Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

SPARE PARTS & WORKING MATERIALS FOR THE MAINTENANCE & REPAIR OF HEALTH CARE EQUIPMENT

A Workshop held in August 1991
in Lübeck by Deutsche Gesellschaft
für Technische Zusammenarbeit GmbH

Division of
Health, Population and Nutrition

Editors : C. Temple-Bird, H. Halbwachs
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1. OPENING OF THE WORKSHOP

1.1 Opening Address by the Head of the Department of Health, Population and Nutrition of the GTZ, Dr Rolf Korte.

The GTZ recognizes the importance of this workshop, and welcomes the opportunity to hold this meeting in the Division of Biomedical Engineering of the Fachhochschule of Lübeck. Here the delegates can learn about the work of the department and discuss issues of medical equipment maintenance for the future.

The GTZ has established a tradition of these workshops for developing knowledge and advancing skills in order to improve the medical services in developing countries.

This workshop necessarily focuses on the specific issue of spare parts, however it is important to consider this topic in the wider context of the district health system as a whole. A district health service usually serves a population of several hundred thousand - this is a very substantial target group. The issue of spare parts and maintenance must be considered within the context of the problems faced by this target group and their health providers. As Figure 1.1.1 shows there are important issues which affect the provision of district health services and these all impact on the role of the technical services within the district.

1. District Health Problems. There are health, epidemiological, and demographic problems within a district. These can be objective problems, measurable using epidemiological tools, or subjective problems felt by the local population to be essential. Since the population notices whether the equipment and furniture in the health facilities are in working order, the technical role within the district health service already becomes apparent. The condition of the equipment and furniture then becomes one of the essential components which determine whether the population accepts and utilizes the health service on offer.

2. Organization of District Health Services. There must be adequate planning of the structure, appropriateness, functioning and efficiency of the services. These are issues which affect all the sectors within the health service including the technical sector. An approach is necessary which ensures that technical personnel are always part of a team together with the district health staff.

3. Distribution of District Health Facilities. Access and availability of health services is very critical and in some countries there are great difficulties with the physical remoteness of health facilities. Where there are problems of access by the population, there are problems with the time, transport, money and effort required in order to receive health care. This problem extends to any technical service trying to support rural facilities.

4. Delivery of District Health Services. Effective delivery depends broadly on four factors:- content and objectives, finances, logistics and administration.
   a. The content and main objectives of the health service must be decided upon. Technical personnel should be a part of the health team, so that everyone works together to achieve the health goals.

Figure 1.1.1 : The Maintenance of Health Care Equipment within the Wider Context of the Problems Facing the District Health Services

```
1. District Health Problems:-

 - health, epidemiological
   and demographic problems
                         ........
 - both objective and           :             2. Organization of District
   subjective problems          :                Health Services:-
                                :
                                :              - structure
                                :
                                :              - appropriateness
                                :   ........
3. Distribution of District     :   :          - functioning
   Health Facilities:-          :   :
                            ....:...:....      - efficiency
 - availability             :Maintenance:
                     .......:    of     :
 - access                   :Health Care:
                            : Equipment :
                            :...........:
                                :   :         4. Delivery of District
                                :   :            Health Services:-
                                :   :
5. Wider Issues Affecting       :   :          - contents and objectives
   District Health Services:-   :   :.......
                                :              - finances
 - socio-cultural               :
                         .......:              - logistics
 - socio-economic
                                               - administration
 - geographic

 - political
```

b. It is very important that there are sufficient finances. It is necessary to know how much money is available per capita. In addition there is funding per sub-sector; one sub-sector is maintenance and it is too often neglected, so it is necessary to press for adequate funding of technical services. Also there is funding per geographic sub-unit; often the balance is in favour of the central facilities leaving the peripheral and rural facilities neglected, although this is where the majority of the population lives and the greatest needs are found.

c. All health personnel and sub-sectors depend on adequate logistics to function effectively. The technical service is not only affected by the various aspects of logistics but also has a great effect on them:-
   * physical infrastructure - the responsibility of the technical service
   * personnel - technical personnel are grossly under-represented
   * equipment and materials - the main domain of the technical service
   * transport - the lack of transport is an eternal problem and attempts must be made to find solutions within existing constraints
   * communication - very important for all sectors.

d. All sub-sectors of the district health system are affected by the administration:-
   * by the ability of the system to support continuous training
   * by the system of supervision
   * by the management information system. Health personnel should not only collect data but also receive feedback; this should be in the form of analysis of their data so that adequate management decisions can be made.

5. <u>Wider Issues Affecting District Health Services</u>: Health work is done within an existing social, political, cultural and geographical system. Only limited funds are available. The funds for health have been drastically declining; over the last 10 years the funds available for public sector health care have been reduced by 50% in many developing countries. Nowadays in the rural areas in many developing countries, the availability of funding for health care is in the order of DM 5-10 per capita. It is a challenge in the technical field to see what can be done reasonably within these serious financial constraints. Politicians must realize that this is not a funding level for running efficient health services.

Against this background the developing countries face a very serious technological dilemma. Industrialized countries have for many years lived under the illusion that the best available technology in medical care could be provided to virtually the entire population. As costs have sky-rocketed and health care consumed a disproportionate share of the national income, control measures had to be taken. It has been extremely difficult to find a consensus amongst professionals and politicians on the criteria for cutting costs. These choices are of course even more difficult in developing countries. Consensus in the political sphere has been even more difficult to attain in view of the vested interests of the many influential pressure groups, including industry which is the key provider of technological tools. In industrialized countries where everybody has access to essential medical care, the difficulties of balancing the level of desirable technology against affordability are almost negligible compared to the situation in developing countries where large populations have virtually no access to modern life-saving medical care.

Technological choices become crucial when the investment in an x-ray machine has to be weighed against the provision of an adequate supply of penicillin to prevent death from pneumonia. It is important to always remember that we are working within a system; so when we demand spare parts and equipment, we must realize that there are other sectors in the health service which are also facing serious shortages.

When studying needs, there are those that can be objectively determined by epidemiological studies. However "felt" needs may differ from these very significantly depending on the social and economic group involved. It is often the most powerful social and economic group that determine the demand, although most countries have opted for a primary health care policy. Demand is frequently also determined by the desperate foreign exchange situation and requests are submitted for urgently needed consumable supplies to sustain the routine health services. Thus precious technical assistance funds are used for the continuation of existing services rather than for the transfer of technological knowledge.

Only a cautious dialogue between representatives from developing countries and industrialized countries can bring solutions which provide for a maximum of equity without excluding developing countries from technological progress. As Elliott (Brit.med.J., 1984, p.1251) states, "technologies provided"...to developing countries and industrialized countries alike..."must be effective, culturally acceptable, affordable, sustainable locally, not overdependent on external skills, measurable as to their performance, and last but not least politically responsible".

It is also obvious that the mere supply of technological tools without the fundamental transfer of technological knowledge as well, can only be second choice and can only be justified on a short term basis. There is the risk of an ever widening technological gap between developing countries and industrialized countries if no serious efforts are made to transfer tools, knowledge and skills in a co-ordinated and forceful manner. The technology transferred must never be stigmatized as second rate. There must be general acceptance of the fact that developing countries should have access to the most advanced technologies, as long as they meet the criteria outlined above. Modern technologies may at times also be more economical and easier to use. Critical areas of potential saving in running costs and foreign exchange should receive special attention.

The topic of this conference is a key entry point into this very important area. It will contribute to advancing our knowledge and produce practical solutions in this important endeavour. Medical maintenance services are in an early stage of development. It is still a fairly new area in Germany also, where training courses have only been established relatively recently. Action has to be taken immediately instead of waiting for non-existent easy solutions. I wish the participants all the best of luck with this conference.

1.2 Welcome Address by the Rector of the Fachhochschule of Lübeck, Prof.Dr. Taurit.

Within the German federal structure, there are 70 fachhochschulen which were founded in 1969. Originally they evolved from our engineering schools, but nowadays we consider them to be a real alternative to universities. The main difference is that the training, teaching, and research is application orientated, and the research leads to the development of products and systems. The training consists of theoretical studies, of practical laboratory work, and of external practical experience in industry and usually in the field of engineering. Our institution offers all engineering subjects, but other institutions have business administration, social studies and design subjects.

The fachhochschulen in Germany are accepted by business, industry and society, and it is said that in comparison to universities, fachhochschulen are equivalent but different! The differences are: the number of semesters and the number of weeks per semester; the practical orientation of the courses which leads to good professional opportunities for graduates; the insistence that professors at fachhochschulen have a PhD and 5 years industrial practice.

Of the 1.4 million students in Germany, 25-30% attend fachhochschulen and the aim is to reach 40%. In the engineering field, 75% of all engineering diploma degrees are undertaken at fachhochschulen. The plan is to increase the available study places at fachhochschulen in Germany by an additional 50,000.

We consider that a fachhochschule corresponds to a polytechnic in the UK and the grande école nationale supérieure in France. There is an equivalent system in the Netherlands. Some Scandinavian countries are interested in developing the fachhochschule system and are in consultation with institutions in Germany at present. Greece and Spain have shown an interest in developing their institutions in this direction. The former East German states do not have such a system, so there is now the challenge to extend this system into the new unified Germany.

In Lübeck, the fachhochschule has 113 professors on the staff making it an average sized institution. At present there is a shortage of engineers who undertake practical tuition in the laboratories; with only 45, there is not a good enough ratio to professors and this is a problem we want to address.

The Lübeck fachhochschule teaches 7 courses: architecture, and civil, mechanical, electrical, physical, chemical and health engineering. The plan is to also offer business administration.

The fachhochschule in Lübeck has 1000 places, however there are at present 3000 students; this has great implications on practical work. There is building construction and renovation in progress around the campus, and when it is complete we will have a larger and better equipped institution. At present only a small percentage, 4-7%, of the students are from overseas. The fachhochschule has partnerships with London, Staßbourg and Copenhagen which we find very beneficial. We are also developing partnerships in Finland, the USA, and China through existing links established by the town of Lübeck.

Lübeck provides a beautiful environment and is a city of culture. I hope you enjoy what it has to offer whilst working hard to produce a very successful workshop. I am very happy to pronounce this workshop open.

2. INTRODUCTION

2.1 Activities of the World Health Organization
(J.McKie, on behalf of A.Issakov, WHO, Geneva)

I thank you for inviting a representative of the World Health Organization (WHO) to your symposium. I am here to talk on behalf of Dr A. Issakov of the Division of Strengthening of Health Services of the WHO.

During most of its lifetime, the WHO has underestimated the use of advanced technology in health care. Very properly, it wanted priority to be given to primary care which would bring most benefit to the majority of the population in developing countries through clean water, good sanitation and nutrition. Thus scarce resources would not be spent on the costly technologies used at second or third referral levels. Such technologies consume vast funds in the developed countries, where the more basic needs of the community were more or less dealt with in the earlier days of their industrial revolutions.

However well-intentioned, these policies would work only in a fantasy world. Real people want the benefits of development at all levels of health care concurrently. The sequential, historical development of an industrialized country cannot be imposed upon a developing country. People will not wait for their renal dialysers until every village has a sewage disposal plant, any more than they will delay building airports until they have worked through the sequence of coaching inns, canal ports, railway termini and bus stations.

Finally WHO had to recognize that every country had advanced technology either indigenous or, more commonly, imported from or gifted by an industrialised country. Like it or not, significant resources were being used for this technology. Further more these resources were being wasted because the working lifetime of the technological equipment was very short - sometimes even zero. WHO began to get involved in technician training, as many of us did, thinking that with technicians to maintain the equipment, the problems would be solved. From costly experience we learned that training technicians is only part of the answer, and by itself is far from an effective answer.

In February 1986, the WHO Programme Committee decided to place more emphasis on the management, maintenance and repair of health care equipment. Subsequently, Andrei Issakov began to make contact with the main centres who were working on these problems and he did much to persuade WHO headquarters that it should do more than set up training centres for "polyvalent technicians". Still it was not clear whether there were problems common to all countries or a wide variety produced by different country circumstances.

So an "Inter-regional meeting" was held in Cyprus in November 1986, attended by representatives from most WHO regions, training centres, health ministries, governmental and non-governmental organizations, international organizations, professional organizations and major medical equipment manufacturers. There was surprising agreement on the nature of the difficulties and the action which was needed. The whole problem was described and analyzed in some detail. I believe that since that time there has been no significant addition or alteration suggested to the description and the analysis, although there may have been many different ways of presenting the issues.

This meeting made many recommendations to governments and to the WHO; this led the Geneva Headquarters to produce the Global Action Plan. The objectives of the plan are stated as follows:

"By building up common collaborative action at all levels, facilitating WHO's liaison with the other organizations and agencies concerned and mobilising resources for comprehensive, integral and coherent action to promote countries' awareness and to facilitate necessary changes pertaining to the strengthening of national capabilities in the field of management, maintenance and repair of health care equipment, particularly policy formulation, planning, budgeting, development of national health care technical services' infrastructure, information support and manpower training".

The proposed activities are grouped under three headings:

1. Promotion of awareness of the problem, policy formulation and information exchange.
2. Strengthening of National Health Care Technical Services.
3. Manpower development.

Under each of these headings, activities are detailed at international, regional and national levels, with methods of monitoring progress. Initially the intention was for activities to take place in one or two countries in each of the six WHO regions (AFRO, EMRO, EURO, PAHO, SEARO, and WPRO).

The Global Action Plan is an excellent concept, the trouble is that WHO has virtually no money to fund it. It emerged at a time when the available funds were diminishing and when new problems such as AIDS were receiving priority. WHO made a start on the first activities listed, such as preparing standard guidelines for Country surveys, and funding a second inter-regional conference on manpower development in Campinas, Brazil, in November, 1989. In collaboration with Joe Noble of ECRI in USA, it started a newsletter.

The Cyprus meeting stressed the need to train for the highest managerial level in Health Ministries, thus WHO has proposed the setting up of an International School for Management of Health and Medical Care Support and Technical Services. The detailed curriculum of a specialised MBA degree is being drafted in the Centre for Medical Education, Dundee University, Scotland. Negotiations are in progress with a donor for the funding of the School, and to make arrangements similar to those which have made possible the Malmo International Maritime University. The scheme will progress later this year.

However, for most of the activities which are envisaged in the Action Plan, WHO has to rely on Governmental or other organizations carrying out some part of the plan, or making one of its on-going activities available as part of the plan. Unfortunately, the plan emerged at a time when most aid-giving countries were suffering economic recession. The WHO has found it very difficult to achieve collaboration within the scope of the Global Plan.

A notable exception has been GTZ. I wish to express the gratitude of WHO for your collaboration which has made possible a variety of activities which contribute to the plan, such as strengthening the HCTS in Kenya and your organization of the conference in Nairobi. This symposium is exactly the type of activity envisaged in the plan to generate practical data of global applicability. By inviting WHO to participate and, hopefully, by making the results of your work available through WHO, the GTZ has deservedly earned the gratitude of WHO. More importantly, you will have made a significant contribution to the Health Care of many nations. On behalf of WHO I congratulate you on your enterprise.

2.2 The Need for Spares: Excuse or Reality?
(H.Halbwachs, GTZ, Germany)

When people involved with technology in health care are questioned about major problems, one of the first and quickest replies is "A Lack of Spare Parts". The reasons given are widely known, here are just some of them:
- diversity of equipment
- equipment too old
- limited local market
- the purchaser/the donor does not care
- the administration/the user does not care
- import/currency restrictions
- manufacturers/local branches are not cooperative
- stock keeping and stock distribution inefficient or unsecured.

This list is quite impressive and should therefore give reason for doubt. Human nature tells us that when we hear so many excuses for a deficiency, usually they are hiding an even bigger failure - in this case the failure to keep equipment in working condition. Still, a lack of spare parts constitutes a serious difficulty for maintenance services:- when asked for a reason for being unable to repair a customer's car, a mechanic explained that he had been forced to use too many bent nails and string the last time! Reliable information on the nature and quantity of the parts needed is unavailable in most developing countries. Thus, solving these problems and the related planning is being obstructed.

Some Definitions:
The German Institute of Standards (DIN) has developed standardized technical terms related to our theme. This might seem a bit over sophisticated, but it could provide a common language for our discussions here and in the future. Here are some brief terms based on those standards which describe spare parts:

Wear parts:	Parts which are used at positions which are exposed to wear and tear. Such parts are often designed to be exchanged, thus to protect other, more critical parts. Exchange can be pre-planned. Examples: sole of a shoe, tyres for a wheel chair, ball bearings, gaskets.
Safety breaking parts:	Parts which protect other parts from excessive (mechanical) stress by disintegrating at a predefined force. Examples: safety pin of an outboard propeller, thermo-fuse.
Specific spare parts:	Parts to replace parts of one or more pieces of equipment and which can often be repaired. These parts are designed for specific equipment and cannot be used independently from this equipment. Examples: valves of an engine, level glass tube of an autoclave.
General spare parts:	Parts which are similar to spare parts but which are not designed for specific equipment. Usually, they can be universally utilized and may be modified or further processed. Examples: circuit breakers, switches, castors, heating resistors.
Consumable parts:	These are similar to spare parts but cannot be repaired. These parts are designed to be consumed during utilization of the equipment. Exchange can be pre-planned. Examples: brake and clutch linings.
Minor parts:	Parts which can be utilized universally and which are of minor value according to ABC-Analysis. Examples: nuts and bolts, fuses.

To assess and set priorities for the real spare part requirements is a prerequisite for any improvement. This is true even for countries which have serious problems in providing the simplest material. For industrial purposes often complex mathematical assessment formulas have been developed. It is doubtful whether such formulas have significant practical value, in particular for maintenance services in health care. The next section will deal with an alternative approach.

Assessing Spare Part Requirements:
If it is agreed that abstract formulas are of little help, one can only look for an empirical way of estimating spare part requirements, taking into account the limiting circumstances in most developing countries. As a first step for a specific instrument, the typical break-down behaviour must be investigated. It appears that no relevant study has been undertaken for any developing country, and available information from industrialized countries is of little help since it generally does not relate to the situation in these areas. This workshop has been set up to draw attention to this problem and to work in particular on compiling spare part lists which can be used for some types of equipment. It is doubtful if it can go beyond this and consider brands and models. Such information and more detailed base-line investigations must take place in the developing countries themselves.

With some idea on the breakdown rates of designated spare parts, one could try to characterize the importance of every part. Thus, one can determine which parts should be bought, budgeted or applied for. This is necessary due to the extreme financial restrictions governing health services in most developing countries. The routine shown in Figure 2.2.1, although simple, helps define priorities for the purchase of spares by using a step-by-step selection of options.

In addition to such considerations it is evident that the ordering of spare parts should take place together with the equipment order. This should not only apply to the supply management of health services, but also to any donor. To repeat and emphasize the respective recommendation made in 1989 during our Nairobi meeting:

> "Recipients must openly clarify their policies on maintenance and spare part requirements in connection with equipment donations or equipment supply as part of grants. Donors are asked to respect these policies and to actively adopt or develop such policies for themselves."

Industrial establishments try to minimize the capital buried in spare part stocks by purchasing a certain part only at the moment it is needed. The opposite option, i.e. keeping each and every part in stock, would be ideal for health services, at least for parts with sufficient shelf-life. The long-winded importation and distribution procedures in many developing countries do not allow for spontaneous actions in this field.

Figure 2.2.1 : A routine to help define priorities for the purchase of spares

(0 = lowest priority, 6 = highest priority)

```
Are qualified in-house or external      no
maintenance staff available?          ...........>  priority 0

                 :
                 : yes
                 :
                 V

Can a failure of the part
endanger health or life of              no
patients or equipment operators?      ...........>  priority 1

                 :
                 : yes
                 :
                 V
                                        no
Is the rate of failure high?          ...........>  priority 2

                 :
                 : yes
                 :
                 V

Is the part relatively cheap            no
(e.g. a minor part)?                  ...........>  priority 3

                 :
                 : yes
                 :
                 V

Can the frequency of necessary
part exchange be preplanned             no
(wear parts, consumable parts)?       ...........>  priority 4

                 :
                 : yes
                 :
                 V

Can the part be used for
different equipment (e.g.               no
general spare parts)                  ...........>  priority 5

                 :
                 :                      yes
                 :...........................>  priority 6
```

Supply of Spare Parts:
Suffering from scarce financial resources, maintenance services have to be very flexible and inventive on how to make spare parts available. Besides the basic step of setting rational priorities, there exist various possibilities for obtaining parts as shown in Table 2.2.2 below.

Table 2.2.2 : The Methods and Implications for Obtaining Spare Parts

METHOD	LOCAL AVAILABILITY	SKILLS NEEDED	COST	DANGER FOR PATIENT & OPERATOR
Purchase through agent	bad	low	high	low
Importation through own means	good*)	low	medium*)	low
Purchase together with equipment	good	low	medium	low
Cannibalizing obsolete equipment	poor	medium	low	medium
Fabrication by maintenance staff	good	high	medium	low-medium**)
Using "Pirate Parts"	poor	medium	medium	low-high***)
"String & Wire" (improvisation)	good	medium	low	high

*) this remains to be seen. Doubts for some countries may be allowed: the health authorities may have great difficulties in dealing directly with private firms in foreign countries (e.g. inability to establish a foreign exchange account overseas). Also, the logistic requirements for efficient distribution of imported parts to the various health facilities is quite demanding. The hope of getting substantial quantity discounts may prove to be treacherous. In most cases the number of identical parts required by a country is much too low to qualify for the discount.
**) depends largely on the qualification of the staff.
***) depends largely on how scrupulous the manufacturer is.

The few options which are applicable under the notorious financial constraints involve compromises with some serious disadvantages. It is unrealistic to assume that the majority of developing countries will be able to significantly increase their health budgets in the foreseeable future. Improvements can only be made by introducing preventive maintenance systems, thereby minimizing the need for repairs and consequently for spare parts. However preventive maintenance only makes sense if the equipment is in technically acceptable shape, which is normally not the case. Donors and recipients are called upon to change their approach: rehabilitation of health facilities and their equipment must be accompanied by preventive maintenance programmes during which local personnel can be sufficiently trained.

But Table 2.2.2 implies something else too: some options have not been satisfactorily explored and developed. This is one result of neglecting research.

Operational Research for Maintenance:
At least in the maintenance projects in health care in which GTZ is involved, the term operational research seems to be a completely foreign word. Admittedly, it is a rather pompous expression, but its implications should draw our attention to one of our most prominent problems:

> Much too little is known about the specific technical situation of health services in developing countries to allow an effective, and sustainable realization of modern equipment management principles with an acceptable coverage.

Usually all project members agree to undertake base-line investigations in connection with progress indicators as part of the project planning procedure, however results worth mentioning are not yet available. This is due not only to the lack of time, but also to the lack of experience of maintenance personnel in undertaking such tasks. Important issues to pursue are:

- failure characteristics and types, typical down-times
- pattern of failure causes (user, climate, design etc.)
- (partial) self-financing schemes for maintenance services
- potential of obsolete equipment for the extraction of spare parts
- planned preventive maintenance schemes for specific equipment
- mean life-time for specific equipment
- simple modifications/improvements of some equipment
- equipment standards
- application of personal computers in maintenance
- costs of maintenance services
- integration of equipment/maintenance management into local health management systems
- local production of spare parts
- ABC-analysis on spare part costs.

ABC-analysis can assist with the calculation of spare parts costs. For each piece of equipment, a list is made of all the parts needed, the numbers of each part required per year, and the cost per part. As Table 2.2.3 shows, from this information can be calculated the total cost per year for each type of part, and the total costs for all parts. In addition, it is possible to find out which parts constitute 70% of the total costs over a year and which parts constitute 30% of total costs.

The second part of the analysis is to establish which spares are required the most over the year and whether these are the ones incurring the most costs. As can be seen from Figure 2.2.4, invariably it is found that most of the spare part requirements for a year only require 30% of the budget. Thus, in this example, it is only 8% of the yearly spare part requirements that are taking 70% of the budget, and it is in this area that the possibility for savings could be addressed.

Table 2.2.3 : ABC-Analysis Part I (Example)

PART DESIGNATION	NO. PER YEAR	COST PER PART	TOTAL COST PER YEAR	COST RATIO
Thermostat	1 (8%)	280.00	280.00	70%
Level Glass	3 (23%)	30.00	90.00	
Main Gasket	1 (8%)	36.00	36.00	30%
Valve Gasket	8 (61%)	00.50	4.00	
TOTAL	13 (100%)		410.00	100%

Figure 2.2.4 : ABC-Analysis Part II (Example)

```
                  _:
 Total Cost        :
     %            _:
                   :.............
                  _:            :
                   :            :
                  _:     70%    :
                   :            :..............
                  _:            :             :
                   :            :     30%     :
 _________________:____________:_____________:_______________
                   :............:             :
                  _:     8%     :             :
                   :            :             :
                  _:            :             :
                   :            :     92%     :
                  _:            :             :
                   :            :             :
                  _:            :             :
 Spare Part        :            :.............:
 Requirements     _:
     %             :
```

These themes must be subject to detailed investigation within developing countries. Views and models from industrialized countries can only be adopted to a limited extent and are mostly restricted to principles. These principles must be locally adapted and it would be a serious mistake to believe that an adaptation developed for one country can be implemented in another one without modification.

The majority of the issues presented are connected to the spare part problem. As long as the questions implied are not answered, it is an oversimplification to reduce the cause of ineffective maintenance to the universal claim of "a lack of spare parts". Therefore all donors, implementing personnel and partners in the developing countries must place more attention on operational research for the sake of an improved sustainability of practicable spare part logistics as part of rational equipment management systems.

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2.3 The Future for GTZ Programmes in Medical Equipment Maintenance (R.Korte, GTZ, Germany)

The concept of GTZ 15 years ago was mainly to do in-service training for hospital technicians - people were trained on the job in the hospitals which were supported by GTZ at that time. This gradually changed because it soon became apparent that full professionals are needed to run medical and technical services. Thus, together with various developing countries, curricula and training courses for such activities were developed. This work has been taking place in three main language areas: anglophone Africa, francophone West Africa, and Latin America. GTZ now has training material for all three main language groups.

Without trained personnel you cannot achieve very much. But training is not enough by itself, it is necessary to look at the health system as a whole and how the students will be employed after training. They need workshops, finance, spares, a national maintenance system, an influence on procurement and operational practices, etc. All these concepts are very good and tremendous progress has been made together with colleagues from developing countries in elaborating this overall framework for the maintenance services. However in order to achieve a sustainable success which can spread to all countries, these ideas must be disseminated more effectively in the future. Collaboration with the World Health Organization is a good way of getting the message to as broad an audience as possible.

Some people are concerned about where GTZ is going, and whether maintenance programmes are part of a development downward trend. As maintenance must be part of the health service, maintenance staff are affected as well as the medical doctors and the nurses by the plight of the health sector in general. This state of affairs must be counteracted by making politicians aware that the health sector requires a minimum of funding. They must be made aware of the importance of this sector. This can be done by more effectively selling the strategies which have been developed in the course of GTZ supported projects, to the politicians and to the decision makers within the ministries of Health and beyond in the ministries of Planning and Finance.

It is necessary to stress the enormous potential savings that an efficient maintenance service can make. In order to do this GTZ has probably neglected one area, that is Operational Research. This not only includes analyzes of how to repair items, what breaks down, how often, and under which conditions, but also the economic aspects. More studies are needed on the cost effectiveness and cost benefits of specific interventions and strategies in health care equipment maintenance services.

Some people do not think highly of research, and it is more difficult to promote the idea of research as a target for technical assistance funding. However it must be made clear that research is essential to promote knowledge and to develop new strategies. GTZ cannot develop strategies further if it does not have solid facts. There may not be immediate effects from such analysis, but operational research in the long run will lend enormous credibility to the sector. This is not a call for everyone to become research crazy, but it is worth publicizing any new concepts which are developed since it is the facts which impress political decisions.

Decision makers in the developing countries and donors must be convinced that they have to support this important sector. This needs a continuous, long term effort. This is not achieved in 1 or 2 years; pushing new ideas takes 3 or 5 or even more years.

The needs for health care equipment maintenance seem self-evident, but not everyone is as enthusiastic about this sector as are the specialists in this field. But there are lots of other priorities in the world and there is competition with other sectors which need and attract attention also. If an x-ray machine is not working no-one dies immediately but the indirect effects are enormous. These indirect effects must be made evident to the decision makers. One should not be discouraged if there are not a massive number of new projects, all these activities take a long time and require a continuous effort.

It even continues to be necessary to promote the idea in the health department within GTZ, that district health services need a maintenance component. One of the hardest things in development work is to bring people together in intersectoral cooperation. Everybody tends to think only of their own area, and are often so over burdened with work that they just don't think of collaborating and integrating with others. This situation must be counteracted. To achieve this, the maintenance service must be placed where it belongs, in other words as an integral part of the district health services and the national health system.

Discussion:
At present, GTZ has 6 hospital equipment maintenance projects employing long-term personnel; they are in El Salvador, Jordan, Kenya, Peru, the Philippines, and Senegal. In addition GTZ is involved in many others with a smaller input in terms of manpower, where experts are involved for a few months at a time. There is a new project, in the field of forensic medicine, imminent in Columbia which is not a typical one for GTZ but has a large technical component.

Great interest was shown in the benefits to be gained from sharing information between the different GTZ projects; benefits such as sharing ideas, problems and solutions. Although it was acknowledged that it was the GTZ Head Office's responsibility to make information available, it would be impractical for it to try to forge links between the projects. The individual projects should establish direct links with each other, and there could be visits by individuals from project to project. There is project money set aside for the training of counterparts which could perhaps be used in this way, if the requests and proposals come from the individual projects themselves. At the Nairobi meeting of 1989 this same issue was raised, but no proposals have materialized from the projects and good opportunities are being missed.

There was agreement that the GTZ projects focusing on training and maintenance were very important and had been beneficial for the countries concerned. But everyone agreed that there are additional areas in this sector which still need to be developed such as: a stronger management focus, assessment of appropriate levels of technology, the use and helpfulness of personal computers in the maintenance field, and the constraints faced by maintenance staff after training. Requests were made for such considerations to be brought into projects not only so that the medical equipment sector improves, but also so that countries can continue the technical work when GTZ has left.

It was reiterated that GTZ is not a donor and has no funds of its own; the Ministry for Economic Cooperation and other bilateral and multilateral organizations are the donors, and GTZ is responsible for the technical implementation of the projects and spending the donation wisely. Requests for projects and for money have to come from the developing countries themselves, and be addressed to the Ministry of Economic Cooperation or other funding bodies.

In the future GTZ hopes to forge links with other institutions involved in this field so that this work can go ahead jointly. Besides their current work with the WHO, GTZ will try to intensify co-operation with fachhochschulen, polytechnics, non-governmental organizations and others to coordinate and share work in the field of hospital equipment maintenance and training. In addition, with the new European cooperation starting in 1992/3, GTZ hopes to play a part in formulating and implementing European strategies in this sector.

It was felt that training courses in one country should be opened for students from other countries and that there should be a greater emphasis on international training courses in the GTZ framework. It was explained that this is the intention, but many countries must use the courses to fill their own considerable national needs first, and as soon as possible will be opening their doors to students from elsewhere. Accepting foreign students is an essential aspect of the survival of courses, otherwise training facilities will soon die out without such additional inputs.

The WHO has been participating in talks on the establishment of an international school for health care equipment services. The idea is to have an institution with only a small resident faculty, but making use of 50 or so external personnel who work in this field and can be called in as and when required. In this way a global community will be formed which is able to share information concerning each others' current activities. The meeting welcomed this idea and hoped that these talks would come to fruition soon.

In many developing countries, anything up to 6 different organizations can be working in the same field with no coordination and no real knowledge of each others' activities. The WHO had hoped to set up a clearing house for sharing information, however this has proven to be very difficult. Often donors feel themselves to be in competition for spheres of influence and power bases, especially as the medical equipment sector is pressured by industrial interests and the need to develop markets for products. Whilst understanding these pressures, the meeting appealed to donors to cooperate in the medical equipment maintenance sector. With such limited resources in the health sector, any attempts to establish maintenance services will only be successful if they are rationalized, coordinated, and work towards a common goal.

Departmental changes are currently going ahead within GTZ. The GTZ is in the process of re-assessing its priorities and this will have an effect on departments and projects. This process will be completed by early 1992. Since the maintenance of health care equipment is accepted as being of such importance, there is virtually no doubt that medical equipment maintenance work and projects will be retained.

3. ABSTRACTS OF KEYNOTES, SUMMARY OF DISCUSSIONS, AND RECOMMENDATIONS/INNOVATIONS

3.1 Anaesthesia Equipment - Function and Spare Parts (H.Frankenburger)

Wherever you are, it is necessary to decide what type of anaesthesia system to use, and it will depend upon the logistics and supplies available. In developing countries for example, some gases are available and some are not, sometimes there is an electricity supply and sometimes there is not. Factors such as these will dictate what type of anaesthesia system is employed, and must be considered prior to any decisions concerning purchase of equipment.

Inhalation anaesthesia - basic components of an anaesthetic machine
Anaesthesiology, as a medical discipline, specializes in the medical management of patients who are rendered unconscious and/or insensible to pain during surgical procedures. General anaesthesia is produced by dispensing and delivering medical and anaesthetic gases and vapours to a patient. Table 3.1.1 shows the 4 steps in the anaesthetic process, and the actions required.

In anaesthesia, two media are important:-
i) the gas such as air, oxygen, nitrous oxide, and
ii) the various volatile anaesthetics such as ether, trichloroethylene, halothane, enflurane or isoflurane.

