6. ENGINEERING

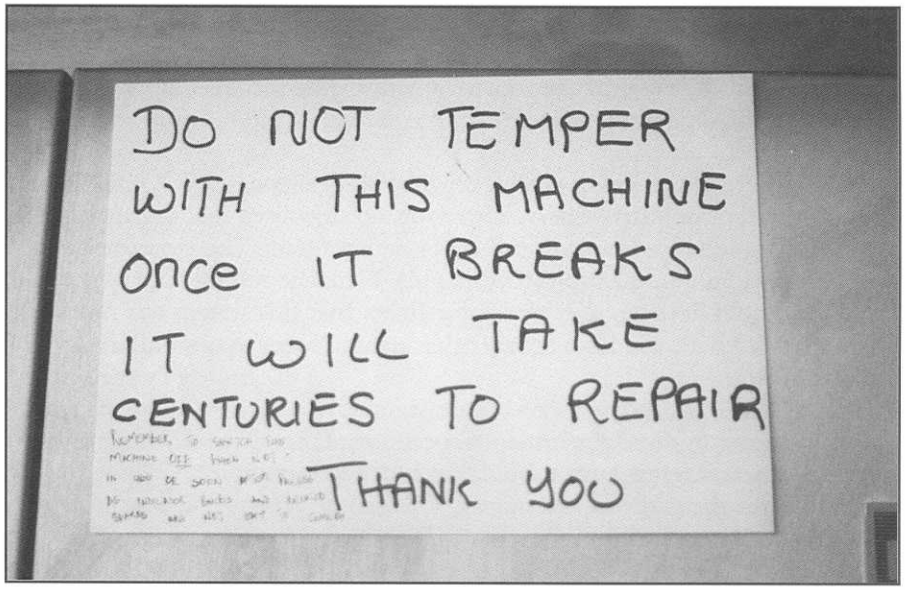
This chapter, while not a comprehensive description of every aspect of engineering relevant to planning and designing health facilities, sounds a few notes of warning derived from our experiences in the region.

The most serious hindrance to a health institution's efforts to provide correct hygienic conditions within reasonable cost is often the malfunctioning of various inappropriate mechanical installations or equipment.

High-technology autoclaves

The types referred to here produce their own steam and are intended to control each cycle completely automatically. But the fine-diameter copper tubing in which the steam is passed is sensitive to hard and muddy water common in most African countries, and quickly becomes blocked. It is not always easy to find repairmen who can weld copper expertly. Electronics problems are also common. Usually within a matter of a few months the new units work only intermittently, and the hospital (and in particular the operating theatre) is deprived of properly-sterilised utensils. Simpler, pressure-cooker-type autoclaves are strongly recommended.

Notice in a Zimbabwean district hospital



Medical gas reticulations

Built-in medical gas reticulations present potential dangers, such as contamination through cleaning, people mixing-up connections at the supply end, and maintenance problems. A frequently observed problem is the extremely high wastage of gas.

During a large rehabilitation project at a ten-storey high 1400-bed university hospital in East Africa, it was suggested that the hospital should be provided with its own oxygen manufacturing plant. This could be justified economically, and a feasibility study showed that, according to the actual consumption of oxygen in the hospital, the plant would pay for itself within 6 years. Throughout the hospital there was a regular monthly consumption of plus or minus 25 000 cubic metres of oxygen, giving an annual total of 296 000 cubic metres. This amount initially seemed reasonable until it was compared with the British DHSS Technical Memorandum on Medical Gas Systems, which showed that an annual consumption of 42 000 cubic metres was considered reasonable for a British hospital of comparable size. It was difficult to identify the reasons for this 700% over- consumption. The oxygen reticulation was in good condition. It was eventually found that the problems were apparently caused by faulty valves and connections at one end of the system or by faulty user procedures at the other end.

In most situations it is difficult to recommend built-in medical gas reticulations. From experience the most efficient and safe provision of medical gases is by cylinders. There are now on the market cylinder trolleys and anaesthetic machines which transport gas cylinders safely and conveniently.

Air-conditioning systems

Discussions of air-conditioning easily bring out myths and fantasies and can become highly emotional. It certainly is not only a Third World problem. Even in Europe the claim that normal air-conditioning can be used to create positive pressure in the operating environment and so control the movement of bacteria, is very short of positive proof (with the exception of high velocity and laminar flow systems).

