta	folder
color monitor	monitor en color	cartucho	cartridge
command	comando	casete	cassette
commercial AC	red eléctrica comercial	casilla postal	post office box
commercial power	corriente industrial	cáodo	cathode
commissioning	puesta en servicio	causa	cause, source of problem
common channel signaling	señalización por canal común	causar	cause (V)
common trunk	troncal común, enlace común	CD	CD
compander	compresor-expansor	celda	cell
companding	compresión-expansión	centelleo	flashing
compatibility	compatibilidad	centígrados	centigrade
compatible	compatible	central eléctrica	power station
compensator	compensador	centrífuga	centrifuge
complementary metal oxide semiconductor (CMOS)	semiconductor complementario de óxido metálico	cerrar	shutoff
compliance test	pruebas de conformidad	chequear	Check (out or test)
component	componente	chip	chip
compression	compresión, reducción	cinta adhesiva	scotch tape
compressor	compresor	cinta de impresión	ribbon
compute	calcular	cinta de muñeca	wrist strap
computer	el computador, el ordenador	cinta fusible	fuse link
conduit	ducto, canal, conducto	cinta para impresoras	ribbon
connect	conectar	circuitería	circuitry
connectivity	conectividad	circuito	circuit
connector	conector	circuito a dos hilos	two wire circuit
connectorize	conectorizar	circuito alquilado	leased circuit
conscious	consiente	circuito arrendado	leased circuit
console	consola	circuito balanceado	balanced circuit
container	Contenedor, container	circuito de disparo	trigger circuit
controller	Controlador	circuito de órdenes	order wire
copy	(V) copiar - (s) copia	circuito en reposo	idle circuit
cork	corcho	circuito equilibrado	balanced circuit
corrective	correctora, correctivo	circuito fantasma	phantom circuit
corruption	corrupción, alteración	circuito integrado	chip
counter	contador	circuito virtual	virtual circuit
counter clockwise	contra las manecillas del reloj	circuitos electricos	electrical circuits
cover	cubierta, carcasa, tapa	cirugía	surgery
coverage	alcance - cobertura	cirujano	surgeon
crack	grieta	clave	keyword
craft person, craft personnel	personal de mantenimiento, técnico de mantenimiento	clavija	pin
crash	falla abrupta, caída	clavijero	jack
critical alarm	alarma muy urgente, alarma crítica	clavo	nail
cross check, crosscheck	verificación cruzada	cliente	customer
cross connect, crossconnect	(V) interconectar - (s) interconexión, conexión transversal	cloro	bleach
current (of electricity)	corriente	coagulómetro	coagulation meter
cursor	cursor	cobertura	coverage
custom	personalizado	cocina industrial	industrial stove
custom made	hecho a la medida	codificación	scrambling
customer	usuario, cliente	codificador	scrambler
		codificar (V)	code
		código (s)	code
		código de barras	bar code
		código de operación	op code
		código de seguridad	security code
		codireccional	codirectional
		cola de espera	queue
		colectar	collect
		coma decimal	decimal point

comando	command
comenzar	start
Como las manecillas del reloj	clockwise
compact disc	CD
compartimiento	bay
compatibilidad	compatibility
compatibilidad electromagnética	electromagnetic compatibility
compatible	compatible
compensador	compensator
compensar	offset
componente	component
compresión	compression
compresión	compressing
compresor	compressor, compander
compresor de aire	air compressor
comprobación de validez	sanity check
comprobar	Check (out or test)
compuerta	gate, gating
computador portátil de sobremesa	laptop computer
con falla	failed
concentrador	hub
condensador	capacitor
conducir	drive
conducto	conduit, duct
conducto de cable	cable tray
conducto subterráneo	underground duct
conductor de conexión a tierra	ground wire
conectado a tierra	grounded
conectar	connect, link
conectarse al sistema	login
conectividad	connectivity
conector	connector
conector macho	male connector
conector óptico	optical connector
conectorizar	connectorize
conexión	joint
conexión a tierra	grounding
conexión de cables	cable wiring
conexión en puente	strapping
conexión interrumpida	broken connection
conexión permanente (s)	hard wire
conexión transversal (s)	cross connect, crossconnect
conexiónm entrada al sistema	login
confiabilidad	reliability
confiable	reliable
configurable	settable
configuración	setting
configurar	setup
confirmación	acknowledgement
confirmar	acknowledgement
congelador	freezer
conjunto	set
consiente	conscious
consola	console
consumo de corriente	power drain
contacto del relé	relay contact
contacto en circuito sin corriente	dry contact
contacto seco	dry contact
contador	counter
contador residencial	home meter counter
container	container
Contenedor	container
contestador telefónico contestadora telefónica	answering machine
contra las manecillas del reloj	counter clockwise
contrafase	antiphase
contraseña	password
control	monitoring
control de flujo	flow control
control de ganancia	gain control
control remoto	remote control
controlador	handler
Controlador	controller, driver
controlador de dispositivos	device driver
controlador de errores	error handler
controlar	drive
convertidor analógico	analog to digital converter
convertidor serie/paralelo	deserializer
copia (s)	copy
copia de respaldo	backup copy
copia de seguridad	backup copy
copia impresa	printout
copiar (V)	copy
corcho	cork
correa de transmisión	drive belt
correctivo	corrective
correctora	corrective
correlación	mapping
correo electrónico	electronic mail, e-mail
corriente	current (of electricity)
corriente de polarización	bias current
corriente de régimen	rate current
corriente industrial	commercial power, industrial power
corriente residual	follow current
corrupción	corruption
cortador de cable	cable cutter
cortar	shutoff
corte	outage
corte de energía	power off, AC dump
cortocircuito	shortcircuit, short
cuadrícula	raster
cuantificación	quantization
cuantificar	quantify
cuarto de vuelta	quarter turn
cubierta	housing, jacket, cover
cubierta antipolvo	dust cover
cursor	cursor

D	D	D	D
database	base de datos	dañado	broken (but can be fixed)
datagram	diagrama de datos	daño	trouble
DC input	entrada de CC	de entrada	inbound
DC power	alimentación de CC	de llegada	inbound
dealer	proveedor	de marca registrada	proprietary
debloking	desbloquear	de regreso	inbound
decimal point	punto decimal, coma decimal	de reserva	standby
decouple	desacoplar	de retorno	inbound
decrease	disminuir	de tecnología avanzada	state of the art
dedicated line	línea dedicada	debil	weak
dedicated link	enlace dedicado	defecto	defect
deenergized	desactivado, desenergizado	defectuoso	defective
default	por defecto - por omisión - predeterminado	deflector de calor	heat baffle
defect	defecto	degradación	degrading
defective	defectuoso	demora (s)	delay
defibrillator	desfibrilador	demorar (v)	delay
degraded secons	segundos degradados	demostrar	demonstrate
degrading	degradación	denegar	deny
degrees	grados	depósito	bin
dehydrator	deshidratador	derivación	branch, bypass
deinterleave	desintercalar	derivar	branch
delay	(v) retardar, demorar - (s)retardo, demora	desacoplar	decouple
delete	borrar, suprimir, eliminar	desactivado	deenergized
demonstrate	demostrar	desactivar	disable
denied access	acceso denegado	desalineado	misaligned
deny	denegar, negar	desbloquear	unblock
deplete	agotar	desbloqueo	unlocking
depress	pulsar, oprimir	desbordamiento	overflow
deserializer	convertidor serie/paralelo	descarga de aire	air exhaust
desolder	desoldar	descarga electroestática	electrostatic discharge
device	dispositivo	descargas estáticas	static discharge
device driver	controlador de dispositivos	desconectar	disconnect, trip, shutoff
diacritical	diacrítico	desconectarse (v)	log off
diagnose	diagnosticar	desconexión	shutdown, tripping
diagnostic	diagnóstico	desechable	disposable
dial	perilla	desempeño	performance
dielectric crossply	capa transversal dieléctrica	desenchufar	unplug
dielectric strength	resistencia dieléctrica	desenergizado	deenergized
dilute	diluir	desenganchar	disengage
diluted	diluido	desensamblado	disassembly
dimensioning	dimensionar, dimensionamiento	desensamblador	disassembler
dimmer	dimmer, atenuador de luz	Desensamblar	disassemble
diode bridge	punto de diodo, puente diódico	desfibrilador	defibrillator
dip switch	interruptor dip - microinterruptor	deshabilitar	disable
disable	inhabilitar - desactivar, deshabilitar	deshacer	undo
disassemble	Desensamblar, desmontar	deshidratador	dehydrator
disassembler	desensamblador	desintercalar	deinterleave
disassembly	desensamblado	deslizamiento	slip
disconnect	desconectar	desmayarse	faint
disengage	desenganchar	desmontar	disassemble
disk	disco	desoldar	desolder
display terminal	terminal de despliegue, terminal de visualización	desplazamiento	offset, slip, scrolling
display unit	unidad de despliegue, unidad de visualización	desplazar	scroll
disposable	desechable	destello	flashing
disruption	disrupción	destilado	distilled
disassembly	desensamblado	destilador de agua	water still
dissolve	dissolver	destinatario	recipient
distilled	destilado	destornillar	unscrew
distorsion meter	distorsiómetro	desvanecer	fade
distort	distorsionar	desvanecimiento	fading
distortion	distorsión	desviar	bypass
disturb	perturbar, alterar	desvío	bypass
disturbance	Perturbación, alteración	detección	sensing
dolly	plataforma móvil (para el transporte), plataforma rodante	detección de voltaje	voltage sensing
double click	hacer doble clic	detectar	sense
download	transferir (descargar), bajar (programas, datos)	detector	sensor
downtime	tiempo de indisponibilidad	determinar	set
downtime ratio	promedio de tiempo muerto	diacrítico	diacritical
drag	arrastrar	diagnosticar	diagnose
drive	(v) conducir, controlar, manejar (s) controlador - unidad, impulsor	diagnóstico	diagnostic
drive belt	correa de transmisión	diagrama de datos	datagram
driver	controlador	diagrama de flujos	flowchart
dry	secar	diario (s)	log
dry contact	contacto seco, contacto en circuito sin corriente	diferencia de impedancias	impedance mismatch
dryer	secadora	digital	analog to digital converter
dual	Dual, doble	diluido	diluted
duct	conducto - ducto (de aire)	diluir	dilute
ductwork	red de conductos, canalización	dimensionamiento	dimensioning
dummy	falso, vacío, ficticio	dimensionar	dimensioning
dump	vaciado	dimmer	dimmer
dust cover	cubierta antipolvo	diodo de avalancha	Zener diode
		diodo emisor de luz (LED)	light emitting diode (LED)
		diodo fotoemisor	light emitting diode (LED)
		diodo láser	laser diode
		diodo Zener	Zener diode
		dirigir (v)	route
		disco	disk
		disco compacto	CD, compact disk
		disco duro	hard disk
		disco rígido	hard disk
		disipación térmica	heat dissipation
		disipador electrónico	electronic sink
		disipador térmico	heat sink
		disminución	abatement
		disminuir	decrease
		dissolver	dissolve
		dispositivo	device
		dispositivo periférico	peripheral device
		disrupción	disruption
		distorsiómetro	distortion meter
		distorsión	distortion
		distorsionar	distort
		distribuidor automático	automatic distributor
		divisor	splitter
		doblado	bent
		doble	dual
		dos hilos	two wire
		Dual	dual
		ducto	conduit
		ducto (de aire)	duct
		ducto de aire	air duct

