INTERNATIONAL ENERGY AGENCY
energy conservation
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systems programme

ANNEX XIII - «ENERGY MANAGEMENT IN HOSPITALS»
A GUIDE FOR ENERGY MANAGEMENT IN HOSPITALS

BOOKLET V

SERVICES

PFE
Via Nizza, 128
00198 Roma
Dicembre 1989

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CONTENT OF THE SIX BOOKLETS

<u>Booklet I</u>

Introduction to the Booklets and the Management Perspective

Object of this Booklet is helping Institutions to identify the requirements, fund structures which support the initiatives, carry out certain procedures and ensure that the comfort of the facility is maintained, as well as the proper service, and energy with its associated cost is minimized.

Objectives of an Energy Management Program are reported, with indications for the development of such program.

Practical worked examples for Energy Conservation Opportunities are also included.

Content:

<u>Booklet II</u>

Heat Generation and Distribution
Cold Generation and Distribution

The main objectives of this Booklet are to provide a sound basis for the approach of thermal energy management, including both heat and cold generation; it is divided in three main parts: heat generation, heat distribution, cold generation and distribution.

The heating energy may be supplied by means of conventional boilers, heat pumps, or through a district heating system.

The cooling energy is usually provided by chillers equipped with compression or absorption cycles.

All systems are described, in order to understand their principles and mode of operation, pointing out how to act on them, in order to attain an energy efficient operation.

Energy Saving Opportunities are reported, mostly with minor changes on existing installations.

Content:

Booklet III

Heating, Ventilating, Air Conditioning
Domestic Hot Water

The Booklet focuses on the requirements of the various zones of a hospital, and how they can be met in an energy efficient way, by means of Heating, Ventilating, Air Conditioning systems (**HVAC**).

Detailed description of such systems is reported with indications of the Standards and special requirements specified for hospitals.

Examples of Energy Conservation Opportunities for the management and maintenance of systems are also included.

A chapter deals with Domestic Hot Water (**DHW**) production and distribution, referring to the hospital requirements, pointing out the problems related to an energy efficient operation of this systems.

Content:

Booklet IV

Electrical System

This booklet aims to give practical assistance to the technical hospital staff, with the intent to reduce electricity cost, describing possibilities for an efficient and cost-saving use of electrical energy in hospitals.

The electricity supply system from the public grid to the individual users or groups of users within the hospital is examined, specially relating to electricity consumption.

Examples of practical cases are also reported.

Lighting is treated in a separate chapter.

Content:

Booklet V

Services

In this Booklet are considered the auxiliary systems which are generally present in hospitals, such as: hospital medical equipment, laundry, kitchen, sterilization.

A description of all systems considered is reported, with indication of amount of energy required in each case.

For each system, Energy Conservation Opportunities are included, both in the purchasing phase and during operation, in order to reduce the energy cost.

Content:

Booklet VI

Building Envelope

This Booklet treats the problems related to the losses of energy occurring through the building envelope, which includes: walls, windows, roofs, floors, and fresh air intakes.

For hospital buildings, the following items have been considered: air infiltrations, walls, floors, roofs, windows.

Energy Conservation Opportunities are reported, with the aim to attain reductions in the energy required for the operation of HVAC systems in these buildings.

Content:

FOREWORD

In many hospitals, apart from HVAC systems, considerable amounts of energy are required and actually consumed by many other systems and services, such as Laundry, Kitchen, Sterilization, etc.

These systems, taking into account their design and operational characteristics, must be considered as technical process systems.

They are not always present in all hospitals, mainly in the smaller ones; in these cases the trend is to employ external organizations which may offer good services at reasonable costs.

When these services and systems exist in the hospital, proper design and wise operation of such equipment may permit significant reductions of energy consumption.

In this booklet the following systems are considered:

1- hospital medical equipment
2- laundry
3- kitchen
4- sterilization

CHAPTER 1. HOSPITAL MEDICAL EQUIPMENT

1. Introduction

Medical equipment is obviously the heart of the many installations required in a hospital; however their peculiarities impose strict requirements on the support services demanded including energy supply.

1.1 Description

Hospital medical equipment as referred to in this chapter consists of all the technical power aids in the hands of the medical staff for proper diagnosis and therapy.

It is practically impossible to classify equipment by energy consumption: the load range varies extensively, from 100 W to 100 kW, as also the length of time of operation, from fractions of a second (and high load) as with X-ray equipment to several minutes (and low load) as with aerosoltherapy. Furthermore, the high rate of evolution of medical equipment increases the difficulty of equipment classification.