A research project carried out with the support of the Danish Hospital Institute in Copenhagen in the early 80s investigated operating theatres in various hospitals, using coloured smoke to test the efficiency of gas removal from the operating area. The researchers observed that in every instance, the heat build-up from the operating lamp created a static but revolving sphere of air and gases completely isolated from air-movements created by the ventilation system in the rest of the theatre In short, the volume of air in the theatre most contaminated by gases and bacteria, is usually not greatly influenced by the air conditioning system.

In Africa the concept of bacterial control through air-conditioning is even more debatable because the quality of the air being pushed into the theatre is often the most critical factor. In a recent discussion with European-based consultants offering 'totally' filtered air in theatres, experiences in investigating the theatres in public hospitals in a country in southern Africa were recollected. At that time not one of the fourteen systems investigated was functioning as intended.

Some were not working at all (perhaps the ideal situation). Of those working, all had very badly contaminated or defective filters There was no organised maintenance of the systems at that time, and there was probably no money available to buy replacement filters. The worst situation was encountered in the newest and most sophisticated installation (5 years old). Here the rolling filter had run out and there was a great gap where the filter should have been. It was unfortunate that this system was not functioning since this theatre had not been provided with windows or any other natural form of ventilation, and working conditions were clearly unacceptable.

When drawing-up a performance specification for air-conditioning systems a basic requirement is that the operating theatre temperature should be kept at a constant 21-22 degrees Celsius, to provide good working conditions for the surgeon and nurses. This can be achieved in a number of ways. Asking for or promising more than this is very optimistic

An appropriately designed operating theatre in the southern Africa region should be in a building oriented precisely on an east-west axis, with windows facing due north or south. The roof should have 80 cm overhang, the roof space should be well ventilated and the ceiling should be insulated. Floor-to-ceiling height should be over 3 metres, preferably 3.5. There should be adequate floor space in the theatre, and high cross-ventilation from windows. With simple easily-cleaned finishes and minimum horizontal dust collecting surfaces to promote hygiene, in most climatic conditions normal in the region, it should be possible to maintain reasonable working temperatures by having simple split units mounted on the ground outside the theatre or by using fans mounted on the theatre ceiling.

APPROPRIATE MAINTENANCE

Maintenance should be a key factor in the design of any health capital investment project. Governments usually are not able to pay the high wages required by technicians, and it may be difficult to finance the training of specialised maintenance technicians for the health sector, or to fund the establishment of teams of biomedical engineers.

In proposals made for investments in buildings and equipment, problems with maintenance should be anticipated in the following ways:

- Materials and items should require a minimum of maintenance, or be maintained by simple means.
- In all procurements of equipment and plant, adequate spare parts should be included for 3 years maintenance and service. Further service contracts with suppliers should be proposed and funded where possible.
- Small workshops and maintenance stores should be provided at all facilities being upgraded.
- Providing improved transport and communications in new projects will help the correct utilisation of maintenance services.

Maintenance is as much a management problem as it is a technical problem. For many individuals and organisations it is also a psychological problem.

Much of the maintenance required for health facilities (particularly in rural areas) can be done using basic level skills, requiring few spare parts and very little organisation.

Appropriateness is a key word when discussing maintenance. Regrading is the process of changing the contents and components of a building in order to make it maintainable.

Establishing an effective system for dealing with simple routine maintenance requires the following activities:

- The team should meet the maintenance workers employed by the health directorate
- Workers should be asked to help prepare the documentation on which maintenance planning can be based. This will include:
  - a list of all medical, kitchen and laundry equipment and its location;
  - a list of all sanitary fittings and their location;
  - a list of all preventive maintenance jobs which have to be undertaken every day / week / month /year;
  - a list of all repair / maintenance jobs which normally occur, with some indication of frequency;
  - a list of the tools and equipment required to carry out the repair and maintenance activities which have been described;
  - a schedule allocating the tasks to the members of the maintenance staff.

This approach will entail the project team and others

- Drawing-up work programmes and schedules and allocating responsibilities according to the different proposals and lists made;
- Inviting proposals from staff members for documenting information regarding breakdowns and the need for maintenance;
- Listing the spare parts required to carry out the tasks described;
- Listing any maintenance task not been included above.

Despite sincere efforts, not all maintenance work will be covered. However, the scope of work which will have to be programmed and undertaken by higher level expertise will be significantly narrowed. Maintenance of medical equipment is dealt with in chapter 8.