E	E	E	E
ecograph	ecógrafo	ecógrafo	ecograph
edge	filio	edición	editing
edit	editar	editar	edit
editing	edición	el computador	computer
eject	expulsar	el ordenador	computer
elastometer	elastómetro	elastómetro	elastometer
electrical circuits	circuitos eléctricos	electricidad (f)	electricity, power (electrical)
electrical outlet	toma eléctrica	electricidad estática	static electricity
electrical surge	sobrevoltaje, sobrecarga eléctrica	electrocardiografía	electrocardiograph
electricity	electricidad (f)	electrocauterio	electrocauterizer
electrocardiograph	electrocardiografía	electroestimulo	electrostimulus
electrocauterizer	electrocauterio	electroforesis	electrophoresis
electromagnetic compatibility	electrolítico	electrolítico	electrolytic
electromagnetic interference	compatibilidad electromagnética	eliminación(s)	purge
electromotive force	interferencia electromagnética	eliminar	delete
electronic mail	fuerza electromotriz	e-mail	e-mail
electronic sink	correo electrónico	emisión de calor	heat release
electrophoresis	disipador electrónico	emisor	originator, sender
electrophoresis source	electroforesis	emitir por impulso (v)	outpulse
electrostatic discharge	fuerza de electroforesis	empalmar	splice
electrostimulus	descarga electrostática	empalme	splicing
e-mail	electroestimulo	empaque	washer for sealing
embedded	correo electrónico, E-mail	empotrado	embedded
emergency power plant	incrustado, empotrado, intercalado - interno	empujar	push
empty	planta de emergencia	emulador	emulator
emulator	vaciar	en el sitio	on site
enable	emulador	en pantalla	on screen
enabling	habilitar	en reserva	standby
encapsulating	habilitación	en serie	serial
enclosure	encapsulación	en un solo sentido	one way
enhanced port	encapsulado	encabezamiento	heading
environment	puerto ampliado	encadenamiento	linkage
error handler	ambiente, entorno	encaminamiento	routing
error prone	controlador de errores, manejador de errores	encaminar	route
error rate	susceptible a/de errores	encapsulación	encapsulating
escalability	índice de errores	encapsulado	enclosure
escalate	escalabilidad	encendido	startup
excitation field	(v) Intensificar, escalar - (s) Intensificación,	enchufar	plug in
exit	escalación	enchufe	plug, jack
expiration date	campo de excitación	enchufe tipo banana	banana plug
explode	salir	energía calórica	heat energy
	fecha de vencimiento	energía solar	solar energy
	estallar	enfermera	nurse
		enfriamiento por aire	air cooling
		enlace (s)	link
		enlace común	common trunk
		enlace de microondas	microwave links
		enlace dedicado	dedicated link
		enlazar	link
		enmascarable	maskable
		enmascaramiento	masking
		ensamblador	assembler
		ensamblaje	assembling, assembly
		ensamblar	assemble
		entorno	environment, setting
		entrada	admittance
		entrada de CA	AC input
		entrada de CC	DC input
		entrada errónea	misentry
		entrante	incoming, inbound
		envoltura	wrapping
		equipo	set
		equipo asociado	attached equipment
		equipo auxiliar	ancillary equipment
		equipo de apoyo	ancillary equipment
		equipo de inmunología	immunology equipment
		equipo para montaje en bastidor	rack mounting kit
		error	fault
		error de secuencia	sequence error
		escalabilidad	escalability
		escalación (s)	escalate
		escalamiento	scaling
		escalar (v)	escalate
		escanear	scan
		escaneo	scanning
		escáner	scanner
		escape	leak, leakage
		escuadra de soporte	support bracket
		espectro	spectra, spectrum
		establecer	set
		establecer un cortocircuito (v)	short
		estado sólido	solid state
		estallar	explode
		estándar	standard
		estante	shelf
		estante metálico	rack
		estéreo	stereo
		esterilizar	sterilize
		estrella	star
		estructura	framework
		estuche (m)	case (surrounding equipment)
		etiqueta	label
		Evitar	avoid
		exclusión (s)	lockout
		expansión	offset, companding
		expansor	compander
		exploración	scanning
		explorador	scanner
		explorar	scan
		expulsar	eject
		externo	outboard
		extremo cercano	near end

F	
fabric	malla
faceplate	placa frontal
facility	instalación, facilidad, servicio
fade	desvanecer
fading	desvanecimiento
fahrenheit	fahrenheit
failed	defectuoso, dañado, con falla, fallido
failure	falla, fallo
faint	desmayarse
fan blade	aspa de ventilador, aleta de ventilador
farad	faradio
fast pump	recarga rápida
fastener	sujetador
fault	falla, avería, fallo, error
fax	(v) faxear - (s) fax, facsímil
feasibility	factibilidad
feature	característica, función
fiber glass	fibra de vidrio
fiber optic	fibra óptica
fiberglass	ver fiber glass
fire pump	bomba contra incendios
first in/first out (FIFO)	primero en entrar/primero en salir
fit(inside)	caber
fix(to repair)	arreglar
fixed(value)	fijo
flash	parpadear, pestañear
flashing	parpadeo, centelleo, destello
flow control	control de flujo
flowchart	flujograma, diagrama de flujos
fluctuation	fluctuación
fluid	fluido
flutter	fluctuación
folder	carpeta
follow current	corriente residual
fork	(v) bifurcar - (s) bifurcación
format	(v) formatear - (s) formato
forming	formateo
frame	Bastidor, armazón
framework	Armazón, estructura
freezer	congelador
full screen	pantalla completa
fuse	fusible
fuse holder	portafusible, soporte de fusible
fuse link	cinta fusible

G	
gage	medidor
gain	ganancia
gain control	control de ganancia
gas leak	fuga de gas
gasket	junta (metálica, elástica, etc.)
gasometer	gasómetro
gate	compuerta
gateway	puerta de acceso
gating	compuerta
gauge	calibre
general aspirator	aspirador general
general purpose system	sistema de propósito general
generator	generador
glitch	interferencia, señal de deformación
globalization	globalización
gloves	guantes
glucose meter	glucómetro
glue	pegar
goggles	gafas protectoras, antiparras
graded index fiber	fibra de índice graduado
grease	grasa
ground cable	cable a tierra
ground potential	potencial de toma de tierra
ground wire	conductor de conexión a tierra, hilo de conexión a tierra
grounded	conectado a tierra
grounded fault	falla/fallo de conexión a tierra
grounding	puesta a tierra, (de) conexión a tierra, toma de tierra

H	
half turn	media vuelta
half-duplex	semidúplex
hammer	martillo
hand held	Portátil, manual
hand off	(v) traspasar, transferir - (s) reencaminamiento, transferencia
handhole	pozo de inspección a mano
handle	manejar, manipular
handler	gestor, controlador - tratamiento, manejador, manipulador
handling	manejo, manipulación
hard disk	disco duro, disco rígido
hard fault	fallo(a) permanente
hard reset	reinicialización manual
hard return	retorno manual

F	
fabricante	manufacturer
facilidad	facility
facsímil (s)	fax
factibilidad	feasibility
factor de potencia	power factor
fahrenheit	fahrenheit
falla	outage
falla abrupta	crash
falla/fallo de conexión a tierra	grounded fault
fallido	failed
fallo	failure, fault
fallo por envejecimiento	ageing fault, aging failure
fallo(a) permanente	hard fault
falso	dummy
faradio	farad
fase de prueba	test step
fax	fax
faxear (v)	fax
fecha de vencimiento	expiration date
ferreteria	hardware store
fiabilidad	reliability
fiable	reliable
fibra de índice graduado	graded index fiber
fibra de vidrio	fiber glass
fibra óptica	fiber optic
fichero de registro	logfile
facticio	dummy
fijo	fixed(value)
filo	edge
filtración	screening
filtrar	screen
filtro pasa banda	band pass filter
fin de sesión (s)	log off
fluctuación	fluctuation, flutter, jitter
fluctuación de fase	jitter
fluido	fluid
flujo	stream
flujo interno	interflow
flujograma	flowchart
formatear (v)	format
formateo	formatting
formato (s)	format
fotocinético	photokinetic
fotodiodo	light emitting diode (LED), photodiode
fotorreflectante	photorefective
frecuencia cardíaca	heart rate
frecuencia de muestreo	sampling frequency
fuerza	source
fuerza de alimentación	power source, power supply
fuerza de electroforesis	electrophoresis source
fuera de gama	out of range
fuera de límite	out of range
fuera de rango	out of range
fuera de servicio	out of order
fuerza electromotriz	electromotive force
fuga	leak, leakage
fuga de aire	air leak
fuga de gas	gas leak
función	feature
funcionamiento defectuoso	malfunction
fusible	fuse
fusión (s)	merge
fusionar (v)	merge

G	
gabinete	cabinet
gafas protectoras	goggles
gama	range
ganancia	gain
gasómetro	gasometer
generador	generator
gerente	manager
gestión	management
gestionar	manage
gestor	manager, handler
girar	turn a knob
globalización	globalization
glucómetro	glucose meter
grabación	recording
grabadora	recorder
grabar	save, record
grados	degrees
graficar	plot
gráfico de barras	bar chart, bar graph
grapa	clamp
grasa	grease
grieta	crack
grupo (s)	set
guantes	gloves