The choice of which gas and which anaesthetic agent to use dictates the type of equipment to be employed and the sort of spares problems which may be faced. For example, here are some factors to consider when choices must be made:-

GASES	: Availability; costs; risks.
Air	: Always available; no spare parts problems; costs nothing if used as atmospheric air.
Oxygen	: Not always available; must be stored in cylinders; oxygen concentrators required; is added to atmospheric air.
Nitrous oxide	: Not always available; it is necessary to add it to oxygen; expensive.
ANAESTHETICS	: Availability, costs, risks.
Ether	: Can be used with air as a carrier gas without adding oxygen; slow induction; highly flammable in air; can be used with vaporizers.
Halothane	: Powerful anaesthetic, poor analgesic; a calibrated vaporizer is necessary; oxygen should be added.

The composition of the gas mixture is controlled by actuators in the form of the gas delivery module and the anaesthetic agent delivery module. These two modules are basic components of an anaesthetic machine. In addition to the medical and anaesthetic gases and vapours, muscle relaxants are often necessary to provide relaxation in order to improve operating conditions for the surgeon. These medicaments also paralyse the muscles of respiration. As a consequence of this treatment the patient must be mechanically ventilated. The above mentioned variable mixture of gases is transported to the patient's lungs by a ventilator via a breathing system. The ventilator as a further actuator, and the breathing system, are also basic components of an anaesthetic machine.

Table 3.1.1 : Steps in the Anaesthetic Process, and Actions Taken

Steps \ Actions	1 Pre-medication	2 Induction: a) Loss of consciousness	2 Induction: b) Pre-surgical anaesthesia	3 Maintenance	4 Recovery
Sedation	X				
Inhalation		X	X	X	
Intubation			X		
Relaxation			X	X	
Ventilation			X	X (controlled)	

Figure 3.1.2 : Essential modules in an Anaesthesia Machine

```
                                   Gas Delivery System
                                            |
ANAESTHESIA                     Anaesthetic Delivery System
SYSTEM                                      |
                 Measuring System --> Breathing System <-- Ventilator System
                                            |
.................................................................................
                                     Alveolar Volume
                                            |
PATIENT                                Blood Volume
                                            |
                                          Organs
```

The concentrations of the media delivered to the patient must be kept within the following boundary conditions:

- The concentration of the oxygen administered on the inspiratory side may not fall below a certain value.
- The concentration of the volatile anaesthetic administered may not rise above a certain value.

To guarantee patient safety during anaesthesia a wide range of protection and monitoring modules are used together with the anaesthetic machine. Monitoring modules for protection against hazards from the anaesthetic machine are as mandatory as patient monitoring modules for the prevention of incidents. Each actuator module dictates that the anaesthetic machine is operated with specific modules for protection against hazards from delivery of energy and substances to the patient. For example, if the anaesthetic machine is configured with a gas delivery module for gases other than air, it must be operated with an auditory alarm to indicate failure of the oxygen supply, whether that supply is derived from cylinders or from a pipeline system.

Hypoxia (a lack of oxygen) may result from many different causes, for instance it can occur if there is unrecognized oesophageal intubation (unknown to the anaesthetist, the breathing endotracheal tube pierces the trachea of the patient and oxygen escapes into the oesophagus and therefore to the stomach of the patient instead of being delivered to the lungs). Patient monitoring devices such as pulse-oximeters give the anaesthetist the possibility of detecting this incident at an early stage.

During anaesthesia further procedures may become necessary, such as the replacement of blood and body fluids, and these require active medical devices. All the equipment necessary for performing anaesthesia surrounds the anaesthetist in the operating room, and makes up the anaesthesia workstation. Figure 3.1.2 shows the essential modules which make up anaesthesia machines.

The relationships between the various activities of these modules are illustrated in more detail in the block diagram of Figure 3.1.3. Having discussed the monitoring systems briefly, I now want to discuss in more detail the other modules.

<u>1. Gas delivery module</u>

Gas delivery modules require a range of reproducible fresh gas flows starting from 1 l/min up to 12 l/min to cover semi-open and semi-closed breathing systems. In a wide range of conventional anaesthesia machines the adjustment of flow control is performed by the operator (ie. the anaesthetist) with a flowmeter (ie. the measuring device) and a needle valve (ie. the actuator). Usually there is one flow adjustment control for each gas. Each flowmeter shall be graduated in units of litres per minute and shall be calibrated for discharge into an ambient atmosphere of 101.3 kPa at an operating temperature of 20° C. The accuracy of the graduations of any flowmeter shall be within ±10% of the indicated value. If a bank of flowmeters is fitted, the oxygen flowmeter shall be placed at the left extremity. In addition the gas delivery module shall be fitted with a manually operated single purpose oxygen-flush for the delivery of a limited but unmetered flow of oxygen (between 35 l/min and 75 l/min) directly to the common gas outlet of the anaesthetic machine. The gas flow from the oxygen-flush shall be delivered without passing through the vaporiser.

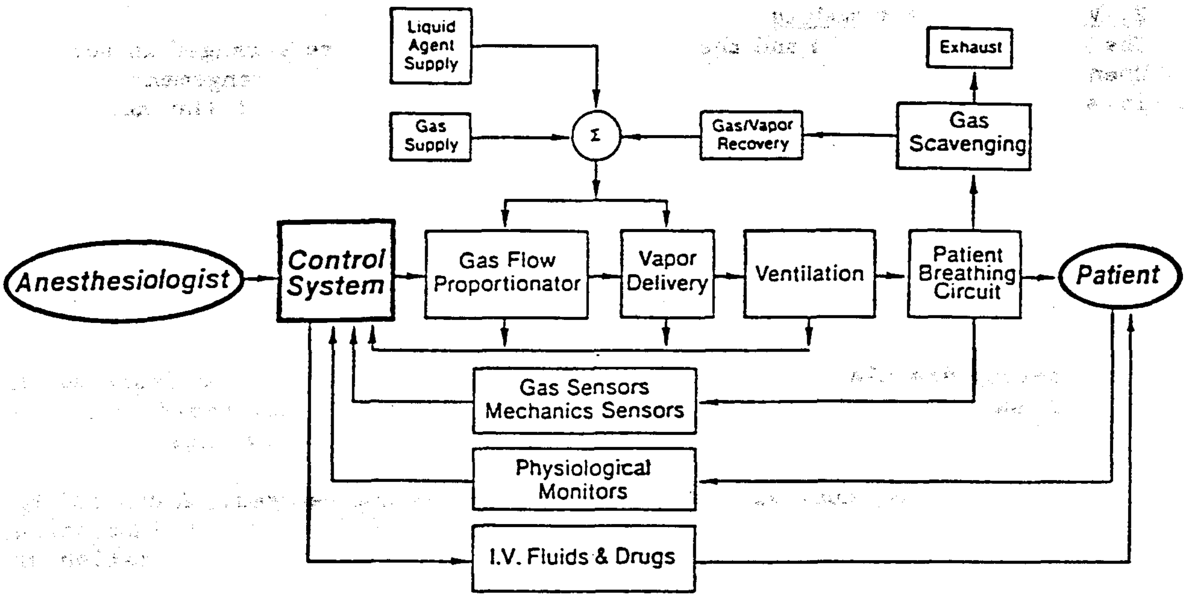


Figure 3.1.3 : The role of the anaesthetist is that of a decision maker and controller of the anaesthesia delivery system, which can be considered in terms of integrated functional subsystems. (Waterson & Calkins)

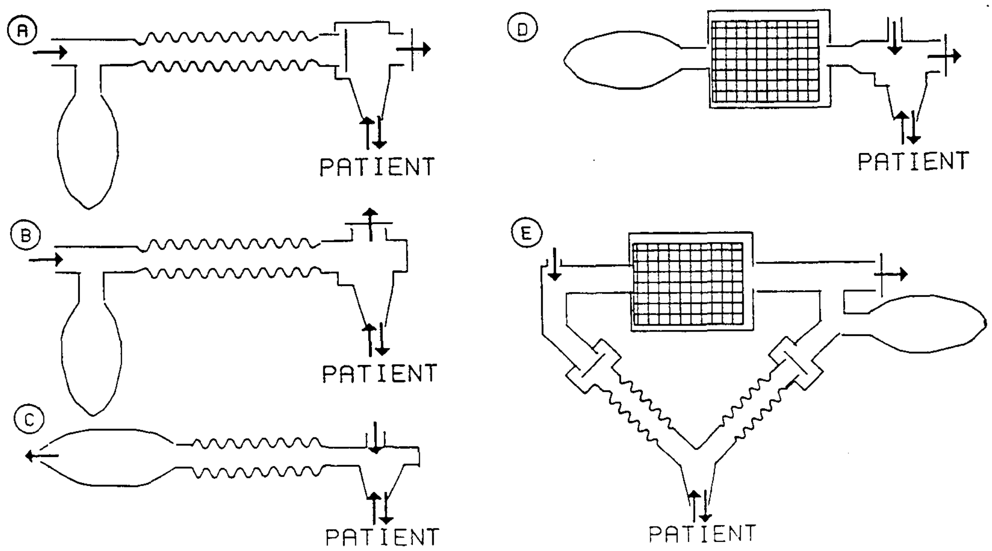


Figure 3.1.4 : Examples of Breathing Systems In Use.
Non-rebreathing systems: a) systems with non-rebreathing valves,
b) Magill systems, and c) T-piece systems without using valves.
Re-breathing systems with provision for carbon dioxide absorption:
d) To and fro systems, and e) Circle systems.

2. Vapour delivery module

The gas delivery module and the vapour delivery module are arranged in series. When surface-evaporation vaporizers are used, the serial arrangement results in a physical coupling between the amount of gas flow and the amount of volatile anaesthetic. Within these vaporizers the gas stream is divided into two parts: one passes through the evaporation chamber and the other through a bypass. The portion passing through the evaporation chamber will be fully saturated with the vapours of the liquid anaesthetic and then recombined, within the vaporizer unit, with the portion flowing through the bypass. Since the portion passing through the evaporation chamber is fully saturated with the volatile anaesthetic vapours, a fixed coupling results between the amounts of gas and anaesthetic transported. Modern vaporizers for volatile anaesthetics are placed outside the breathing system. They are designed in such a way as to guarantee that the concentration delivered will be independent of temperature, gas composition and the gas flow rate.

For safety reasons, non-calibrated vaporizers must not be used. A control to adjust the vapour concentration must be provided, and it must be impossible to set the control above the calibrated range. To prevent contamination of the contents of one vaporizer with another agent, means shall be provided to prevent gas passing through the vaporizing chamber of one vaporizing system and then through the chamber of another. When operated in accordance with the manufacturer's instructions, it must be impossible to overfill the vaporizing system such that its performance is affected and the fluid level is no longer visible.

3. Breathing systems

Breathing systems represent the interface between the anaesthetic machine and the patient. A breathing system is an assembly of components through which the patient breathes. Breathing systems may be classified not only with respect to the proportion of rebreathing and processing of expiratory gases (CO_2 absorption), but also with respect to their design principles. Examples of the breathing systems which are in use are shown in Figure 3.1.4.; they are described as follows:-

Non-rebreathing systems:
- systems with non-rebreathing valves,
- Magill systems,
- T-piece systems without using valves.

Re-breathing systems with provision for carbon dioxide absorption:
- To and fro systems,
- Circle systems.

The first three systems listed above have 2 factors in common:-

i) no processing of the breathing gases occur, and
ii) the concentrations of the various gases reaching the patient from the breathing system correspond to those introduced by the gas and anaesthetic delivery modules.

The circle system is widely used in Germany and the United States. Its first implementation worldwide was in an anaesthetic machine developed by the Dräger company in 1925. While the principles of the circle system have remained unchanged since then, additions have been made allowing the connection of a ventilator and measuring devices for oxygen, pressure, volume, etc.

4. Ventilator

Ventilators used in anaesthesia provide the patient with adequate volumes of breathing gas. Both manual resuscitators and mechanical ventilators are in use which rhythmically inflate the patient's lungs by the application of intermittent positive airway pressure. The operation of ventilators may be divided into four phases:

- Inspiratory phase
- Change over to the expiratory phase
- Expiratory phase
- Change over to the inspiratory phase.

Depending on the change-over, the cycling, ventilators can be classified as follows:

- Volume cycled ventilators: the preselected volume of gases supplied from the ventilator during one breath is the cycling criterion.
- Pressure cycled ventilator: the pressure of gases in the airway rising to a preselected level is the cycling criterion.
- Time cycled ventilator: the preselected time, which may be determined by means of an electric or pneumatic timer, is the cycling criterion.
- Flow cycled ventilator: the flow rate falling below a preselected level is the cycling criterion.

Initially, pressure cycled ventilators were used in anaesthesia because of their small size, however they require frequent adjustments of the tidal volume for changes in lung compliance. Most of the anaesthesia ventilators used today are volume or time cycled ventilators, which usually allow the following functions to be preset: Respiratory rate, I/E ratio, & tidal volume.

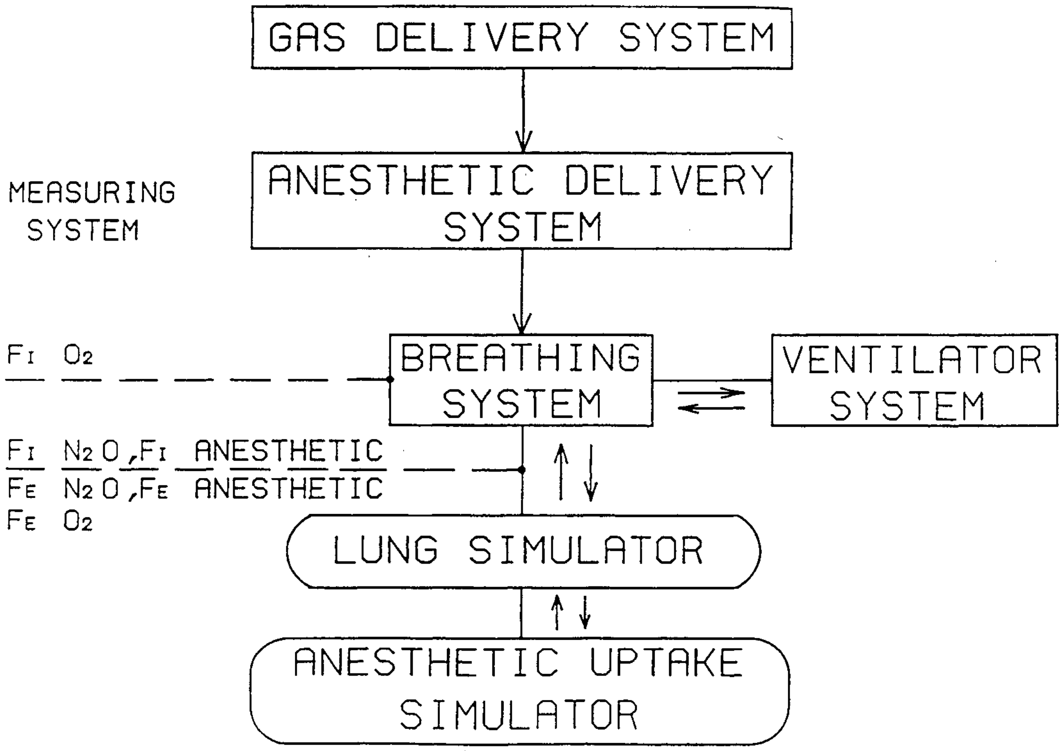
Preanaesthesia machine check

The majority of incidents involving anaesthetic machines are a result of failure in checking the equipment prior to use. The extent of functional checks depends on the modules integrated into the anaesthetic machine. Each anaesthetic machine must be provided with a check list, which indicates the test procedures which have to be performed by the user prior to the initial operation of the machine. If modules do not comply with the tests, there must be complete modules available in the maintenance unit as spares. This means that vaporizers, ventilators, breathing systems, oxygen monitors, airway pressure monitors, tidal volume monitors, and minute volume monitors, etc. should be available within a short time from the stocks.

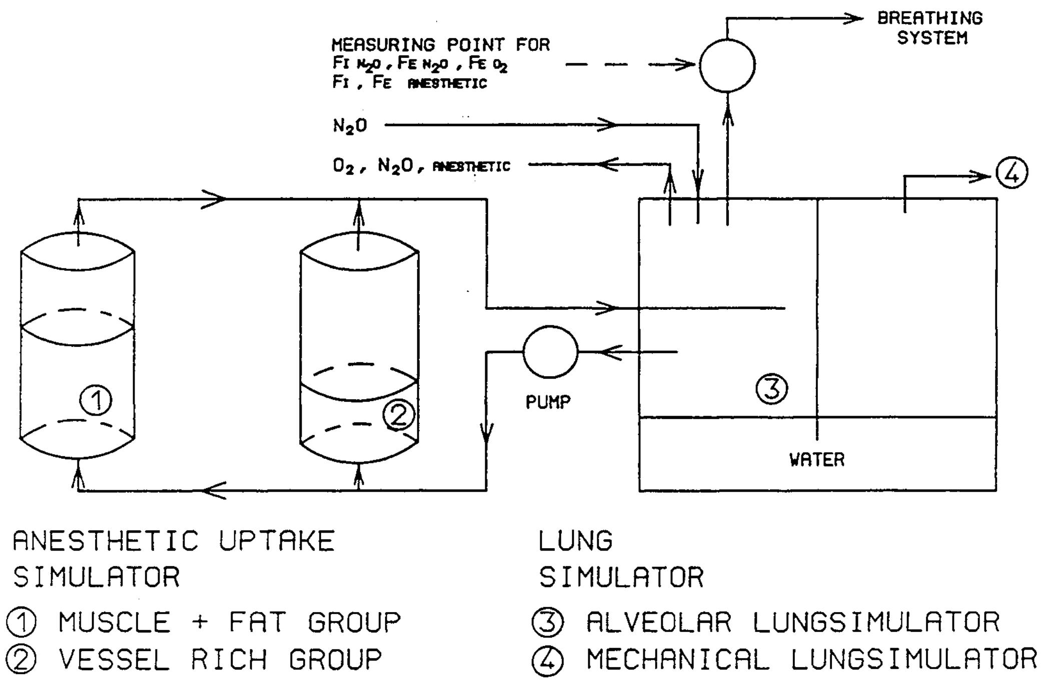
Maintenance of anaesthetic machines

It is more efficient to inspect and service anaesthetic equipment periodically than to wait for a malfunction. Anaesthetic machines should be given maintenance in regular intervals by qualified personnel. Inspections at least twice a year can be considered as a standard for anaesthetic machines. Each inspection should be documented on a form. Evaluating these forms enable predictions and plans to be made for the spare parts of the anaesthetic machines in use. The spare parts list for the same type of anaesthetic equipment may vary from hospital to hospital depending on the care, cleaning and sterilization procedures used in the hospital.

Apart from maintenance check lists for anaesthetic machines, special test devices are necessary for performing the checks, such as: calibrated flowmeters; calibrated pressure gauges; measuring devices for oxygen, halothane, enflurane, isoflurane; etc. With the increased complexity of anaesthetic workstations, preventive maintenance and repairs are associated



ANESTHESIA SIMULATOR-WESTENSKOW



Above - Figure 3.1.5 : Components of a training system using simulators.
Below - Figure 3.1.6 : Use of Simulators.
NB: F = Flow, I = Inspiratory, E = Expiratory

with hazards, if these procedures are performed by amateurs. Unauthorized modifications not approved by the manufacturer or notified bodies are not allowed in many countries.

Training

Training is necessary for operators and maintainers, but it is not possible to practise on patients or to bring anaesthesia systems into the training laboratory. Thus training programmes are required which use anaesthetic machines, measuring devices, and simulators. Figure 3.1.5 shows how different components can be linked together for a training system, and the points where the flow of different media can be measured. Figure 3.1.6 shows how the simulators are linked together. Anaesthetic uptake in different types of patients can be simulated in a system using 2 cylinders containing different amounts of oil. The different concentrations of anaesthesia dissolved in the oil can be measured. The systems can be changed to simulate adults or children, and different parameters can be measured and monitored as though in the operating room. In addition simulators can be used for testing and calibration procedures.

Findings and Recommendations

A reference book recommended to the meeting is "Primary Anaesthesia" edited by Maurice King, published by Oxford University Press/GTZ, 1986.

The meeting recognized that the choice of which type of anaesthesia equipment is best for use in developing countries, will depend on the availability of adequate finances and correct logistics such as electricity and gases. For example:-

* If all the right logistics are available in a country then there should be few problems with Boyles machines; however if the logistics are not present, this machine cannot be used.

* There is a considerable difference in the cost of anaesthesia depending on which gas system is used; this factor could assist with the choice of which system to employ, for example:-

	1 hour using nitrous oxide	costs	US$	8.6
whereas	1 hour using air and ether	costs	US$	0.2-0.3

* If anaesthetic agents are used they are very expensive. The circle system of patient breathing apparatus has the advantage that it uses only a 2% concentration of agent and the exhaled gas can be regained. However this saving in the cost of anaesthetic agent has to be balanced against the major disadvantage that circle systems are difficult to maintain.

There were lengthy discussions on the advantages and disadvantages of promoting the use of the drawover method of anaesthesia as employed by the EMO (UK) and AFYA (German) machines for example. This method uses ether and air, does not require compressed gases and is easy to maintain. It uses the same basic method as other machines but the patient can breathe through it at atmospheric pressure, whereas other machines do not allow this due to the resistance they offer in the breathing circuit. The World Federation of Societies of Anaesthesia has stated that the use of Drawover anaesthesia is still widely practised and is in fact probably the most widely used method of anaesthesia throughout the world; this is because it is simple, inexpensive and can be used in difficult situations where compressed gases are unavailable.

TABLE 3.1.7 : ANAESTHESIA EQUIPMENT - Boyles and Drawover Machines

COMPONENTS OF AN ANAESTHESIA SYSTEM	COMMON TECHNICAL PROBLEMS	SOLUTIONS
Gas Delivery System	Diaphragm spoilt. Regulators - wrong pressure.	Use general part for O-ring on regulator - possible problem with fumes if material not identical, so identify: * appropriate material * working pressure, then cut to size.
	Sieves blocked.	Sieves: clean and re-use, replace every 2-3 years rather than annually.
	Threads spoilt (on regulators).	Re-threading (if possible).
Measuring System	Flowmeters (the bobbin sticks). Spoilt needle valves. Broken glass parts eg. in rotormeters.	Cleaning only, no improvisation possible.
Anaesthetic Delivery System	Calibration of vaporizers. Sticking vaporizer rotor.	Drawover only (ether), mechanical calibration possible. All other vaporizers - manufacturer only.
Breathing System	Plastic parts break easily (eg. carbon dioxide absorber). Rubber tubing worn out. Masks and breathing bags damaged. Problems with valves (inspiratory & expiratory).	Research needed into: - tropicalized rubber to combat perishing - original manufacturers of tubing, so that tubing can be bought direct - possibility of vulcanization repair for splits in rubber - possibility of chloroform welding for broken plastic - repair of valve seat (by turning, or grinding).
General	Seals wear out - leakages.	
	Castors spoilt or broken.	As castors are often too small and thus over-stressed, replace with larger ones.

QUANTITY	TOOLS / OTHER REMARKS
O-ring: 2 per year. Diaphragm: 1 per year. Sieves: 1 every 6 months.	Beware of reaction between rubber and oxygen or nitrous oxide. Need grease applicable to uses with oxygen. Need pressure meters with millibar range. Problems of static electricity when using flammable gases, try metal chain or similar hanging down from metal of machine to drag along antistatic floor - reliability is affected by floor cleaning methods.
Depends on user handling, thus training of operators needed.	Calibration of flowmeter with: - another flowmeter - home made volume meter.
Manufacturer service: 1 per year.	A tool set is available from Penlon to open Drawover machines, then make sets locally. Clean rotors with "Brasso" to prevent sticking.
Tubing: 1 set every 3 years.	
	Can be legal problems associated with repair of items supplying gas to patients. Castors need conductive rubber to maintain the discharge path for static electricity.

Georg Kamm, in Tanzania (Machame Lutheran Hospital, Moshi) has studied the use of the Drawover method for a long time. He found that for nearly all the anaesthesia he performs, he can safely use air and ether (with concentrations between 2-8% of ether) and in a very few cases he needed the addition of oxygen depending on the condition of the patient's lungs. He feels that if you have healthy lungs there is no problem with this method and the risk rate is very low. As university trained anaesthetists were not available, he trained personnel who work in the operating theatre to use the equipment and to understand what is going on. Since this training is very important, training course materials were developed as described in the presentation.

It was recognized that in places where even ether is unavailable, intravenous methods of applying anaesthesia are the only available options. Inhalation methods of anaesthesia are advantageous because the anaesthetist can make instantaneous changes in response to the patient's condition if necessary. However if an injection is given it has its own reaction time in the patient's body, and subsequent changes cannot be made as quickly as with inhalation methods.

The working group presented their recommendations which are summarized in Table 3.1.7. They concentrated on Boyles and Drawover machines. For the Boyles machines especially, they recognized that the use of manufacturers' spare parts is usual. Often maintainers are constrained to this method of working, due to the legal issues which could arise if subsequent problems were found where genuine parts had not been used. However in many countries manufacturing agents are scarce, and alternatives are required to the necessity for shipping whole machines back to the manufacturer.

3.2 Infant Incubators - Specifications, Standards, Spare Parts and Test Equipment (W.Trampisch)

Spare parts problems should be discussed as an important component of a maintenance organisation as a whole. The responsibility of a hospital service group should not finish in the workshop with the replacement of a spare part in a piece of equipment. They should also have the responsibility for controlling the proper functioning of the equipment, undertaking safety checks, and discussing correct operating procedures with the users. In this way the maintenance technician will get an idea of the way in which the equipment is used, and can reduce the number of breakdowns by providing continuous user training.

Remarks on Perinatal Intensive Care:
All of you may have seen or serviced an Infant Incubator, however you may be unaware of the present high levels of perinatal mortality (and maternal deaths) in developing countries. In the past it was expected that this high percentage (about 100 deaths per 1000 births) could be drastically reduced. However this did not happen because the incubator has been looked upon as a technically sophisticated and very able device, and mistakenly was thought to be able to do the work alone.

Often there is little understanding by persons in charge, that the running of neonatal intensive care units is very expensive; it is estimated that in industrialized countries the costs are about US$ 1000 a day for a baby to be in intensive care with an average stay of 23 days. The costs are due to the need for appropriate consumables including oxygen, as well as adequate equipment eg. ventilators, infusion pumps, control and alarm equipment. Any unit must have an adequate number of trained nurses, staff skilled in arterial catherisation and administration of intravenous therapy, and a reliable laboratory to carry out essential biochemical tests. In the absence of these facilities there is little point in trying to run a neonatal intensive care unit. It is well known from published figures that if incubators are used for intensive care in spite of these other facilities not being available, then incubators may even cause the death of infants. In short, the existence of an incubator is often confused with an intensive care unit itself.

Physiological Characteristics of Prematures:
The most important factor for the survival of newborns is stabilizing the body temperature. The measured rectal temperature ranges from 34° C (birth weight 3000-3500 g), to 31° C (birth weight less than 2500 g). This means a baby weighing less than 2000 g will die without help, due to cooling down and the symptoms of lung bleeding. This can be well understood by considering the relationship between body weight and area of skin. The heat loss of the small infant is so great that they need all their energy (nutrition) to compensate for their heat losses. You can imagine the size of a premature baby, when you compare the infant's hand with the finger nail of an adult.

The reason for the heat loss is not only the low ambient temperature, i.e. heat loss by radiant energy off the body, but as important is the evaporation of water through the very thin skin of the body. Each gram of evaporated water consumes 2000 J or 500 cal of energy. In the first days of their life these small babies loose 70% of their body-heat due to evaporation. So besides the drop in body temperature, the second main problem for the survival of premature babies is dehydration.

Normally an incubator should prevent infections of the infant, but in addition to infection of the infant by the mother or the nursery, we should consider the contamination caused by the ventilation of the incubators themselves. If you open a polluted incubator used in a hot climate, you would be amazed by the layers of germs and fungi existing beneath the incubator bed in the water insert.

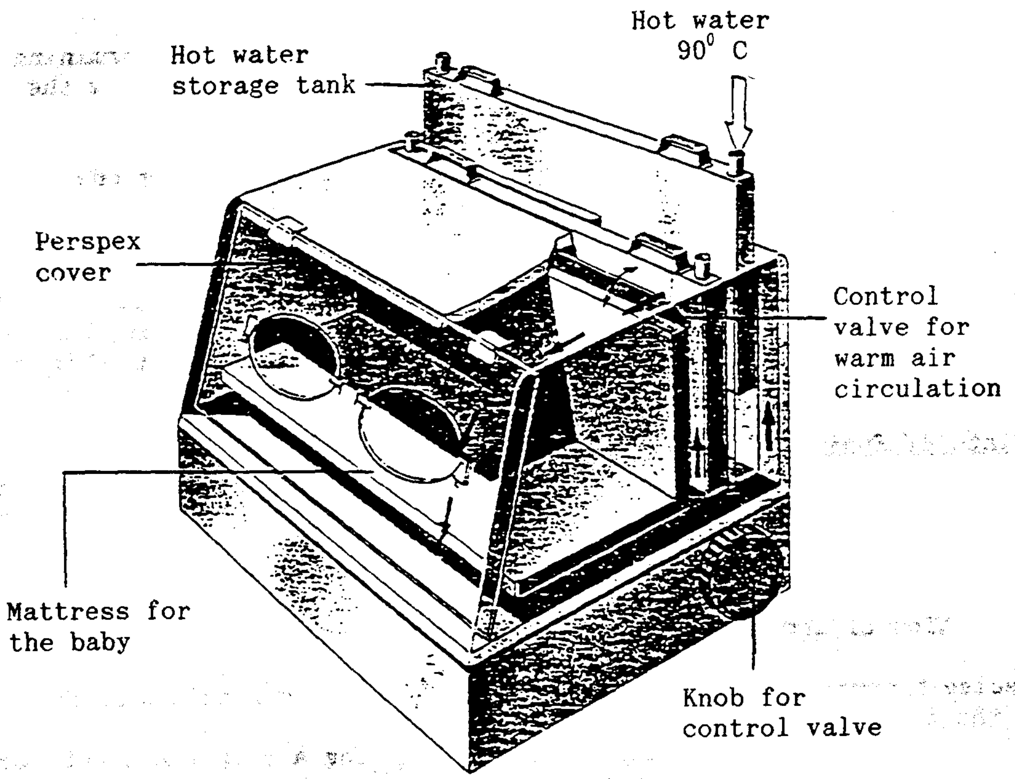
Often the newborn is unable to breath alone (eg. born in the 28th week of pregnancy), because the lung is insufficiently developed. Therefore an infant respirator should be available. If the newborn cannot breathe alone, a higher concentration of oxygen is necessary to compensate for the as yet incomplete lung function. However we must issue a WARNING here: it should be mentioned that a high level of oxygen (hyperoxemia) causes eye damage, and too low an oxygen concentration (hypoxemia) may result in irreparable brain damage. It is absolutely ESSENTIAL that the oxygen enrichment of the incubator is controlled on the basis of the arterially measured oxygen partial pressure in the blood of the baby (ie. transcutaneous oxygen measurement).

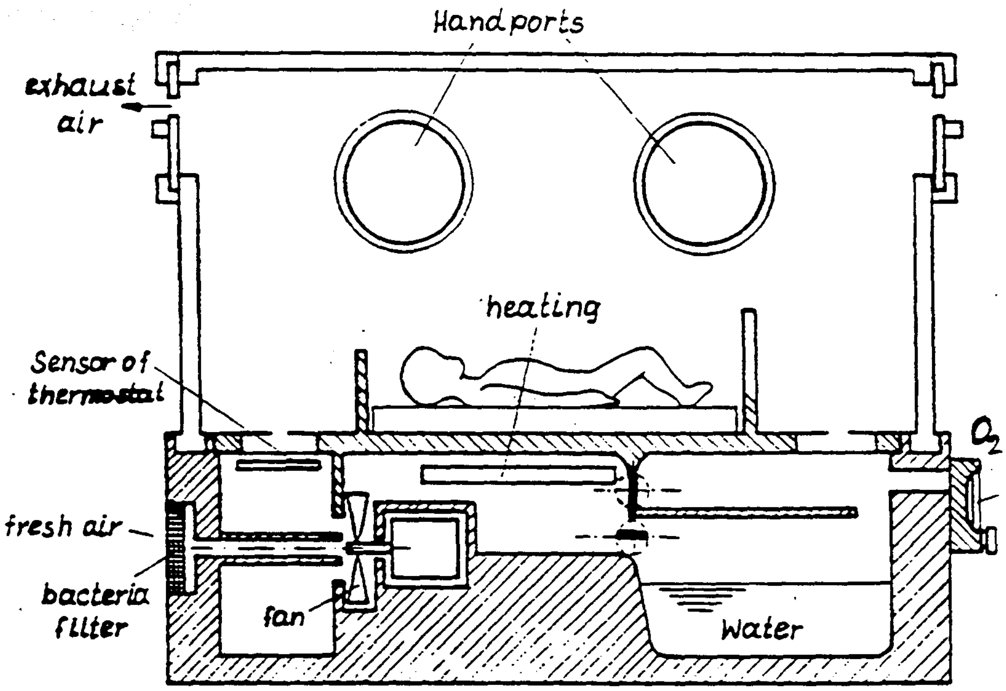
Table 3.2.1 below shows the different technical features available in incubators depending on the required physiological condition for the infant.

Required Physiological Conditions for the Infant	**Technical Realization in the Incubator**
* STABLE TEMPERATURE * STABLE HUMIDITY	1. AIR SENSOR CONTROLLED INCUBATOR: controlled from sensors in the air circulation system without any reference to the baby's temperature. 2. BABY SENSOR CONTROLLED INCUBATOR: baby temperature is sensed by means of a probe attached to the baby's skin and connected to the incubator control system.
* STABLE OXYGEN	1. CONTINUOUS OR INTERMITTENT OXYGEN CONCENTRATION MEASUREMENT IN THE INCUBATOR'S AIR: an oxygen meter is attached to the incubator through a hole in the hood. 2. ARTERIAL MEASUREMENT OF OXYGEN PARTIAL PRESSURE IN THE BABY'S BLOOD: transcutaneous oxygen measurement.
* REDUCED INFECTION RATE	1. AIR FILTER.