FIRE PROTECTION AND FIRE-FIGHTING SYSTEMS

The layouts of the different health facility sites and the design of the form and contents of the individual buildings should reflect consideration of fire safety. An effective system achieves maximum safety by safeguarding against the possible occurrence of fire and, when fire does occur, by ensuring the protection of the occupants and contents of the buildings, and by providing the means to quickly extinguish the flames and restrict the dispersion of fumes and smoke.

Generally health facilities should aim to rely on passive protection, rather than technology:

A Ensuring low combustibility

- Use low ignitable and none-combustible materials such as ceramic tiles, concrete, brickwork.
- Ensure absence of thermo-plastic materials such as polystyrene, PVC, or vinyl, materials which easily ignite and which give off toxic gases.
- Remember that though bed linen can easily ignite, it never bursts into flames. Normal bed sheets and mattresses have been proved by experiment not to be easily ignited by a cigarette.

B Preventing the spread of fire

- Leave adequate space between buildings so that fire cannot easily spread from one building to another.
- Ensure that all parts of the complex have reasonable access for fire-fighting appliances
- Properly locate stores for consumables and medical gases, so that these are not kept in large quantities in close proximity to other buildings

C Giving proper protection to people and building contents in case of fire

- Consider each ward and room as a fire compartment. Make sure that there is easy access directly to the outside.

D Providing reliable fire-fighting equipment which is easy to use and which does not require maintenance

- Fire blankets, sand buckets and water buckets are more effective than fire extinguishers which have not been maintained. Choose types of extinguisher according to appropriateness and ease of proper maintenance.

E Taking maximum advantage of the situation where health facilities are staffed by trained individuals who will (with proper instruction) be able to maintain a high level of safety with non-technical devices

- One task of the Hospital Engineer member of the Hospital Management Team, should be to evaluate the fire protection quality of the buildings, and to draw up instructions to the staff to make any improvements needed.

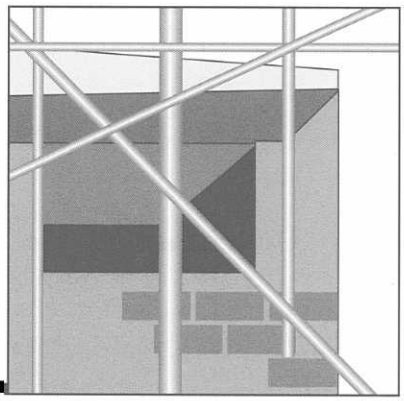
F Understanding the limitations of patient mobility

This influences the distribution of fire escape routes. Agree on the desirability, suitability and positioning of fire alarms with those limitations in mind. (It is often safest for patients to stay where they are, protected by the partitions and doors which enclose the room.)

- Implement regular and unscheduled fire drills for staff.
- Monitor and record the time needed to evacuate the buildings of patients and staff.

A high level of fire safety can be achieved in the new and refurbished facilities without substantial requirements for technical installations and maintenance. With a good system in place (no matter the financial constraints) the system will be continually sustainable with a minimum requirement for recurrent costs

Simple instructions should be provided to the facility staff during their training, be repeated during on-the job training, and be subsequently repeated at reasonable intervals.



7. COSTS MANAGEMENT DURING CONSTRUCTION

As part of carrying out the services of cost management the Quantity Surveyor usually produces:

A CASH FLOW REPORT

A cash flow report for each site is submitted to the client at the commencement of construction work and updated periodically as required. It is usually prepared by the Consultant Quantity Surveyor (not the contractor) and is based on the programme of works drawn up by the contractor.

B COSTS REPORTS

Costs reports for each site are financial statements which are drawn-up monthly by the consultant Quantity Surveyor. The costs report includes:

1 Original contract sum
2 Detail list of approved and costed variation orders
3 Balance of contingency sum / anticipated variations
4 Increased costs of labour and materials
5 Value of sub-contracts placed
6 Revised anticipated final cost of contract

C PAYMENTS CERTIFICATES

Payments certificates are issued monthly with the costs reports for each site. Certificates are drawn up by the Consultant Quantity Surveyor and calculated on value of work done, plus value of materials on-site, less previous payments, less an agreed retention amount, and should indicate how much the client should authorise to be paid. The costs of services provided by the client, such as water, electricity, and accommodation, are subtracted from the payments certificates.