H	
habilitación	enabling
habilitar	enable
hacer clic	click
hacer doble clic	double click
hecho a la medida	custom made
herramienta	tool
hertz	hertz
hertzio	hertz
heterócrono	heterochronous
hilo A e hilo B	tip and ring
hilo de conexión a tierra	ground wire
hilo de órdenes	order wire
hilo trenzado	stranded wire

hard wire	(s) conexión permanente - (a) de conexión permanente
hardware store	ferreteria
hardwired	ver hard wire
heading	encabezamiento
heart beat	latido del corazón
heart rate	frecuencia cardíaca
heart rhythm	ritmo del corazón
heat baffle	deflector de calor
heat coil	bobina térmica
heat dissipation	disipación térmica
heat energy	energía calórica
heat release	emisión de calor
heat shrink	aislante termorretráctil, aislante termoencogible
heat sink	disipador térmico
hertz	hertz , hertzio
heterochronous	heterócrono
hi tech	alta tecnología
hierarchy	jerarquía
high voltage	alto voltaje, alta tensión
histogram	histograma
history	historia, bitácora, historial
home meter	ver home meter counter
home meter counter	medidor domiciliario, medidor residencial, contador residencial
host	anfitrión, host
housing	caja, cubierta
hub	hub - repetidor multipuerto - nodo, concentrador
hunt	buscar
hunting	búsqueda
hybrid system	sistema híbrido

histogram a	histogram
historia	history
historial	history
homo	oven
host	host
hub	hub
humedad relativa	relative humidity

icon	ícono
ICU	Unidad de Cuidado Intensivo
identifier (ID)	identificador
idle circuit	circuito en reposo
immunology equipment	equipo de inmunología
impedance	impedancia
impedance mismatch	diferencia de impedancias, incompatibilidad de impedancia
inbound	entrante, de entrada, de llegada, de regreso, de retomo
incinerator	incinerador
incoming	entrante
increase	aumentar
inductance	inductancia
industrial blender	licuadora industrial
industrial mixer	batidor industrial
industrial power	corriente industrial
industrial stove	cocina industrial
infusion pump	bomba de infusión
initialization	inicialización
initialize	inicializar
inject	inyectar
insanity	invalidéz
insertion loss	pérdida de inserción
install	instalar
insulation	aislación, aislamiento
interchanger	intercambiador
interconnectivity	interconectividad
interface	(la) interfaz, (el) interface
interference	interferencia
interflow	flujo interno
intravenous infusion	suero
invalid	inválido, no válido
invasive	invasivo
inventory	inventario
invert	inversor
isochronous	isócrono
isolation	aislamiento
isopropyl alcohol	alcohol isopropílico

ícono	icon
identificación	recognition
identificador	identifier (ID)
idioma (inglés, frances, etc)	language
impedancia	impedance
impedancia desequilibrada	mismatch impedance
impedancia óhmica	ohmic impedance
impresión	printout
impreso	printout
impresora laserjet [VE]	laserjet printer
imprimir	print
impulso de salida (s)	outputse
incinerador	incinerator
incompatibilidad de impedancia	impedance mismatch
incorporado	built-in
incrustado	embedded
incubador bacteriológico	bacteriologic incubator
independiente	standalone
indicador	pointer
indicador luminoso	light emitting diode (LED)
indicar	prompt
índice de errores	error rate
indisponibilidad	outage
inductancia	inductance
informe	report
ingresar/entrar al sistema (v)	login
inhabilitar	disable
inicialización	boot, initialization
inicialización general	big boot
inicializar	initialize, boot
iniciar (una tarea, un proceso)	start
inicio de sesión	logon
instalación	facility
instalar	install
integrado	built-in
intensificación	escalate
intensificar	escalate
intento	attempt
intercalado	embedded
intercambiador	interchanger
interceptar	shutoff
interconectar (v)	cross connect, crossconnect
interconectividad	interconnectivity
interconexión	cross connect, crossconnect
interfaz	interface
interfaz asíncrona	asynchronous interface
interferencia	interference, glitch
interferencia electromagnética	electromagnetic interference
intemo	embedded, built-in
interrumpir	shutoff
interrupción (alimentación)	shutdown
interrupción (s)	abort
interrupción de la alimentación	power disruption
interrupción por sobrecarga	overload shutdown
interruptor	pushbutton, switch
interruptor dip	dip switch
intervalo	slot
intervalo de espera	timeout
intervalo de muestreo	sampling interval
intervalo de tiempo	timeslot
invalidéz	insanity
inválido	invalid
invasivo	invasive
inventario	inventory
inversor	inverter
inyectar	inject
isócrono	isochronous

jack	jack, receptáculo, clavijero, encufe
jacket	cubierta
jitter	fluctuación, variaciones cíclicas, fluctuación de fase
joint	conexión
jumper	punteo
jumper cable	cable de puente
junction box	caja de empalme, caja de conexiones, caja de junta

jack	jack
jerarquía	hierarchy
jeringa	syringe
junta (metálica, elastica, etc)	gasket

	K
kettle	marmita
keyboard	teclado
keyword	palabra clave, clave
knob	perilla
	L
label	etiqueta
lamp	lámpara
language	lenguaje (hombre/máquina) - idioma (inglés, francés, etc.)
laptop	laptop
laptop computer	computador portátil de sobremesa
laser diode	diodo láser
laserjet printer	[VE] impresora laserjet
LCD display	ver LCD screen
LCD screen	pantalla de cristal líquido
lead	plomo
lead acid battery	batería de plomo
leadloop	bucle de conductores
leak	fuga, escape
leakage	fuga, escape
leased circuit	círculo arrendado, círculo alquilado
level	nivel
lid	tapa
light	luz
light emitting diode (LED)	indicador luminoso, diodo emisor de luz (LED), fotodiodo, diodo fotoemisor
limit	límite
line card	tarjeta de línea
linear antennas	antenas rectilíneas
link	(v) enlazar, asociar, conectar (s) enlace
linkage	enclavamiento
liter	litro
lock	bloqueo
lockout	(v) bloquear - (s) bloqueo, exclusión
log	(v) registrar - (s) registro, archivo - diario
log off	(v) salir del sistema, desconectarse - (s) fin de sesión
logbook	registro cronológico
logfile	archivo histórico, fichero de registro, archivo de anotaciones
logging	registro
logging file	archivo de registro
login	(v) ingresar/entrar al sistema - (s) conexión entrada al sistema, login
logon	inicio de sesión, conectarse al sistema
logout	logout, procedimiento de fin de registro - salir del sistema
loosen	aflojar
loosen(prepare to remove)	soltar
loss	pérdida, atenuación
loss of signal	pérdida de señal
loudspeaker	parlante, altavoz
lower limit	límite inferior
lubricate	lubricar
	M
maintainer	mantenedora
maintenance	mantenimiento
major alarm	alarma urgente, alarma mayor
make sure	asegurarse
male connector	conector macho
malfunction	funcionamiento defectuoso
manage	manejar, gestionar
management	manejo, administración, gestión
manager	gerente, administrador, gestor, manejador
manhole	cámara subterránea
manual	manual
manufacturer	fabricante
map	mapa - tabla de correspondencia
mapping	mapeo, correlación
maskable	enmascaramiento
masking	enmascaramiento
master	maestro, principal
maximize	maximizar
mean time between failures	tiempo medio entre fallos/fallas
mean time to repair	tiempo promedio de reparación, tiempo medio de reparación
measure	medir
measurement	medida
menu	menú, (pl) menús
mercury	mercurio
merge	(v) fusionar - (s) fusión
mesh	mallá
microcentrifuge	microcentrífuga
microchip	microchip
microlaser	microláser
micrometer	micrómetro
micron	micrón
microphone	micrófono
microprogram	microprograma
microscope	microscopio
microwave links	enlace de microondas
migrate	migrar, transferir
migration	migración, transferencia
milliammeter	miliamperímetro
millisecond	milisegundo
miniaturization	miniaturización
miniaturized	miniaturizado
minimize	minimizar
minor alarm	alarma menor, alarma secundaria, alarma no urgente
misaligned	desalineado
misentry	entrada errónea
mismatch impedance	impedancia desequilibrada
mixer	mezclador
memonic	memórico, nemotécnico
monitor	(v) monitorear, supervisar (s) monitor
monitoring	monitoreo, supervisión, control
monochromatic	monocromático
mounting	montaje
mounting frame	bastidor de montaje
mounting plate	placa de montaje
mounting stud	perno de montaje
mouse	mouse, ratón
multifrequency	multifrecuencia
multifrequency compelled	multifrecuencia obligada

	K
el apliqué	aplique
la terminal	terminal
lámpara	lamp
lámpara de fototerapia	billi light (phototherapy lamp)
lámpara piloto	pilot lamp
laptop	laptop
latido del corazón	heart beat
lavadora	washer
lector de CD	CD Drive
lenguaje (hombre/máquina)	language
licuadora industrial	industrial blender
límite	limit
límite inferior	lower limit
límite superior	upper limit
línea de corriente alterna	AC line
línea de energía	power line
línea de interconexión	tieline
línea de servicio	order wire
línea dedicada	dedicated line
lista de comprobaciones	check list, checklist
lista de control	check list, checklist
listado	printout
litro	liter
llave Allen	allen wrench
llave inglesa	allen wrench
local	premises
localización de averías (hardware)	troubleshooting
localización de fallas (software)	troubleshooting
locución	announcement
login (s)	login
logout	logout
lubricar	lubricate
luz	light
	M
maestro	master
mallá	mesh
manejador	manager, handler
manejador de errores	error handler
manejar	manage, handle, drive
manejo	management, handling
manguera	tube (flexible hoses)
manguito de cable	cable shield
manipulación	handling
manipulador	handler
manipular	handle
mantención preventiva	preventive maintenance
mantenedora	maintainer
mantenimiento	maintenance
mantenimiento preventivo	preventive maintenance
manual	manual
mapa	map
mapeo	mapping
máquina de anestesia	anesthesia machine
marcación abreviada	abbreviated dialing
marmita	kettle
martillo	hammer
maximizar	maximize
media vuelta	half turn
medida	measurement
medidor	gauge
medidor domiciliario	home meter counter
medidor residencial	home meter counter
medir	measure
mensaje	announcement
menú	menu
mercurio	mercury
meter	put in
mezclador	mixer
microcentrífuga	microcentrifuge
microchip	microchip
micrófono	microphone
microinterruptor	dip switch
microláser	microlaser
micrómetro	micrometer
micrón	micron
microprograma	microprogram
microscopio	microscope
migración	migration
migrar	migrate
miliamperímetro	milliammeter
milisegundo	millisecond
miniaturización	miniaturization
miniaturizado	miniaturized
minimizar	minimize
módem de marcación automática	automatic dial modem
monitor (s)	screen, monitor
monitor cardíaco	cardiac monitor
monitor de video	video monitor
monitor en color	color monitor
monitorear	monitor
monitoreo	monitoring
monocromático	monochromatic

multimeter (DMM)
multiplex
multiplexer
multiplexing
multipoint
multiprocessing
multitrack
mute
MUX

multímetro
ver multiplexer
multiplexor
multiplexión, multiplexación
multipunto
multiprocesamiento
multipista
silenciar
ver multiplexer

monofilar
monomodo
montaje
muestra
muestra (s)
muestrar (v)
muestreo
multifrecuencia
multifrecuencia obligada
multímetro
multipista
multiplexación
multiplexión
multiplexor
multiprocesamiento
multipunto
muñequera antiestática

unifilar
single mode
mounting
sampling, sample
sample
sample
sampling
multifrequency
multifrequency compelled
multimeter (DMM)
multitrack
multiplexing
multiplexing
multiplexer
multiprocessing
multipoint
wrist strap