Table 3.2.1 : Differing Technical Features of Infant Incubators to Facilitate Physiological Conditions for the Infant.

Operating Principle of the WHO Incubator:-





Above - Figure 3.2.2 : A transport incubator containing no electronics
Below - Figure 3.2.3 : Basic features of the latest generation of incubators

Technical Features of Incubators:

1. Approach to Appropriate Technology

In the last century incubators were developed with their determining design parameter being to offer a balanced heat flow between the body of the newborn and the environment; this was achieved with a water reservoir, where the water circulated by heating. Currently the WHO are considering proposals for the construction of transport incubators using hot water as their energy source. In third world countries in which hypothermia (loss of heat) of the newborn represents a frequent cause of death immediately after birth, transport incubators of highly sophisticated design have proved unsuccessful. To help to overcome this problem, an incubator containing no electronics has been developed which can be heated simply with the use of hot water; Figure 3.2.2 shows such a design. It should be possible to construct this type of incubator in any workshop.

2. State of Engineering of Modern Incubators

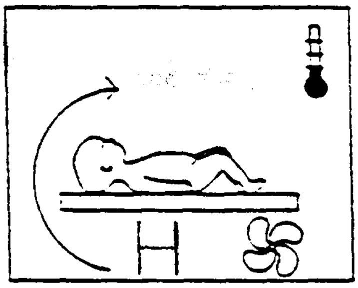
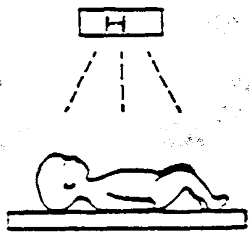
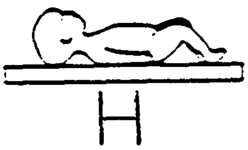
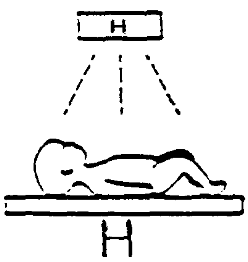
In the last two decades knowledge has considerably increased regarding the preservation of the vital functions of prematures. Based on this knowledge, demands for the construction of incubators were derived; these demands have been met by the industry with the last generation of incubators, whose basic features are illustrated in Figure 3.2.3. The catalogue of demands for the construction of the incubators are the following:

- precise thermoregulation with minimal temperature variations at the surface of the infant
- adjustable relative humidity of the ventilating air in the incubator
- adjustable oxygen partial pressure of the incubator air
- minimal noise production inside the incubator
- ergonomic design
- possibilities of weight control in the incubator
- effective and user oriented disinfection methods
- easy access to the patient
- fulfilment of all safety standards

This catalogue of demands refers to infant incubators for intensive care with a specific internal climate (humidity, temperature, oxygen). But often under the difficult conditions in developing countries, in practice a heat source (warming bed) would be a very good and adequate compromise. When this is obviously the case, different technical realizations with less running costs and less maintenance costs may be offered. Some options are summarized in Figure 3.2.4. In many situations incubators, which are designed for complex intensive care functions, are used merely as cots for babies to sleep in, or as places for keeping babies warm. If the main priority is to keep the infant warm, it would be much more effective to use the simpler options shown in Figure 3.2.4, rather than incubators which require so much maintenance attention.

National Standards and their Consequences for Maintenance and Safety Testing:
Standards such as those of the IEC, lay down the required state of engineering of equipment as well as the accuracy of their operating data; maintenance personnel should be familiar with such standards. General regulations of the safety of medical electrical devices are fixed in the International standard IEC 601, and in the German standard DIN VDE 0750 Part 1. More detailed regulations not included here may be formulated in special drafts by paediatric experts, staff members of test or control departments, and the industry.

Figure 3.2.4 : The Different Types of Infant Care Equipment Which Can Be Used to Create Different Environments for Infants

Key:  = Heater = Fan	Type of Equipment	Heating Principle	Conditions You Can Provide With This Type Of Equipment
	Incubator	Convection (Air Flow)	Intensive Care Functions Oxygen Heat
	Transport Incubator	Convection	
	Infant Radiant Warmers: - Manually Controlled - Skin Temperature Controlled	Radiation	Heat
	Heated Mattress	Conduction	Heat
	Open Intensive Care Unit Radiator,	Radiation	Heat
	Combined With Mattress Heater	Conduction	

To give an idea of the contents, I will refer to the German Standard for Infant Incubators - DIN VDE 0750 SECTION 212. The main points defined are:

* the nominal value of the temperature can vary from 30° C to not more than 38° C
* the maximum tolerable deviation of the temperature is fixed in the following way:
  - a maximum of 0.8° C of the indicated (read) temperature compared to the actual temperature of the incubator
  - a maximum of 1.5° C between the fixed nominal value and the incubator temperature
  - a maximum of 0.5° C for the temperature deviations with time
  - changing the nominal value from 30 to 34° C, the incubator temperature should not overshoot by more than two degrees
* the maximum velocity of the air flow is limited to 35 cm/s, to reduce the heat loss by convection
* the noise level in the interior of the incubator is fixed to be 60 dB(A), but most incubators have only 50 dB(A).
* the alarm in case of breakdown of the external power supply has to be indicated optically and acoustically.

A very important question relevant to security is the maximum temperature of walls or parts which can be touched by the infant or the nurses. Even in case of failure, the value of 40° C for metal and 43° C for other materials should not be exceeded. Special construction efforts are necessary to avoid inflammability in view of the increased oxygen level in the incubator.

Similar regulations were published for transport (mobile) incubators. The main points are :

* the transport incubator must keep the inner temperature for at least 90 minutes at 36° C, when the exterior temperature is about 15° C
* if the outdoor temperature is -5° C, the temperature in the interior must be kept for at least 15 minutes
* the transport incubator must have its own oxygen supply, which permits a flow of 6 l/min for 50 minutes.

Standard equipment comprises the incubator, the oxygen and energy supply, and nowadays also an ECG monitor, infusion pump, infant ventilator, suction machine, oxygen monitor, etc.

DIN VDE 0750 SECTION 227 deals with electrically powered infant radiant heaters. Due to physical reasons, the heat transfer by radiation is more effective than convection and therefore is more dangerous. Thus skin temperature measurement is necessary.

DIN VDE 0750 SECTION 228 refers to electrically powered infant heat mats including different devices such as heat cushions, heat beds, and water cushions. All these devices maintain a direct contact to the patient, so the maximum temperature of the cushion surface must be limited in the case of failure to 40° C. This means the same safety devices must be included as for incubators.

Maintenance, Safety Checks and Spare Parts

I talked to various biomedical engineers in German hospitals in order to get an idea of the maintenance problems of incubators:

- Some hospitals have maintenance contracts with the manufacturer.
- Hospitals without full service for incubators have mechanical problems

mainly with hinges or the doors of the hood. In one model there existed problems with the overheat control but this was a warranty case. A typical user fault is exposing the incubator to direct sunlight.

The reason for the relatively rare problems found may lie in the high safety level as a result of the German Medical Regulation for medical equipment. In addition to maintenance procedures safety checks must be done every 6 months.

1. Safety Checks

In accordance with the standards mentioned above, regular safety checks for infant incubators have to be included in the daily work even if the German Medical regulation is not valid:

* Visual checks
  - the plugs to the central gas supply must be non-interchangeable and the pipes marked with different colours
  - air and oxygen supplies must pass through bacteria filters
  - skin temperature sensors must be of a form which cannot be used for rectal temperature measurements.

* Operational checks
  - examination of the necessary monitoring, safety, display, and alarm installations
  - the presence of an oxygen measuring device with adjustable alarm levels
  - measuring device for the temperature of the interior of the incubator
  - displays must exist for every type of temperature regulation such as skin temperature or ventilation temperature regulation
  - absence of current must be indicated optically and acoustically
  - in case of failure, the skin temperature control device must give an optical and acoustical alarm and limit the maximum temperature of the incubator to 40° C.

* Verification of electrical safety
  - the main points are identical to the instructions for preventive maintenance of infant incubators as proposed by the American Hospital Association.

Including periodic safety checks into both routine work and after any maintenance procedure, is an important task for a service support group and may significantly improve their acceptance in the hospital organisation. In addition, special care is necessary in cleaning and disinfection of the incubator according to the operating manuals.

The consequences of deciding to do regular safety checks may be:
* maintenance personnel must be familiar with the operation of the equipment
* maintenance personnel must be trained in electrical safety measurement
* test equipment must be available for tests of
  - temperature, humidity, oxygen,
  - electronic circuits by special logic analyzer
  - electrical safety

2. Maintenance strategy and spare parts

If trouble shooting is included in the maintenance tasks, the service group may arrive at basically two different conclusions for their maintenance strategy. This will depend upon the technical documentation and aids available for fault finding:

Example 1: You identify the type of fault following the trouble shooting table in the operating manual, and the recommendation is to shut down the equipment and to contact the nearest manufacturer's agent. To follow this policy you need good cooperation with the manufacturer which is hardly possible in most developing countries.

Example 2: You try to identify the reason for the fault and even the necessary spare parts. In order to do this a prerequisite is for all technical information to be available.

The number and type of spare parts to be kept in stock can only be determined on the basis of experience which should be laid down in service records. The knowledge that a part needs to be exchanged can be obtained if there is continuous inspection as part of a planned preventive maintenance system. Based on the spare part lists the item can be ordered in time, before the shutdown of the equipment.

With an incubator of the latest generation, the type of maintenance may drastically change. Nearly all functions are controlled by ICs. A self-test is conducted when the incubator is switched on. This test is repeated during operation (every ten minutes). This involves a test of all memories in the microprocessor control system and a check to establish whether the various programme segments are running correctly. The maintenance job is restricted to replacing faulty boards by new ones. In this way service changes from repair to exchange. The service group saves time in repairing in favour of testing the equipment and training the medical and paramedical staff, thus enhancing the safety of the equipment.

Before handing equipment back to the user after failure or after a service, there must be checks on the correct function of the different systems. For this a variety of test instruments are needed. The tests may be very time consuming, such as a temperature test of the incubator. To respond to this new challenge in the maintenance field, the whole set of test instruments are required as well as the complete technical documentation, and an intensive training of technical personnel in the special knowledge required to use this equipment.

References:

- German standards DIN VDE 0750 Section 212, 217, 227, 228
  0751 Section 1, VDE-Verlag Berlin
- Operating Manual/Instruction for the use of
  Dräger Incubator 8000 and 7320/7520
  Vickers Medical Model 89
  Isolette Infant Incubator Models C 100 and C 200
- Health Equipment Information No 83 Feb. 1980, DHSS, England
- Elektromedizinische Geräte in der Pädiatrie - Stand der Normung J. Koch, mt-Medizintechnik 111 (1991) Nr.2, S.51
- Care of the Newborn, Appropriate Technology, British Medical Journal Vol.289,6.10.1984, p.899
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- Über die Entwicklung der Inkubatortechnik, M. Schinkmann, TIT-Fachwissender Medizintechnik, MTD-Verlag, Amtzell
- Technicians Handbook for Hospital Engineering, J.Neureiter, A.Tschank, 1989,ACME, Wien

Findings and Recommendations
Many developing countries have problems with infant incubators. There are the usual troubles arising from a profusion of different models, with many incubators out of operation due to a lack of spares, manuals or knowledge. In addition many models can be found which offer sophisticated facilities that are not put to use, begging the question of why they were purchased in the first place. Often medical staff want sophisticated equipment and technical staff find it difficult to convince them otherwise. Due to the problems of maintenance perhaps we should looking to see what is the minimum level of technology that we can get away with. These issues illustrate the importance of the correct selection of equipment in the first instance. Developing countries need to make investigations into the level of technology which is appropriate for their needs. In addition it was stressed that technical personnel should be represented on equipment selection committees.

The meeting was told of a new approach being tried in Kenya which was instigated by the number of infant incubators found to be out of use, for the usual range of reasons. Instead of trying to maintain many incubators, a whole room has been developed as an incubator in which the babies are kept. The temperature of the room is kept at approximately 38° C using heaters, and a humid environment is provided. In addition, ultraviolet lights are used to sterilize the air.

The advice offered in technical manuals creates many problems for technicians in developing countries; often manuals simply say that the equipment should be shut down and the manufacturers contacted for maintenance assistance. For customers thousands of kilometres away, this advice is totally impractical. Similarly it proves to be very difficult to obtain spares, get help, maintenance support or generally communicate with the manufacturers. In addition to this lack of communication, manufacturers are not making infant incubators to suit the needs of rural areas. It was realized that many of the problems of spares start with the choice of equipment. In countries where there are many incubators broken and not in use, cannibalization of the equipment was recommended in order to obtain spare parts.

The question was raised of the possibility of manufacturing solar powered incubators since sun is readily available in rural areas! The meeting was told of the WHO transport incubator using a solar heat store which provides a warm environment for the baby whilst it is travelling, although it has no other facilities such as oxygen etc. The infant can be in the incubator only for a limited time due to heat loss. Another recent development is to use gels as heat stores, this is not cheap but it is instrumentation free. There have been investigations into appropriate technology in this field, however it is recognized that governments are often wary of buying "alternative" equipment and prefer items used in the industrialized countries. In addition "alternative" technologies are often just as expensive as their high technology counterparts. It was decided that this meeting was not the forum for entering into an in-depth discussion on appropriate technologies; such a topic would require a conference all of its own. It was decided that since so many incubators are already present in hospitals, the correct course of action would be to address the problems of spares requirements whilst collecting information on other alternatives so that medical staff have a basis on which to make decisions about the different choices.

After further discussion it was agreed that the power supply is not the major issue with incubators, instead it is the control mechanisms which provide the main problems. Controls and alarms break down often or are overridden due to user error, thus infants are exposed to potentially fatal temperatures due to a mixture of broken equipment and a lack of monitoring of conditions by the

TABLE 3.2.5 : INFANT INCUBATORS

MODEL	SPARE PARTS & CONSUMABLES	QUANTITY
Basic type for normal use only (ie. in Kenya), not intensive care model nor microprocessor controlled model	1. MECHANICAL PARTS	
	* Castors/wheels,	
	* Paint for stand/trolley,	
	* Hinges, screws (non-rusting),	7.5 pa
	* Plexiglass/perspex (P) & special glue (G) to replace 1 hood,	1 pa
	* Air Filter: # 2 stage filter - 1st dust - 2nd bacteria,	(Q)4 pa
	* Thermometer (alcohol).	
	2. ELECTRONIC/ELECTRICAL PARTS	
	* Buzzers/alarms, (S)	
	* Fan, (N)	
	* Fan Motors, (N)	
	* Fan bearings, (S)	
	* Heating elements,	0.2 pa
	* Fuses,	
	* Electric cords, plugs, & sockets	1 pa
	* Lamps, (S)	0.2 pa
	* Batteries, (S)	1 pa
	* LEDs, (S)	0.2 pa
	* Potentiometer,	
	* Electronic components,	
	* Electronic workshop.	
Intensive Care model	If oxygen is used, will need oxygen flowmeters as spare parts although they are not incorporated into the incubator itself.	

NOTES:-

(G) : ensure the type of glue will not produce fumes hazardous to the baby.
(N) : the choice of replacement fan or fan motor is crucial since the noise they produce can damage the infant's health and development.
(P) : the perspex must be heat resistant to protect it from heat lamps above.
(Q) : the quantity depends on the dust and other environmental conditions of each country.
(R) : follow manufacturer's recommendations or risk making perspex opaque and creating fumes hazardous to infants.
(S) : find local substitute.
(T) : some temperature tests take many hours; there should be a strict timetable adhered to, and a means of recording the results.

SPECIAL TOOLS & MATERIALS	TEST & SAFETY EQUIPMENT	ADDITIONAL SUGGESTIONS #
Cleaning Agent for Perspex - alcohol (pure) - toothpaste. (R) Disinfection and cleaning materials. (R) Hand operated drilling rig & drills - will prevent damage to the perspex of the hood when worked on.	Electrical Safety Tester, Testing protocol (T), Multimeter, Temperature adaptor, Recorder, Insulation tester, IEC Standard for incubators, gives temperature tests to undertake with methods.	Air filters should be bacteriological. It is easy first to just provide a dust filter. The small holes of filters stop the flow of air - need the fan working. Alternatives for filters are:- - cotton wool, - coffee filter, - filter cone used in suction pumps. Put gauze first to catch dust and to protect the bacteriological filter behind it. Carefully clean dusty fan blades.
If oxygen used - flowmeters - oxygen monitors	Oscilloscope, Simulator, Special test equipment as recommended by the manufacturer.	

staff. It was suggested that manual controls may be better than electronic ones:- an upper temperature limiter could be provided to prevent heat distress or death to the infant in the case of system failure; and the temperature in the incubator could be monitored and controlled manually. In many countries mothers sit with their babies all the time in hospital; since they are always present, they would be ideal for the role of checking the thermometer and adjusting the temperature.

Since so many different models exist, separate training on each individual model is not the most effective course of action; it is preferable to have courses which train technicians to feel confident in approaching any model they encounter. Sending technicians to existing training courses is costly, and although in-service training would be preferable, there is no evidence of any manufacturers offering such a facility. An additional problem has arisen since manufacturers have been subject to liability insurance - they will not provide technical information to the customer unless they feel the customers' technicians are sufficiently qualified or have been trained by the manufacturer themselves. For most developing countries it is not possible to continuously send people abroad for training on only one particular item. These constraints should help managers to decide what level of repair the in-house maintenance team should attempt.

However even with manufacturers' training, it often still proves very difficult to obtain service manuals. The meeting felt that since maintenance technicians will attempt to repair an item anyway, the technical manuals should be provided by the industry. It was recognized that there is a major problem of manuals going missing, never reaching their destination, or being locked away. A request was made for donors to assist governments in obtaining manuals, translating them, and establishing central library facilities so that the manuals remain available.

There are some publications available which list the type of equipment recommended for use at different levels of health care, such as:

- Knebel P, 1984, "Furniture & equipment in relation to activities, personnel & architecture", Primary & Secondary Health Care in Developing Countries, Club du Sahel, OECD.
- Mallouppas A,"Draft manual of essential medical equipment for hospitals at district & provincial levels", HTI/WHO Collaborating Centre, Nicosia.
- A guide book for equipping health facilities in developing countries will be available by the 1st quarter of 1992 from GTZ-HQ.

The working group presented their recommendations which are summarized in Table 3.2.5. They decided to concentrate on the problems associated with the basic range of incubators most commonly found in a developing country, such as Kenya, and not those brands which are microprocessor controlled. In addition, they chose mainly to concentrate on normal use and not intensive care applications. They found that the main spares identified could be produced locally. A problem that consumed much discussion was that of the fan motor, because if the wrong fan or fan motor is used the noise produced can damage the baby's health and development. Thus the choice of spares for this part is critical. It was felt that the fan itself will not break often therefore no figure was given for stocks to be held, however the fan blades should be carefully cleaned when dusty.

The recommendations were based on a very simple incubator. The group felt that the main question to ask is whether the functions of an "incubator" are really needed in this simple version, or can the functions of the incubator be replaced by warming the area by other heating methods. This question should be taken up by medical experts also.

3.3 Spare Parts and Working Materials for X-Ray Equipment (max 800mA and 200 kV) (R.Schmitt, Senegal)

Even under optimum conditions, it remains realistic to state that the need for spare parts and working materials to maintain the most basic x-ray equipment will always exist. In developing countries, conditions are often far from our concept of "optimum" or "ideal" ie. hostile environments, poorly trained personnel etc., therefore we can more easily understand the high demand for availability of spares and working materials to keep the equipment functioning.

In addition, complex technological x-ray equipment frequently can be found in developing countries. Here unfortunately there exists not only a lack of technical support but often inadequate financial funds to maintain a proper service, especially when the question of consumables and spare parts availability arises. Quite often equipment is very sophisticated and not appropriate for the basic needs of such populations, thus further complicating the problem.

Evidently, the operation of a proper x-ray service is largely dependent on having the required working materials and spares to hand. In developing countries however, even if these items are available, the x-ray equipment may remain non-functional due to a variety of other problems, which are also directly related to the demand on spares and working materials.

```
.....................       ................      .....................
:Supplier           :       : Maintenance :       : Working Materials :
:                   :.......:             :     ..:                   :
:(locally available):   :   : (in-House)  :     : : ie. x-ray films,  :
:...................:   :   :.............:     : : Developing baths, :
                        :          :            : : etc.              :
                        :          :            : :...................:
                       .:..........:.......     :
..............          :                 :.....:  ................
: Spare parts :.........:  X-Ray Machine  :.........:  Operator    :
:.............:         :                 :         :..............:
                        :.................:
                  ......:       :       :............
                  :             :                   :
..................:....     ....:.....         ..:..............
: Adequate location   :     : Proper  :        :  Budget &     :
: ie. X-ray protection:     : Power   :        :  Procurement  :
: from dust, sand etc.:     : Supply  :        :...............:
: Storage for Spares  :     :.........:
: & Consumables.      :
: Radiation Protection:
:.....................:
```

Figure 3.3.1 : Basic Requirements for the Operation of X-Ray Equipment

Figure 3.3.1 illustrates that spares and working materials are but two of the essential factors necessary for the proper functioning of x-ray equipment. They remain however, an important "link" in this "chain" and their demand and availability are directly influenced by all the other factors. For industrialized countries the supply and availability of spares and working materials do not pose the problem that they do in developing countries. This is largely attributable to the fact that they are usually the only varying items within the chain. The other components remain more or less constant, ie.: the presence of fully trained and suitably experienced operators and maintenance staff; well located equipment with adequate and proper storage facilities; protection from any environmental hazards; manufacturing representatives based within a 72 hour response range; funds available from the hospital budget, etc. The presence of all these factors allow spares and working materials to be more easily calculated and planned for.

This not usually the case in developing countries. Instead, many of the "links" in the "chain" function poorly, and some are absent altogether. Analysis of each section when applied to developing countries, reveals the following problems:-

1. <u>The Equipment Itself</u>: X-Ray and Developing Machines
 - often too long in service, too old and outdated
 - incomplete documentation and not always in the required language
 - too sophisticated ie.micro-processor based.

 When equipment is a donation additional problems can arise:
 - several brands ie. no standardization
 - who shall install it ? Where should it be installed ?
 - how to operate it correctly - is there a trained operator?
 - not functioning correctly, missing parts or options
 - spare parts & working materials not usually part of the donation
 - no warranty.

2. <u>Location</u>
 - inadequate pre-planning performed for good location site
 - lack of protection from hostile environments ie. dust, heat, humidity, poor ventilation
 - no storage facility for spares, etc
 - inadequate radiation protection.

3. <u>Power Supply</u>
 - inconsistent delivery of correct voltage
 - too often no power generator for power interruptions; and if present it often does not function
 - increased incidence of damage to sensitive parts of equipment.

4. <u>Operators</u>
 - unskilled or inadequately trained leading to overexposure of films etc., which increases the demand for consumables and parts ie. films and tubes
 - often only one operator employed; if they are transferred or resign, the replacement is untrained or there is no replacement
 - demotivated due to low salary, inadequate training, or no working materials
 - no-one accepts responsibility for equipment
 - poor security guidelines creating job hazards ie. no lead aprons, no radiation counters for personnel
 - recruitment difficulties for jobs.

5. Maintenance Engineers and Technicians
 - inadequate training, inexperienced
 - having gained experience often transferred
 - even with a competent in-house service, an outside service from supplier or manufacturer is required on occasions
 - replacement of spares often is dangerous due to high technology, high voltage, the need for special or expensive tools
 - Centralized Technical Services of Public Health Departments are inefficient due to lack of experience, limited training, lack of time and capacity.

6. Local Agency
 - local market in developing countries remains unattractive to private companies
 - if engineers or technicians are available from manufacturers they are often very expensive and not very experienced
 - only small stocks of spares & working materials maintained, so generally the items must be ordered from the manufacturer.

7. Budget Restraints
 - absence of logistics inhibits planning and calculation of requirements for spares & working materials
 - the budget often is inadequate for the provision of a proper maintenance service or the needed spares and consumables.

8. Spare Parts and Working Materials

In addition to the influence of factors 1 to 7 on the requirements for spares and working materials, the following co-existing problems should not be overlooked :-
 - if stored, short shelf life; old stocks not returned for replacement; items under or over stocked
 - replacement often complex and may require an expert from supplier ie. tubes often dispatched to factory for replacement; PC-Boards in some cases require re-calibration after replacement
 - local production of spares is very limited and is mainly for mechanical parts
 - if available locally, generally only the less expensive or common items can be found ie. films, developing baths.

Recommendations

There is no simple solution to improving the x-ray services in these countries, and to reducing the requirements for spare parts and working materials. Possible solutions are :

1. Establishment of a consulting board for medical equipment

This could be a non-governmental institution, consisting of competent persons with experience in this field of medical technology (ie. professors, doctors, engineers, decision makers at ministry levels), authorized to review all questions concerning X-ray equipment (in this particular case) and to make decisions in accordance with guidelines which should be compiled with regard to the standardization of equipment for the various regions within the country. The presence of such a board should effectively ensure:-

1.1 Advance consultation with donors

Donors internationally should be aware that the board must be consulted prior to the presentation of donations. This would eliminate many of the problems encountered with the appearance of high technology medical equipment for x-ray units in medical facilities in developing countries, as it would ensure that the following factors can be effectively approached:

a) installation of equipment
b) operator training
c) training of engineers and technicians for maintenance
d) provision of correct documentation
e) calculation of spare parts and consumable requirements
f) back-up budget
g) presence of local agency for particular manufacturers to assist with installation, commissioning, maintenance during warranty period, etc.

2. Establishment and Application of a PPM-Programme

In order to reduce the problems associated with the requirements for spare parts and working materials for x-ray equipment, a planned preventive maintenance programme should be established. This programme can only be effectively developed however, through the presence of a maintenance team, trained and equipped to deal with the handling and repair of medical equipment on a regular basis.

It is unrealistic to have an engineer specifically trained by the manufacturer, and then hope that they will be able to diagnose and repair any fault on a particular machine. Customers cannot reproduce the activities of companies like Philips and Siemens who manage to produce technicians highly skilled in the faults of a particular line of equipment. The companies achieve this by ensuring that their technicians are daily involved in the repair of particular models. In addition, prior to achieving this level of skill, the technicians will have received intensive training and fulfilled assignments under close supervision from experienced colleagues.

In most developing countries (and in many industrialized countries too) it is not possible for customers to reproduce such a work environment, mainly because hospitals do not own a large enough number of machines to provide sufficient opportunities for technicians to gain experience repairing them. It is envisaged therefore, that each medical facility or group of facilities would have trained engineers or technicians capable of performing PPM along with their other duties. They may share responsibility for the care of x-ray machines at a number of facilities so that there are more opportunites for them to gain experience repairing them.

There is no doubt that an effective PPM-programme would bring us closer to the more economic usage of x-ray equipment and also eradicate many of problems associated with the non-availability of spare parts and working materials.

3. Adequate Funding for Spare Parts and Working Materials

This is not only a recommendation, but a fundamental request and cannot be emphasized enough. If equipment cannot be replaced, and must be retained for a longer period, it is essential that it receives a regular and adequate preventive and curative maintenance service as well as proper operational handling from the very beginning. In addition, the environment plays a key factor in determining how well equipment will last over long periods.

In order to reduce the demand on spare parts and major consumables, the public health sector must recognise the importance of an adequate budget for the maintenance service, otherwise the equipment will be ineffective and at the end, too costly. Normally 15 to 20 % per annum of the investment costs should be provided to meet daily running needs of the equipment. This should cover all costs ie. power and other supplies, consumables, staff, maintenance, etc.

Spare parts and consumables must be calculated when new equipment is being acquired, to ensure their availability before the equipment becomes outdated. This requires an accurate record of all maintenance activities, so that the necessary information is always updated on any piece of equipment. The upkeep of these records, which would register all maintenance activities on each equipment, is an essential task of any maintenance service in the hospital. Based on this information, hospital administrators or directorates must forecast these costs and include them in their budget requirements, which then will be presented to the financing authority.

It must be kept in mind that manufacturers do guarantee the availability of spares only for 10-12 years. After this period it becomes a matter of luck, if you can find the needed parts. The manufacturers are more or less forced to met the demands of the market in industrialized countries, where a continual evolution of products is a must to survive within the international competition. This automatically increases the amount of equipment being supplied to these markets and speeds up the frequency of change and replacement of equipment.

It is possible that the population (patients themselves) could contribute a limited payment for the x-ray services rendered. This could be incorporated with the budget to fund the maintenance of the equipment. However, we should keep in mind, that often those most in need of the service cannot even afford the travel costs to reach the next available unit, should their local x-ray unit be out of order.

Conclusion
Without a doubt, the evidence is overwhelming, that the problems of spare parts and working materials for x-ray equipment in developing countries, cannot be solved in isolation from other co-existing factors. Proper standardization and more appropriate technologies to cope with the existing needs could greatly reduce the problems within the maintenance services, as well as those concerning the working materials. Indeed it would bring us closer to a more economical usage of such equipment.

The solutions presented should in general address most of the obstacles facing x-ray equipment in developing countries; thereby ensuring that an efficient and practical x-ray service can be offered by the provision of the appropriate equipment, which is easily operated, technically maintained and financially supportable by the users.

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Findings and Recommendations
Radiological equipment face many problems before technical issues even arise; such problems are the supply of film and chemicals, and suitable water supplies for the developing process. There was general agreement that the major problems with maintenance were mechanical ones. There are many electro-mechanical problems with items such as the focusing system, brakes, and cassettes, and with the developing units. But electronic problems do occur and when this happens the equipment is often not repairable due to a lack of

trained staff. Even after training, maintenance staff are fearful of the electronic systems of x-ray machines; this may well be because they are not called upon to use these their skills that often. They greatly benefit from some system of supervision and support. (perhaps this could be offered by agents or training instructors). There is a dilemma on what type of training would be most suitable - mechanical training is being forgotten and may be the most useful.

The general consensus was that safety issues are not addressed sufficiently in many developing countries. Shielding of rooms and users, training in radiation protection, quality assurance, and safety regulations and procedures are all areas that were lacking and need attention.

With radiological equipment it was felt that there is not a simple choice of either in-house maintenance or manufacturers' contracts. It is essential that a balance of both systems be used as they are complementary to each other; it is not possible for in-house personnel to cover the whole technical area. Some countries had efficient agents who could take care of this complicated field. But many countries were not so lucky, if in-house teams could undertake first line maintenance such as attending to routine mainly mechanical tasks, then the manufacturer's time would not be wasted with simple broken switches. The only way forward is to achieve co-operation between in-house personnel and the local agents.

There was a discussion of the WHO-Basic Radiological System (BRS) which was developed to be more "appropriate" for developing countries. It was designed to be easy to use and to have a low fail rate, unfortunately this does not necessarily mean that it is easy to maintain - for one thing it has a high technology generator. An additional problem is that this system costs as much as other higher technology units. It was recognized that there are conflicts between promoting low technology basic electro-mechanical systems which are easier to maintain, versus the desire of the medical staff to have sophisticated equipment and to feel equal to their counterparts in industrialized countries.

Nowadays most reputable manufacturers will guarantee the availability of spares not only whilst the equipment is in production, but also for 6-10 years after the end of production of the piece of equipment. However since this stock of spares will inevitably dwindle away, it was felt that donors should start addressing the problem of sustaining the equipment they provide, by supplying spares with the equipment in the first instance and by establishing budgets for the on-going purchase of spares.

Interest was shown in the recommendation to establish a consulting board for medical equipment, and whether such a system had operated successfully anywhere else. An example was given of a consultation board which was created in Iraq for the biomedical technology sector. Competent people within the country came together to form the board and to undertake planning activities. A project was implemented to discuss with suppliers and manufacturers the equipment which was required and to put forward the country's own ideas. This of course is a long developing process and at first there were misunderstandings. However, the people within the country have the local experience, and are the best at identifying their own needs and identifying their own administrative constraints. It is essential that donors be forced to consult such competent people, in order to avoid the frustration of donations arriving without the technical department or even the ministry knowing anything about them. In addition such a board may be able to institute a degree of standardization. Another comment made was that the advisory function of such a board should be separated from the procurement activities in order to avoid corruption.

The working group presented their recommendations which are summarized in Table 3.3.2. They decided that it would be impossible to talk about specific models of equipment within the extensive range of x-ray equipment, and therefore decided to comment on systems, sub-systems, and components of x-ray facilities. There is a problem with how much intervention can be expected from technicians in any particular location, whether they can be expected to undertake electro-mechanical or electronic repairs will depend on how they have been trained. Thus the table was divided into general basic considerations, and then types of repairs that can be undertaken depending on whether local training or factory training had occurred.

The type and complexity of the tools specified depend on how far the technicians can go into electronic repairs. The technicians would need some tools for simple diagnosis which in fact might be their most important function, rather than intervening themselves. In this way, they can give a sensible diagnosis to the manufacturer before calling out manufacturers' technicians or agents. The group felt that the usefulness of intervention did not depend so much on the spares available but on the knowledge of the technicians; if you don't have the knowledge no amount of spares can help.

The group found it impossible to make any generalizations concerning the quantities of spares which would be required since some component parts have very different lifetimes. In addition the quantities held would depend on the numbers of similar pieces of equipment being maintained, and whether the shelf life was sufficient to make it worth keeping an item in stock compared to the replacement intervals.

With dark room processing units, there cannot be much technical intervention with the modern complex daylight processing units, thus simple manual tanks would be preferable. It was recommended that silver recovery units be employed. Although they are not generally available, they are fairly simple to use and can offer considerable economies because the fixer can last much longer and the recovered silver is valuable.