D VARIATION ORDERS

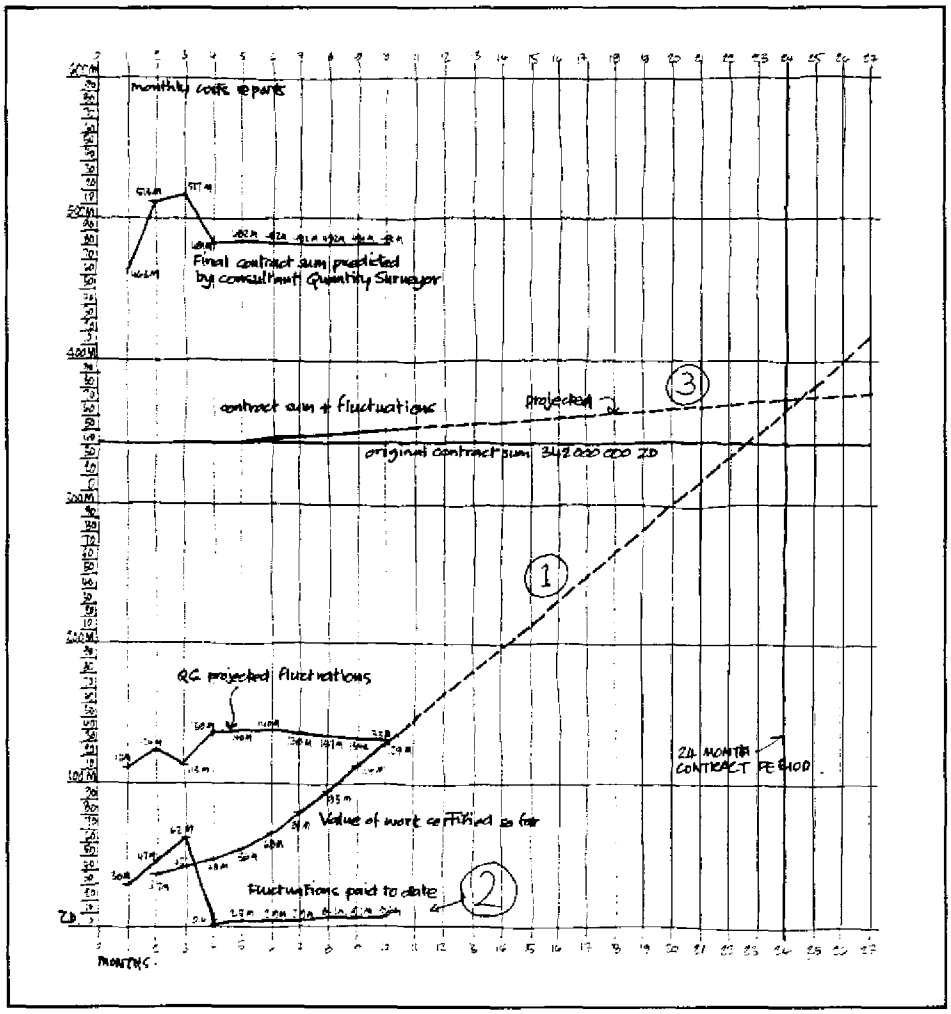
Variation orders should be drawn up by the Architect or Engineer for all proposed changes to the contract and be processed by the Quantity Surveyor.

The variation orders should be numbered sequentially and should describe the items in the bills of quantities to be omitted with costs, the new items to be substituted, again with costs, and the cost-value of the difference.

The variation orders should be submitted to the client who must sign his approval. Usually the costs can be taken straight out of the bills, but sometimes the Quantity Surveyor has to make his own estimates. It is important that these estimates be as accurate as possible.

MONITORING COSTS REPORTS BY THE CLIENT

Clients are often intimidated by the technical nature of Costs Reports and have difficulty in monitoring them. A good method of analysing the different figures supplied is to transfer them manually or by computer to a simple graph.



Graph showing costs reports for the first 10 months of a 24-month construction programme.

The graph shows the following:

The rate of construction is reflected by the monthly certificates (1). This was slow in the beginning of the programme but now (between months 7 and 9) can be seen to be moving at a rate which should facilitate completion of the project within the 24 months.

The amount of payments so far in additions (2) is under USD 10,000,000.