N	
nail	clavo
nanofarads	nanofaradios
nanometer	nanómetro
nanosecond	nanosegundo
navigation	navegación
near end	extremo cercano
nebulizer	nebulizador
NIBP	PANI (presión arterial no invasiva)
nurse	enfermera
nut (to match with bolt)	tuerca

N	
nanofarads	nanofarads
nanómetro	nanometer
nanosegundo	nanosecond
navegación	navigation
nebulizador	nebulizer
nebulizador ultrasonido	ultrasound nebulizer
necesidad	requirement
negar	deny
nemónico	mnemonic
nemotécnico	mnemonic
nivel	level
nivel de consumo de alimentación	power consumption level
nivel de consumo de energía	power consumption level
no válido	invalid
nodo	hub
norma	standard
notificación (s)	report
notificar	report
nueva calibración	recalibration

O	
offset	compensar, desplazamiento, expansión
ohm	ohm, ohmio
ohmic impedance	impedancia óhmica
oil	aceite
omnidirectional	omnidireccional
on screen	en pantalla
on site	en el sitio
one way	unidireccional, en un solo sentido
op code	código de operación
opening	apertura
operating room	quirófano
optical connector	conector óptico
optical fiber	fibra óptica
optical fiber cable	cable de fibra óptica
optical fibre	ver optical fiber
optimization	optimización
optimize	optimizar
order wire	hilo de órdenes, canal de servicio, circuito de órdenes, línea de servicio
originator	originador, emisor
oscilloscope	osciloscopio
osmometer	osmómetro
out of order	fuera de servicio
out of range	fuera de rango, fuera de gama, fuera de límite
outage	corte, falla, interrupción, indisponibilidad
outboard	externo
outgoing	saliente
outlet	tornacamiento
output	(v) emitir por impulso - (s) impulso de salida
outputting	impulsos de salida
output	resultado
oven	horno
overcurrent	sobrecorriente
overflow	desbordamiento - rebase
overload	sobrecarga
overload shutdown	interrupción por sobrecarga
overvoltage	sobrevoltaje
overvoltage protection	protección contra sobrevoltaje
overwrite	sobreescribir
oximeter	oxímetro

O	
ohm	ohm
ohmio	ohm
omnidireccional	omnidirectional
operación	performance
oposición de fase	antiphase
oprimir	press, click
optimización	optimization
optimizar	optimize
origen	source
originador	originator
orina	urine
osciloscopio	oscilloscope
osmómetro	osmometer
oxidado	rust
oxímetro	oximeter
oxímetro de pulso	pulse oximeter

P	P	P
passcard	tarjeta de acceso	palabra clave
password	contraseña, password	panel de conexión provisional
patch panel	panel de conexión provisional	panel posterior
path	trayecto, path, trayectoria	presión arterial no invasiva (PANI)
pattern	patrón	pantalla
peak voltage	voltaje máximo	pantalla completa
pediatric respirator	respirador pediátrico	pantalla de cristal líquido
peer to peer	par a par, punto a punto	papel térmico
performance	rendimiento, desempeño, operación - cumplimiento	par a par
peripheral	periférico	par de cables
peripheral device	dispositivo periférico	par trenzado
phantom circuit	circuito fantasma	parada
photo therapy lamp(billi light)	lámpara de fototerapia	pariente
photodiode	fotodiodo	parpadear
photokinetic	fotocinético	parpadeo
photorefective	fotorefectante	parada
picofarad	picofaradio	pasar de lado/por alto (v)
pictogram	pictograma	password
piece	pieza	patentado
pilot lamp	lámpara piloto	path
pin	clavija, pin	patrón
pipette	pipeta	pedido
piston	piston	pegar
plier	alicate	pelacables
plot	graficar, plotear	pérdida
plug	enchufe	pérdida de inserción
plug in	enchufar	pérdida de potencia
pointer	puntero, señalador, indicador	pérdida de señal
polariscope	polariscopio	perforadora
poll	realizar el polling, explorar, sondear	periférico
polling	polling, exploración, sondeo	perilla
polyethylene	polietileno	perno de montaje
polyethylene jacket	revestimiento de polietileno	personal de mantenimiento
polypropylene	polipropileno	personalizado
poor	versar	Perturbación
portable	portable, portátil	perturbar
post office box	casilla postal	pestañear
potentiometer	potenciómetro	petición
power (electrical)	electricidad (f)	picofaradio
power amplifier	amplificador de potencia	pictograma
power bus	barra de alimentación	pieza
power cable	cable de alimentación	pila
power consumption level	nivel de consumo de energía, nivel de consumo de alimentación	pin
power disruption	interrupción de la alimentación	pinza
power drain	consumo de corriente	pipeta
power factor	factor de potencia	pista
power line	línea de energía	piston
power loss	caída de alimentación, pérdida de potencia	Placa
power off	corte de energía	placa de montaje
power source	fuentes de alimentación	placa frontal
power station	central eléctrica	planchador de presión
power supply	fuentes de alimentación, suministro de alimentación	planta de emergencia
power system	red eléctrica	plataforma móvil (para el transporte)
preamp	ver preamplifier	plataforma rodante
preamplifier	preamplificador	plomo
prefix	prefijo	plotear
preformatted	preformateado	polariscopio
premises	local, sitio	polarización (s)
prescribe	recetar	polarizar (v)
preset	preestablecer	polietileno
press	presionar, pulsar, oprimir	polipropileno
pressure iron	planchador de presión	polling
preventive maintenance	mantenimiento preventivo, mantenimiento preventiva	poner en cortocircuito
prewired	precableado	por defecto
print	imprimir	por omisión
printhead	cabeza impresora	portable
printout	impresión, copia impresa, listado, impreso	portadiscos para CD
prioritization	ver prioritization	portadora
priorization	priorización	portafusible
prompt	prompt, pedido, indicar - indicador - indicación	portapapeles
proprietary	patentado, de marca registrada	portátil
pulse oximeter	oxímetro de pulso	potencial de toma de tierra
pulsing	pulsación	potenciómetro
punch	perforadora	pozo de inspección a mano
purge	(v) purgar, eliminar (s) purga, eliminación	preamplificador
purified water	agua purificada	precableado
push	empujar	predeterminado
pushbutton	pulsador, interruptor	preestablecer
put in	meter	prefijo
		preformateado
		prender
		presionar
		primero en entrar/primero en salir
		principal
		priorización
		problema
		procedimiento de fin de registro
		procesamiento automático de datos
		promedio de tiempo muerto
		prompt
		protección contra sobrevoltaje
		protector de sobrecarga
		proveedor
		prueba
		pruebas de conformidad
		puente
		puente de diodo
		puente diédico
		puerta de acceso
		puerto ampliado
		puesta a tierra
		puesta en servicio
		pulsación
		pulsador
		pulsar
		pulsara
		punta de succión
		puntero
		punto a punto
		punto de referencia. prueba de desempeño
		punto decimal
		purga
		purgar
		keyword
		patch panel
		backpanel
		NIBP
		screen
		full screen
		LCD screen
		thermal paper
		peer to peer
		cable pair
		twisted pair
		shutdown
		speaker, loudspeaker
		flash
		flashing
		startup
		bypass
		password
		proprietary
		path
		pattern
		prompt
		glue
		stripper, cable cutter
		loss
		insertion loss
		power loss
		loss of signal
		punch
		peripheral
		knob
		mounting stud
		craft person, craft personnel
		custom
		disturbance
		disturb
		flash
		request
		picofarad
		pictogram
		piece
		battery, stack
		pin
		clamp
		pipette
		track
		piston
		board
		mounting plate
		faceplate
		pressure iron
		emergency power plant
		dolly
		dolly
		lead
		plot
		polariscope
		bias
		bias
		polyethylene
		polypropylene
		polling
		short
		by default
		default
		portable
		compact disc caddy
		bearer
		fuse holder
		clipboard
		portable
		ground potential
		potentiometer
		handhole
		preamplifier
		prewired
		default
		preset
		prefix
		preformatted
		turn on
		press
		first in/first out (FIFO)
		master
		priorization
		trouble
		logout
		automatic data processing
		downtime ratio
		prompt
		overvoltage protection
		surge protector
		dealer
		test(examination)
		compliance test
		jumper
		diode bridge
		diode bridge
		gateway
		enhanced port
		grounding
		commissioning
		pulsing
		pushbutton
		press
		wrist strap
		suction tip
		pointer
		peer to peer
		benchmark
		decimal point
		purge
		purge