It was noted that it is necessary to purchase most of the parts from the manufacturer; it was felt that only some of the casings, cabling, fixings, mechanical parts, and hydraulic parts could be manufactured locally. To save on wear and tear, it is a good idea to provide mechanical protection for the cables.

Since the lead sheets required for radiation protection are difficult to buy, it is also possible to obtain lead from car batteries and melt it down into lead sheets. A cheaper method than using lead, is to build x-ray rooms with walls of concrete which must be thick enough to offer the equivalent protection of lead; however this usually is only possible if a new building is being planned, it is very difficult to suitably alter existing buildings in this way. It had been thought that steel could be used instead of lead if sufficient thickness is used to obtain the equivalent protection; however steel sheets about 10 times the thickness of lead would be required and their weight is normally too prohibitive for this alternative to be used.

TABLE 3.3.2 : X-RAY EQUIPMENT:

COMPONENTS	MODE OF INTERVENTION		TOOLS (T)		SPARE PARTS & CONSUMABLES
	ELECTRO-MECHANICAL	ELECTRONIC	GENERAL	SPECIAL	
General			Multimeter (digital), Electro-mechanical tool set.		Documentation
Generator & Control Desk	X on fuses, switches, limiters, cables, connectors etc.	(X) if factory trained - some electronic repairs on boards.	X	Oscilloscope, (D) Old Image Intensifier/ Fluoroscopy Screen, Spinning top, Step wedge.	Fuses, Indicator lamps, Buttons, HT transformer oil, silicone grease for cable entry.
Tube Head	To be dispatched to Manufacturer or Agent or risk invalidating warranty.				Bulbs for collimator.
Mountings	X		X		Micro-switches, Limit-switches, Brake solenoids, Toggle switches.
Fluoroscopy System	X on mountings only.				
Image Intensifier		X if factory trained.			
Table	X		X		Micro & limit switches, Brakes, Cassette holder.
Bucky	X		X		
Developing Unit (M)	X		X		Immersion heater, Rollers, Thermostat, Dark room lightbulbs.

NOTES:

(D):Tools for diagnosis - old screens to see if x-rays are being produced; spinning top for timer calibration and to check tube anode; step wedge to check the kilovolts produced by the HT side of the generator.

TRAINING REQUIREMENTS		CRITICAL ASPECTS & SAFETY	ADDITIONAL SUGGESTIONS
Local Training on the Equipment	Factory Training	Knowledge of, & Provision for Radiation Protection	Mechanical protection of cables. Manufacture of lead sheets from vehicle batteries.
X for simple inter-vention	(X) required for more complex tasks due to high voltage & radiation safety.		
			If have specialized knowledge of old models, can take from the tube head the transformer if tube faulty, & vice versa.
X			
X			
	X	Only basic intervention	If well trained can calibrate and adjust intensifier & TV systems, & improve performance ruined by user errors.
X			Might be able to use general types of switches locally available.
X			Generally cannot hold spares.
X		Silver recovery unit recommended - offers economies.	Manual tanks should be kept as spares if the more complex machines break down.

(M):Manual type not daylight processing units of considerable complexity.
(T):The type and complexity of the tools specified depend on how far the technicians can go into electronic repairs.

3.4 Spare Parts and Materials for Mobile Medical Suction Machines (W.Green and H.Litschauer, Kenya)

The suction apparatus we have chosen to illustrate is the diaphragm suction pump. This pump is widely used in Kenya because of its low initial cost. Repair and maintenance of this pump is taught in practical workshops in Hospital Maintenance Training Institutions of Kenya. Young technicians have little problems working with this pump. The diaphragm pump is technically uncomplicated compared to the rotary pump.

However because of its inexpensive structure the pump requires comparatively more attention due to its high break down rate. The major cause of break down is fluids entering the pump housing due to overflow protection failure. Users seldom keep the overflow protection in clean condition and anti-foam solution is rarely available.

Literally hundreds of these pumps lie idle throughout Kenya. This is primarily because technicians do not have spare parts for maintenance or repair. A small fraction of the spare parts are available in the larger cities of Kenya. But even if the spare part were available, the most critical factor effecting whether the technician will be able to obtain the spare part for repair and maintenance is economical. In reality, budgets are limited.

We have studied this pump to find methods of repair whereby the technician is able to substitute some of the spare parts by making them from simple materials. The technician is instructed how the spare part is manufactured and what tools are needed. The spare part they produce must be reliable and not change the original function of the machine. We then determine which spare parts can be purchased from a manufacturer other than the medical firm selling or distributing the medical apparatus. Medical equipment firms often only assemble the apparatus, they do not manufacture the apparatus in entirety.

Also we demonstrate other methods whereby the technician can modify the manufacturer's design to better protect the diaphragm suction pump from damage.

THE DIAPHRAGM PUMP

The Manufacturers Suggested Spare Parts List.
A list of spare parts recommended by the manufacturer is condensed to include only the parts listed below. The rest of the suggested list is very rarely used.

1. The rubber diaphragm
2. The con-rod
3. The pump housing
4. The inlet and outlet valve
5. Screws
6. Filter cartridge assemble with spare cartridges
7. The electric motor
8. Suction jar and tubing
9. Overflow protection device
10. Motor main bearing
11. Vacuum gauge

The diaphragm:
Examination and replacement of the rubber diaphragm is the technicians most common task. Cutting the diaphragm from sheets of rubber is already a common maintenance procedure. Tools needed are a hollow punch set and a pair of scissors. Selection of the rubber diaphragm material must be correct. If material hardens with use the motor will over-heat. Many different thicknesses and types of rubber have been tried. Slightly-reinforced, oil resistant rubber sheet, one millimetre thick is being used but the life time of this diaphragm is short. We plan to test neoprene and other types of sheet for even better durability.

The inlet and outlet valves:
The manufacturer's valve is made of soft silicon latex, 0.6 mm thick. These valves can be cut from old damaged rubber bags used in the cuff of blood pressure machines. This material functions well and durability is good.

The con-rod bearing:
Manufacturers usually will not sell the bearing without the con-rod. Seldom is the con-rod damaged. The con-rod bearing is always subject to at least water vapour. It is easily pushed out and replaced using locktite to fit. When replaced, it should be replaced with a sealed water proof bearing instead, the extra cost is minimal if at all. Most manufacturers do not utilize this extra protection. A sealed water proof bearing available on the market is known as R62RSY.

The electric motor:
The capacitor run motor is the most expensive part to replace on the pump. To rewind this motor in Kenya is also expensive and is a large demand on maintenance budgets. The motor protection provided by the manufacturer is a simple fuse not sensitive enough to properly protect the motor. We recommend installing a thermal operated miniature circuit breaker, (MCB). The MCB rating should be selected as close as possible to the running current. Its size enables the technician to install it inside the machine housing. The MCB is also inexpensive.

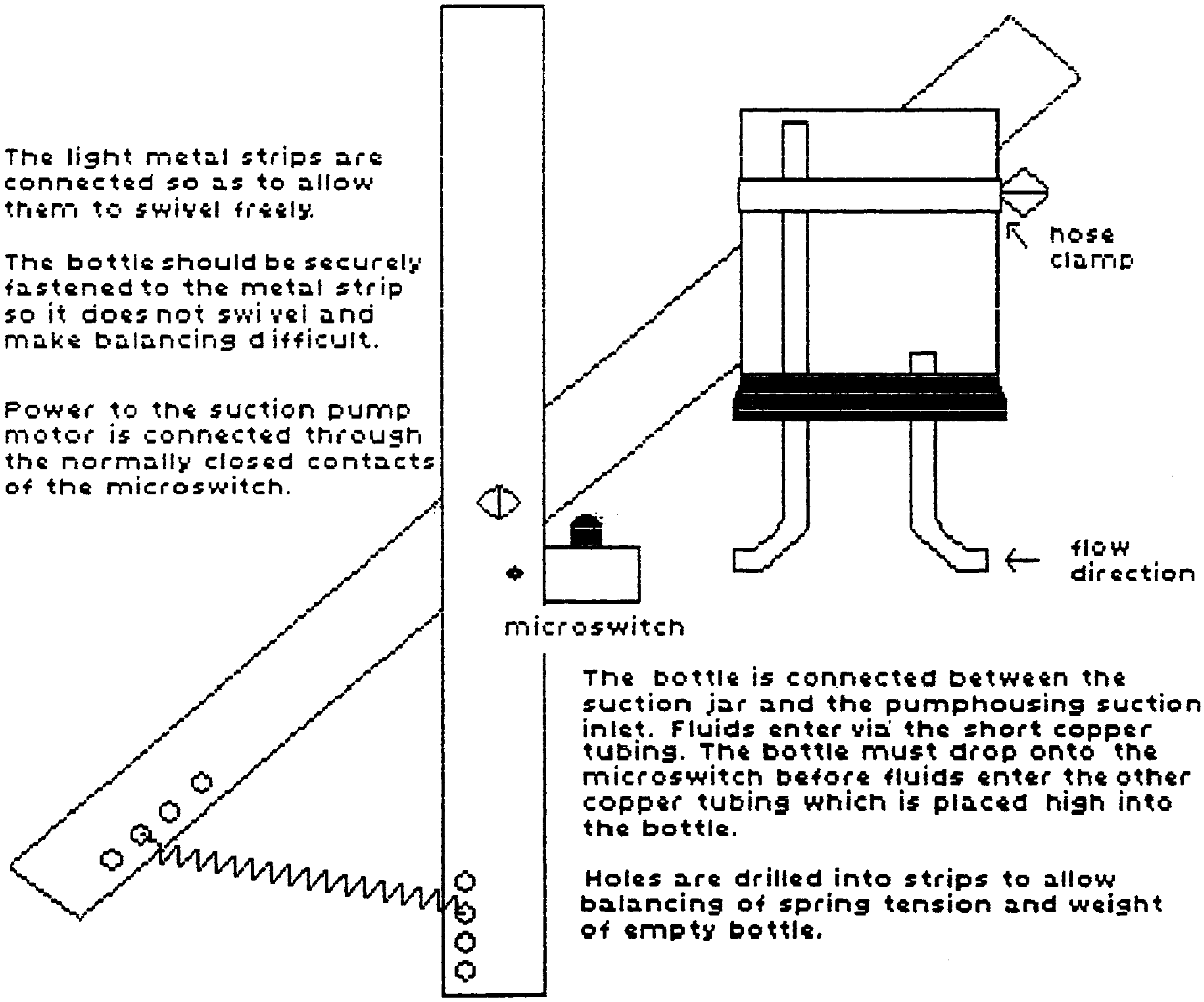
Motor main bearing:
The motor main bearing could also be replaced with a watertight sealed bearing.

Screws:
Metric size five and under are required for many different medical apparatus and are very difficult to purchase anywhere in Kenya. Buying screws from a medical manufacturer can be very costly and unwise.

The pump housing:
When the aluminum pump housing is damaged by corrosion and because of frequent removal of screws during service, helicoil sets have helped to repair damaged screw slots. The helicoil size is M3 or M3.5. All screws as they wear should be replaced by metric sizes. This will standardize all screws stocked for the suction machine to metric.

Modifying the manufacturer's design.
Alternatives were studied to modify the pump housing so that when the overflow protection device failed, the pump housing did not flood with fluids. We felt the problem was due to cost considerations in the design. The pump housing is always vented so that the downward stroke of the piston does not work

Figure 3.4.1 : Simple Design for an Additional Overflow Protection Device



against pressure. Manufacturers vent the pump housing with the discharge tubing connected through the pump housing. This also functions to reduce noise and eliminates the need for filters to keep the housing clean. Unfortunately this means if the overflow protection fails the pump housing and motor are flooded.

We moved the discharge tubing from the pump housing to vent directly outside the machine housing. This modification saved the pump housing from fluids. Undesirable results are a very slight increase in noise from the pump, and much to the nurses' dismay, fluids which now bypass the overflow protection empty onto the floor.

The overflow protection device.
Manufacturers have full confidence in their overflow protection devices. Ideally, using anti-foam solution and keeping the overflow protection clean means there should never be a failure.

We wanted a simple device that would sever power to the suction motor if the float type overflow protection failed. It was also important that the device be built with materials easily attainable by Hospital Maintenance Workshops. Another important factor was to build it as small as possible to mount on the access panel inside the machine housing. After the device is activated and power is terminated to the machine, then a technician must restore power to the motor again after checking the reason why the overflow failed. Materials used to build this device are:-

1. 25 cm 1/4" copper pipe
2. 250 ml jar with rubber stopper
3. micro-switch
4. 10 cm light spring
5. hose clip to fit bottle
6. three screws and nuts
7. light metal strip 200 x 4 x 20 mm or similar.

Our simple design operates in such a way that as fluids pass through the overflow protection and enter the machine housing, they will enter our jar mounted on the access panel before reaching the pump housing. The jar is balanced on a fulcrum counter-weighted with a spring. The weight of fluids entering the jar would then open the micro-switch cutting power to the motor. Only after the jar is emptied by the technician and the faults determined and repaired can the suction machine be operated again. The design is shown in Figure 3.4.1.

For the diaphragm suction pump, we have given examples of:-
i) selection of spare parts and materials, and
ii) modification for protection against damage;
these examples are applicable to many other items of basic medical apparatus found in Kenya. They greatly reduce the cost of repair and maintenance. They also provide the technician with greater involvement for a better understanding of the apparatus.

Findings and Recommendations
There was great interest shown in Mr Green's description of his design for a overflow limiting switch. There was discussion on the dangers of the suction machine stopping in the middle of an operation and the suggestion that instead of stopping the machine the fluid could divert into a second emergency bottle with some indicator to show that this was happening to warn the users.

TABLE 3.4.2 : SUCTION PUMPS

TYPE	SPARE PARTS & CONSUMABLES	QUANTITY	SPECIAL TOOLS	CRITICAL ASPECTS
Foot Operated Pump	Hose, Valve rubber. Consumables: Cotton for filter.	3m pa	Epoxy glue to mend rubber, but it does not last long.	Cleaning is a hazard to technicians. Contaminated parts must be disinfected.
Diaphragm Pump	Rubber diaphragm, Valves (inlet/ outlet) Jar & tubing, Bearings, Screws, Vacuum gauge, Pumphead nozzle. Consumables: Filter media, Anti-foam solution, Rubber sheets, Silicone, Neoprene.	4 pa 1 pa 1 pa 2 pa 1 sq.m pa	Taps and dies, Helicoil, Scissors, Hole punch.	Cleaning is a hazard to technicians. Contaminated parts must be disinfected. Electrical safety to be observed.
Rotary (sliding vane) Pump	Vanes, O-rings-original Jar & tubing, Bearings, Housing cover, Screws, etc. Pumphead nozzle. Consumables: Filter material, Special compressor oil.	5 pieces -matched, 2 sets in stock 1 pa 2 pa 1x5 litre container	Puller, Callipers.	Cleaning is a hazard to technicians. Contaminated parts must be disinfected. Electrical safety to be observed.
General for all	* Buy a set of spares when new equipment is bought. * Keep stocks of standard spare parts(nuts & bolts) * Keep spare parts lists. * Spares supply: a) initial supply, b) after repair, c) regular ie. annual. * All spares have indefinite shelf-life.		Test equipment: (10% precision) vacuum gauge. Service and repair manuals.	

IMPROVISATIONS	ADVANTAGES	DISADVANTAGES
* Disinfection agent: sodium hydrochloride.	Easy to operate. No "energy" required. Cheap investment.	Repair of pumps is nearly impossible. Low suction.
* Add motor protection: thermal overload, MCB.	Easy to repair (no special tools required). Can run off 12 V DC motor if available.	Requires electric power. Motor burnout.
* When replacing bearings - replace with water proof bearings.	Sufficient for general medical purposes.	Overheats when used for long periods.
* When doing repairs with damaged threads or lost screws, recut threads to get a unified system.		
	Long lifetime if operated properly.	High precision tools required for repair.
* Diesel or alcohol can be used as anti-foam solution.	High suction.	Most costly pump. Requires many original spare parts eg. due to the high pressure they must withstand, the original O-rings should be used not substitutes
* Rubber substitute: cuff of BP apparatus.		Runs hot & oil heats
* Jar substitute: plastic jar or dextrose bottles with rubber bung.		
* Special motor cut-off balance using spring-loaded jar (ref.Green).		

However it was generally agreed that it was highly unlikely that staff would watch the indicator, and so the mere provision of a second bottle would not protect the motor from overflow fluids. In addition it was felt that if nothing was done the suction machine would stop in the middle of the operation anyway due to the fluid in the motor, so it was preferable for the motor to be protected and the equipment to be returned to the maintenance unit for restarting.

It was recognized that whatever safety steps were taken, users generally get round them, this was why the whole bottle and switch unit was hidden inside the housing so that users could not see it and bypass it. An additional advantage was that the broken instrument had to be returned to the workshop for attention, the causes of the break down could be noted, and motors were saved therefore fewer spares were required. This topic again highlighted the importance of an on-going user training programme.

The group was told that the costs of such a device were very low due to the use of available materials, only a few Deutschmarks were required for the microswitch, and the labour was only 1 hour and was part of the staff's duties. The principle of this sort of modification was highly praised.

This was a good example of modification which not only prevents breakdown but can also save on spares purchase. It was felt that such a design should be published, at least in Kenya to start with, amongst technicians so that the idea could be spread. The meeting was told that a quarterly paper was appearing soon, in Kenya, which would contain information on this idea.

There was a brief discussion on the problems of replacing broken suction unit bottles. The meeting was told that dextrose bottles with a rubber bung can be used as an alternative.

The working group presented their recommendations which are summarized in Table 3.4.2. They concentrated on the 3 most common suction pumps in use: the foot-operated pump, the diaphragm pump, and the rotary (sliding vane) pump. It was stressed that suction pumps are easily contaminated with body fluids and therefore become a hazard for the technicians expected to handle them; there must be procedures for cleaning the pumps and for decontaminating them. It is not possible to disinfect the whole machine, but the parts that technicians come into contact with can be treated with the sterilizing fluids which are normally used in hospitals; often sodium hydrochloride is used and it is cheap. Some of the suction pump accessories which are connected to the patient can be disinfected in a sterilizer, as long as care is taken regarding perishable rubber.

Since so many broken suction pumps are found in hospitals, it was recommended that a policy of equipment cannibalization be pursued. In addition some of the simple mechanical parts could be manufactured locally in the maintenance workshops themselves eg. the camshaft of the motor.

3.5 Autoclaves
(S. Njoroge, Kenya)

Sterilization in a hospital is very important as it prevents transmission of disease and infections. This is achieved by exposing micro-organisms in instruments and linen to high temperatures using steam and vacuum. In Kenyan hospitals, sterilization is done mainly by use of autoclaves and table water boilers (which in many places are incorrectly called table sterilizers since they can boil water at temperatures as low as 93° C in some places). The goods to be sterilized should be subjected to high temperatures of up to 121° C or 134° C depending on the sterilizing time required.

It is important that the user knows how to handle the autoclaves so as to achieve the required sterilization as well as safeguard himself from any hazard which could possibly occur due to careless handling. Safety is very important and has to observed fully. An autoclave operates under pressure, normally around 250 kPa (2.5 bar), and without proper safety measures accidents can occur. This means that maintenance on the equipment should be done regularly and properly. One of the things we did to ensure safety is to test the autoclave on pressures above the normal operating pressure using compressed air, though it would be safer to use water under pressure.

In many of the Kenyan hospitals, different types of autoclaves from different countries of origin are used ie. from Britain, Japan, Germany, USA, USSR, etc. For example, in Nyeri Provincial General Hospital, we have a variety of different types i.e. Van Rietschoten and Howens, K.S.G., Practitioner, Jacob White Webeco, and M.M.M.

In our country, simplicity and standardization of equipment is very necessary due to a lack of knowledgeable personnel to use them, and to repair and maintain them. Standardization also helps with the procurement of spare parts because not so many different types of spares need be purchased. The autoclaves required in our hospitals need to be easy to operate, maintain and repair, and be of good quality. They need an automatic cycle of operation to avoid mistakes and manipulations by the user; and no need for special tools for service or repair. The service manuals should also be easy to understand with complete instructions on installation, hints on maintenance, and detailed information on spare parts commonly required. Since much of the equipment in our hospitals are not on contract, procurement of spares becomes very difficult because we must contact either the manufacturers or their local agents who normally sell spares very expensively. The procedure for obtaining spare parts is so long and complicated that a lot of time is wasted while ordering and waiting for these parts. At times it is even impossible to order them due to language differences between ourselves and the country of origin.

Maintenance and Repair of Autoclaves

Our hospital does not perform central sterilization due to a lack of space and planning, although we do have an autoclave for that purpose it unfortunately has never been unpacked. Thus sterilization is undertaken in different departments of the hospital ie. in the theatre, maternity, pharmacy, intensive care unit, and the eye drop production unit; all other departments depend on these facilities as required. The disadvantage of this arrangement is that specific personnel do not exist for sterilization tasks. Therefore problems arise in the operation of the autoclaves since they are handled by many different people. In addition the autoclaves operate continuously and on a daily basis hence proper maintenance is very necessary.

AUTOCLAVE

TYPE: VAN RIESCHOTEN AND HOWENS

Inspection actions:
■ Weekly
● Every 3 months
▷ Half yearly
⚠ When needed

Part of equipment, Machine and Installation.	Visual inspection of wiring, tightening of connections	Insulation resistance, current leakage and safety line resistance	cleaning contacts or replacing	Corrosion, rust, cracks, wear and painting	Cleaning scale deposits (by dismounting)	Leakage	Greasing	Calibration	Replacement when needed	Functioning			Mark part checked (✓) Name, Date of inspection(I) or major Maintenance(M)
Switches, contactors, timer and fuses	▷		▷						⚠				
Float switch	▷		▷		▷								
Contact thermometer and thermostat	▷							▷		■			
Heating elements	▷	▷			▷	▷							
Ins. transf., wiring and supply connections	▷												
Operation indicators	▷								⚠	■			
gaskets						■							
Lid lock mechanism				■			●			■			
Safety valve								▷		▷			
Valves					▷	▷				■			
Ejector, strainer and filter					▷				⚠				
Inner chamber and outer chamber				▷									
Piping and joints						▷							
Thermometer pressure gauge and sight glass				▷	▷								
Complete unit		▷							⚠	■			

Figure 3.5.1 : Planned Preventive Maintenance Matrix Chart for an Autoclave

Due to a lack of distilled water, the autoclaves must use tap water from the local supply which is not very clean, giving rise to an accumulation of mud and the formation of scale in the autoclaves. Planned preventive maintenance is very important to prevent the problems which can occur as a result, ie. accumulation of mud in the float switch causing heating elements to operate without water and to burn out; sight glasses indicating the presence of water when there is none, or vice versa.

In order to be able to perform proper planned preventive maintenance, we have developed a matrix chart for every piece of equipment in our hospital, which is followed either weekly, monthly half-yearly or yearly depending on the parts to be maintained, an example is shown in Table 3.5.1. A typical example of equipment requiring PPM is the Van Rietschoten and Howens autoclave. It has a central locking mechanism with a lid screw which has to be greased every three months by use of heat resistant grease. Failure to do so might cause the lid to stick and opening it becomes very difficult. This has happened resulting in an autoclave being taken 60km from a district hospital to the maintenance unit, where part of the mechanism had to broken in order to open the lid. The broken screw was worn out due to lack of lubrication and we had to fabricate one in our hospital maintenance unit from bronze material. To avoid such problems in future, this type of autoclave should either have an emergency means of opening or have instructions on how to open it in such an event. From this and similar problems with equipment spares we have formed a classification of the spares as either critical or non-critical as shown in Figure 3.5.2.

The Van Rieschoten and Howens autoclave is quite effective unlike other types of autoclaves. Since it is double walled, it saves time and energy because once it is heated up, it is not necessary to pre-heat it in subsequent sterilization cycles.

Maintenance and Repair Tips

1. Function of the autoclave would be much better if distilled water was used.
2. The gasket used can be improvised by use of silicone material.
3. The lid screw can be fabricated by use of a lathe machine.

Note

An additional report on vertical autoclaves which was submitted but not presented at the workshop is included in Annex IV. This report offers an example of work undertaken on a specific type of autoclave, with the spares used and tools required.

Findings and Recommendations

It was noted that on many hospital sites there is a large central area containing immense boilers fuelled by crude oil; these are used to generate steam that then travels long distances around the site to relatively small consumers. Systems such as this have many leaks and losses; in fact sometimes the energy loss is greater than the energy requirement of the health facility. These energy issues for hospitals are nearly always neglected; at the planning stage there needs to be a study of:-

i) energy requirements,
ii) fuel consumption, and
iii) operating costs.

In addition, a system should be established for on-going monitoring and control of these three factors.

It was appreciated that many problems faced by autoclaves are due to the water they are supplied with. They require distilled water and invariably receive only water straight from the tap. The meeting discussed various filters that

Figure 3.5.2 : Classification of Autoclave Spares

```
                       ........................
                       :Spare Parts Requirement:
                       :  and Classification   :
                       :......................:
                                   :
                ...................:...................
                :                                     :
                :                                     :
     ...........:..........               ............:.............
     :Critical Spare Parts:               :Non-Critical Spare Parts:
     ::::::::::::::::::::::               ::::::::::::::::::::::::::
     :Special spare parts :               :Part available on the   :
     :available only from :               :local market. Substitute:
     :manufacturer. No    :               :available. Repair or    :
     :local substitute    :               :spare part can be       :
     :possible.           :               :locally manufactured.   :
     :....................:               ::::::::::::::::::::::::::
                :                         :                        :
          ......:..............           :                        :
          :                   :           :Immersion heating       :
          :                   :           :elements,               :
..........:.........  ......:.......      :Valves,                 :
:Normal Wear        :  :Accidental   :    :Gauges,                 :
:and Tear           :  :Breakdown    :    :Strainer,               :
:::::::::::::::::::::  :::::::::::::::    :Pressure switch,        :
:Air filter,        :  :Safety valve,:    :Sight glass,            :
:Lid gasket,        :  :Float switch.:    :Switches and indicators,:
:Lid screw (could be:  :             :    :Copper-Asbestos ring for:
:non-critical if one:  :             :    :heating elements.       :
:had a lathe machine:  :             :    :                        :
:and material),     :  :             :    :                        :
:Silicon ring for   :  :             :    :                        :
:sight glass,       :  :             :    :                        :
:Silicon gasket for :  :             :    :                        :
:lid.               :  :             :    :                        :
:...................:  :.............:    :........................:
```

can be used with the tap water in order to provide the autoclaves with a better supply: either ceramic cartridge filters, or Katadyn (silver catalyst) filters can be used successfully.

The meeting was told of a programme in Senegal to train technicians to build water softeners and in so doing learn how essential they are. The water softeners are based on the ion/resin exchanger principle. These water softeners are then included in the regular PPM schedules, and thus any future problems of micro-organisms, such as algae, fungi, etc., are caught in time. It was recognized that filtered rain water is also a suitable supply since rain water is softer than ground water.

There are problems with the amount of energy autoclaves require, and often when sterilization is in progress, hospital generators cannot cope with other hospital needs. An alternative to this is to use diesel or kerosene burners instead to drive autoclaves, which preferably should be well insulated. Burners are available that can be pumped manually for one sterilization process after which staff must repeat the process. Users must be aware of how critical the pump is to give enough pressure of fuel to the nozzle of the burner. The sort of pump used is very important as some makes are too flimsy and are designed for activities such as camping and not for hospital work. Suitable burners are provided by Webeco, and by other companies as long as they can maintain pressure without pumping. In addition, FAKT has already been supplying such burners to mission hospitals and are willing to supply them to other interested parties.

Mr Huys is in the process of preparing teaching material which he would be happy to send to people for them to evaluate. Information is available on sterilization and for blood pressure apparatus. In the future there will be information on operating tables, operating lamps, and suction pumps.

It was recognized that many of the autoclaves existing in hospitals are old, but this often means they are less technically complex. A regular PPM system can greatly benefit them. It was noted that the company MMM have stocks available of old autoclaves, from Europe and the USA, produced from 1970 onwards. In many situations electronically controlled autoclaves turn out to be too complex and complicated to maintain. Electro-mechanically controlled autoclaves are available and even old purely mechanically controlled ones can still be found; these options may well be preferable as they are much easier to maintain. Machines can still be found from manufacturers in Europe and the USA, such as those mentioned in the presentation above.

The working group presented their recommendations which are summarized in Table 3.5.3. There are many types and sizes of autoclaves which can be run on steam or gas supplies; the group decided to concentrate on medium sized horizontal autoclaves which are supplied externally from the hospital steam supply.

A problem which is often overlooked is the effects of steam quality, and steam inconsistency in terms of pressure and saturation. If the pressure of the incoming steam is very low it can affect the performance of the autoclave; furthermore if the saturation level is not correct, the steam may contain a lot of water droplets and give rise to excessive condensation.

There was discussion about the need for a vacuum pump as a spare part. Manufacturers state that these pumps are very seldom damaged, and some build

TABLE 3.5.3 : AUTOCLAVES

HORIZONTAL AUTOCLAVE - MEDIUM SIZE - EXTERNAL STEAM SUPPLY	SPARES AND CONSUMABLES	LIFE-TIME	SPECIAL TOOLS
Electrical Controls	Relays/overloads,	2 yrs	Temperature probe.
	Thermostats,	1 yr	
	Pressure switches,	5 yrs	Multimeter.
	Timer,	1 yr	
	Float switch,	2 yrs	Timer (for testing)/ stopwatch.
	Recorders for temperature & pressure,	6-months	
	Electric door switches,	1 yr	
	Fuses,	5 yrs	
	Control lights.	5 yrs	
Steam circuit	Solenoid valve,	2 yrs	Could use steam tables to determine temperature.
	Safety valve,	1 yr	
	Pressure gauges,	1 yr	
	Valves,	10 yrs	
	Steam trap,	3 yrs	Microbiological tests.
	Steam filter/ strainer,	3 yrs	Special type-related tools (spanners, etc.).
	Steam pressure reducing valve,	2 yrs	
	Vacuum pump,	2 yrs	Gloves as protection from burns.
	Condensate pump,	10 yrs	
	Gaskets,	stocks	
	Hemp/teflon/PTFE,	6 m	Temperature/time indicator tape.
	Vitron O-ring.		
Mechanical parts	Door gasket material,	6-8m	Silicone grease,
	Door chain (for electric sliding doors).	3 yrs	Gasket cutting tools.

CRITICAL ASPECTS	IMPROVISATIONS
Safety :- high pressure - vacuum - steam.	Door gasket: - turn around if possible - substitute if possible - repair if possible (can use bicycle repair kit but the repairs have only a limited duration).
Burn hazards :- heat - electrical.	
Steam quality and steam inconsistency in terms of - pressure - saturation.	PPM : grease the gaskets to avoid - hardening - tearing and sticking.
Heavy door & counterweight could pose a hazard whilst under repair.	Can grease with silicone spray or talcum powder.
Short shelf life of rubber and silicone gaskets.	Grease the gaskets often, to keep the gaskets soft.
	Manufacture gaskets for steam piping.
The vacuum pump is a critical part:- the cost is high - it's complex to repair.	If there are round gaskets, can use a square substitute; if the gasket is square cannot substitute with a round one; thus better to stock square gaskets.
The problem of sterilizing thermally unstable, or thermally sensitive goods.	Relocate chart recorder (usually exposed to steam when the door is opened).
Good co-operation is needed between operators and technical staff. Proper operating practices mean much less technical intervention.	For autoclaves with venturi-vacuum system: save water by installing a tank and pump and recycle the water. Investigate possible heat recovery (but not condensate recovery).

in a warning noise to occur if the pump is in danger of being damaged. However members of the group felt that it was very important to have a second pump, so that sterilizing can go ahead whilst the pump is rebuilt and ensures that one pump is always ready in stock. The damage is caused by the lack of water treatment, which means the pumps corrode and salt up. Since the cost of the vacuum pump is so high, it was decided to call it a critical part. To rationalize spares and to make cost savings, one spare vacuum pump could be held for 5 autoclaves, for example, of the same type. In addition more attention should be given to the issue of water treatment plants.

In smaller hospital units, often the sterilization process is achieved without using a vacuum system at all; this avoids the high costs of spares. However in order to achieve reliability of sterilization, the sterilizing process must take longer. An example was given where a simple venturi pump, able to create 4 bars to achieve the vacuum, was installed beside a water tank with a small and simple water pump. In this way the venturi pump does not require a continuous, and therefore expensive or scarce, water supply from outside. An alternative option is to use a steam jet pump.

There are many different methods of sterilization depending on the goods involved and their subsequent use. This meeting has only been discussing autoclaving, which is an example of sterilization by heat. However, some goods cannot withstand the high temperatures of steam sterilization cycles and require different methods. For items made of materials which should not be boiled, an alternative is ethylene oxide gas sterilization but this requires a high level of capital investment. There are other forms of chemical sterilization each with its own advantages and disadvantages, but the whole field is a complex one and has not been addressed in this meeting. In many situations recommendations for the correct method of sterilization are ignored, thus leaving items either damaged or inadequately disinfected. Basic health facilities should use autoclaves, identify the items for which there are strong recommendations against boiling, and try their best with chemical sterilization. It was suggested that GTZ take up this issue in the future. A good reference book would be: Hospital Hygiene, I.M. Maurer, published by Edward Arnold, 1990.

There are different methods for testing the temperature levels attained by the contents of the autoclave. A temperature probe is the most accurate although the most expensive. Alternatively, there are temperature indicator tapes which change colour at certain temperatures; they are placed in the folds of linen or inside glassware, whilst it is autoclaved, to see if the correct temperature is reached. In addition, there is a microbiological test; special sealed vials of culture of bacillus are obtained from the hospital laboratory and are placed in the autoclave. After the steam sterilization cycle, the laboratory undertakes tests to ensure that the contents of the vials are dead.