Medical equipment is connected to other hospital systems, mainly the electrical system from which it draws 20-95 % of its power. But other systems are involved, such as

- medical gases, in order of consumption
- compressed air (at 8 bar)
- vacuum
- nitrogen
- oxygen
- cool air, to cool equipment and/or rooms heated by operating equipment
- cold water, for equipment cooling
- demineralized water

The total power load of the medical equipment only amounts to a small fraction of the total hospital load; correlation of energy consumption is difficult, given the variety of equipment and their distribution.

Medical equipment is mostly used in daytime, with peaks late in the morning, but the installation capacity must be designed to meet the worst case condition, i.e. the simultaneous use of all the equipment.

1.1.1 Location of medical equipment

Most of the hospital medical equipment is located in the diagnostic and the therapeutic departments. The areas with higher energy consumption are the following:

- Laboratories

Probably the highest energy consuming area, due to the use of high power equipment and of low and high temperature cabinets.

Energy consumption levels are indicated in table 1.1.A.

item	Energy consumption		
	Low	Medium	High
Cold water			x
Demineralized water		x	
Hot water	x		
Methane and/or similar gases	x		
Vacuum		x	
Electric power, mains			x
Electric power, stabilized		x	
Electric power, emergency circuit		x	
Conditioned air			x
Exhaust air			x
Special gases (oxygen, butane, propane, acetylene, nitrogen)	x		
Compressed air		x	

Fig. 1.1.A

Electric power is the single most relevant consumption item; it is estimated to range from 500 to 100 installed Watts per square meter of lab. area. Also important therefore is the consumption of conditioned air required to remove the heat produced by the equipment.

- Radiodiagnostic Dept.

Most of the equipment used in this area operates for very short periods but under very high electric current load.

More recent equipment such as C.A.T. and MR units have contributed to high load energy consumption for longer periods than in X-ray units.

- Pathological Anatomy Dept.

The energy consumption in this area is comparable to that of the laboratories. More hoods for direct air exhaustion and freezers are used here.

- Operating theatres

Energy utilization by specialized equipment is characterized by high loads for relatively short periods of time.

Energy consumption levels are indicated in table 1.1.B.

item	**Energy consumption**		
	Low	Medium	High
Electric power			x
Compressed air			x
Vacuum	x		
Oxygen		x	
Nitrogen protoxide		x	
Nitrogen	x		

Fig. 1.1.B

Electric power is the single most relevant consumption item. Estimated installed load is 5-8 kW per operating theatre.

- Intensive care and critical care

Similar to the operating theatre conditions.

- Radiotherapy

High power equipment, up to 10 kW and ancillary cooling system, is installed in this area.

- Dialysis

A large volume of demineralized water is consumed in this area.

- Physiotherapy

Energy is consumed only when hydrotherapy and thermal equipment are present.

1.2 Strategy

Top priority is assigned to the patient care in any energy saving program of hospital medical equipment.

This leaves very little flexibility for the activity of the energy manager. There are two areas, however, where energy savings can be considered feasible:

- the choice of medical equipment
- energy recovery

1.3 How to save energy in the purchasing phase

Great attention should be paid in the specification and purchasing phase so as not to overspecify the medical and energy requirements. The energy manager should assist the doctor in selecting the medical equipment that will satisfy the doctor's requirements and his own.

When specifications are prepared for purchasing equipment which have a high energy use, a specific section should be included on energy. Thus, when bids are being analyzed, a comparison of long term energy consumption of such tenders can be prepared and should form part of the purchasing decision (see also Booklet IV for tariffs and load evaluation, in electrical systems case).

Often some equipment can be purchased to operate on different power values or pressures. If this is not taken into account, a major system change might be needed to make the equipment usable.

1.4 How to save energy in the installation phase

Conditions can exist in some hospitals where large volumes of air and/or water are required to cool medical equipment. Due consideration should be given in such cases to whether some energy can be recovered by heat pumps or other systems.

1.5 Maintenance

Equipment should be maintained in top working order. This is important for the efficiency of medical use but also for energy consumption.

1.6 Checklist

Often a simple list of items which can be carried out as a part of the normal practice of doing one's job can be very effective in accomplishing energy savings. Such a list of management and operation items follows.

1.6.1 Checklist for laboratory staff

- Check equipment periodically for efficiency.
- Do not leave faucets running.
- Turn off burners, ventilation hoods, or any other energy consuming equipment when not being used.
- Turn off lights when rooms are not occupied.
- Sterilizers and glassware washers should be used at full load rather than two part loads.
- Use proper temperature.
- Keep walls, ceilings and light fixtures clean to reflect maximum light.
- Place frequently used items in front of unit to reduce length of time doors are open.