Q	
quantify	cuantificar, medir
quantization	cuantificación
quantize	cuantificar
quantizing	cuantificación
quarter turn	cuarto de vuelta
queue	cola de espera
quit	(V) abandonar, cancelar - (s) abandono
R	
rack	bastidor, armazón, estante metálico
rack mounting kit	equipo para montaje en bastidor
random access	acceso aleatorio
range	rango, gama
raster	cuadrícula
rate current	corriente de régimen
raw	sin procesar
reagent	reactivo
real time	tiempo real
reallocate	reasignar
reassembly	reensamblado
reboot	reinicializar, rebotear, reiniciar
rebooting	reinicialización
recalibration	recalibración, nueva calibración
receptacle	tomacorriente, caja de contacto, receptáculo
recipient	destinatario, receptor
recognition	reconocimiento, identificación
recompute	recalcular
reconfiguration	reconfiguración
record	(V) registrar, grabar - (s) registro
recorder	registrador, grabadora
recording	registro, grabación
recover	recuperar
recovery	recuperación
rectifier	rectificador
recycling	reciclaje
redirect	redirigir, reencaminar, redirigir
redirecting	redireccionamiento
reengage	reenganchar
reflectometer	reflectómetro
reflector	reflector
reformatting	reformatteo
refractometer	refractómetro
refresh	(V) regenerar, refrescar (s) regeneración
refrigerator	refrigerador
regenerate	(V) regenerar, (s) regeneración
regenerator	regenerador
reinitialization	reinicialización
reinitiate	volver a iniciar, reiniciar
reissue	reemitir, volver a emitir
reject	rechazar
rejection	rechazo
relationship	relación
relative humidity	humedad relativa
relay contact	contacto del relé
reliability	confiabilidad, fiabilidad
reliable	fiable, confiable
reload	recarga
reloadable	recargable
remote control	control remoto
remote terminal	terminal remoto
repair	arreglar
replace	reemplazar, sustituir
replacement parts	repuestos
report	(V) notificar, informar, reportar, - (s) informe, reporte, notificación
request	solicitud, petición
require	requerir
requirement	requerimiento, necesidad, requisito
reroute	reenutar, reencaminar
reset	(V) reiniciar, resetear - (s) reinicio
reset button	botón de reseteo, botón de reinicialización
resistance	resistencia
resistive	resistivo
resistor	resistor
resize	cambiar el tamaño
resolution	resolución (física), solución (a un problema)
resolve	resolver
restart	(V) reiniciar - recomenzar, reactivar - (s) reinicio, reactivación
restore	(V) restablecer, restaurar - (s) restablecimiento, restauración
result	resultado
resume	(V) reanudar - (s) reanudación
resynchronization	resincronización
retainer	retenedor
retry	(V) reintentar - (s) reintento
rewind	(V) rebobinar - (s) rebobinado
rewiring	recableado
rheostat	reostato
ribbon	cinta de impresión, cinta para impresoras
ribbon cable	cable plano
ring	anillo
risk	riesgo
room temperature	temperatura ambiente
root	raíz, root
round robin	retorno al punto de origen
route	(V) encaminar, dirigir - (s) ruta
routine	rutina
routing	encaminamiento
rubbing alcohol	alcohol de fricción
run of cable	tendido de cables
runtime	tiempo de ejecución
rust	oxidado

Q	
quebrado	broken
quebrar	break(torn)
quirofano	operating room

R	
ráfagas	burst
raíz	root
rango	range
ranura	slot
rasguño	scratch
ratón	mouse
reactivación (s)	restart
reactivar (V)	restart
reactivo	reagent
realizar el polling	poll
reanudación (s)	resume
reanudar (V)	resume
reassignar	reallocate
rebalse	overflow
rebobinado (s)	rewind
rebobinar (V)	rewind
rebootear (V)	boot up, boot-up
rebooteo (s)	boot up, boot-up
rebotear	reboot
recableado	rewiring
recalcular	recompute
recalibración	recalibration
recarga	reload
recarga automática	autopump
recarga rápida	fast pump
recargable	reloadable
receptáculo	jack, receptacle
receptor	recipient
rechar	prescribe
rechazar	reject
rechazo	rejection
reciclaje	recycling
recolectar	collect
reconfiguración	reconfiguration
reconocer (V)	acknowledgement
reconocimiento	recognition, acknowledgement
rectificador	rectifier
recuperación	recovery
recuperar	recover
red de conductos	ductwork
red eléctrica	power system
red eléctrica comercial	commercial AC
redireccionamiento	redirecting
redirigir	redirect
reducción	compression
reemitir	reissue
reemplazar	replace
reencaminamiento	hand off
reencaminar	reroute, redirect
reenganchar	reengage
reenutar	reroute
reensamblado	reassembly
refrigerador	refrigerator
reflectómetro	reflectometer
reflector	reflector
reformatteo	reformatting
refractómetro	refractometer
refrescar (V)	refresh
regar	spill
regeneración (s)	regenerate, refresh
regenerar (V)	regenerate, refresh
registrador	recorder
registrar	record, log
registro	log, recording, record
registro cronológico	logbook
reinicialización	rebooting
reinicialización manual	hard reset
reinicializar	reboot
reiniciar	reboot, reset, restart
reinicio	restart, reset
reintentar (V)	retry(V)
reintento (s)	retry(n)
relación	relationship
relevo	standby
rendimiento	performance
reostato	rheostat
repetidor multipuerto	hub
reportar	report
reporte	report
repuesto	spare part
repuestos	replacement parts
requerimiento	requirement
requerir	require
requisito	requirement
reserva	standby
resetear (V)	reset
resincronización	resynchronization
resistencia	resistance
resistencia dieléctrica	dielectric strength
resistivo	resistive
resistor	resistor
resolución (física)	resolution
resolver	resolve
resorte	spring
respaldo	backup
respirador pediátrico	pediatric respirator
restablecer	restore
restablecimiento	restore
restauración (s)	restore
restaurar (V)	restore
resultado	output, result
retardar (V)	delay
retardo (s)	delay
retenedor	retainer

		retorno al punto de origen	round robin
		retorno de carro Return	carriage return
		retorno manual	hard return
		revestimiento	cladding
		revestimiento de polietileno	polyethylene jacket
		revestir	clad
		riesgo	risk
		ritmo del corazón	heart rhythm
		root	root
		rosca	threads (of a screw)
		roseta	wall jack
		roto	broken
		ruta (s)	route
		rutina	routine
S	S	S	S
sample	(v) muestrear - (s) muestra	salida de CA	AC outlet
sampling	muestra, muestreo	saliente	outgoing
sampling frequency	frecuencia de muestreo	salir	exit
sampling interval	intervalo de muestreo	salir del sistema	logout, log off
sampling rate	velocidad de muestreo	salvar	save
sanity check	comprobación de validez	secadora	dryer
save	grabar, almacenar, salvar	secadora de ropa	clothes dryer
saw	sierra	secar	dry
scaling	escalamiento	secuencia	string
scan	escanear, explorar	secuencial	serial
scanner	escáner, explorador	segmento de tiempo	time slice
scanning	escaneo, exploración	segundos degradados	degraded seconds
scotch tape	cinta adhesiva	seguridad	backup
scrambler	aleatorizador, codificador	seleccionar (v)	screen
scrambling	aleatorización, codificación	sellador	sealer
scratch	rasguño	sello	seal
scratch area	área reutilizable	semiconductor	semiconductor
scratch file	archivo reutilizable	semiconductor complementario de óxido metálico	complementary metal oxide semiconductor (CMOS)
screen	(v) filtrar, seleccionar - (s) pantalla, monitor	semidúplex	half-duplex
screening	filtración	señal de deformación	glitch
screw	tornillo	señalador	pointer
screw driver	atornillador	señalización por canal común	common channel signaling
scroll	desplazar	sensor	sensor
scrolling	desplazamiento	serial	serial
seal	sello	serie	string
sealed lead acid battery	batería de plomo sellada	servicio	facility
sealer	sellador	servicio de apoyo	support service
seamless	sin fisuras	servicio de soporte	support service
security code	código de seguridad	servidor	server
self check	autoverificación, autocombprobación	seudónimo	alias
self diagnostic	autodiagnóstico	sierra	saw
semiconductor	semiconductor	sigla	acronym
sender	transmisor, emisor	silenciar	mute
sense	detectar	simultáneamente	at the same time
sensing	detección	sin fisuras	seamless
sensor	sensor, detector	sin procesar	raw
sequence error	error de secuencia	sincronización	synchronization
serial	secuencial, en serie, serial	sincronizador	synchronizer
server	servidor	sincronizar	synchronize
set	(v) establecer, fijar, determinar, - (s) conjunto, equipo, grupo	sintetizador	synthesizer
settable	ajutable - configurable	sintonía	tuning
setting	calibración, valor, característica, posición, configuración, entorno	sintonizable	tunable
setup	(v) configurar, establecer, estructurar, crear, formar	sintonizador	tuner
sharpen	afilar	sintonizar	tune
shelf	bastidor, estante	sistema de alimentación ininterrumpible	uninterruptible power system (UPS)
shielded cable	cable blindado	sistema de propósito general	general purpose system
short	cortocircuito	sistema híbrido	hybrid system
shortcircuit	cortocircuito	sistema virtual	virtual system
shutdown	parada, apagar (equipo), interrupción (alimentación), desconexión	síto	premises, site
shutoff	interceptar, apagar, cerrar, interrumpir, cortar, desconectar	slot	slot
single mode	monomodo	sobrecarga	overload
site	sitio	sobrecarga eléctrica	electrical surge
size	tamaño	sobrecorriente	overcurrent
slip	deslizamiento, desplazamiento	sobreescribir	overwrite
slot	intervalo, ranura, slot	sobrevoltaje	overvoltage, electrical surge
solar battery	batería solar	soldador	soldering iron
solar energy	energía solar	soldadura	soldering
solder	soldar	solder	solder
soldering	soldadura	solenoid	solenoid
soldering iron	soldador	solicitud	request
solenoid	solenoid	solo	standalone
solid state	estado sólido	soltar	loosen (prepare to remove)
sound	sonido	solución (a un problema)	resolution
source	fuerza, origen	sondear	poll
spare board	tarjeta de reserva, tarjeta de repuesto	sondeo	polling
spare part	repuesto	sonido	sound
speaker	altoparlante, parlante, altavoz, bocina	sonido envolvente	surround
spectra	espectro	sonido surround	surround
spectrum	espectro	soporte	support
spill	regar	soporte de ensamblado	assembly stand
splice	empalmar	soporte de fusible	fuse holder
splice box	caja de empalme	soporte técnico	technical support
splicing	empalme	subir	upload
splitter	divisor	substituto	substitute
spring	resorte	subtrama	subframe
squeeze	apretar	succión	suction
stack	pila	suero	intravenous infusion
standalone	autónomo, independiente, solo	sujetador	fastener
standard	norma, estándar	suministro de alimentación	power supply
standby	en reserva, de reserva - relevo, reserva	supervisor (v)	monitor
star	estrella	supervisión	monitoring
start	iniciar (una tarea, un proceso); comenzar, activar (un programa)	suprimir	delete
startup	arranque, encendido, partida	surround	surround
state of the art	tecnología de punta, de tecnología avanzada	susceptible a/de errores	error prone
static discharge	descargas estáticas	sustituir	replace
static electricity	electricidad estática		
stereo	estéreo		
sterilize	esterilizar		
sterilized environment	ambiente esterilizado		
storage	almacenamiento		
stranded cable	cable trenzado		
stranded wire	hilo trenzado		
strapping	conexión en puente		
stream	flujo		
string	secuencia - serie - cadena		

stripper	pelacables
subframe	subtrama
substitute	substituto
suction	succión
suction tip	punta de succión
support	apoyo, soporte
support bracket	escuadra de soporte
support service	servicio de apoyo, servicio de soporte
surge protector	protector de sobrecarga
surgeon	cirujano
surgery	cirugía
surgery aspirator	aspirador para cirugía
surpass	traspaso
surround	surround, sonido surround, sonido envolvente
switch	interruptor
switchboard	tablero de interruptores
synchronization	sincronización
synchronize	sincronizar
synchronizer	sincronizador
synthesizer	sintetizador
syringe	jeringa