Problems arise with autoclave chart recorders which record the temperature cycle; they break down often, and there can be shortages of the special paper which they use. Since this part is so expensive, the meeting expressed concern at the positioning of the recorders by manufacturers; when the autoclave door is opened, the recorder is always saturated with steam.

The meeting stressed the importance of co-operation between the autoclave operators and the technical department, in this way correct daily usage and handling of the machines could be improved thus reducing the maintenance requirements.

3.6 Laundry and Washing Machines (S.Njoroge, Kenya)

A properly functioning laundry is an essential part of a well run hospital. It is necessary to pay attention to the correct flow of the laundry, not only because of washing but also for disinfection of the hospital linen. The dirty linen should not contaminate the clean linen; it would be even wiser to wash infected linen separately.

The washing machines in our hospital are loaded and unloaded through the same door. This fact makes it impossible to have a clear division between the dirty and clean operating areas. When the laundry equipment is purchased, the manufacturers should provide the plan for installing the equipment since there is a lack of experts in the hospital. For example in our hospital laundry, the washing machines are installed at a distance of about fifteen metres from the hydroextractor and more than fifteen metres further from the driers; also some of the machines are installed too near to the wall making it difficult to maintain them.

To meet the requirements of the Kenyan hospitals the laundry equipment should be easy to maintain and repair, that means the equipment should be of good quality but not complicated, and possible to repair and maintain with no need for special tools. The washing programme should be automatic to avoid errors an manipulations. Also service manuals should be easy to understand, with complete instructions for mounting and dismounting with all the hints for maintenance and repair.

The spare parts data should have specifications for the commonly used spares and not just an order number from the manufacturer, eg. a capacitor should be described in µF or a transformer in V, VA and the number of windings. Circuit diagrams and wiring diagrams should be included as well. There should be hints on planned preventive maintenance for example on how to determine if a certain part has to be exchanged. In our case, we have a washing machine in which the bearing for the drive motor should be changed after 5,000 working hours, but the machine has no running hours counter installed.

The Maintenance and Repair of Laundry Equipment
Our laundry not only washes linen for the provincial hospital which has about 440 beds, but also linen from a nearby district hospital which has about 300 beds. Therefore, the only way to maintain the laundry equipment functioning under this heavy load is through proper planned preventive maintenance. Figure 3.6.1 shows an example of a washing machine matrix chart in the format we have developed for all equipment in our hospital.

The machines have weak construction points, for example the drainage valve is inadequate since it is missing a drainage filter; the screws for the gear wheel are not prevented from unscrewing due to vibrations, and in fact because of a loose nut the gear wheel was broken into pieces. They also have too many different types of energy supply to control the steam and drainage valves - we have electricity and air pressure or water pressure which in developing countries is always a problem. The control switches are not water proof and therefore water penetrates through when cleaning. The thermostat is not necessary for our situation because if the user selects temperatures below boiling point, then the linen will not be disinfected or boiled. From these and other similar problems we have formed a classification of spares as either critical or non-critical as shown in Figure 3.6.2.

Figure 3.6.1 : Planned Preventive Maintenance Matrix Chart for a Washing Machine

WASHING MACHINE

INSPECTION ACTIONS
■ Weekly.
○ Monthly
▷ Half yearly
▶ Yearly
◬ When needed

PART OF EQUIPMENT, MACHINE AND INSTALLATION.

PART OF EQUIPMENT, MACHINE AND INSTALLATION.	Visual inspection of wiring,tightening of connections.	Insulation resistance current leakage, safety line resistance.	Cleaning contacts or replacing.	Corrosion,rust,cracks,wear,painting, and cleaning	Inspection and maintenance by dismounting	Oil change	Running noise,truth of rotation, tightening fastening screws.	Lubrication	Leakages	Belt tension,adjustment,calibration.	Replacement when needed.	Functioning	Mark part checked (✓) Name,Date of inspection (I) or Major Maintenance (M).
Contactors,timer,fuses, switches and pushbuttons.	▷		▷								◬		
Wiring and supply connections	▷												
Level switch	▷		▷										
Drive motor	▷	▷											
Overload protection	▷									▷		▷	
Magnetic valves,drainage valve	▷			▷	▷				▷			■	
Piping and joints.				▷	▷				○			■	
Valves				▷	▷							■	
Operation indicators	▷		▷									■	
Programmer	▷		▷								◬	■	
Dial thermostat										▷			
Bearings								▷	▷		◬		
Seals,Gaskets				○	▶				○				
Door and door lock							▷	▷					
Gearbox						▷	▷						
V-Belt					▷					▷			
Steam control valve					▷			■					
Drum							▷						
Mechanical joints							▷						
Housing				▷									
Complete unit							▷				◬	■	

Figure 3.6.2 : Classification of Washing Machine Spares

```
                    ........................
                    :Spare Parts Requirement:
                    :  and Classification   :
                    :.......................:
                                :
             ...................:...................
             :                                     :
             :                                     :
   ..........:.........                 ...........:.............
   :Critical Spare Parts:               :Non-Critical Spare Parts:
   ::::::::::::::::::::::               ::::::::::::::::::::::::::
   :Special spare parts :               :Part available on the   :
   :available only from :               :local market. Substitute:
   :manufacturer. No    :               :available. Repair or    :
   :local substitute    :               :spare part can be       :
   :possible.           :               :locally manufactured.   :
   :....................:               ::::::::::::::::::::::::::
             :                          :                        :
        .....:..............            :                        :
        :                  :            :Pole change switch,     :
        :                  :            :Reverser,               :
..........:.........  .....:......      :Contactors,             :
:Normal Wear       :  :Accidental -:    :Thermostat,             :
:and Tear          :  :Breakdown   :    :Mercury level switch,   :
::::::::::::::::::::  ::::::::::::::    :Door switch,            :
:Special ball-     :  :Gear wheel, :    :Overload switch,        :
:bearings,         :  :Worm gear,  :    :Water valves,           :
:Door rubber ring, :  :Shaft,      :    :Solenoid coils,         :
:Diaphragm for steam: :Sight glass,:    :Seals,                  :
:valve,            :  :Steam valve,:    :Front panel seals,      :
:Diaphragm for drain: :Programmer. :    :Ball-bearing for drive  :
:valve.            :  :            :    :motor,                  :
:                  :  :            :    :V-Belt,                 :
:                  :  :            :    :Safety ring for ball-   :
:                  :  :            :    :bearing top.            :
:..................:  :............:    :........................:
```

modification by placing an upper limit on the thermostat, however it was stressed that there would have to be a timer since a temperature of 75° C is only sufficient over a period of time. It may be better to stick with boiling linen so that the users did not have to worry about time. An additional factor is that any economy may be offset if it was found that linen life-time is reduced. There was some concern that if this temperature was sufficient, laundry machine manufacturers would have already incorporated this temperature into their designs instead of bothering with the need for reaching higher temperatures, unless there was a good reason for it. At present there does not appear to be any commercial machines offering a 75° C wash cycle instead of the 90 or 95° C cycle normally offered for linen. Thus the meeting recommended that more detailed authoritative advice is required from research institutes before assuming that linen has been cleaned effectively with a drop in temperature.

The working group presented their recommendations, which are summarized in Table 3.6.3. They stressed that some of the most important issues affecting laundries are connected with the initial installation of the equipment. The issue of decentralized small laundries, and obtaining suitable room plans have already been discussed. In addition to this however, they noted that whichever room is chosen for the laundry, there will always be the problem of adequate disposal of the waste water. The sheer volume of liquid produced requires careful attention to the capacity and route of the chosen waste water disposal system.

Figure 3.6.4 summarizes the problems which must be considered when running a laundry system. One topic in particular is often forgotten and that is the risk associated with infected material and therefore the need for adequate hygienic practices.

The issue of which type and quantity of spare parts to stock is obviously dependent on the conditions and needs in each country. If complex equipment is chosen, such as those controlled by electronic programmes, there are direct implications for spares provision. In addition, equipment is commonly overloaded or underloaded; such incorrect usage will also affect the stocks of spares required. Therefore it is important to adequately train laundry operators so that the machines are correctly used. Planned preventive maintenance is a very important tool, not only for catching technical problems at an early stage, but also for seeing what is actual happening in the laundry and thus catching the operational problems early on as well. It should not be forgotten that proper use of equipment and technical care of its parts will ensure prolonged life for the linen.

Although it was realized that energy can be saved in hot climates by drying the laundry in the open air, it was stressed that this should be followed by an ironing process with high temperatures in order to kill the eggs of, for example, the mango fly which settle on items drying in the open air. If such an ironing process is not followed, there is a health risk from the larvae hatching out of the eggs and burrowing into the skin of patients and staff who subsequently wear or use the linen.

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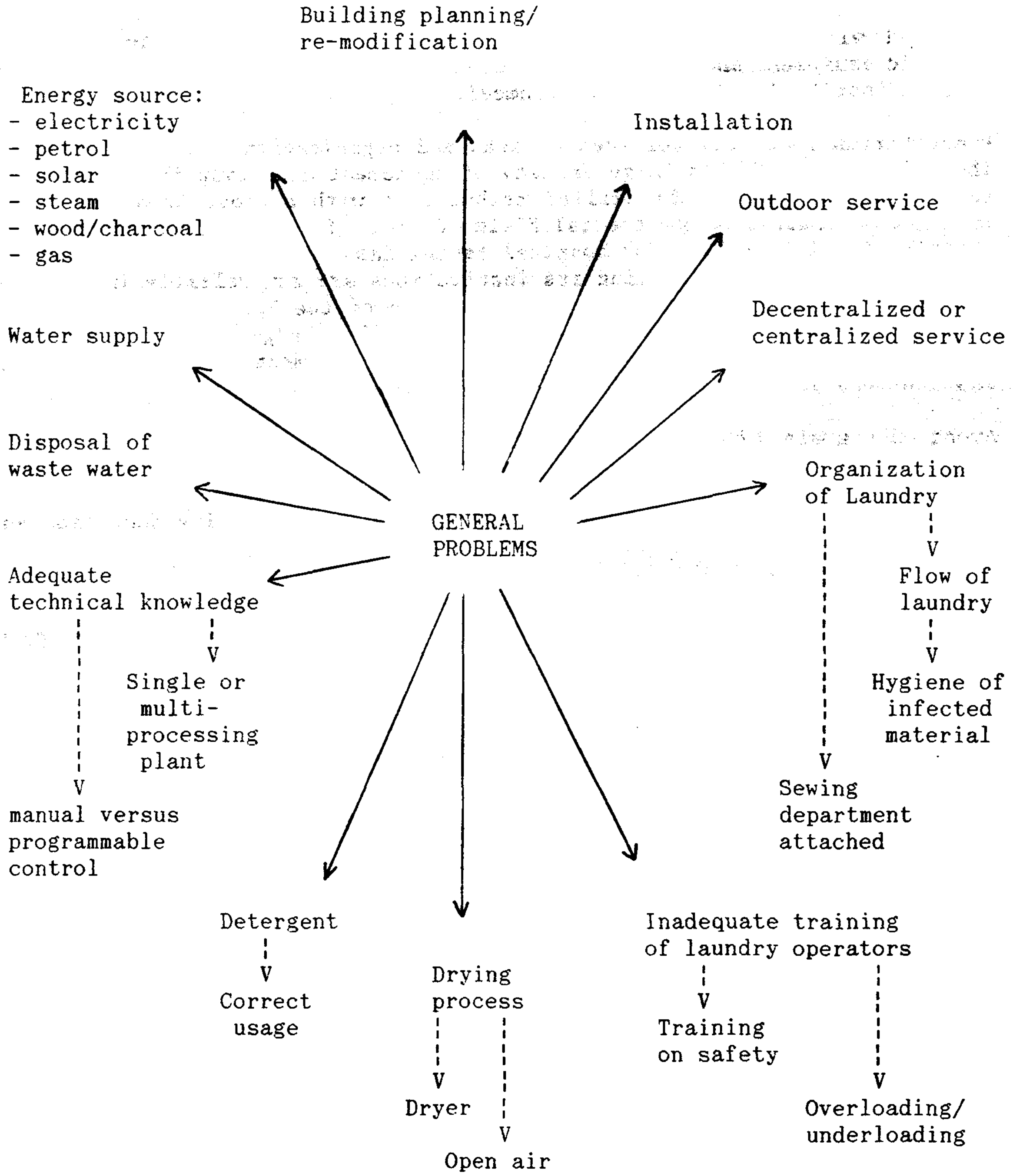
TABLE 3.6.3 : LAUNDRY EQUIPMENT & SERVICES

COMPONENTS OF LAUNDRY PROCESS	TECHNICAL PROBLEMS	SPARE PARTS	RECOMMENDATIONS
Washing Unit	Quality of energy & water supplies. Lubrication oil for steam valve (must be heat resistant).	Sealing rings, Relays, Switches, Belts,	Operator training, Water treatment, Planned preventive maintenance including:
Hydro Extractor	Drive systems and mechanisms. Scale on heating elements.	Heating elements, Extractor motor,	- Inspection - Lubrication, Trained crafts-personnel :
Dryer	Leakages - water - steam. Inadequate waste water disposal system.	Water pipes, Steam pipes, Bearings, Steam valves,	- plumber - electrician - mechanic, Adequate tools, Technical
Ironing Machine	Corrosion. Faulty switches. Programmable control systems.	Gaskets, Timer, Consumables.	documentation, Ironing required to kill eggs of the mango fly.

FIGURE 3.6.4 : General Problems to be Considered When Running Laundry Systems



3.7 Structure of Spare Parts Supply and Storekeeping System for Engines, Alternators, and Water Pumps (J.Clauß, Cameroon)

The Presbyterian Church in Cameroon and its technical set-up
The sphere of activities of the Presbyterian Church in Cameroon extends through the two anglophone provinces of the bilingual country. The Church is running 3 hospitals, 1 rehabilitation centre, 7 health centres, 2 rural training centres, 2 woodworking enterprises, 1 printing press and several schools. Since most of the institutions are located in rural areas they are equipped with autonomous power and water supply systems. In addition, specific equipment and installations are in use according to the nature of the various institutional tasks, eg. biomedical equipment for health facilities.

Presbyterian Technical Services - tasks and organisation
The maintenance of this large variety of equipment and plant in the tropical rain forest requires well skilled technicians with a broad knowledge which must not be limited to one special field of work. Since there are no official training facilities, eg. for hospital technicians, the Church was looking to find its own means of ensuring its institutions are run reliably in terms of technical maintenance. With the introduction of the Presbyterian Technical Services (PTS) a system was found to provide knowledge, skills, tools and equipment in order to keep the technical equipment and plant in the institutions in good condition.

Among the goals of organized Technical Services two aspects have to be emphasized in terms of storekeeping of spare parts:
- Introduction of guidelines for standardization of technical equipment in order to economize the use of spare parts and to simplify operation and maintenance.
- Development of a structure for maintenance and repair of technical equipment in the various institutions. Creation of an inter-project system for the economical purchase and use of spare parts and tools.

The activities of the Technical Services are divided into the institutional, the regional and the church-wide level. Within the Church institutions three well-equipped technical workshops constitute the regional level. Two of them are attached to hospitals, the third is a garage. The Technical Adviser acts as coordinator of the various activities of the Technical Services and as contact person to the various boards of the Church and their institutions. A proposed Technical Board will lay down the policy of the technical work within the Church and ensure its execution in future.

3.7.1. PTS Inventory and Storekeeping System

General structure of the inventory
The entire technical equipment in use within the Church institutions has been gradually compiled in an inventory system. Each individual device has been registered on an Equipment Record Sheet (refer: Annex V, Fig.1) with all its particulars and important data. It is provided with a unique inventory number which also distinguishes the different kinds of equipment. Main groups, for example, are: alternators, engines, water pumps, medical equipment. As a "speaking number", the inventory number in addition contains information about the type of device, and a serial number. Among the main group of alternators, for example, we find sub-groups of devices such as single phase and three phase models, and integrated portable generating-sets. Within the sub-groups a serial number is allocated to the individual devices or machines.

Figure 3.7.1 :

PRESBYTERIAN TECHNICAL SERVICES

INVENTORY and STOREKEEPING SYSTEM

The items of the entire stock of all Technical Departments within the Church are allocated to laid-down MAIN GROUPS. These Groups are related to MAJOR EQUIPMENT and DEVICES if possible and appropriate.

The MAIN GROUPS are as follows:

short term	EQUIPMENT	MATERIALS kept in store	Examples
A	Alternators	spares for alternators	carbon brushes, bearings
B		Electric Materials	cables, sockets, lamps switches, components
C		Consum ables	sandpaper, adhesives
D			
E	Engines	spares for engine	joint sets, pistons
F		Fuel&Lubricants	petrol, oil, grease
G			
H			
I			
K			
L			
M	Medical Equipment	spares for medic. equipment	bulbs for Op-lamps, glasses for suct.-pump
N			
O	Office Equipment	spares for office equipment	bulbs for slides-proj. toner for photocopy-m.
P	Water Pumps	spares for water pumps	packings, valves, pistons, pump-wheels
Q		Plumbing Materials	pipes, fittings, taps, stop cocks, toil.seats
R	Printing Machines	spares for printing machines	switches, light barriers, heater elements
S			
T	Machine Tools	spares for machine tools	V-belts, saw blades, electr. motors
U		Tools	twist drills, special tools, measuring tools
V	Vehicles	spares for vehicles	spark plugs, tyres, brake shoes, filters
W	Woodworking Machines	spares for woodworking machines	Planing knives, belts, switches,
X		Working Material	iron bars, rods, hoses metal sheets, pipes
Y		Mechanic Joining Materials	bolts, nuts, washers, hooks, clips, rivets,
Z		Machine Elements	wheels, bearings, belts gears

Part of the Equipment Record Sheet is the Equipment History. All activities carried out on the equipment should be explained briefly. This is an important data base to determine the storekeeping of spare parts. An example is shown in Annex V, Fig.1.

In addition to the care of equipment the technical departments have to deal with a large variety of spare parts and working materials. Each item of the entire stock is also allocated to one of a number of laid-down main groups. These groups are related to major equipment and devices where appropriate. All spare parts for example belonging to alternators are kept in section "A" of the store. Those parts which can be used only for a particular alternator are found in a box labelled with the inventory number of that alternator. Other items such as electrical installation materials, plumbing materials, mechanical joining materials are not related to particular equipment. They have their own main groups and are stored in their respective sections. Figure 3.7.1 shows how stocks of spares are organized into groups according to equipment types.

Institutional procurement of spare parts and working materials
Figure 3.7.2 shows the method used for institutional procurement of spare parts and working materials. An analysis of the procurement of materials will help to answer the question of which parts and materials should preferably be kept in an institutional technical department store.

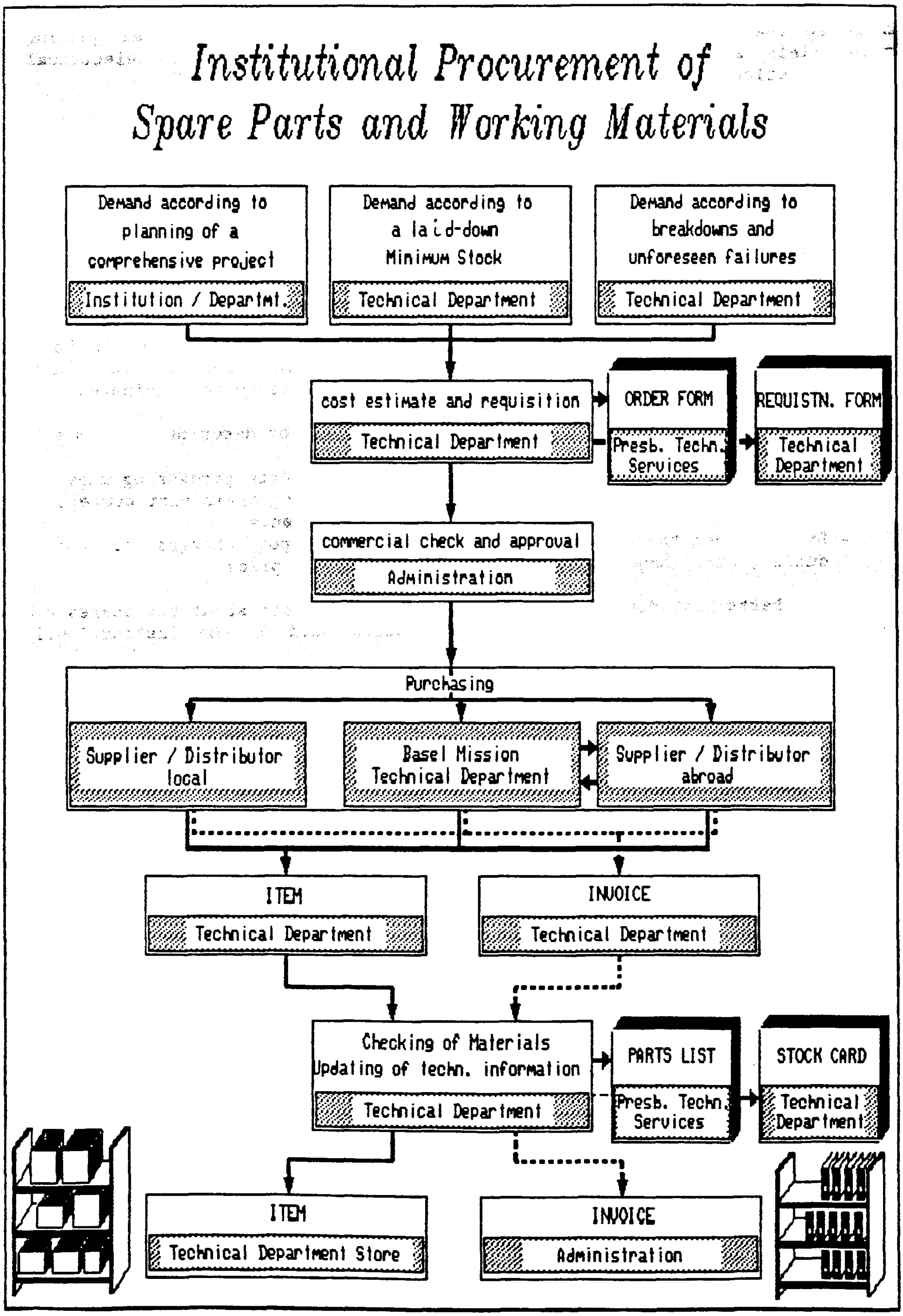
The decision on the purchase of a certain item depends on its demand. There are three kinds of demands:

- Demand according to the planning of a comprehensive project.
  An institution or a department wants to carry out a certain project which requires the purchasing of materials. These materials are needed only to complete the project and will probably not be needed again in future. Long-term storekeeping is not required.
- Demand according to a laid-down minimum stock.
  The technical department of an institution is supposed to carry out regular maintenance on equipment and buildings. According to the recommendations of manufacturers and the experiences of users and technical personnel, a compulsory quantity of various spares and working materials has to be kept in stock.
- Demand according to breakdowns and unforeseen failures.
  Due to accidents, carelessness of users and maintenance personnel and unpredictable circumstances the technical department of an institution has to carry out repairs which were not included in a planned maintenance scheme. Most probably the needed parts and materials are not kept in stock and have to be obtained with great effort depending on the importance of the repair.

After the assessment of the materials needed the technical department has to draw up a cost estimate and to issue a requisition. The forms used are the "Local Purchase Order" for local purchasing, and the "PTS Order Form" for inter-project purchasing or imports.

After a commercial check and approval by the administration, purchasing is carried out. Attempts are made to obtain as much material as possible from local suppliers and distributors. Building and plumbing materials, ordinary electrical installation materials and spare parts for vehicles are usually easily available, however the standard is low. More difficulties are encountered with the purchase of spare parts for water pumps, alternators and

Figure 3.7.2 :


Institutional Procurement of
Spare Parts and Working Materials
Demand according to planning of a comprehensive project
Institution / Departmt.
Demand according to a laid-down Minimum Stock
Technical Department
Demand according to breakdowns and unforeseen failures
Technical Department
cost estimate and requisition
Technical Department
ORDER FORM
Presb. Techn. Services
REQUISTN. FORM
Technical Department
commercial check and approval
Administration
Purchasing
Supplier / Distributor local
Basel Mission Technical Department
Supplier / Distributor abroad
ITEM
Technical Department
INVOICE
Technical Department
Checking of Materials
Updating of techn. information
Technical Department
PARTS LIST
Presb. Techn. Services
STOCK CARD
Technical Department
ITEM
Technical Department Store
INVOICE
Administration

diesel engines, let alone medical equipment. These are rarely available and if so the costs are immense. This applies also to mechanical joining materials such as nuts and bolts, as well as to advanced electrical installation materials like cable shoes or circuit breakers.

As a consequence a number of parts have to be bought overseas and imported. It has proved to be of great advantage for the technical work to involve the Technical Department of the Basel Mission in Switzerland in the purchasing of spares as an agency. Most of the orders are directed through this department with exact details about the materials needed and stating the supplying company. In Basel they are checked for quality and completeness. After compiling a certain quantity of items ordered, a consignment is dispatched and shipped to Cameroon. Thus correct delivery of the parts is ensured and a lot of correspondence can be avoided.

After receiving the items the technical departments of the institutions have to check them. The updating of technical information is a very important activity at this stage. The following information has to be considered:

- Address of supplier and distributor
- Description of the item; if need be translation of description from a foreign language
- Part Numbers; due to introduction of electronic data processing many manufacturers and suppliers are presently changing their part numbers
- Purchasing Price; conversion into the local currency
- Stock Value; the cost of overheads such as transport charges, customs duties, etc., have to be added to the purchasing price.

The PTS Parts List contains all the current information about the spares of a particular piece of equipment. The Stock Card of the institutional technical store contains the details about a particular item which is kept there. After the completion of checking and updating, the item has to be placed in its correct section in the store and the invoice forwarded to the administration.

Financial Aspects of the Procurement and Storekeeping of Spare Parts

<u>Analysis of stock values</u>
The implementation of reliable and economic storekeeping requires detailed and systematic accounting. An important activity in this respect is annual stock-taking; it gives a detailed picture of the financial value of items kept in a technical store. Adequate storage facilities, a good coding system, and the availability of correct data relating to all items kept in stock are the conditions for obtaining a realistic inventory. Figure 3.7.3 shows how the value of stocks vary considerably for the different types of equipment serviced by the Technical Department for the Medical Institutions, Manyemen.

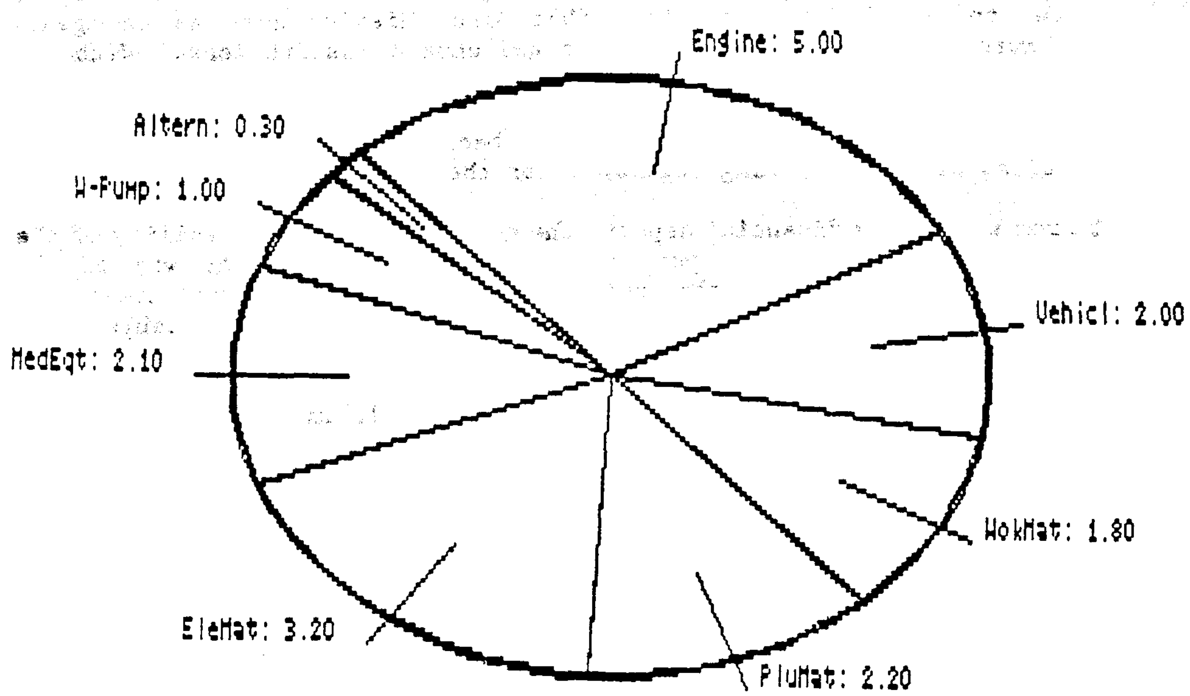
Together with an analysis of the shelf-life of various items, the stock-taking can help to economize the use of financial resources. By considering the particular parts groups and the turnover of their related items, on-going investigations can be carried out in order to find unused or inappropriate stock. Some technical departments tend to keep an excessive quantity of spares in stock in order to avoid blame because of equipment failures due to unavailable spare parts. Therefore it has to be emphasized here that it should be a vital part of the basic training of maintenance personnel to develop their abilities to identify and specify spare parts and working materials correctly in terms of quantity, quality and procurement.

Figure 3.7.3 :

Stock Values of Spare Parts and Working Materials

Technical Department, Medical Institutions Manyemen

Source: Stock-Taking, 1990
Values: in Mio. frs CFA



PARTS GROUP	DESCRIPTION	
A	* Altern.	Spare Parts for Alternators
B	EleMat.	Electrical Installation Materials
E	* Engine.	Spare Parts for Diesel Engines
M	* MedEqt.	Spare Parts for Medical Equipment
P	W-Pump.	Spare Parts for Water Pumps
Q	PluMat.	Plumbing Materials
V	Vehicl.	Spare Parts for Vehicles
C,T,X,Y	WokMat.	various Working Materials

* = including parts for neighbouring institutions

Consideration of availability and costs of spare parts

The comparison of purchasing costs is an important aspect during the procurement of spare parts. If different sources of supply are available the various costs of finally providing a particular item in a technical store have to be determined. The actual stock value is the sum of:-

- the purchase price,
- administrative costs,
- customs duty, if the item was imported directly,
- transport charges,
- and storekeeping costs.

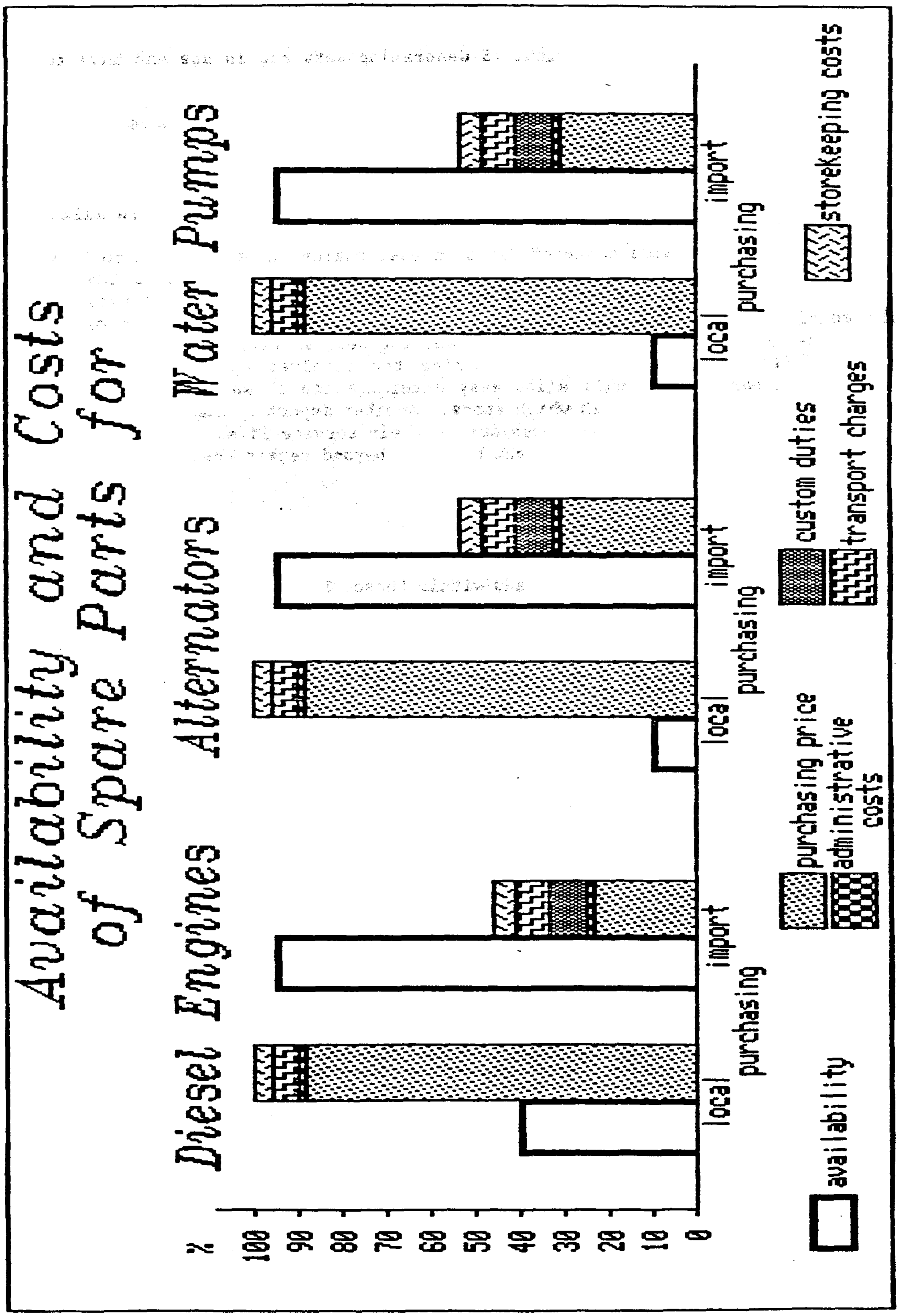
Figure 3.7.4. makes a comparison of spare parts costs of diesel engines, alternators and water pumps. Costs of parts available in the country, regarded as 100%, have been compared with parts imported directly by a church institution. The expenditures for directly imported items of the above mentioned parts groups including spares for medical equipment turned out to be roughly half of the expenditures of locally bought items. In this respect it proves to be of great advantage that Basel Mission acts as an agency between European suppliers/distributors and church institutions. With the help of a foreign exchange revolving fund Basel Mission assists in the purchasing of equipment and spare parts. In general this process does not undermine the principle of self reliance because it is ensured that the institutions are compensating regularly for the expenditures.