1.6.2 Checklist for technical staff

- Develop and practise a preventive maintenance program.
- Check for proper working of control valves, etc. on washers.
- Check refrigerators and freezers for:
  - . cold spots
  - . compressor leaks
  - . low refrigerant level
  - . tight gaskets
  - . dirt or other obstruction of coils, fans, etc.
- Defrost fryers frequently to prevent frost buildup.
- Check timers on equipment to ensure they are working correctly on refrigerators and freezers.
- Check for calibration of thermostats.

1.6.3 Conclusion

The checklist is a guide. Many items are similar to operation of other systems. You are encouraged to develop your own checklist.

CHAPTER 2. LAUNDRY

2. Introduction

A laundry service is normally present in all hospitals, except the smallest ones.

In small hospitals the service is often provided by outside industrial organizations. Otherwise there may be combinations involving several hospitals using one single laundry due to favourable conditions of location and transportation facilities.

Hospitals may send soiled, but not badly infected linen to external laundries for washing, as long as the linen is transported in water-proof and hermetically-sealed bags.

In any case, a room must be provided for the storage of soiled linen.

The cleaning of infected linen in outside facilities is forbidden; it must be cleaned and disinfected in the hospital itself.

The daily need of dry linen ranges from 1.6 to 1.8 kg/patient in general hospitals and rises up to 1.8-2.0 kg/patient in special wards (eg. gynecological and maternity wards, etc.).

Even when a laundry service is not present the sterilization services are required.

2.1 Description

The laundry should always be an airy and well-lit place where the linen and other soiled articles can be collected and sorted to be washed, dried, repaired and ironed; where the linen and other clean articles can be stored; where detergents and other materials used can be kept; and where one may find the dressing rooms and lavatories for the staff.

This area must contain units which eliminate any dust, odours, or moisture quickly and efficiently.

2.1.1 Energy requirements

Laundry is generally an important consumer of energy within the hospital.

According to the type and the size of the hospital, energy required by the laundry may represent from 10 to 20 % of the total heat demand of the considered hospital; sizable amount of energy may therefore be saved by means of a wise management of this system.

The complete process may be described considering three phases:

a) washing of the dirty linen; it requires about 0.4 to 1.2 kWh per processed kg, which represent about 30 % of the total energy involved in the laundry process

b) drying; in this second phase the water is removed from the washed linen by means of heat or using mechanical devices (centrifugal drying). In the former case the energy required is from 0.2 to 1.0 kWh/kg (about 25 % of the total energy of the process), in the latter the energy is negligeable.

c) ironing; the dried linen are folded in special machines using heat; the energy consumption is from 0.5 to 1.5 kWh/kg, and may represent about 45 % of the total energy demand of the laundry process.

The energy consumption pattern is reported in the Sankey diagram in Fig. 2.1.A.

According to the results of analyses made in Switzerland on a large number of medium size hospitals (less then 500 beds), the energy consumption in laundries range from 2.5 to 4.0 kWh per kg of processed linen, with a mean value of about 3.3 kWh/kg.

2.1.2 System boundaries

The laundry service, whenever possible, should be located near the thermal plant; sometimes the heat required (steam, hot water, etc.) is supplied by a separate power station, designed and dimensioned for the specific requirements of the laundry.

The material treated by this service may be not only dirty linen but also infected material; therefore the location of the laundry should permit to reduce the path of infected and dirty material; the clean line should be stored near the users.