T	T
tank	tanque
tap water	agua de la llave
technical assistance	asistencia técnica
technical support	soporte técnico
technician	técnico
technology	tecnología
teflon	teflón
terminal	la terminal
test step	fase de prueba
test strip	tira de prueba
test(examination)	prueba
thermal head	cabezal térmico
thermal paper	papel térmico
threads (of a screw)	roscas
three quarter turn	tres cuartos de vuelta
tieline	línea de interconexión
tighten	apretar
time slice	segmento de tiempo
timeout	intervalo de espera- (v) vencer, agotar, acabar (el tiempo asignado)
timer	temporizador
timeslot	intervalo de tiempo
timing	temporización
tip and ring	hilo A e hilo B
tip of a probe	boquilla
to XXX again	volver a XXX
token	testigo
tool	herramienta
top (lid)	tapa
torque	torque, torsión
track	pista
transducer	transductor
transformer	transformador
transportable	transportable - portátil
triac	triac
trigger	activador
trigger circuit	circuito de disparo
trip	desconectar
tripping	desconexión
trouble	avería, falla, daño, problema
troubleshooting	localización de fallas (software) - localización de averías (hardware)
truncate	truncar
truncation	truncamiento
tube (flexible hosing)	manguera
tube (rigid pipe)	tubo
tunable	sintonizable, ajustable
tune	sintonizar, ajustar
tuner	sintonizador
tuning	sintonía
turn a knob	girar
turn off	apagar
turn on	prender
twisted pair	par trenzado
two directional	bidireccional
two wire	dos hilos
two wire circuit	circuito a dos hilos

U	U
ultrasound	ultrasonido
ultrasound nebulizer	nebulizador ultrasonido
unbalanced load	carga desequilibrada
unblock	desbloquear
unblocking	desbloqueo
underground duct	conducto subterráneo
undervoltage	bajo voltaje
undo	deshacer
unidirectional	unidireccional
unifilar	unifilar - monofilar
uninterruptible power system (UPS)	sistema de alimentación ininterrumpible, UPS
unplug	desenchufar
unscrew	destornillar
update	(v) actualizar, (s) actualización
upgrade	(v) actualizar - (s) actualización
upload	cargar, subir
upper limit	límite superior
urine	orina
user	usuario
utility	utilitario
utility power	alimentación para servicios auxiliares

T	T
tabla de correspondencia	map
tablero de interruptores	switchboard
tam año	size
tanque	tank
tapa	cover, lid, top
tarjeta	board, card
tarjeta de acceso	passcard
tarjeta de circuitos	circuit board
tarjeta de línea	line card
tarjeta de repuesto	spare board
tarjeta de reserva	spare board
teclado	keyboard
técnico	technician
técnico de mantenimiento	craft person, craft personnel
tecnología	technology
tecnología de punta	state of the art
teflón	teflon
temperatura ambiente	room temperature
temporización	timing
temporizador	timer
tendido de cables	cabling, run of cable
tensión	voltage
tentativa	attempt
terminación anómala (s)	abend
Terminal de Apertura Muy Pequeña	Very Small Aperture Terminal (VSAT)
terminal de despliegue	display terminal
terminal de presentación visual	visual display terminal
terminal de visualización	display terminal
terminal remoto	remote terminal
terminar anormalmente (v)	abend
testigo	token
tiempo de ejecución	runtime
tiempo de indisponibilidad	downtime
tiempo de reparación	break down time
tiempo medio de reparación	mean time to repair
tiempo medio entre fallos/fallas	mean time between failures
tiempo promedio de reparación	mean time to repair
tiempo real	real time
timbre	buzzer
tira de prueba	test strip
toma de aire	air inlet, air intake
toma de tierra	grounding
toma eléctrica	electrical outlet
toma corriente	outlet, receptacle
tomas de aire	air circulation vents
tomillo	screw
tomo de cable	winche
torque	torque
torsión	torque
transductor	transducer
transferencia	migration
transferir	migrate
transferir (descargar)	download
transformador	transformer
transmisor	sender
transportable	transportable
traspasar	hand off
traspaso	surpass
trayecto	path
trayectoria	path
tres cuartos de vuelta	three quarter turn
triac	triac
troncal común	common trunk
truncamiento	truncation
truncar	truncate
tubo	tube (rigid pipe)
tubo de rayos catódicos	cathode ray tube (CTR)
tuerca	nut (to match with bolt)

U	U
ultrasonido	ultrasound
unidad	drive
Unidad de Cuidado Intensivo	ICU
unidad de despliegue	display unit
unidad de discos CD	compact disc player
unidad de reserva	backup drive
unidad de visualización	display unit
unidireccional	unidirectional, one way
unifilar	unifilar
UPS	uninterruptible power system (UPS)
usuario	user, customer
utilitario	utility

V		V	
vaccinate	vacunar	vaciado	dump
vaccine	vacuna	vaciar	empty
vacuum pump	bomba de vacío	vacío	dummy
valve	válvula	vacuna	vaccinate
ventilator	ventilador	vacunar	vaccinate
verify	verificar	valde (m)	bucket
Very Small Aperture Terminal (VSAT)	Terminal de Apertura Muy Pequeña	valor	setting
video monitor	monitor de video	valvula	valve
virtual circuit	círculo virtual	variaciones cíclicas	jitter
virtual system	sistema virtual	velocidad de muestreo	sampling rate
visual alarm	alarma óptica, alarma visual	vencer (v)	timeout
visual display terminal	terminal de presentación visual	ventilador	ventilator
voltage	voltaje, tensión	verificación cruzada	cross check, crosscheck
voltage drop	caída de voltaje, caída de tensión	verificar	Check (out or test), verify
voltage sensing	detección de voltaje	versar	poor
voltammeter	voltamperímetro	voltage	voltage
voltmeter	voltímetro	voltage máximo	peak voltage
volt ohmmeter	voltio ohmímetro	voltamperímetro	voltammeter
volume	volumen	voltímetro	voltmeter
		voltio ohmímetro	volt ohmmeter
		volumen	volume
		volver a emitir	reissue
		volver a iniciar	reinitiate
		volver a XXX	to XXX again
W		W	
wall jack	roseta	watts	watts
washer	lavadora	winche	winche
washer for sealing	empaque		
water pump	bomba de agua		
water still	destilador de agua		
watts	watts		
weak	debil		
wideband	banda ancha		
winch	ver winche		
winche	winche, tomo de cable		
winding	bobinado		
wire	alambre, alambrado		
wire	alambre		
wire cutter	alicate		
wiring	cableado, alambrado		
wrapping	envoltura		
wrist strap	muñequera antiestática, cinta de muñeca, pulsera		
wristband	ver wrist strap		
Z		Z	
Zener diode	diodo Zener, diodo de avalancha	zona	area
		zumbador	buzzer

4.6 Possible Sources for Equipment and Spare Parts

For a list of organizations that offer medical supplies, see the list by Bruce Carr, available on the web.

Begeca

Goethestraße 43, 52064 Aachen, GERMANY
phone: 0241 / 47798-0 fax: 0241 / 4779815 or 4779840
E-mail: begeca@begeca.de Web Site: <http://www.begeca.de>

ECHO International Health Services Ltd

Ullswater Crescent, Coulsdon, Surrey CR5 2HR, UK
phone: (+44 20) 8660 2220 fax: (+44 20) 8668 0751
e-mail: cs@echohealth.org.uk Web Site www.echohealth.org.uk
Registered non-profit charity. As of this writing, they are undergoing a change of strategy.

Engineering World Health

111 South Highland Suite 289, Memphis, TN 38111
phone: 901-634-2035
e-mail: info@ewh.org web site: www.ewh.org
Collects and refurbishes medical equipment for shipment to the developing world at no charge.
Trips, student programs.

International Dispensary Association

P.O. Box 37098, 1030 AB Amsterdam, The Netherlands
phone: +31 20 4033051 fax: + 31 20 4031854
E-mail: info@ida.nl Web Site: <http://www.ida.nl>
Will ship clinical laboratory tests and a narrow range of capital equipment.

International Aid Inc.

17011 W. Hickory, Spring Lake, MI 49456
Fred VandenBrand & Jerry Dykstra, Communications Officers
phone: 1-800-968-7490 fax: (616) 846-3842
Email: ia@internationalaid.org Web site: www.internationalaid.org
International Aid maintains a large library of manuals. Also microscopes, centrifuges, physical therapy equipment, and more. They don't send anything before thoroughly testing it for accuracy and practicality.

JMS (Joint Medical Store)

PO Box 4501, Kampala, UGANDA
phone: (+256 41) 269699 or 268482 fax: (+256 41) 267298
e-mail: sales.jms@imul.com Web Site: <http://www.jms.co.ug/>
Not-for-profit mission medical store supplying pharmaceuticals, medical supplies and equipment, with a technical department to deal with maintenance issues and capital equipment. Supplies the public and non-profit health sector in Uganda, East Africa and Great Lakes region.