Apart from the purely financial aspect, the generally poor availability of the required materials sometimes puts a lot of obstacles in the way of the technical departments. Since the equipment was bought at different times from different companies in different countries, in many cases the suitable spare parts are not available in Cameroon at all. A comparison of the availability of important materials for the above mentioned parts groups indicates advantages in importing the items directly from abroad. Availability has been considered as a combination of the possibility of getting an item and the related delivery time.

The result of this investigation shows that both aspects, availability and costs, give every reason to believe that direct imports are most economical under the present circumstances.

In order to achieve more independence of the institutions in the provision of spare parts, standardization of equipment should have a very high priority in purchasing procedures. Standardization helps to reduce the variety of spare parts to be kept in stock. Even though Cameroon at present is in a difficult economic situation all possibilities should be pursued in order to find and support local suppliers. Unfortunately the pricing and supply policies of most European manufacturers limit the establishment of a reliable local distribution infrastructure.

Figure 3.7.4 :


Availability and Costs
of Spare Parts for
Diesel Engines
Alternators
Water Pumps
%
100
90
80
70
60
50
40
30
20
10
0
local
import
purchasing
availability
purchasing price
administrative costs
custom duties
transport charges
storekeeping costs

3.7.2 Spare Parts for Diesel Engines

Introduction to the plant
Within the Church institutions 15 Generating Sets are in use and have to be maintained. They range over a capacity of up to 52 kVA. Apart from a few portable petrol and diesel sets, stationary generators have been put to use. The prime movers are mostly air-cooled diesel engines, 1 - 6 cylinder, manufactured by Lister, England. For the water supply of some institutions a wide range of different types of water pumps are in use. Four of them are driven by diesel engines of the same make and types as those of the generators (Lister). In addition another two diesel engines are driving corn mills.

Considering the wide range of use of diesel engines it turned out to be very appropriate to treat them as a separate main group in the equipment inventory. A generating set consists of an engine and an alternator. A water pump consists of an engine and a pump unit. In terms of the keeping of spare parts, it is more advisable to consider engines, alternators and water pumps as different parts groups. Comparing the required spare parts within a certain parts group will allow easy determination of which parts should be kept in which quantity in which store. Another aspect is that engines can be utilized for different purposes during their service life. If, for example, an alternator of a generating-set has gone beyond repair the engine can still be used to drive a corn mill.

Comparison of the engine types
The variety of types of engines used in PCC institutions is wide even though almost all of them are from one and the same manufacturer. Out of 21 engines, 20 of them are made by Lister; and within these, 14 different types are found. However these 14 types are of the same or similar range. For example:
- Within the HR-range 3-, 4-, and 6-cylinder engines are in use. Some of the most essential components are in common such as cylinder heads, pistons, cylinder barrels, fuel injectors, filters.
- The HA-range was the precursor to the HR-range. Some important components are also in common such as filters, oil pump, fuel- and oil-pipes, starter motor, dynamo.
- The LD- and SL-ranges differ in cylinder heads, pistons, con-rods and cylinder barrels but most of the other components are interchangeable.
- Within the ST-range 1- and 3-cylinder engines are in use. Here too some of the most essential components are in common such as cylinder heads, pistons, cylinder barrels, fuel injectors, filters.
- In general a certain number of parts were put into use in different ranges. Mechanical joining materials such as bolts, nuts, copper washers, seals and fuel- and oil-filters of the same size and design are found in several engine types.
- Even though some of the engines are rather old the spare parts are still supplied by the manufacturer.

Assessment of compulsory spare parts lists
For the execution of planned maintenance it is necessary for the technical departments to keep a certain minimum stock of essential spare parts available. The determination of these parts depends on various aspects:
- Which parts need regular replacement according to the maintenance schedule of the manufacturer (consumables, eg. filters)?
- Which parts are likely to be replaced due to ageing and wear (e.g. valves, nozzles, gaskets, piston rings)? The assessment of these components depends very much on the experiences of users and maintenance personnel.

- Which parts should be kept in stock as standby parts for emergency repairs in case of breakdowns and unforeseen failures (eg. cylinder barrels, injection pumps, con-rods)? The assessment of these parts depends also very much on the experiences of the technical personnel and on the availability of the spare parts in an acceptable period of time.
- What is the quantity of parts needed for a certain maintenance period? To answer this question the maintenance schedule of the manufacturer, the running hours and the type of engine have to be considered. A 3-cylinder engine needs a larger quantity of certain items than a 1-cylinder engine of the same range.
- The minimum stock of components depends a lot on the procedure for procurement. Long delivery times require an increased stock of parts.

In order to compile all information and experiences related to the keeping of spares for a particular piece of equipment, it was decided to issue specific parts lists. They contain the following:

- parts group related to the kind of equipment,
- a short description of the equipment with its inventory number or numbers,
- the supplier of spare parts,
- an extract of the complete manufacturer's parts list according to the aspects mentioned above,
- updated part numbers,
- purchasing price and stock value,
- minimum stock level.

This clear summary allows the maintenance personnel, and in particular the storekeeper, to make use of the most important data from an over-abundance of information.

Taking into consideration the particular running hours of an engine in an institution, the required spare parts for medium-term storekeeping can be determined. The necessary consumables can be itemized as well as those materials which are likely to be replaced within this period. In addition it has proved to be appropriate to permanently keep in stock those parts which are needed to carry out the decarbonising of an engine. This covers also, at least partially, the demand required by unforeseen breakdowns. For that reason, the PTS Parts List contains the compulsory stock of parts which has to be available before a major work like decarbonising can be tackled; the list for air-cooled diesel engines is shown in Annex V, Fig.2.

The PTS Parts Lists of different types of engines of the same range (eg. Lister HR range) under the care of a particular regional workshop, can now be compared. This allows the easy determination of parts which are common to all types. From this determination the minimum stock of a certain item can be assessed. It is advisable to choose the quantity for the engine which has the biggest demand.

Another aspect is the consideration of materials which are not only related to and used for engines, eg. nuts, bolts, washers. The example of copper washers shows the economical utilization of materials. Copper washers are used in engines, vehicles and medical equipment. Some of them are supplied in joint sets for engines, in larger quantities than required. The surplus can be utilized for other purposes. For that reason all required and available copper washers have been compiled in a parts list. The comparison shows that the Lister copper washers cover almost the entire range of internal and external diameters and thicknesses, and thus, in many cases, can replace washers for many different types of equipment.

3.7.3 Spare Parts for Alternators

Comparison of the alternator types

Similar to the diesel engines the variety of alternators used in generating sets is wide. The 16 alternators in use were made by five different manufacturers. Among them 13 different types are found. Four of them are single phase, the rest are three phase models. Only two of them are brushless whilst the others are equipped with carbon brushes, which is an important aspect in terms of maintenance and storekeeping.

Since all of the alternators are coupled to Lister engines and the complete generating-sets were purchased as Lister sets the spare parts for alternators are also obtainable from Lister. A certain number of identical parts such as carbon brushes, bearings and rectifiers were put into use in different types.

Assessment of compulsory spare parts lists

In general the same aspects of how to determine the storekeeping of engine parts are to be applied to alternators. The PTS parts list is used to compile important information on the spare parts of the various types of alternators. In most cases the generating sets were supplied with spare parts lists from the manufacturer of the alternator. If they contain part numbers at all, they do not correspond with Lister part numbers, and lists for comparison are not available. Another common problem is that either the lists contain insufficient information, or they contain too much information and are very confusing for the maintenance personnel.

Therefore the PTS parts list is used as a means of standardizing the extent of information on spare parts according to the needs on the spot. As regards the maintenance of alternators, they require permanent attention to carbon brushes, if fitted, and bearings. In rare cases the rectifier diodes of the exciter circuit and the voltage control unit are destroyed by an external short circuit or by over-voltage due to lightning. While the latter effects can only be avoided by connecting external protective devices, brushes and bearings are affected by wear and ageing.

Another example is the compilation of all ball and roller bearings in use. Dimensions, designs and descriptions are listed. Sometimes different descriptions are allocated to one and the same type of bearing. Here too, the inventory numbers indicate the number of devices using the same type of bearing. From such lists it is possible to determine which regional workshop has to store which type of bearing according to the equipment under its care. It will even enable the workshops to transfer such spare parts from one station to another since the information is available.

3.7.4 Spare Parts for Water Pumps

Comparison of the pump types
A wide range of different types of water pumps are in use. There are hand pumps and hydraulic rams with no need for separate drives; submersible pumps and some circular pumps driven by electrical motors; and, two circular pumps and two piston pumps driven by diesel engines. Annex V, Fig.3 shows the different types of water pumps used in PCC institutions.

The variety and different design of water pumps in use requires an individual treatment of the pumps in terms of spare parts. The 15 pumps in use were made by nine different manufacturers. Only two piston pumps are of the same type. Spare parts can only be obtained directly through the different manufacturers.

Assessment of compulsory spare parts lists
Following the aforementioned guidelines the PTS parts lists have to be issued to gather all required information, enabling the technical departments to ensure a reliable spare parts supply. The following example concerning a circular pump illustrates some problems arising in terms of updating ordering information. The manufacturer of a High-Lift Centrifugal Pump provided a parts list containing an illustration and the related illustration numbers of the various components as well as the description of the parts. However, some of the most essential items for maintenance, for example, the gland packings, were not even mentioned nor their required quantity stated.

After placing an order in english an invoice was received, stating the description of the items in German and part numbers with 12 digits. The various items of the invoice had to be identified and were compiled in the PTS parts list. Other manufacturers sometimes provide documentation only in foreign languages not understood by users and maintenance personnel. In such cases manuals and parts lists have to be translated on the spot. The PTS parts lists ensures that for future orders the necessary information is easily available and missing information can be added as soon as it is at hand. Another important aspect of using these parts lists is training the maintenance personnel in using the correct terminology.

As regards the maintenance of water pumps they require permanent attention to stuffing boxes, valves, gaskets, piston cups and bearings. Under no circumstances must any mineral lubricant come into contact with the water to be pumped.

Findings and Recommendations

<u>The Inventory and Storekeeping System</u>
The meeting felt that the inventory and storekeeping system established for the PTS in Cameroon was a good system, but had doubts as to whether this system could work in the public sector. The supply system was successful due to the link with, and role of, the agency in Europe. The PCC workshops in Cameroon can specify the supplier they wish to use, a decision made perhaps for standardization purposes or due to proven good service in the past. Then the agency in Switzerland undertakes all the procurement, ensures the adequate flow of supplies, and manages the foreign exchange account. All these activities are very important to the success of the enterprise. Is it possible for public sector establishments to recreate these conditions if they do not also have this missing link with Europe or the USA where the manufacturers are currently situated?

The experience of the participants was that money can be saved if spares are bought abroad and not locally, even when custom duties and transport costs are taken into account. The presentation had implied that in Cameroon if you chose to import spares, the cost incurred is only 50% of the money required if the spares are purchased locally. Other participants felt that this comparison appears too favourable because it had been difficult to include the true cost of the agency's services. They felt it would be more realistic to say that the cost incurred if spares are imported is only 70-80% of the money required if spares are bought locally, and this is the situation currently existing in both Kenya and Uganda.

Many participants wish to purchase locally, but must employ a limit to the increased cost. Some felt that if local spares cost up to 30% more than imported ones, they could still be purchased locally; however when the costs start to rise above this level, the spares are purchased from abroad. In addition if the local quality is poor, the spares will be purchased abroad. The GTZ uses a higher limit; spares purchased locally can cost up to 50% more than imported alternatives before external sources will be considered, because they have found that any savings made are lost in the time and overheads incurred in sourcing parts abroad.

It was stressed that these price comparisons only show imported goods in a favourable light because of the use of agencies whether they are purchasing organizations or donor projects. However these organizations will not be around forever, and if countries have not established there own systems of supply, when the agencies leave the supply system often collapses. An example was given of Peru where Siemens and Philips left the country, and the hospitals turned to neighbours or Germany for the purchase of parts. Nowadays this arrangement means that spares are not cheap, and in hindsight it is realized that the development of a local supply would have been better.

The meeting realized that there is a balance to be achieved in purchasing spares locally and abroad. If spares are not bought locally, the local market does not develop and this affects the price of any parts available. On the other hand existing purchasing agents are often low both in quality and technical skills, and they can cost 3-4 times more mainly because not many people make use of them. If greater use was made of them, they could improve and reduce costs. Many participants would like to try to support the local and private sectors as well, but at present they cannot afford it.

In order to efficiently organize storekeeping, it is essential that workshop or stores personnel know the ordering and delivery times of different items. In addition, calculations must be made of the minimum stock levels necessary for the parts held. When using a purchasing agent, these figures might have to change due to:-

i) delays in placing orders until there are enough items to make the process worthwhile, and
ii) delays in despatch of goods until there are enough items to make the cost of transport worthwhile.

The system set up in Cameroon ensures that the PTS receives 2 consignments a year from the agent in Europe; this has proven to be perfectly satisfactory.

Everyone appreciated the importance of inventories, but concern was expressed at the real time and commitment necessary for running such systems. For the system to work, the organizational requirements should not be underestimated:

- qualified personnel are required to classify equipment, and to identify the brand, model, serial number, etc.;
- a system must be developed and time set aside to gradually inventorize items;

- there needs to be adequate hospital administration and organization;
- an inventory is only valuable if it is updated regularly, this requires additional time, personnel and a methodology;
- just updating the spares lists as repairs are undertaken is time consuming for the workshop and stores' administration.

The presentation gave an example of a computerized system which only had to cater for a few hospitals, however a system for use in the public sector would have to cover many more institutions. It would be very difficult to manually enter all the data for so many parts, and once all the information was entered the process of updating it would cause bottlenecks. There is a great danger in assuming that it is easy and simple to computerize your inventory system.

It is necessary to develop a computer inventory system which can expand to cope with the final amount of items you will be managing. A personal computer (PC) can cope with 500-1000 items; however Prof. McKie illustrated that the circumstances are very different if you want your system to cater for much larger quantities of equipment. He was involved in a process in Scotland to establish a regional inventory system; they had 32,000 items of equipment worth DM 360 Million, which were situated at 600 locations under 30 different purchasing authorities. They found that a PC system was of no use because it required 10 hours to resort all the information for 32,000 items when changes were made. So they decided to use a VAX computer with their own customized software; to run and update the system they found that they required a permanent staff of 3 including a clerk and a computer specialist. All the technicians had to be able to feed in their own information and in addition be able to take items off the lists also; this proved to be very difficult. Eventually the problems incurred forced them to change to a system of individual PCs based at each separate workshop; therefore they now have a system of 70 PCs, they do not network but use common discs. A great deal of thought is required before a computer system and an inventory system are decided upon; you need to know where you are heading, the number of items involved, how the system will be organized, the sub-systems and sub-parts necessary, etc. There is great danger in the common belief that personal computers are the answer to all our maintenance organization problems, without any thought being given to how they will be used.

Mr Clauß felt that their computerized inventory system for spares had enabled them to reduce the value of their stockholdings by 10%, from 30 Million CFA to 27 Million CFA. This was achieved by studying the details of spares in stock and in use, and rationalizing on the quantity of stocks and the time they were held. It was tedious identifying all the parts initially, but once it was done the process continued effectively. Their total stocks are worth DM 450,000 spread between 3 stores and consist of 500 items. The computer system in use by the GTZ project in Kenya incorporates, in addition, a picture of the spare part which is shown on the computer screen when information is being updated. In principle it is very useful to try to identify those spares which are held in stock but are not of any use. However, there were considerable doubts if this sort of efficiency could be achieved in the public sector, due to the financial and organizational constraints which would affect any computerized system necessary.

In the 1960s and '70s, Lister equipment were sold all over Africa and it is still possible to buy whole engines, this explains why it appears so often in the presentation. Since one company is relied upon, there would be problems if it closed down; but for the PTS, standardization is a higher priority.

TABLE 3.7.5 : ENGINES

TYPE	SPARE PARTS & CONSUMABLES	SPECIAL TOOLS
General	Consumption of parts and consumables according to manufacturers' instructions. Quantity of stocks: keep parts in stock which are needed for the period between 2 decarbonizings.	Stroboscope lamp. Taps and Dies (UVF, metric, & UNC). Torque wrench.
Petrol Engine only	Spark plugs, Condenser, Points, Carburettor nozzles, Ignition cables/coil, Starter string.	Manufacturers' manuals. Valve grinding set and paste.
For both Petrol and Diesel Engines	Engine oil, Oil filters, Air filters, Fuel filters, Starter brushes, Gasket sets, Single gaskets, Gasket sheets, Piston rings, General bearings, Fuel pumps, Water hoses, Air hoses, Fuel hoses, Hose mounting materials, Fan belts.	Special tools - individual to different kinds of engines. Valve spring compressor. Piston ring compressor and expander. Self-designed tools.
Diesel Engine only	Fuel injection pump - single cylinder, Injector nozzle, Heater plugs.	Hand pump injector tester. Bearing withdrawal tools. Pressure gauges for oil and for compression.

CRITICAL ASPECTS / SAFETY	IMPROVISATIONS AND REMARKS
Flammability of petrol.	Fuel supply pump fails: temporarily raise fuel tank above engine level - gravity feed
	Use "liquid" gasket, available in tubes, hardens in operation.
Rust protection of radiator by using substance such as antifreeze, for water cooled engines.	If thermostat is removed (in water cooled engines), the bypass must be blocked (remember there is a 3-way valve).
	To cut paper gaskets, guide steel balls around edge of part or old gasket.
Ensure proper ventilation of engine room or the engine will overheat.	Ensure proper alignment of engine and device to be driven or couplings wear out.
	Use refrigerator copper pipes for repairs on fuel system.
Additional oil cooling device if necessary (extra radiator depending on make).	Self-made fuel injection pump tester.
	Radiator: sealing of small leaks with oat-meal or mustard seed flowers.
Safety guards should be replaced after work on engines is completed.	Change air filters from paper cartridges to oil medium filters - more available.
	Use appropriate oil according to the environmental conditions: cold climate - low viscosity; hot climate - high viscosity
	Sell old engines to 1st world collectors.
	Keep a log book of all maintenance tasks.
	Preferable to use air-cooled engines, they cause less problems than water-cooled ones.
	Lifetime of paper air filter element is extended if cyclone filter is added.
	Do not forget the exhaust system - can use flexible exhaust pipe.
	If possible, hand-started machines up to Lister HR3 are preferable.
	To choose slow versus fast engines/ alternators depends on intensity of use.
	Brushes for collectors must follow hardness specifications.

Engines
The working group presented their recommendations which are summarized in Table 3.7.5. There are so many different types of engines that the group decided to simply divide them into petrol engines and diesel engines, and not to specify details such as whether they are 3 or 4 stroke engines, or direct injection engines, etc. It was not possible to state the quantities or life-time of spares since these issues depend on how much the engines are used; they recommend that the consumption of parts and consumables should be calculated according to the manufacturers' instructions for the numbers of running hours between changes.

It must be noted however, that other participants felt environmental conditions often make it necessary to alter the advice given in manuals; for example, if it is dusty air filters must be changed more frequently than the manufacturers suggest. Thus there can be a conflict of interests between:-

i) the need to convince technicians that they should refer to the manual for guidance, and
ii) the need to adapt manuals to your own requirements.

Often there is confusion amongst staff concerning whether the manual is valid or not, and when it can be ignored.

Attention was drawn to the spares list which contained both gasket sets and single gaskets. A whole gasket set is always used when a general overhaul is done; however sometimes it is necessary only to adjust the valves, for example, in which case a gasket for the cylinder head cover is required by itself. In this case someone goes into the gasket set and takes out the single gasket required, and later when you need the whole set for an overhaul this gasket is missing. Thus the recommendation is to stock whole gaskets sets for the general overhauls, and also different single gaskets which from experience are known to be required more frequently.

Most people do not keep fuel pumps as a spare because they are too expensive, however if you have models of engines which have a fuel pump for each single cylinder, then it is advisable to have a spare fuel pump available. Normally a fuel injection pump lasts a long time and you will not need to tamper with it; as it is factory set you should not try to adjust it if possible, and you will find that it will usually outlast the life of the engine.

Injector nozzles can be repaired with the right equipment, if not the nozzles should just be kept in stock and changed when necessary. In the nozzles, the elements can be changed using the necessary measurement pump which is required to adjust the injection pressure to its correct value.

To make readjustments on petrol engines, some people may even be able to just use their ears and eyes but a stroboscope lamp is very useful for this purpose; it is cheap and would be an asset for any workshop. A piston ring compressor and a piston ring expander are useful; often people try to push the rings down using a screwdriver but this can lead to broken rings or scratches on the piston surface which reduces the life of the piston. If you want to change valves, the valve springs can be compressed using a special tool, however you could easily design a tool of your own. It is good to have a torque wrench in a workshop; when changing the cylinder head, for example, you must turn the bolts according to the manufacturer's instructions.

Often people say that you do not need antifreeze in tropical areas because the climate is too warm, however this is not true due to the other advantages it can offer:

i) it provides rust protection for the radiator, and
ii) it raises the boiling temperature of the water in the radiator.

In addition, in hot countries people tend to remove the thermostat because they feel that it is a restriction in the water cooling circulation system. However people often forget that because of the thermostat there is a three-way valve, and having removed the thermostat they do not block what has effectively become a bypass for the radiator. Thus they get the exact opposite to what they hoped for, and the water takes the easiest route bypassing the radiator and the engine gets hotter not cooler.

A common problem is dust collecting in air filters of engines. However it was stressed that cyclone filters cannot be used as a replacement, though a cyclone filter can be used in addition to the normal air filter, and this will extend the life of the paper air filter.

The grade of oil used in engines is very important, however there are very different qualities of oil on the market and it was recommended that both these factors must be considered when purchasing oil. By asking around in the local industrial sector it may be possible to find the oil that is locally thought to be of a better quality.

If you have plant which uses electric starting systems, you will have problems when the electrical systems fail. Therefore it would be better, for small plant, to have hand starting systems which are also cheaper.

Some manufacturers design their engines to be bolted directly onto concrete floors and not to be installed on vibration mountings; problems will arise if additional mountings are placed under the engines if they have not been designed with this in mind, therefore it is necessary to check such details with the manufacturers.

Frequently safety guards and grills are removed from engines in order to make access for maintenance easier, however these safety devices are often not replaced making the machine hazardous for operators and maintainers alike. It was recommended that safety rules be observed as far as possible since maintenance is even more difficult if the maintainer is injured !

Generators and Pumps

The working group presented their recommendations which are summarized in Table 3.7.6. They recommended the use of generators with brushes rather than brushless machines. The working group felt that for machines up to 60 kVA those with brushes have less problems, whereas brushless machines require the use of automatic voltage regulators which create problems of their own. Voltage regulators are expensive, also they are sensitive and therefore break down frequently, for example when x-rays are taken, surges of power are required from generators; these surges can cause the diodes to blow in sensitive brushless machines whereas generators with brushes will perform better in these circumstances. In addition machines with brushes are easier to maintain; brushless machines contain complicated electronic circuits which are in sealed units - when replaced, complete units which are cumbersome and expensive must be bought.

TABLE 3.7.6 : WATER PUMPS AND GENERATORS

EQUIPMENT	SPARES		SPECIAL TOOLS
	COMMON TO ALL	SPECIFIC	
WATER PUMPS			
- Piston pump	Gaskets, Bearings,	Valves, Foot valves, Piston rings, Oil, Oil seals.	Pullers.
- Centrifugal pump	Sieves/ Filters.		
- Submersible pump		Water seals, Insulation material.	
GENERATORS			
- with Brushes	Fuses, Bearings, Diodes, Meters for:- V, A, Hz,	Brushes.	Frequency meter, Low resistance meter,
- Brushless	Overload protector.	Voltage regulator.	Insulation tester.

CRITICAL ASPECTS	IMPROVISATIONS /MODIFICATIONS	GENERAL REMARKS
Installation - alignment - mountings.	Try to modify:- Gaskets, Sieves,	* Require documents and manuals for all pumps.
Motor overload protection.	Water seals, Valves.	* Planned Preventive Maintenance is essential.
Low water level protection.		
Installation - alignment - mountings.	Preferable to have a wall-mounted meter cubicle away from machine vibrations.	* Require documents and manuals for all generators. * PPM is essential. * Require lightning protection. * Brushes for collectors must follow hardness specifications. * Recommended make: Lister / BKB.
Overload protection.	Cut brushes from bigger sized old brushes.	* Need appropriate location: - clean and away from dust, - not the storeroom. * Preference for generators with brushes because brushless types require the use of AVRs. * AVRs (voltage regulators) are:
Earthing.		- expensive, - not repairable, - more sensitive ie. breakdown often.

A great deal of data is required in order to be able to decide whether it is best to use "fast" or "slow" generators or engines. A "slow" machine is one that operates at 750-1000 rpm; machines found at hospitals are usually "fast" machines operating at 1500 rpm. "Slow" machines are 4-6 times as expensive as fast ones, however there are claims that "slow" machines can outlast "fast" ones by so much that this will counteract the initial cost difference. There were differing opinions about whether this claim was true with regard to the context in many developing countries. Various considerations should be taken into account when making a choice, and it will depend on whether considering a generating set or an engine only:-

- if a machine is in constant use, a "slow" one is preferable; if used infrequently (a few times a month) 1500 rpm can be employed;
- the noise produced increases greatly with "fast" machines;
- fuel consumption decreases with "slow" machines;
- "slow" machines are only found for high power models never for low powers; the lowest power using 750 rpm is 100 kVA;
- "slow" machines are 4-6 times as expensive as "fast" ones;
- "slow" machines may be exposed to less wear.

Some countries experience great problems with lightning striking the power lines from generators, thereby causing considerable damage to the control boards. For lightning protection, it was recommended to mount arrestors along the power lines around the site and to establish a good earthing system.

It was stressed that the improvisation of cutting brushes from bigger old ones, should only be used in emergencies due to the problem of different hardness specifications; it is alright for slipring brushes but is not recommended for collector brushes.

3.8 Layout and Equipping of Maintenance Workshops for Hospitals (50-100 beds) (D. Horneber, Philippines)

Hospital Maintenance in the Philippines
Among Philippine Government Hospitals of all levels and sizes, there are none which house adequate workshop facilities to maintain hospital and medical equipment. Some bigger hospitals have limited space for a workshop, but there is a lack of tools, equipment, spare parts and skilled manpower.

The Department of Health (DOH, formerly Ministry of Health) is fully responsible for the maintenance of hospital buildings and equipment, unlike some other countries where there are other Ministries involved (e.g. Ministry of Works, for maintenance of buildings and plants). In 1986, a Hospital Maintenance Service was created in the organization of the DOH in Manila, directly under one of the Undersecretaries of Health. There are 40 staff members (engineers, technicians, administrative staff) in this Central Workshop in Manila, responsible for the nationwide maintenance of all hospital and medical equipment. Although there are several qualified engineers and technicians, the centralized establishment cannot cover the whole of the Philippines. The Philippines is made up of 7,107 islands, of which 200 are the main ones, through these islands are spread a total of 537 government hospitals. (In addition there are 1,230 private hospitals).

One objective of the on-going Philippine-German Hospital Equipment Maintenance Project is the decentralization of this maintenance system by establishing three Regional Workshops to care for the maintenance needs of hospitals in the respective regions. These regional workshops are located at a main hospital (400 beds) of the region. The staff requirement is approximately 20 per workshop. In the current pilot phase of the project, there is no plan to build or upgrade additional workshops in other hospitals.

General situation in most developing countries
Since there is no high level policy, managerial support and interest in maintenance, there is hardly any organized maintenance service in the Government Health System, i.e. a lack of staff, facilities, tools, equipment, spare parts, and funds. One first step usually undertaken is the establishment of a Pilot Maintenance Workshop in a main hospital, or the establishment of a Centralized Workshop in a large city (e.g. in the Philippines at the compound of the Department of Health, in the national capital Manila).

Establishing Maintenance Workshops for Hospitals (category 50 - 100 beds)
Before establishing maintenance workshops on the provincial/district level (in a hospital with 50 - 100 beds), various factors need to be considered:-

* is there an existing workshop in the hospital, eg. for building and plant maintenance ?
  if yes:- is it under the Ministry of Health or another Ministry ?
  - is it still functioning, and what is the scope of its duties ?
  - can it be integrated, upgraded, or is it better left alone ?

  if no :- the scope of work of an equipment maintenance workshop will unavoidably include some maintenance of buildings and basic facilities;
* are there technical staff employed by the hospital ? How many are there, what are their qualifications, and can or should they be integrated ?
* will there be new, qualified positions created to run the workshop ?

* are there funds available for the operation of the workshop eg. capital investments, salaries, operational costs, spare parts and maintenance funds?
* what kind of equipment is to be serviced, and is there a priority list ?
* are there other hospitals of a lower level to be serviced ?
* what kind of repair can be performed more economically by contracting it out ? Is such service readily available nearby ?
* is there an existing workshop in a nearby hospital of a higher level ? Can it perform specialized repair work ?

Practical aspects concerning the layout of the facilities
* is there existing space available for a workshop in or near the hospital ?
* depending on the type and volume of repairs, the numbers of staff and the availability of space, there is a need for:-
  - separate working areas for clean and dusty work procedures e.g. clean - electronics which may require air-conditioning, and dusty - mechanical work which may require space in the open air;
  - offices including space for record-keeping, library, etc.;
  - storage facilities for tools, equipment and material (usually too small);
  - auxiliary facilities eg. toilet, shower, locker-room, social room;
* supply connections for electricity, water, drainage, communication. Electricity supply - preferably 3-phase power, with ground wire for safety and for test purposes.
  NOTE: In the Philippines there is hardly any grounding system, not even for the application of medical equipment !
* location aspects:-
  - vehicular access from outside;
  - access to hospital - short routes, paved, covered;
  - away from noise and vibration, e.g. not in the standby generator room;
  - natural and forced ventilation from heat and fumes;
  - natural and artificial light;
  - away from sensitive hospital areas which are disrupted by effects of the workshop such as noise, vibration, fumes;
  - electrical interference, eg. from electrical sub-station or welding, can disturb electronic repair work and also the use of some electronic medical equipment in the hospital;
  - possible expansion of workshop later on;
  - safety provisions such as safety locks, barred windows, security guard;
* size of workshop:-
  - Recommendations are usually based on the number of beds and scope of work, however no plans are available for the hospital category of 50-100 beds.
  - The WHO proposals for a "District Workshop" located at a hospital with 200 beds is 140 m^2 (see Figure 3.8.1). For a 100-bed hospital: 90 m^2. For a 50-bed hospital: 65 m^2.
  - British-DHSS recommendation for an Electronic and Medical Equipment Workshop for a hospital with 300 beds: 37 m^2 (separate from existing hospital engineering workshops).
  - Realistically, in a hospital with 50-100 beds, there will not be much more space available than 1-2 rooms with a total of 10-40 m^2, which sets definite limits to the layout. A bigger workshop might be desirable but it requires higher investments and may not be appropriate at this level.

Tools, equipment, supplies
The provision and variety of tools, equipment and supplies depends upon:-
* the range of repair work to be performed;
* the number and qualification of staff;
* availability of space;
* availability of funds.