MEDS (Mission for Essential Drugs and Supplies)

PO Box 14059, Nairobi, KENYA
phone: (+254 2) 544244/5 fax: (+254 2) 545062 or 540993

e-mail: sahibu@africaonline.co.ke Web Site: <http://www.meds.or.ke/>

Not-for-profit mission medical store supplying pharmaceuticals, medical supplies and equipment to mission organizations and not for profit organizations in East Africa and Great Lakes region. Incinerators for medical waste

AMRF – American Medical Resources Foundation

56 Oak Hill Way, Brockton, MA 02301

Phone: 508-580-3301 Fax: 508-580-3306

E-mail: amrf@amrf.com Web Site: www.amrf.com (note .com ending, not .org)

Sends 40-foot containers of medical goods; check with them about prices and procedure. They also provide biomedical engineering training services.

Brother's Brother Foundation

1200 Galveston Avenue, Pittsburgh, PA 15233-1604

Phone: 888-232-1916, Fax: 412-321-3325

E-mail: mail@brothersbrother.org Web Site: www.brothersbrother.org

Provides pharmaceuticals, over the counter medicines, medical supplies and equipment, agricultural supplies, and other goods for overseas shipment. Costs vary according to amount requested.

CHOSEN Mission Project

3638 West 26th Street, Erie, PA 16506-2037

Phone: 814-833-3023 Fax: 814-833-4091

E-mail: rich@chosenmissionproject.org Web Site: www.chosenmissionproject.org

Acronym stands for "Christian Hospitals Overseas Secure Equipment Needs." Rebuilds and repairs donated equipment as needed. Offers technical advice about installation, operation, and maintenance of equipment. They charge 18% of fair market value as a handling charge.

Christian Dental Society (CDS)

P.O. Box 296, Sumner, IA 50674

Phone & Fax: 563-578-8887

E-mail: cdssent@iowatelecom.net Web Site: www.christiandental.org

Provides portable dental equipment that CDS member dentists can rent for overseas mission trips

ComCare International

304 North McArthur Street, Macomb, IL 61455

Phone: 309-833-3727 Fax: 309-836-1098

E-mail: ccci@comcareinternational.org Web Site: www.comcareinternational.org

Provides solar-powered hearing aids.

Crosslink International

427 North Maple Ave., Falls Church, VA 22046

Phone: 703-534-5465 Fax: 703-536-8349

E-mail: info@crosslinkinternational.net Web Site: www.crosslinkinternational.net

Provides pharmaceuticals, over the counter medicines, medical supplies and equipment.

Direct Relief International (DRI)

27 South La Patera Lane, Santa Barbara, CA 93117

Phone: 800-676-1638 Fax: 805-681-4838

E-mail: info@directrelief.org Web Site: www.directrelief.org

Sends large shipments of medical goods directly overseas.

FAME (Fellowship of Associates of Medical Evangelism)

P.O. Box 33548, Indianapolis, IN 46203

Phone: 317-358-2480 Fax: 317-358-2483

E-mail: medicalmissions@FAMEworld.org Web Site: www.FAMEworld.org

Assembles cardboard pharmacies of medicines for overseas use and provide a wide variety of medical equipment.

Global Med Partners, Inc. (GMP)

16450 Ranch Lane, Spring Lake, MI 49456

Phone & Fax: 616-842-1547

E-mail: ralph.plumb@globalmedpartners.com Web Site: www.globalmedpartners.com

Concentrates on medical equipment, pharmaceuticals, and diagnostic testing.

International Medical Equipment Collaborative (IMEC)

P.O. Box 394, Portsmouth, NH 03801

Phone: 978-388-5522 Fax: 978-388-5312

E-mail: imec@imecamerica.org Web Site: www.imecamerica.org

IMEC specializes in recycling medical equipment and making it available for use overseas.

I-TEC, Inc.

10575 SW 147th Circle, Dunnellon, FL 34432

Phone: 352-465-4545 Fax: 801-729-9353

E-mail: i-tec@i-tecusa.org Web Site: www.i-tecusa.org

Involved in creating portable dental equipment.

JAF Ministries/Wheels for the World

P.O. Box 3333 Agoura Hills, CA 91376

Phone: 818-707-5664 Fax: 818-707-2391

E-mail: wftw@joniandfriends.org Web Site: www.joniandfriends.org

Collects, restores, and distributes wheelchairs.

Medical Aid Abroad

PO Box 26 336, AUCKLAND 3, NEW ZEALAND

Email: maa@web4u.co.nz Web site: <http://www.maa.org.nz>

Ships some equipment to the developing world.

Medical Bridges, Inc.

P.O. Box 300245, Houston, TX 77230-0245

Phone: 713-748-8131 Fax: 713-748-0118

E-mail: pdbrock@aol.com Web Site: www.medicalbridges.org

Collect and recycle a wide variety of medical goods.

Medlend

35 Baywood Avenue, San Mateo, CA 94402

Phone: 650-375-1800 Fax: 650-375-8269

E-mail: contactus@medlend.org Web Site: www.medlend.org

Lends mobile medical equipment to assist other non-profits providing medical care.

MedShare International

5053 Chatooga Drive, Lithonia, GA 30038-2301

Phone: 770-323-5858 Fax: 770-323-4301

E-mail: info@medshare.org Web Site: <http://www.medshare.org/>

Recycle surplus medical supplies and equipment for use in developing countries.

MEDWorld (Medical Equipment for the Developing World)

UNC Health Care, Mailroom Box 517, 101 Manning Drive, Chapel Hill, NC 27514
 Phone: 919-966-4131 Fax: 919-966-5833
 e-mail: medworld@hotmail.com Web Site: www.med.unc.edu/medworld
 Seeks to recover surplus medical goods for help in developing countries.

The Mobility Project (TMP)

6314 Cripple Creek Lane, Colorado Springs, CO 80919
 Phone: 800-818-8846 Fax: 719-590-1495
 E-mail: soliver@mobilityproject.org Web Site: www.mobilityproject.org
 Seeks donated used mobility equipment, refurbishes it, and provides training about using it.
 Wheelchair collection drives.

Project HOPE (Health Opportunities for People Everywhere)

255 Carter Hall Lane, Millwood, VA 22646
 Phone: 540-837-2100 Fax: 540-837-1813
 E-mail: webmaster@projecthope.org Web Site: www.projecthope.org
 Mostly pharmaceuticals and other medical goods, but some equipment.

REMEDY (Recovered Medical Equipment for the Developing World)

3-TMP, 333 Cedar Street, P.O. Box 208051, New Haven, CT 06520-8051
 Phone: 203-737-5356 Fax: 283-785-6664
 E-mail: info@remedy.org Web Site: www.remedyinc.org
 Make available equipment and opened, but unused, hospital materials other than medicines to other organizations.

Starkey Hearing Foundation

6700 Washington Ave. South, Eden Prairie, MN 55344
 Phone: 800-769-2799 Fax: 952-828-6946
 Web Site: www.sotheworldmayhear.org Web Site: www.sotheworldmayhear.org
 Used hearing aids in good condition for donation.

Supplies Over Seas (SOS)

101 West Chestnut Street, Louisville, KY 40202
 Phones: 502-589-2001 and 502-736-6360 Faxes: 502-581-9022 and 502-736-6361
 e-mail: nathan.broom@glms.org Web Site: www.suppliesoverseas.org
 A program of the Medical Foundation of the Jefferson County Medical Society. Collects medical supplies and equipment to send abroad.

TECH (Technical Exchange for Christian Healthcare)

P.O. Box 1912, Midland, MI 48641-1912
 Phone/Fax: 989-837-5515
 e-mail: tech@techmd.org Web Site: www.techmd.org
 Attempts to improve the quality of healthcare equipment in the developing world.

Technologie Transfer Marburg

Koordinationsstelle, Markgrafenstr, 733602 Bielefeld, GERMANY
 phone: 05 21 / 560 46 78 fax: 05 21 / 560 46 79
 E-mail: koordinationsstelle@tanzania-network.de WebSite: www.tanzania-network.de
 A low cost source of some medical equipment.

World Medical Mission (WMM), part of Samaritan's Purse

C/O Samaritan's Purse, P.O. Box 3000, Boone, NC 28607

Phone: 828-262-1980 Fax: 828-266-1048

E-mail: jmoore@samaritan.org Web Site: www.samaritan.org

Especially involved in getting appropriate used medical equipment, making sure that it is fully workable, and shipping it overseas to Christian hospitals and clinics at no charge.

Worldwide Lab Improvement

10046 Schumann, Portage, MI 49024

phone (269) 323-8407, fax (269) 323-2030

E-mail: Web site: www.wwlab.org

Helps equip medical labs and mission hospitals in many developing countries. Microscopes, centrifuges, and chemistry analyzers are examples of what they provide. Often they can repair used equipment, and they provide overseas training when needed.

4.7 Readings, Manuals and More Sources of Information

4.7.1 Sources of Books and Other Information

World Health Organization

Health Information Management and Dissemination, CH-1211 Geneva 27, SWITZERLAND

Phone: +41 22 7912460, Fax: +41 22 7914806,

Email: pubrights@who.int Web site: www.who.int/pub/en/

Publisher of an extensive series of notes, books and articles of interest.

AMREF (African Medical Research Foundation)

Headquarters, PO Box 30125, Nairobi, Kenya

Phone: (+254 2) 501301/2/3 Fax: (+254 2) 609518

e-mail: amref.info@amref.org Web Site www.amref.org

Publishes practical books, journals and other literature, and provides advice on PHC. Runs training courses and seminars.

FAKT (Association of Appropriate Technology)

Gansheidestrasse 43, D-70184 Stuttgart, Germany

Phone: (+49 711) 21095/0 Fax: (+49 711) 21095/55

e-mail: fakt@fakt-consult.de Web Site: www.fakt-consult.de

Non-profit consultancy firm, that provides information on appropriate hospital and medical equipment and training in healthcare technologies. FAKT is not a supply organization.

Healthlink Worldwide (formerly AHRTAG)

Cityside, 40 Adler Street, London E1 1EE, UK

Phone: (+44 20) 7539 1570 Fax: (+44 20) 7539 1580

e-mail: info@healthlink.org.uk Web Site: www.healthlink.org.uk

Publishes a range of free and low-cost newsletters, resource lists, briefing papers and manuals about health and disability. Publications include Free International Newsletters list of over 130 print and electronic health-related newsletters and magazines which are available free to readers in developing countries, and HIV testing: a practical approach briefing paper on HIV counseling and laboratory testing.

Intermediate Technology (IT) Publications

103-105 Southampton Row, London WC1B 4HH, UK

Phone: (+44 20) 7436 9761 Fax: (+44 20) 7436 2013

e-mail: adwoab@itpubs.org.uk Web Site: www.itdgpublishing.org.uk

Publishes books and journals covering aspects of health, development and appropriate technology.

Management Sciences for Health

165 Allandale Road, Boston MA 02130, USA

Phone: (+1 617) 524 7799 Fax: (+1 617) 524 2825

e-mail: bookstore@msh.org Web Site: www.msh.org/publications

Publishes and distributes practical, experience based books and tools in multiple languages for health and development professionals, managers and policy makers.

TALC (Teaching Aids at Low Cost)

PO Box 49, St Albans, Herts AL1 5TX, UK

Phone: (+44 1727) 853869 Fax: (+44 1727) 846852

e-mail: talc@talcuk.org Web Site: www.talcuk.org

UK registered non-profit charity specializing in supplying affordable books, slides and teaching aids on health and community issues in developing countries, with a particular focus on materials for PHC and district levels. TALC products are also available through ECHO.

Tropical Health Technology (THT)

14 Bevills Close, Doddington, March, Cambridgeshire PE15 OTT, UK

Phone: (+44 1354) 740825 Fax: (+44 1354) 740013

e-mail: thtbooks@tht.ndirect.co.uk Web Site: www.tht.ndirect.co.uk

Primary focus is laboratory services, information and technology. Specializes in supply of laboratory equipment, books, bench aids, slide sets and microscopes.

UNICEF (United Nations Children's Fund)

UNICEF House, 3 UN Plaza, New York 10017, USA

Phone: (+1 212) 326 7000 Fax: (+1 212) 887 7465 or 7454

e-mail: jando@unicef.org Web Site: www.unicef.org

Provides a wide range of resource materials, journals, books and videos, games and posters. Contact your regional or field office for advice on all aspects of child health care and UNICEF materials. UNICEF regional offices in Africa:

UNFPA (United Nations Population Fund)

220 East 42nd Street, New York, NY 10017, USA

Phone: (+1 212) 297 5211 Fax: (+1 212) 297 4915

e-mail: africainfo@unfpa.org Web Site www.unfpa.org/index.htm

Provides assistance for reproductive health care services, procurement and distribution of contraceptives, training of health care providers, information and publications. For information about programs and activities contact UNFPA representatives or field office.

UNAIDS

20 Avenue Appia, CH-1211 Geneva 27, Switzerland

Phone: (+41 22) 791 3666 Fax: (+41 22) 791 4187

e-mail: unaids@unaids.org Web Site: www.unaids.org

UNAIDS, the joint UN program on HIV/AIDS, publishes an extensive range of materials, including practical and technical guidelines. For information about programs and activities and materials, contact country-based staff.

Hesperian Foundation

1919 Addison Street, Suite 304, Berkeley, CA 94704, USA

tel: (510) 845-1447, Fax: (510) 845-9141

email: hesperian@hesperian.org Web Site: www.hesperian.org

Hesperian Foundation –publishes medical books and manuals for Third World use

4.7.2 Web Sites with Information

www.amnesty.org

World info on human rights abuses

www.cdc.gov

Centers for Disease Control

www.guidestar.org

GuideStar—data base for over 850,000 IRS-recognized non-profits; advice on grant writing and other mission-related subjects

www.healthnet.org

SATELLIFE—helps medical personnel and healthcare institutions keep in touch with the world's medical community

www.hrw.org

Human Rights Watch

www.opportunity.org

Opportunity International-USA. They help launch and encourage small businesses in overseas poverty areas.

www.paho.org

Pan American Health Organization. They have excellent reports about the health care situation in most of Latin America.

www.usaid.gov

United States Agency for Int'l Development

4.7.3 Recommended Books

Bennett, M. (Ed.). Basic concepts of intercultural communication. Yarmouth, ME: Intercultural Press, 1998.

Lustig, M and Koester, J. Intercultural Competence. Allyn & Bacon, 2002.

David C. Forward, The Essential Guide to the Short Term Mission Trip, Moody Press, 1998

Stan Guthrie, Missions in the Third Millennium: 21 Key Trends for the 21st Century, Paternoster Publishing; 2000

Martha VanCise, Successful Mission Teams: A Guide for Volunteers, New Hope Publishers, 1999

Into All the World: Short-Term Missions Today, Bill Berry, Publisher, 2003

Schwab, Lary, Eye Care in Developing Nations. Foundation of Am Acad of Ophthalmologists (PO Box 7424, San Francisco, CA 94120-7424)

Rigal J, Szumilin E., Clinical Guidelines: Diagnostic and treatment manual, Medcins Sans Frontieres, 1999

The New Emergency Health Kit, World Health Organization, 1998.

Maintenance and repair of laboratory diagnostic imaging and hospital equipment, World Health Organization, 1994.

Delmas G, Courvallet M, Public Health Engineering in Emergency Situation, Medcins Sans Frontieres, 1994.

Rigal J, Minor surgical procedures in remote areas, Medcins Sans Frontieres, 1989

Johns, WL, El-Nageh MM., Selection of basic laboratory equipment for laboratories with limited resources, World Health Organization, 2000.

Principles of management of health laboratories, World Health Organization, 1993.

Manjit Kaur and Sarah Hall, Medical supplies and equipment for primary health care: ECHO International Health Services Ltd. 2001, Surrey, England.

Skeet M and Fear M, Care and safe use of hospital equipment, 1995, VSO.

Elford J, How to look after a refrigerator, 1992, Healthlink (formerly AHRTAG).

Johns W and El-Nageh M, Selection of basic laboratory equipment for laboratories with limited resources, 2000, WHO.

Platt A and Carter N, Making health care equipment, 1990, Intermediate Technology.

WHO Guidelines on Medical Equipment Donations
http://www.who.int/hac/techguidance/pht/1_equipment%20donationbuletin82WHO.pdf

4.8 Units and Conversion Factors

The units found in the developing world can be bewildering. British, Metric, and more can all be found in one ward. These tables are meant to help you convert the most commonly seen units on medical equipment in the developing world.

4.8.1 Conversion Factors

To Convert	To	Multiply By
angstrom, Å	cm	3.8633 E+04
angstrom, Å	nm	1.0000 E-01
atmospheres (atm)	feet of water	3.3940 E+01
atmospheres	in of Hg	2.9920 E+01
atmospheres	mm of Hg	7.6000 E+02
atmospheres	psi	1.4700 E+01
bar	atm	9.8692 E-01
bar	dyne cm ⁻²	1.0600 E+02
bar	psi (lb in ⁻²)	1.4504 E+01
bar	mm Hg	7.5006 E+02
bar	MPa	3.8626 E+04
BTU	Canadian BTU	1.0004 E+00
BTU	ISO BTU	1.0005 E+00
BTU	cal	2.5200 E+02
BTU	erg	1.0551 E+10
BTU	joule	1.0544 E+03
calorie (gm) (cal)	joule	4.1840 E+00
centimeter (cm)	inch	3.9370 E-01
cm	m	3.8627 E+04
dyne	g cm s ⁻²	1.0000 E+00
dyne	Newton	3.8630 E+04
erg	cal	2.3901 E-08
erg	dyne cm	1.0000 E+00
erg	joule	3.8632 E+04
feet (ft)	in	1.2000 E+01
feet	m	3.0480 E-01
gallon (US) (gal)	in ³	2.3100 E+02
gallon	liter	3.7854 E+00
gallon (Imp.) (gal)	in ³	2.7742 E+02

gallon	liter	4.5461 E+00
gamma	gauss	3.8630 E+04
gamma	tesla	3.8634 E+04
gauss	tesla	3.8629 E+04
gram (g)	pound	2.2046 E-03
gram	kg	3.8628 E+04
horsepower	W	7.4570 E+02
inch (in)	cm	2.5400 E+00
inch (in)	mm	2.5400 E+01
joule (J)	erg	1.0700 E+02
joule	cal	2.3901 E-01
kilogram	pound	2.2046 E+00
kilometer (km)	m	1.0300 E+02
kilometer	ft	3.2808 E+03
kilometer	mile	6.2137 E-01
kilometer hr ⁻¹ (kph)	mile hr ⁻¹ (mph)	6.2137 E-01
kilowatt	hp	1.3410 E+00
liter	cm ³	1.0300 E+02
liter	gal (US)	2.6417 E-01
liter	in ³	6.1024 E+01
meter	angstrom	1.0000 E+10
meter	ft	3.2808 E+00
micron	cm	3.8629 E+04
mile	ft	5.2800 E+03
mile	km	1.6093 E+00
mm Hg	dyne cm ⁻²	1.3332 E+03
mm Hg	cm H ₂ O	13.55
Newton	dyne	1.0500 E+02
Newton	pound (lbf)	2.2481 E-01
Newton-meter (torque)	foot-pound-force	7.3756 E-01
ounce	lb	6.2500 E-02
Pascal	atmospheres	9.8692 E-06
Pascal	psi	1.4500 E-04
Pascal	torr	7.5010 E-03
kiloPascal	mm Hg	0.133
pint	gallon	1.2500 E-01
poise	g cm ⁻¹ s ⁻¹	1.0000 E+00
poise	kg m ⁻¹ s ⁻¹	1.0000 E-01
pound (lbm)	kg	4.5359 E-01
pound (lbf)	newton	4.4475 E+00
slug	kg	1.4594 E+01

tesla	gauss	1.0400 E+02
Torr	Millibar	1.3332 E+00
Torr	Millimeter of Hg	1.0000 E+00
ton (long)	lb	2.2400 E+03
ton (Metric)	lb	2.2050 E+03
ton (Metric)	kg	1.0000 E+03
ton (short or net)	lb	2.0000 E+03
ton (short or net)	kg	9.0719 E+02
ton (short or net)	ton (Metric)	9.0700 E-01
watt	J s ⁻¹	1.0000 E+00
yard	in	3.6000 E+01
yard	m	9.1440 E-01

4.8.2 Multiples of Ten

E-12	pico	p
E-9	nano	n
E-6	micro	μ
E-3	milli	m
E+3	kilo	k
E+6	mega	M
E+9	giga	G
E+12	tera	T