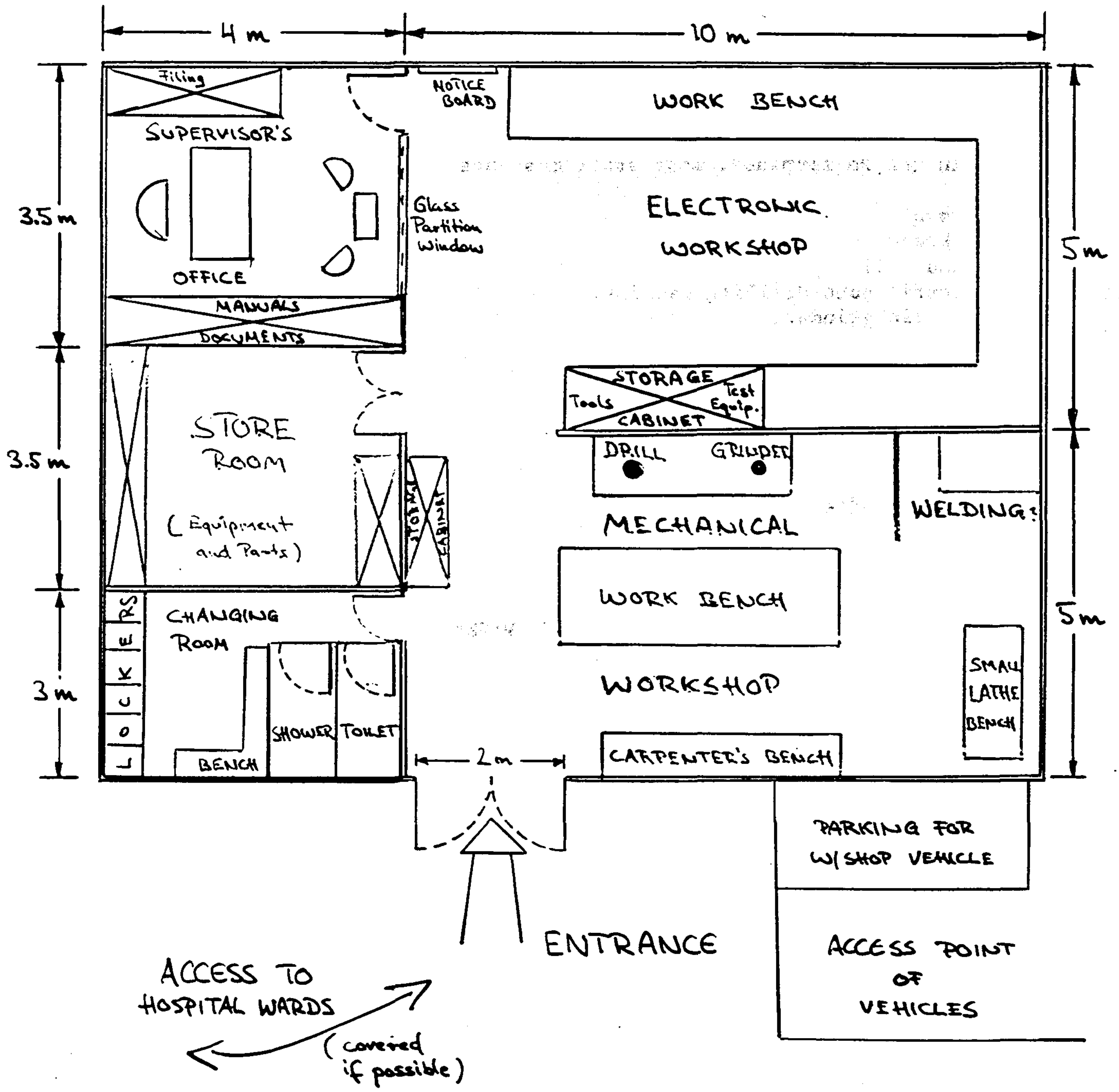


Figure 3.8.1 : Typical Layout for District Workshop
140 m^2 - located at a 200-bed hospital.
from: WHO-document SHS/86.5, by A. Mallouppas, Cyprus.

A possible provision should consider the following categories:

* Tools
  - Basic hand tools - preferably complete tool sets for each technician. A set of screwdrivers, pliers, cutters, adjustable spanners, files, etc.
  - Readily available tool kits like biomedical tool kit, electronics tool kit, mechanical maintenance tool kit, etc.
  - Various categories of tools for: electronics, general metal work, masonry, carpentry, plumbing, refrigeration, etc.

NOTE: In the Philippines, most staff must use their privately owned tools.

* Equipment
  - Workbench and vice;
  - Stand drilling machine;
  - Electric hand drilling machine;
  - Electric grinder;
  - Gas/arc welding kit;
  - Air compressor;
  - Test equipment, eg. multimeter, insulation tester;
  - Soldering iron;
  - Fire extinguisher, first aid kit, trolley, ladder, etc.;
  - Office equipment and furniture;
  - Storage equipment and shelving.

* Supplies, materials
  - Basic stocks of screws, bolts, nuts, washers, nails, rivets, o-rings, gaskets, etc.
  - Electrical supplies like cable, wire, plugs, connectors, fuses, switches, insulation tape, electronic components.
  - Plumbing, welding, soldering, carpentry, metal work supplies.
  - Material for fabrication of spare parts, eg. gaskets.
  - Chemicals, eg. oil, grease, paint, thinner, glue, etc.
  - Oft needed spare parts for existing hospital and medical equipment, eg. gaskets, ball bearings, thermostats, etc.

NOTE: This "preventive" stock keeping of spare parts is not possible under Philippine Government regulations

These lists are far from complete. The range and type of items depend very much on the envisaged workshop organization and implementation in the respective country. Detailed lists and specifications of tools/equipment categories are available from WHO (through EMCO or Regional Training Centre, Cyprus), or OED (Austrian Service for Development Cooperation) which established several Hospital Maintenance Workshops in Kenyan hospitals.

Further references:

- WHO - document SHS/86.5 by Dr. Andreas Mallouppas. "Maintenance Strategies and Facilities"
- WHO - WPR/PHC/OCH(1)/INF/1 by Dr. Andreas Mallouppas. "Guidelines on Development and Strengthening of National Health Care Technical Services"
- British-DHSS Engineering Data (Reference EU7.1). "Electronic & Medical Equipment Maintenance Facilities"

Findings and Recommendations
The presentation of the WHO proposed layout for a maintenance workshop provoked much discussion. Many suggestions were made on what improvements would be necessary to make the workshop a suitable working environment:-
* a reception area is necessary for accepting, recording and storing all items brought for repair;
* the welding area is too near to the carpentry section;
* the welding area is barely 2 m^2 and therefore is too small when larger items are worked with;
* there is inadequate protection between the welding area and anyone working at adjacent benches;
* the mechanical area is too small compared to the electronic area considering the materials to be worked on ie. long lengths of pipe, metal sheets, etc.;
* there is inadequate physical separation to prevent dust created in the mechanical area from causing problems in the electronic area;
* no open air working area is provided, especially to offer well ventilated welding space;
* the carpentry area is too small to allow for manoeuvring of large pieces of wood;
* a blackboard for training is necessary;
* a separate additional toilet for female members of staff should be provided; some countries have female technicians already and others hopefully will follow suit.

If there is the possibility to have showers then they should be provided, since any recommendations should be as complete as possible. In many countries the maintenance personnel have no other facilities to use if a shower is required. If maintenance personnel are working on equipment in the mortuary, for example, they would wish to shower before going on to repair equipment in other parts of the hospital.

The meeting noted that there have been many other recommendations, in the past, for workshop designs from GTZ and others. The workshop layout by WHO was only one of many proposals, and countries should adapt designs for their own needs.

The meeting stressed the importance of the adequate provision of tools for maintenance staff. In many countries sometimes staff must bring their own personal tools to work, in order to be able to function adequately. If tools were originally available often it is not possible to get replacements. In addition, there is generally a serious shortage of test equipment. However countries which do provide tools often find that they must continually replace them for many reasons: loss, theft, misuse, taken for private use, no-one responsible for them, etc. Countries should instigate some new approaches to this problem. For example, in Senegal a survey was undertaken to discover which tools were actually needed and used, and what were the main problems facing the use and provision of tools. Armed with this information, the government was able to derive a policy for a new approach to tools. Currently they are implementing plans which will address the issues raised.

There was a discussion regarding suitable staffing levels for different workshops. For each country any figures derived are dependent on: whether the work undertaken is for medical equipment, plant, and/or hospital services; the organizational structure of workshops nationally; the placement of staff around the country; the skill level of staff; etc. Since these factors are tied to country characteristics and circumstances, it is unrealistic to specify a universal "ideal" number of staff.

It is also misleading to compare productivity levels between countries since these are dependent on factors often outside the control of the staff: availability of spares, time for delivery of goods, availability of transport, delays due to administrative procedures, financial constraints, differing skill levels. In addition there will be factors that vary from country to country such as: working practices, hours in a working day, cultural considerations, etc. There is a danger of discrimination when comparisons are made between productivity levels of workshops. Comparisons may produce figures which only serve to discourage and demoralize staff if taken out of context. However some comparisons can produce unexpected results; for example, Siemens of Nairobi was surprised to find that the output of their workshop was only 55%, so when the public sector workshop in Mombasa was found to have an output of 48% they felt encouraged!

In some countries money cannot be spent on spares which will be held in stock. The reason for this is that the spares are viewed as items which are tying up valuable money and foreign exchange allocations, that could otherwise be actively used. In certain situations it is only possible to obtain a spare part either by proving that the equipment is already broken, or by presenting the broken part for replacement. Although the meeting recognized the financial constraints facing many countries, they stressed that it is impossible to undertake maintenance in this way.

In many countries, the maintenance of health facilities is the joint responsibility of the ministries of Health and Works. The division of labour between medical equipment, plant, buildings and services depends on the country concerned. This division of labour requires collaboration, good will, and effective working practices, very often all these factors are missing and a great many problems subsequently arise. When it was pointed out that the Ministry of Works is not involved in the maintenance of health facilities in the Philippines, people wondered how they could be so lucky!

There was considerable interest in any methods in use for public sector maintenance workshops to charge out their services to the community at large. Many countries and organizations are considering different approaches, and the participants outlined the methods being tried in several countries:

In Kenya there is a spare parts supply project which was set up primarily for the government sector, but it was felt that the private sector should be able to participate. It was decided that there should be charges to cover the overhead costs of this supply system. The guidelines for suitable charging levels are 15% to the public sector and 25% to the private sector. The principle of this project has not been extended as yet to charges for maintenance work. It will be necessary to calculate the moneys which should be fed back to the workshops. If a system of job cards are used which are correctly completed noting the hours worked, distance travelled, and the spares used, maintenance jobs could be effectively costed.

Mombasa polytechnic has a status similar to a parastatal organization, and therefore is more flexible to the idea of income generation than other government bodies. The polytechnic is developing proposals whereby staff can undertake private work and the main share of the financial benefits go to the person who undertook the work, and the rest go back to the department or workshop itself. The procedures are not fully finalized as yet.

Educational institutions in Kenya have highly qualified consultants who undertake work privately. In the past, it was realized that it would not be possible, or necessarily desirable, to stop this practice, so a new system was devised. Now, consultancy services can be undertaken by staff at these institutions either individually or collectively as a department as long as a proportion of the financial benefits are returned to the institution. Surely, this idea could be repeated for technicians working in government hospital workshops. They could undertake work commercially for various parts of industry and for private hospitals, such links would be a healthy development for many countries.

In one province of Peru, the maintenance workshop staff are divided into 2 crews - those allocated to internal services and those for external work. The benefit of this system is that the management ensures that not all the technicians are undertaking private work all of the time. The staff alternate between the 2 crews so that they all have a chance at private work. As yet, a system has not been devised for dividing financial gains and ploughing the benefits back into the workshop.

In Egypt, they found they needed incentives to try and retain technical personnel within the maintenance service; the possibility of undertaking and charging for private work was just such an incentive, and they established a system for charging. In the maintenance sector the largest expense is labour costs, therefore if the public sector workshops can charge out labour costs at a slightly lower rate they will be able to remain competitive in comparison with the private sector.

Cost-sharing is a principle used in some countries, whereby the general population can participate in financing the health services provided. The percentage contribution will depend on the country and the socio-economic group; for some, the percentage will be zero. Hopefully if money is generated and fed back into the health system, some of it logically should reach the maintenance workshops in the long run. A restriction to the concept of income generation is the administrative constraints. There need to be treasury rules and regulations developed so that government organizations can identify and recognize income so generated, and find means of entering it into their financial records; otherwise there is the danger of accusations of misuse of government funds. A comparative system can be seen where government hospitals charge private patients and manage to distribute the money to the doctors concerned and the health institution as a whole. With this model it should be possible to devise a system for the maintenance workshops, without being accused of misuse of government funds.

In workshops where a system has not been devised for private work, often this type of work will continue anyway, especially in areas where salaries are low. In these instances there may be problems with the use of valuable public sector spares for private jobs. Fears were expressed of the danger of undermining the small private maintenance sector which already exists. However in general it was felt that the public and private sectors are aiming at different levels of maintenance. It is important that there is cooperation between the health authorities and the private sector companies. The private sector is required to undertake the more sophisticated maintenance tasks that the public sector cannot attempt, so there need be no conflict of interests.

Graduates from training centres may set up businesses of their own when they have gained some business experience. Some countries see this as a problem, however others view these skills as a welcome addition to their country's technical resources whether they are in the public sector or the private.

3.9 Supplies of Spare Parts and Working Materials for Maintenance of Health Services (C. Castro and L. Mosquera, El Salvador)

The supply of spare parts and working materials for maintaining public health services in El Salvador has been concentrated nearly entirely in the storage facility of the Central Maintenance Department (Departamento de Mantenimiento Central). This is due to the limited material and human resources available locally and regionally for meeting such needs.

Nevertheless, the last five years have seen the beginning of a gradual decentralization process in the maintenance services, mainly due to the urging of external development cooperation institutions who have also contributed substantial funds for the purchase of supplies.

Procedures and Methods Employed for Storage of Supplies

1. <u>Central level</u>
The central storage facility plays a vital role in ensuring that maintenance tasks are successfully performed. It is responsible for monitoring, controlling and distributing the spare parts, accessories and consumables for routine maintenance work and for the repair requests from health bodies. This work is carried out by the technicians of the Central Maintenance Department and, in many cases, by local maintenance bodies as well.

2. <u>Local and regional levels</u>
At these levels, the storage facilities almost totally lack stocks of spare parts and materials. When the need arises, stocks are requested from the central storage facility, and if they are unavailable they are purchased on a priority basis. Consequently the purchases are not made in a planned manner, instead they merely respond to immediate and limited needs.

3. <u>Technical Equipment Inventory</u>
Many hours have been spent developing an inventory code format for all pieces of equipment. The inventory code has 13 positions as shown in the example in Figure 3.9.1.

Receipt and Dispatch of Supplies

When the storage facility of the Central Maintenance Department receives supplies, the invoice submitted by the supplier is compared with the description given in the contract and the purchase order. This information is entered into a register that is kept at the storage facility and is subject to review by the government auditing department every six months. An example of a receipt form is shown in Annex V, Fig.4.

Once received, the merchandise is classified and shelved according to the area in which it will be used and its funding program. The movement of incoming and outgoing materials are recorded on a daily basis on file cards to ensure up-to-date inventory information; a file card is shown in Figure 3.9.2.

Dispatch is usually preceded by written requests prompted either by work orders for maintenance or repair of equipment, or by direct requests from health bodies. After a request is submitted to the responsible clerk at the storage facility, a check is made to determine whether the requested material or part is in stock, and if so a certificate of issue is drawn up. An example of this certificate is shown in Annex V, Fig. 5.

Figure 3.9.1 : Inventory Code Format

```
                              - equipment family group
                              |
                              |       _ code corresponding to
                              |      |  type of equipment
                              |      |
                              |      |      number corresponding
                              |      |      to individual item
                              |      |      of equipment
                             / \    / \    / \
.....................................................
: 1 : 1 : 0 : 2 : 6 : 4 : 9 : 1 : 5 : 0 : 4 : 0 : 6 :
:...:...:...:...:...:...:...:...:...:...:...:...:...:
 \ / \ /  \ /    \ /   \ /   \ /    \ /    \ /
  |   |    |      |     |     |      |      code identifying a
  |   |    |      |     |     |      |      specific refrigerator
  |   |    |      |     |     |      |
  |   |    |      |     |     |      |_ code corresponding
  |   |    |      |     |     |         to refrigerators
  |   |    |      |     |     |
  |   |    |      |     |     |_ code corresponding to
  |   |    |      |     |        thermodynamic equipment
  |   |    |      |     |
  |   |    |      |     |_ purchase number
  |   |    |      |
  |   |    |      |_ code for location in health care
  |   |    |         unit e.g kitchen
  |   |    |
  |   |    |_ code corresponding to a specific
  |   |       health care unit e.g 2nd hospital in region
  |   |
  |   |_ level of health care facility
  |      e.g  1 - large hospital
  |           2 - small hospital
  |           3 - health centre
  |
  |_ code identifying region
```

1. Administrative reorganization
In line with the administrative reorganization suggested by the GTZ Technical Cooperation project, in the near future it is planned to create regional and local mechanisms for the purchase and storage of spare parts and consumables. This objective is consistent with the institutional policy being considered by the various health programmes for decentralization and local planning of services. Figure 3.9.3 shows the different administrative areas within a national maintenance system, and for which reorganization is taking place under the terms of the policy objectives.

2. Purchasing programme
With the assistance of this same project, the Technical Equipment Inventory is being used to derive a basic set of spare parts needed in order to maintain essential medical and non-medical equipment and systems. Together with the establishment of a minimum stock level, this basic set of parts will allow the central, regional and local storage facilities to apply technical criteria to their purchasing activities.

3. Preventive versus corrective maintenance
Initially the reorganization of maintenance will involve the establishment of a pyramidal distribution of services, training, development of infrastructure, provision of tools for workshops, etc.; once this has gained momentum, then the current predominance of corrective over preventive maintenance will be completed reversed. For this reason, it will become imperative to adjust the criteria applied to purchasing and storage of supplies to take account of this new reality.

4. Automation of storage
In order to impart greater dynamics to the activities related to the storage facility, a computerized system is being developed together with the cooperation of the Government of the Netherlands. This endeavour includes the encoding of supplies linked to the Technical Equipment Inventory, and the design of appropriate utility programs. Once implemented, this system will permit a minimum stock approach to be applied with feedback of data to the system. It will also generate reports that will be very helpful for taking decisions, and it will allow improved monitoring of available stocks. Figure 3.9.4 shows the basic proposal for the storage area; the storage space available will be divided according to the inventory codes, in this way spares common to individual pieces of equipment will be kept next to one another.

In order for this plan to be successful, the staff in charge of the storage facility will have to be trained and the entire organization of the maintenance system will have to be redesigned in keeping with the new situation. Accordingly, efforts are already being made to provide training to the technical and administrative personnel involved in decision-making and system operation.

Findings and Recommendations
Although the presentation included 3 forms, it was clarified that these are only the principle ones. 4-5 forms are required for the stores system, and 10-12 forms are required for the equipment management system as a whole. It was noted that many systems for equipment and stores management employ an over abundance of different forms. The participants felt that the goal should be to keep any system as simple as possible.

Above - Figure 3.9.2 : File cards for recording the movement of stocks
Below - Figure 3.9.3 : Administrative areas of national maintenance system

Descripción del material__________

Unidad de medida__________

Ministerio de Salud Pública y Asistencia Social de El Salvador

DIRECCION GENERAL DE SALUD

Estante ________ Entrepaño________ Casilla________

Precio por unidad ¢________

Almacén ________

Tarjeta No. ________

Artículo No. ________

Existencia mínima________

Fecha	OBSERVACIONES	ENTRADAS			SALIDAS			SALDO		
		Cantidad	Valor		Cantidad	Valor		Cantidad	Valor	

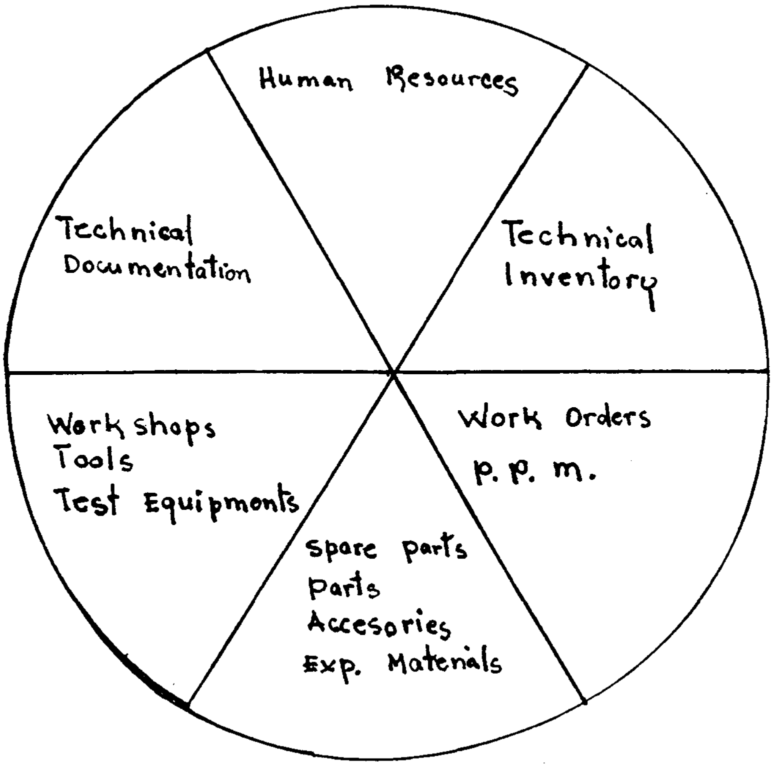
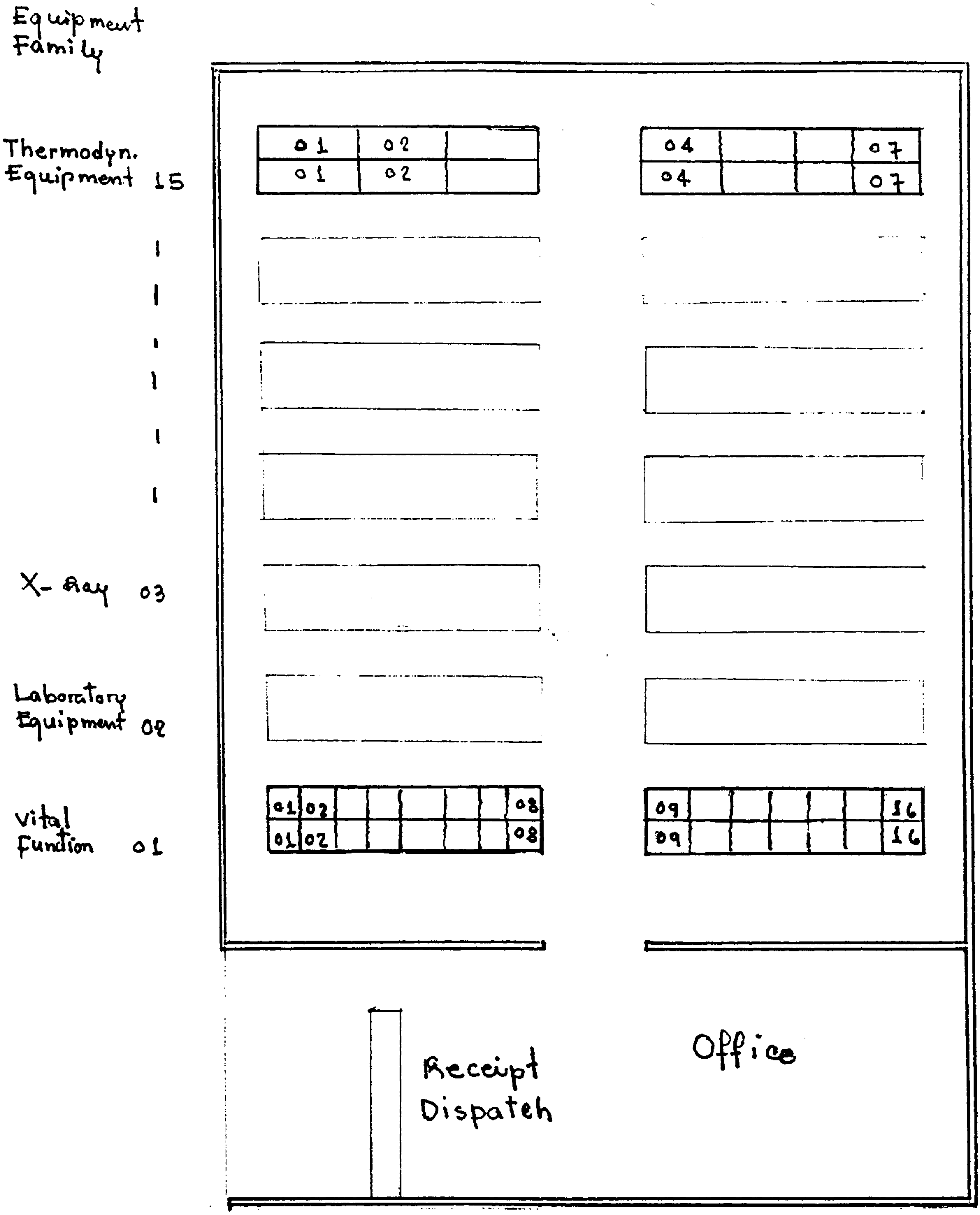


Figure 3.9.4 : Proposal for storage facility



The system presented handles stocks of 1000-1500 different parts; the value of stock bought this year is approx. 600.000 US$. The parts are required for the following health facilities: 15 hospitals with 200-500 beds; 50 hospitals with less than 100 beds; and 300 small health care units.

It was recognized that the system presented has only been set up recently and is not fully functioning. As the work progresses, it will be possible to develop the system and to find out essential information such as:-
i) the kind and number of spares most used,
ii) how to identify and order such spares, and
iii) the minimum stock levels required.
At present this information is not available, so manufacturers' guidelines are currently used for ordering purposes.

The existing proposal for the storage area, with number codes for the shelves, implies that the same area is required for storing spares for each type of equipment. From experience, the participants felt that this would not be true due to the different sizes of parts. In order to prevent running out of space or wasting space, the coding system might have to be adapted in the future as experience with using the store is gained.

The "speaking" inventory code described in the presentation, provoked much discussion. It was recognized that there must be a system for numbering equipment, and that people cannot just allocate any number they wish. In order to do this it may be necessary to set up a team of people whose job it is to provide the numbers, if this is the case all equipment must pass through their hands. The advantage of this method, if it is successful, is that it ensures that equipment is registered into the system at the same time. With a large code, such as the 13-digit example, a great deal of knowledge is required to be able to allocate the numbers correctly - technical, medical, and administrative knowledge; what sort of staff can be identified to do this work, and will this be their full-time occupation? In El Salvador, they initially used suitably knowledgeable personnel to develop a small code booklet and from then on technicians simply look up the correct numbers. Parts of a "speaking" code, such as digits to represent location, imply that equipment must go back to a workshop for its code to be changed if it is to be moved around a hospital or region, etc. A 13-digit code is fairly sophisticated, and some countries might want to try a simplified version.

Good reference materials for store keeping and stock control techniques are:
- How to Assess Health Services Logistics with Particular Reference to Peripheral Health Facilities, A. Battersby, WHO, SHS/85.9
- How to Keep Stocks of Spare Parts, Logistics and Cold Chain for Primary Health Care, No 20, EPI/WHO.

4. FINAL CONCLUSIONS AND RECOMMENDATIONS

Conclusions
Although the Nairobi conference recommended in 1989 that workshops should be held on specific issues such as spare parts, this has proved to be more difficult than anticipated. Specific solutions apply to specific conditions and are connected to various other aspects of technical managment. In other words, we should not ask for recipes but instead for ideas and experiences which will provide the impulse for the improvement of concrete conditions. This study of spare parts is exactly the type of activity envisaged by the WHO in its plan to generate practical data of global applicability.

It was recognized that in the context of the district health system as a whole, the problem of spare parts for health care equipment is only one factor and cannot be solved in isolation from other co-existing factors. However, the importance of the health care equipment sector and the need for maintenance must be highlighted. Therefore such strategies should be sold more effectively to politicians and to decision makers not only in ministries of Health, but also in ministries of Planning, Finance, and Trade and Industry, as well as to donor organizations.

It is a challenge to us in the technical field to see what can be done reasonably within the serious financial constraints which we face; however it is our task to make politicians and decision makers realize that this is not a funding level which enables us to run efficient health services.

A lack of spare parts constitutes a serious difficulty for maintenance services, although it is often not the most important one. Reliable information on the nature and quantity of parts required is unavailable in most developing countries; spare part lists of the manufacturers are rare. Therefore to assess and set priorities for the real spare part requirements is a prerequisite for any improvement.

No relevant studies of typical breakdown behaviour have been undertaken or made public in any developing country. Such information and more detailed base-line investigations must take place in the developing countries themselves. Operational research is needed for the sake of an improved sustainability of practicable spare part logistics. Amongst other things, this research will form a part of rational equipment management systems.

Also, more studies are needed on the cost effectiveness and cost benefits of specific interventions and strategies in health care equipment maintenance services. Due to the extreme financial restrictions it is necessary to have some ideas of breakdown rates of designated spare parts so that we can determine which parts should be bought, budgeted or applied for. Calculations, models and views from industrialized countries can only be adopted to a limited extent and only the basic principles can be adapted for local use.

It is evident that the purchase of spare parts should take place together with the initial equipment order, to ensure their availablity when required and before the equipment becomes outdated. Although this method ties up significant funds, this principle should apply not only to the supply management of health services but also to any donor. In developing countries, acquisition of spare parts after the initial procurement period can in the end prove to be more expensive.

Recommendations
In addition to the specific spare parts recommendations in Sections 3.1 to 3.9, the meeting emphasized on the following recommendations:-

- Recipients must openly clarify their policies on maintenance and spare part requirements in connection with equipment donations or equipment supply as part of grants. Donors are asked to respect these policies and to actively adopt or develop such policies for themselves.

- Donor organizations should address the problem of sustaining the equipment they provide by supplying spares with the equipment in the first instance, and by establishing budgets for the on-going purchase of spares.

- Donors and recipients are called upon to accompany rehabilitation of health facilities and equipment with preventive maintenance programmes during which local personnel can be sufficiently trained.

- Maintenance services should be recognized as an integral part of both the national and the district health services, and in particular should be included in the supervision, monitoring and evaluation system.

- An adequate level of funding for spare parts and working materials is essential and cannot be emphasized enough. It is estimated that 8-20% of investment costs per annum are required for daily running needs.

- Donors are requested to cooperate with each other in the medical equipment maintenance sector. With the existing limited resources in developing countries, any attempts to establish maintenance services will only be successful if they are rationalized, coordinated, and work towards a common goal.

- Countries should investigate the level of technology which is appropriate for their needs. Due to the problems of maintenance, it may be beneficial to have a policy which promotes the minimum level of technology possible whilst still ensuring an adequate level of health care provision.

- Countries should consider an element of standardization which will provide a more economical usage of resources.

- There should be adequate representation of technical staff on equipment selection committees and/or consultation boards.

- Technical staff should collect literature and information on other more "appropriate" levels of technology to enable medical staff to make informed decisions during selection proceedings.

- At national and workshop level, improvements should be made to the means and quality of communication between manufacturers and their overseas customers.

- Manufacturers' spare parts lists should give not only the order number for an item, but also an adequate description in terms of size and rating appropriate to the part eg. diameter, thickness, Amps, Watts, etc., which will assist in the selection and ordering process

- Manufacturers should recognize that manuals are a requirement for national maintenance services. Countries will continue to find it necessary to undertake repairs even if manuals are not available. Their performance would be greatly improved if there was adequate access to technical information.

- Donors could assist governments in obtaining manuals, translating them, and establishing central library facilities in order for manuals to remain accessible to maintenance staff.

- There is a need for a balance between in-house maintenance and the use of manufacturers' maintenance contracts, with in-house teams initially concentrating on first-line maintenance.

- The establishment and application of PPM programmes is essential, since they are closely tied to spare parts management.

- Maintenance records should be kept so that spare parts usage can be assessed and their costs forecast.

- Broken equipment should be cannabilized in order to obtain spare parts.

- Safety issues should be addressed, together with training in radiation protection, quality assurance, and safety regulations and procedures. Besides being valid in their own right, these activities ensure continuing safe use of equipment after repairs have been undertaken and parts have been replaced, and provide methods for monitoring the standard of parts used.

- There is a need to establish procedures for the decontamination of equipment before maintenance personnel are expected to handle them.

- There is a need for on-going user training programmes, since they can contribute greatly to the subsequent requirement for spare parts.

- Detailed authorative advice is required concerning the possibility of cleaning linen effectively without boiling.

- Stores handling systems should be kept as simple as possible, preferably with a reduction in the number of forms required for their administration.

- Countries should investigate the possibility of local production of certain spare parts where appropriate.

- Successful examples of modifications or improvisations to equipment or spare parts should be published in the newsletter of the Department of Health, Population and Nutrition, of the GTZ.

- In the health care equipment maintenance field, individual GTZ-country projects should establish direct links with each other and organize visits between themselves.

- In future, GTZ-country projects in the health care equipment maintenance field should address issues such as:
  * a stronger management focus,
  * assessment of appropriate levels of technology, and
  * the constraints faced by maintenance staff after training.

  This would aid not only the sector as a whole but also the ability of the recipient to continue when the donor has left.

5. A N N E X E S

Annex I-1

G T Z - W O R K S H O P O N
S P A R E P A R T S & W O R K I N G M A T E R I A L F O R
T H E M A I N T E N A N C E & R E P A I R O F
H E A L T H C A R E E Q U I P M E N T

P R O G R A M M E

Venue	Lübeck Fachhochschule, Division of Biomedical Engineering, Lübeck, Germany
Date	27 - 29 August 1991 * Arrival 26 August * Departure 30 August
Organizers	GTZ Department of Health, Population & Nutrition (HoD Dr R.Korte) and Division of Biomedical Engineering, Lübeck Fachhochschule (Prof.Dr H.Frankenberger)
Chairman	H.Halbwachs (GTZ)
Rapporteur	C.Temple-Bird
Contributions by	C.Castro, L.Mosquera, El Salvador J.Clauß, Cameroon H.Frankenberger, Germany/Lübeck H.Halbwachs, GTZ-Eschborn J.McKie, WHO-Geneva B.Green, H,Litschauer, Kenya/Kisumu D.Horneber, Philippines S.Njoroge, Kenya/Mombasa R.Schmitt, Senegal W.Trampisch, Germany/Gießen D.O.Wanzala, Kenya/Mombasa

S C H E D U L E

Tuesday, 27 August	08.00	Opening of workshop: - Dr R.Korte, GTZ - Prof.Dr Taurit, FHS-Lübeck
	09.00	Introduction: WHO Activities (Prof J.McKie) The Need of Spare Parts (H.Halbwachs)
	10.15	Coffee break
	10.45	The Future for GTZ Programmes in Medical Equipment Maintenance (Dr R.Korte)
	11.00	Plenary discussion
	11.45	Anaesthesia Equipment (Prof.Dr Frankenberger)
	12.15	Plenary discussion
	12.30	Lunch break
	13.30	Infant Incubators (Prof.Dr Trampisch)
	14.00	Plenary discussion
	14.30	X-ray Equipment (R.Schmitt)
	15.00	Plenary discussion
	15.30	Tea break
	16.00	Mobile Medical Suction Machines (B.Green)
	16.30	Plenary discussion
	17.00	End of session
	18.30	Dinner buffet

Annex I-3

Wednesday, 28 Aug	08.00	Working groups on previous sessions
	10.00	Coffee break
	10.30	Presentation of working groups
	12.00	Vertical Autoclaves (S.Njoroge) Laundry Equipment (S.Njoroge)
	12.30	Lunch break
	13.30	Tour of Biomedical Engineering Laboratory, Lübeck Fachhochschule
	14.15	Spare Part Storekeeping System (J.Clauß) Engines, Alternators, & Water Pumps (J.Clauß)
	15.00	Tea break
	15.30	Plenary discussion
	16.00	End of session
	17.00	Sight seeing in town
	18.30	Reception at town hall by Health Senator, Mrs Schröder
Thursday, 29 Aug.	08.00	Plenary discussion of previous issues
	09.00	Working groups on previous sessions
	10.00	Coffee break
	10.30	Continuation of working groups
	11.30	Presentation of working groups
	12.30	Lunch break
	13.30	Maintenance Workshops (D.Horneber) Supplies of Spare Parts (C.Castro)
	14.30	Plenary discussion
	15.00	Tea break
	15.30	Plenary discussion
	16.00	Discussion & proposals for future seminars
	17.00	End of meeting.

W O R K I N G   G R O U P S

- Contents and Objectives -

During the working group sessions the themes of the presentations should be discussed and relevant information concerning spare parts and working materials should be compiled.

The compilation should be carried out by using the Meta-Plan technique (cards displayed on pin boards). Each group should select one member acting as moderator and one member as presenter. Roles can be changed from session to session.

The information required comprises:-

- make/model
- critical spares and material including ideas on possibilities of using non-original products and of own production
- critical and special tools for maintenance & repair
- ways of improvising maintenance & repair work
- critical aspects including safety.

Additional categories may be proposed and agreed upon during the workshop.

The individual groups should be comprised of participants with expertise to offer in that subject area, with the provision that there was an attempt to balance numbers between groups.

Annex II-2

MEMBERS OF WORKING GROUPS

28 August - Session I

GROUP I : X-RAY MACHINES

- J.Clauß
- J.Huys
- J.McKie
- M.Raab
- R.Schmitt
- L.Staahl

GROUP II : INFANT INCUBATORS

- P.Achammer
- E.Dietrich
- I.Moubarak
- M.Musau
- W.Trampisch
- H.Wall
- R.Werlein

GROUP III : ANAESTHESIA MACHINES

- M.Elferich
- H.Frankenburger
- M.Groth
- M.Kachienga
- L.Kempe
- L.Mosquera
- S.Njoroge

GROUP IV : SUCTION MACHINES

- C.Castro
- I.Farkouh
- W.Green
- D.Horneber
- K.Peters
- M.Röttjes
- U.Staack

29 August - Session II

GROUP I : AUTOCLAVES

- E.Dietrich
- M.Elferich
- I.Farkouh
- W.Green
- M.Groth
- D.Horneber
- I.Moubarak

GROUP II : LAUNDRY

- M.Kachienga
- M.Raab
- U.Staack
- L.Staahl
- W.Trampisch
- H.Wall

GROUP III : ENGINES

- P.Achammer
- J.Clauß
- L.Kempe
- J.McKie
- K.Peters
- M.Röttjes

GROUP IV : WATER PUMPS & GENERATORS

- C.Castro
- J.Huys
- L.Mosquera
- M.Musau
- S.Njoroge
- R.Werlein

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Annex III-4

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A D D I T I O N A L   S U B M I S S I O N   O N
V E R T I C A L   A U T O C L A V E S

Under the Maintenance Microscope : Vertical Autoclaves
(D.O.Wanzala, Kenya)

Sterilization of porous and non-porous goods is one of the conditions preceding prevention of disease or treatment of illness in patients. The sterilization method most widely used in Kenya's Hospitals is to eliminate micro-organisms in medical supplies and instruments by exposing goods to heat treatment. Machines called autoclaves provide design features to process medical supplies under controllable conditions.

There is a wide variety of autoclaves nowadays to be found within Wards and Central Medical Supply departments in hospitals. Out of this equipment group, one sample has been selected to outline criteria essential in the preventive maintenance of autoclaves.

History of the Kinango Hospital autoclave
During August 1975, the Ministry of Health allocated one new vertical autoclave, to Kinango Hospital. Subsequently the equipment was not installed due to the absence of a three phase mains supply, instead the hospital continued to operate another autoclave connected to 240 Volt AC, which had been installed around 1964. This autoclave has been afflicted by numerous breakdowns during the past 14 years or so, until the hospital administration found it impossible to proceed with repair. Over these years African Marine, a ship yard in Mombasa's Industrial Area had undertaken repairs while personnel of the now defunct Ministry of Public Works occasionally inspected and serviced the machine.

At CPGH-Mombasa, the Hospital Secretary III had been coordinating maintenance of hospital equipment and had come to know the objectives of the training workshop for maintenance technicians, which the Ministry of Health had implemented at CPGH-Mombasa some time earlier, with the help of the German Agency for Technical Cooperation, GTZ.

In September 1990 he, assisted by the Provincial Medical Office, arranged transport of the autoclave vessel and accessories, which Kinango hospital had stored since August 1975, to the training workshop at Coast General. Two technicians and five 7th term HMT-Students took charge of the delivery and modified the autoclave, still unused, to suit conditions at Kinango and to satisfy medical requirements. The machine was dismantled and rebuilt using mostly original fittings. Gauges and control devices lost or damaged were replaced by new components provided by the project.

In order to replace the missing process controls, students fabricated a metal casing designed for wall mounting, to accept the custom made heater control circuitry. Furthermore they made a methodical approach in solving a problem that hampers effective autoclave operation in many hospitals, with results which proved later on to be commendable.
Annex IV-2

First test runs of the rebuilt machine were started in December 1990, in the CPGH-Department of Training and Maintenance. Right from the beginning the autoclave functioned to expectation. Because of limited capacity of TPC wall socket outlets, rated at 30 A within the welding area, immersion heaters rated 11.5 kW could be operated only at 50% load.

A total of three immersion heaters, incorporating two heater elements each are connected to two contactors. Load on each contact pair of the power circuit equals 8 A, hence 6 contact pairs connect 48 A. The control circuit for each contactor includes one rocker switch, in series with a pressure switch, and float switch. Circuit protection according to I.I.E. is provided by fuses type NEOZED, size 00, rating mains supply 240 V, 60 A, heater element 240 V, 16 A, control 24 V, 2 A.

Protection of the step down transformer is realized by two appliance fuses 25x5 mm ϕ, 240 V, 1 A slow blow. The insulation resistance of components in circuit measured better than 5 Mega Ohm. The dissipating current in immersion heaters, at least 15 years old, measured less than 0.005 Amp.

Besides the electric heater controls the control box includes a buzzer alarm for low water level, power supply and protection of the drive motor 240 V AC of the centrifugal pump connected to a water jet pump. At 4 bar the water jet pump generates negative pressure of 0.150 bar average, depending on atmospheric pressure and water density. Pneumatic capacity of the water jet pump is around 12 litres air per minute. After passing the water jet pump, drive water returns into a storage cistern of 150 litres volume, in closed circuit. Thus at the end of the sterilizing cycle, the vacuum device generates a pressure drop from 1.2 bar to negative 0.15 bar in the autoclave chamber.

At low pressure residual heat assists evaporation of excess moisture in sterile goods, and they may be removed from the machine almost in dry condition after elapse of an appropriate drying time. It was found that linen removed from the autoclave at +80° C inside the chamber contained less than 50% relative humidity, that is less moisture than absorbed in linen after 24 hours storage in a sterilizing container in ambient climate.

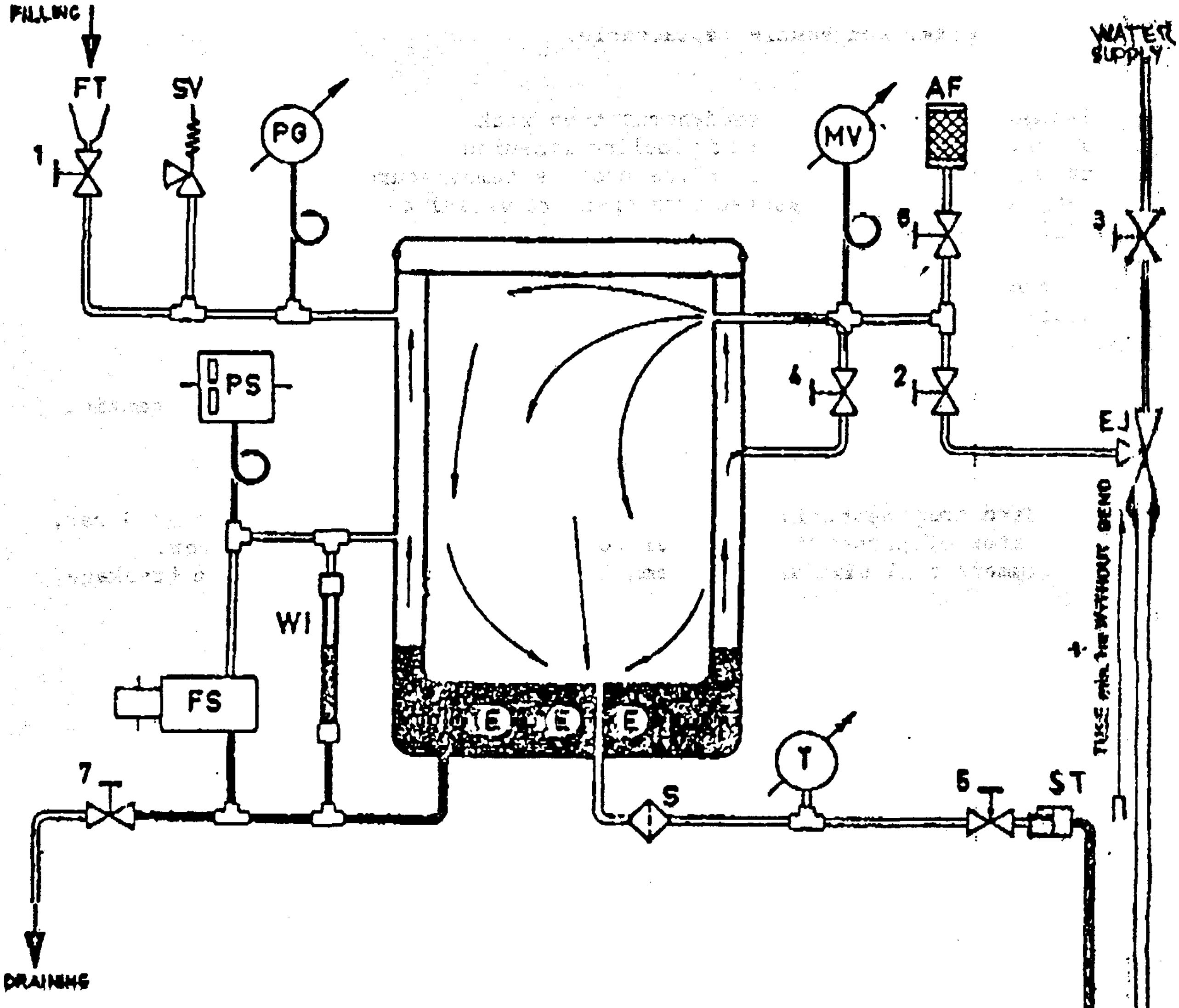
Components of the Vertical Autoclave
Refer to Figure 1 showing the autoclave controls.

- Jacketed pressure vessel.
  existing model, entirely made out of stainless steel, material no. DEW 1880.

- Lid and locking device.
  1/4 inch (6 mm) thick stainless steel, hinged to pressure vessel. Lid secures by means of eight stud bolts stainless steel, M16 hinged individually to pressure vessel. Eye nuts, M16, gun metal, chrome plated, tighten lid to pressure vessel.

- Lid gasket.
  Solid square profile rubber 12^2 mm, seamless. Hardness of gasket new, 90 Shore.

Figure 1 : Autoclave Controls



FITTINGS CODE

FT REPLENISHING CUP
SV SAFETY VALVE
PG PERSSURE GAUGE
MV MANO-VACUUM GAUGE
AF AIR RETENTIVE FILTER
PS PRESSURE SWITCH
FS FLOAT SWITCH
WI WATER LEVEL GAUGE
EJ EJECTOR
ST STEAM TRAP
S STRAINER
T THERMOMETER (centigrode)
E HEATING ELEMENT

HAND OPERATED VALVE CODE

1 FILLING
2 VACUUM
3 SUPPLY TO EJECTOR
4 STEAM TO INNER CHAMBER
5 VACUUM
6 AIRING
7 DRAIN

- Immersion heater element.
  Standard component, socket and sheath stainless steel. Socket diameter B.S.P. 1 1/4 " in modern machines, or in models made before 1979 British Standard Pipe Thread 1 3/4 ".

- Control valves.
  Standard component, material either brass or stainless steel, stem seal, sealing disk, and handle replaceable.

- Steam trap.
  Standard component, thermodynamic type with strainer. Material stainless steel. NB: If the length of pipeline measured from pressure vessel to steam trap is x mm, the result in the process temperature is y° C. Then any length of pipeline measured from pressure vessel to steam trap of x plus mm, will result in a process temperature of y plus degrees C.

- Thermometer in exhaust pipe.
  Standard component, either brass or stainless steel, range 40 to 150° C.

- Strainer.
  Standard component, material either brass or stainless steel. Retention capacity for particle size to match steam trap model.

- Pressure gauges.
  Standard component, indicator of pressure in steam generator range 3 bar, indicator of pressure in chamber compound gauge range -1 to 3 bar. Instrument dial size around 60 mm, bulky instrument size prone to breakage.

- Air filter cartridge.
  Standard component, steam proved. Retention of particle size 5 micron. Prefer filter cartridge type suitable or disinfection or steam sterilization.

- Pressure safety valve.
  Standard component, material either brass or stainless steel. Observe legal requirements for installation.

- Pressure control switch.
  Standard component, prefer type featuring differential pressure of 0.1 bar fixed. Install at a distance from autoclave to keep medium temperature below 60° C.

- Float switch.
  Standard component, material either brass or stainless steel. Prefer magnet operated type.

- Pipe work and fittings.
  Standard components, material either brass or stainless steel. Prefer bevelled seats in union joints. NB: Fittings or pipes made out of ferrous material will corrode quickly when brought in direct contact with steam and resulting ferrous oxide is deposited onto medical instruments and other loads being sterilized. The same is true for zinc coated ferrous metal commonly called galvanized pipe and fitting.

- Sealing compound.
  Teflon tape, PTFE, is used in screwed pipe connections.

Machine Name Plate
Van Rietschoten & Houwens, Medische Instrumenten and Apparaten, Rotterdam.
Year of manufacture: 1976. Capacity: 0,048 cubic m/0.125 cubic m.
Nominal pressure: 2.3 kgf/cm square. Serial number: 1589.
Nominal temperature: 136 Celsius. Test pressure: 3.2 kgf/cm square.

Dimension of Pressure Vessel

Inner chamber diameter	495 mm ϕ
Clearance lid to bottom of inner chamber	720 mm
Overall height, lid shut	1,185 mm
Mass	280 kg

Maintenance of Autoclave
1. Inspection, (autoclave in operation.)
- Ask operator about machine performance since preceding inspection.
- Check record of goods sterilized, if register is kept in Ward.
- Verify leakage in pipe work and valves, visually.
- Verify leakage around lid, visually.
- Verify indication of boiler pressure gauge: 1.8 bar MAX, 1.6 bar MIN.
- Verify indication of chamber pressure gauge: expected reading according to process selected 1.5 bar for 134 Celsius
  1.2 bar for 120 Celsius, at sterilizing cycle.
- Verify exhaust steam temperature: 120 or 134 Celsius at start of sterilizing cycle.
- Verify neat condition of machine components and lid fasteners.
- Verify function of pressure safety valve.
- Verify function of pressure control switch.
- Recommend operator to charge chamber to capacity and to top up boiler with approx. 20 Ltr. demineralized water when top of water column appears in level gauge and boiler pressure gauge indicates zero bar.
- Verify that operator follows start up and shut down procedure adequate for autoclave model under inspection.

2. Service, (autoclave out of operation.)
- Drain boiler and refill with 30 Ltr. DICALOID solution 5%.
- Heat solution in boiler to 70 Celsius and allow about 40 minutes to dissolve scale. If result is not satisfactory extend time.
- Rinse inner chamber.
- Remove strainer insert from exhaust pipe, clean, and fit with fresh sealing washer.
- Check wiring, all electrical connections/mechanically tight, electrically proper. Rectify faulty connections.
- Check all valves complete and normal to operate. Rectify faults.
- Remove lid gasket, clean slot, apply thin coat of silicone grease.
- Clean stud bolts and apply onto thread thin coat of lubricating grease. Prefer lithium based quality.
- Drain DICALOID solution from boiler and rinse with tap water.
- Refill boiler with approx. 40 Ltr. tap water.
- Confirm reliable function of float switch. Low water signal occurs if water level in boiler is 50 mm above top of immersion heater elements.
- Raise boiler pressure to 1 bar. Switch off mains supply and blow down boiler.
- Service or replace air retention filter cartridge.
- Refill boiler with 40 Ltr. water, prefer demineralized water.

- Include in three drums with porous goods maximum thermometers, and test vials 5 ml Stericon and operate autoclave for one full cycle.
- Confirm reliable function of pressure control and record in test sheet readings of all gauges taken in minute intervals.
- At the end of sterilizing cycle remove thermometers and vials.
- Record index temperature in test sheet and dispatch vials to General Laboratory.
- Compare projected values displayed in test sheet with actual measurement. In case difference exceeds projected value plus tolerance report to Section Head.

Tooling Used
- Voltage Tester, Continuity Tester, Insulation Tester, Stop Watch, Pressure Gauge, Measuring Can, Maximum Thermometer, Open End Spanner, Pipe Wrench, Ring Spanner, Box Spanner, Socket Spanner, Belt Spanner, Scraper, Root Brush, Bucket, Hand Lamp.

Materials Used
- De-scaler, Water, WD 40 spray, Stericon Vial, Retinax, Rugs, Sealing washers, Sundry Parts.

Replacement Parts
For new autoclave, to last 3 years (10,000 hrs).
- Lid gasket, Immersion heater element, Steam valve complete, Valve handle, plastic, stem seal packing, sealing disk, Assorted fittings stainless steel, Drain valve complete, Air filter cartridge, Stud bolt with eye nut, Assorted fuses, Glass tube quartz for water level gauge, Grommets, Bulbs for indicator lamps, Thermometer complete.

Note: Van Rietschoten & Houwens sold their business to another company 9 years ago. The new owner discontinued fabrication of this autoclave model which is found in many hospitals all over Kenya.

ADDITIONAL FIGURES

Annex V-2

Figure 1 : Equipment Record Sheet and Equipment History Sheet

ALTERNATOR RECORD SHEET

INVENTORY No. A/TP03

LOCATION: General Hospital Adia Tugi SECTION Power House

TYPE: (Frame): RS3B SERIAL NUMBER 2/56669/37

MANUFACTURER: BRUSH Electrical Machines LTD Light Machines Devision P.O. Box 18, Loughborough, Leicestershire, England YEAR BUILD 1972

PLANT NUMBER 11429 NA PRIME MOVER E/HR42

APPARENT POWER (k VA) 34,4 POWER FACTOR (PF) 0,8 ACTIVE POWER (kW) 27,5

CURRENT (A) 49,5 REVOLUTION (1/min) 1500 No. OF PHASES 3

VOLTAGE (V) 380/220 FREQUENCY (Hz) 50 ∅

SLIPRING BRUSHES AC SIZE 32x10x25 mm QUANTITY 8 GRADE: CM5H 064-82180/004

SLIPRING BRUSHES DC SIZE – QUANTITY – GRADE: –

BEARING DRIVE END 360P Ball Bearing Dout = 130 mm Din = 60 mm Thickn = 32 mm BEARING NON DRIVE END 340P Ball Bearing Dout = 90 mm Din = 40 mm Thickn = 23 mm

ADDITIONAL INFORMATIONS Rotor Insul. Cl. F / Stator Insul. Cl. B
Max Amb. Temperature: 40°C, Conn. Diagramme E98 40071
Brush Holder: Qty: 4, Part No. 064-82170/003

MO; Modification
RP; Repairs
OA; Other activity

Inv No. A/TP03

CODE	ACTIVITY	DATE	REMARKS
MA	Replacement of three brushes and lubrication of the bearings	23/01/90	Present figure run 2300 HRs. It should be rechecked when the run figure is 2550 HRS i.e. after every 250 hrs. run.
MA	Replacement of three brushes and lubrication of the bearings	28/02/90	Present figure run 4583 It should be rechecked when the run figure is 4833 HRS
MA	General Cleaning of the Alternator	27/03/90	Present figure run 4839 HRS ...ld be rechecked ... the run figure 5089 HRS

Figure 2 : Parts List for Air-Cooled Diesel Engines

PRESBYTERIAN TECHNICAL SERVICES	
PARTS LIST issued: 01/91 Regional Workshop	Parts Group E Spares for Engines
DIESEL ENGINE, AIR-COOLED Manuf.: LISTER - PETTER Ltd. Type: HR4 Capacity: 63bhp..1500 1/min..................	Inv.No.: E/HR41 E/HR42
supplied by: UTC - Union Trading Company Ltd Petersgraben 35 CH - 4003 BASEL Switzerland	Compulsory Parts List DECARBONISING

Illustration Numbers refer to "Parts List HR4,6&S6", Publication No.1441PL(HR)

Illus No.	Description	Part No.	Purchasg. Price /Unit	Stock Value /Unit	Min. Stock
			PStg.	frs CFA	
	Workshop Manual H range, Man.No.2004	027-08213			1
	Joint Set, Decarb.	657-19734	29.08	20700	1
HR170A /17	Cylinder Barrel	353-80971	89.49	63600	1
/18	Joint, cylinder barrel	351-10390			4
HR125 /2	Joint	354-18340			1
/4	Joint	354-19499			1
/9	Oil Retaining Ring	291-23542			1
/10	Felt Washer	291-24142			1
HR127 /2	Joint	354-50372			1
/8	Oil Retaining Ring	354-50350			1
/9	Felt Washer	354-50360			1
HR134 /4	Ball Race	011-13321			1
/12	Bearing, Roller	354-18720			1
/13	Felt Ring	354-18710			2
/32	Driving Belt	356-19722	8.12	5800	2

Page 1 of 4

Illus No.	Description	Part No.	Purchasg. Price /Unit	Stock Value /Unit	Min. Stock
			PStg.	frs CFA	
HR124 /4	Thrust Washer	351-50290			2
/5	Bearing, main	351-50260	4.67	3400	5
/9	Con Rod Assy.	572-50350			2
/10	Bolt, con rod	351-50050	3.05	2200	4
/11	Nut, con rod	270-00006			4
/12	Bush, small end	351-50060	1.08	800	4
/13	Bearing, big end	572-50650	4.88	3500	4
/14	Piston Assy.	572-50122	52.86	37600	1
/17-20	Piston Ring Set	572-50622	23.18	16500	4
HR126 /1	Cylinder Head Assy. optional:	572-55050 572-50162	239.15	169800	1
/3	Valve Guide, inlet	351-10400			4
/4	Valve Guide, exhaust	291-50800			4
/6	Valve, exhaust	351-50432	4.96	3550	4
/7	Valve, inlet	351-50420	3.43	2450	4
/8	Valve Spring	351-21401	1.23	880	8
/10	Cotter, valve spring	291-20661			4
/11	Stud, manifold	270-00348			6
/13	Gasket, cylinder hd.	351-50181			4
/15	Nut, holding down	270-00007	2.38	1700	2
/16	Nut, rocker bracket	351-10220	1.--	750	2
/17	Valve Rocker Assy., inlet	572-50170			1
/19	Bush, valve rocker lever	351-50170	2.13	1550	4
/20	Stud, injector clp.	351-36220			4
/21	Screw, adjusting	292-01670			4
/22	Nut	270-00003			4
/25	Valve Rocker Assy., exhaust	572-50280			1

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Illus No.	Description	Part No.	Purchasg. Price /Unit	Stock Value /Unit	Min. Stock
			PStg.	frs CFA	
/29	Push Rod	354-10311			2
/30	Tappet	351-10210	5.57	4000	2
/31	Breather	201-10982			1
HR131 /7	Rubber Joint	351-10220			4
/9	Rubber Cup	354-18830			4
/16	Joint, cyl.hd.cover	351-10510			4
HR173 /10	Filter Assy., fuel	354-28360	17.38	12500	1
/11	Filter Element Kit, fuel	351-29760			5
HR132 /1	Injector Assy.	356-51270			1
*	Nozzle, injector	351-50780	13.53	9650	4
/2	Pipe, leak off	354-54960			1
HR130 /1	Pipe Assy., pump to injector, cyl.1	354-26730			1
/2	Pipe Assy., pump to injector, cyl.2	354-26740			1
/3	Pipe Assy., pump to injector, cyl.3	354-26750			1
/4	Pipe Assy., pump to injector, cyl.4	354-26760			1
HR177 /3	Pipe Assy., end cover to filter	639-12991			1
/7	Filter Element Kit, lubr. oil	291-40910			5
/20	Pipe, flex., by-pass valve to oil cooler	354-52830	14.64	10500	1
HR139 /1	Pipe, flex., oil cooler to crankcase	354-36910	18.03	12800	1
HR129 /3	Pipe Assy., crank-case to cyl. head	354-19802	43.72	31100	1

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Illus No.	Description	Part No.	Purchasg. Price /Unit	Stock Value /Unit	Min. Stock
			PStg.	frs CFA	
HR142A *	Carbon Brush, for starter motor, Type CA45D12	CAV-Part.No. 6068-34			4
HR227 /1	Solenoid, 12V, for starter motor	351-31480			1
HR204 /1	Flexible Disc, for coupling	013-08441			1
/6	Bolt, for coupling	270-00226			3
/9	Nut, self locking	270-00150			3

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Annex V-4
Figure 3 :

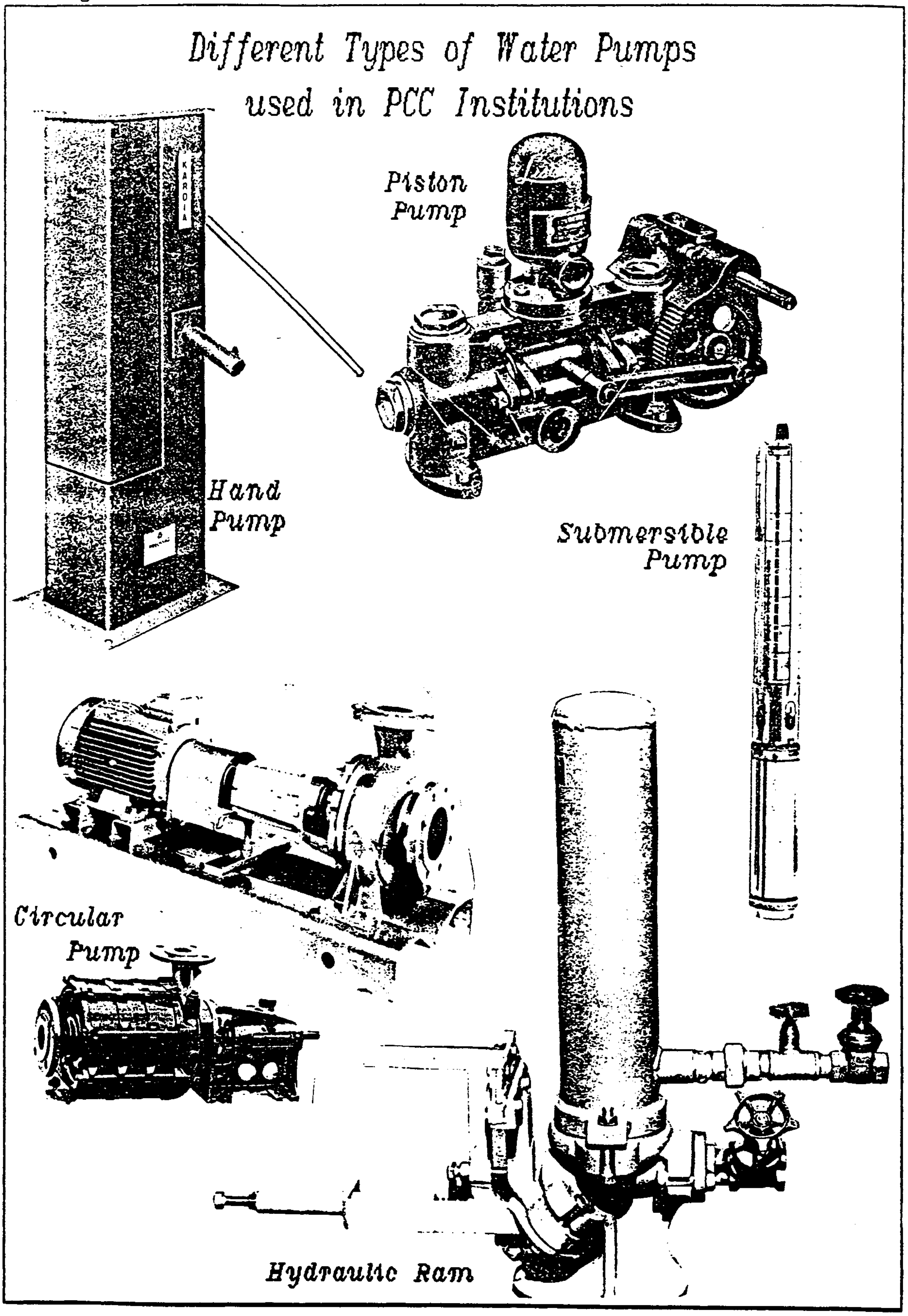

Figure 4 : A Receipt Form

MINISTERIO DE SALUD PUBLICA Y ASISTENCIA SOCIAL

NOTA DE RECIBO DE MATERIALES

NOTA DE RECIBO Nº 01 ______ 04

HOJA ____ DE ____

ALMACEN 05 __ 06

09 10 11 T.O

FECHA DE RECIBO 72 [ ] [ ] [ ] 77 DIA MES AÑO

PROCEDENCIA [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]

SECUEN-CIA		CODIGO	FECHA VENC. MES	FECHA VENC. AÑO	UNIDAD	DESCRIPCION	CANTIDAD RECIBIDA ENTEROS	CANTIDAD RECIBIDA DECIMA-LES	COSTO UNITARIO		IMPORTE	
07	08	12 19	20	21	22 24		37	41	42	49	58	67

SUMA DE CODIGOS 12 [ ] 19 CODIGO MATERIALES — 37 [ ] 41 CANTIDAD RECIBIDA — 42 [ ] 49 COSTO UNITARIO — FIN DE COMPROBANTE 68 [ ]

COLUMNA 10
1 - CONTABILIDAD SECRETARIA DE ESTADO
2 - CONTABILIDAD HOSPITALES
3 - AMBAS CONTABILIDADES

RECIBIÓ:

AUTORIZÓ:

Annex V-6

Figure 5 : A Certificate of Issue

MINISTERIO DE SALUD PUBLICA Y ASISTENCIA SOCIAL

SOLICITUD Y VALE DE SALIDA DE MATERIALES

HOJA ____ DE ____

VALE Nº 01 ____ 04 09 10 11

ALMACEN 05 06 12 TO

FECHA DE SOLICITUD DIA MES AÑO

FECHA DE DESPACHO 72 DIA MES AÑO 77

UNIDAD QUE SOLICITA Y RECIBE

SECUEN-CIA		CODIGO	FECHA VENC. MES	FECHA VENC. AÑO	UNIDAD	DESCRIPCION	CANTIDAD SOLICITADA ENTEROS	CANTIDAD SOLICITADA DECIMA-LES	CANTIDAD DESPACHADA ENTEROS	CANTIDAD DESPACHADA DECIMA-LES	COSTO UNITARIO	
07	08	12 19	20	21	22 24				37	41	42	49

SUMA DE CODIGOS 12 CODIGO MATERIAL 19 37 CANTIDAD DESPACHADA 41 42 COSTO UNITARIO 49 FIN DE COMPROBANTE 58

COLUMNA 10			
1-CONTABILIDAD SECRETARIA DE ESTADO 2-CONTABILIDAD HOSPITALES 3-AMBAS CONTABILIDADES	SOLICITO:	PREPARO:	TRANSPORTISTA:
		GUARDALMACEN:	RECIBIO:

RECOMMENDATIONS FOR FUTURE WORKSHOPS OR RELATED ACTIVITIES

1. Specific equipment categories with regard to spares:
   - Dental units, old and new;
   - Hospital engineering plant;
   - Laboratory analyzers and other equipment;
   - Renal dialysis equipment;
   - Sterilization systems, formaldehyde versus ethylene oxide;
   - Water treatment devices;
   - Waste water plants;
   - Waste treatment and disposal.

2. Equipment and maintenance management systems/issues:
   - Develop recommendations on supply systems and stock control of spare parts;
   - Develop training syllabi for the different functions of maintenance engineers and technicians for both hospital and medical equipment;
   - Inventory systems;
   - Management of equipment;
   - Management of the health care technical service as a whole;
   - Management of health services;
   - Management of maintenance workshops;
   - Manuals;
   - Patient safety, the technical aspects and the legal aspects;
   - Procurement policies;
   - Setting up of maintenance workshops;
   - The role of computers in hospital equipment maintenance;
   - Technical documentation exchange.

3. Future projects on:
   - Local production;
   - Introduction of an agency to assist in spare parts supply;
   - Spare parts funding;
   - Sustainability of projects after the donor leaves;
   - Providing professionals to government and private sectors;

4. Location of future workshops:
   - Next meeting in Africa, preferably in a French-speaking country.