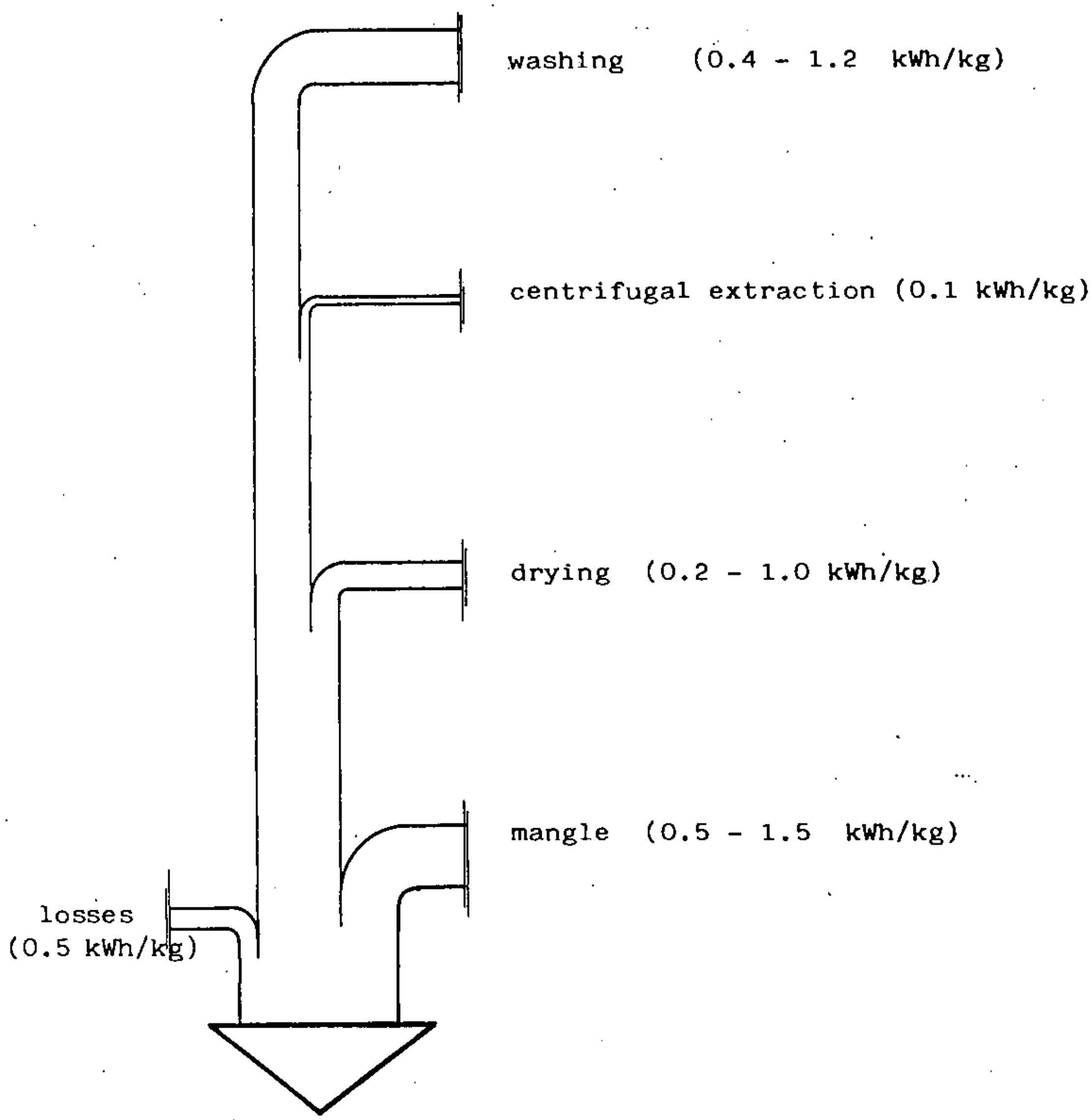


Figure 2.1.A. - Sankey diagram for energy consumption in Laundries: kWh per processed kg of linen

Among operations in the laundry process, the following have significant thermal and/or electrical requirements:

- sterilization
- disinfection
- washing
- drying
- ironing

2.1.3 Components

2.1.3.1 Sterilizers

Sterilization of linen, instruments and other materials in hospitals is considered in Chapter 4 of this Booklet.

2.1.3.2 Washing machines

These machines may be different in size and mechanical complexity according to the type and importance of the hospital in which they are installed.

Basic technology includes two coaxial cylinders, assembled on a horizontal axis, which may have parallel or counter rotation.

The cleaning of linen consists in the removal of dirty particles or impurities performed by a combination of mechanical action of rotating cylinders, thermal action by hot water or steam, chemical action by added products.

The washing process involves different operations in subsequent steps (pre-washing, washing, rinsing) which may be accomplished directly in the same cylinders of the machine in the case of smaller and simpler units or in different cylinders in plants of larger size, type "pullman" or "carousel". In the latter case, continuous cycle processes are becoming more and more popular, with counterflow motion of linen and hot water.

When possible, an auxiliary system is provided for the recovery of waste heat in discharge water.

2.1.3.3 Water extractors/centrifugal extractors

A centrifuge is a rotating device for separating liquids of different specific gravity or separating suspended solid particles.

This operation may be directly performed in the same washing machine whose cylinders are provided with all necessary equipment; in larger installations, the linen is put in "centrifugal extractors", rotating at a very high speed, in which water is eliminated by mechanical action of centrifugal force.

2.1.3.4 Dryers

Dryers are devices designed for removing water from any material by means of heat.

Dryers are employed in hospitals or in other community centres for removing water from damp linen; they are machines, or more generally rooms, in which forced hot air circulation is applied, causing evaporation of water which is eliminated with moist air flow from the machine and discharged to the atmosphere.

Efficiency of this type of machine is generally low; to be economical, modern drying plants require energy recovery devices as well as automatic charging and discharging systems in order to reduce the man power needs.

2.1.3.5 Ironing machines

Ironing is the operation by which linen is folded up and creases are eliminated.

Ironing is mainly performed by means of the following machines:

- Calenders

Calenders are machines in which linen is forced to pass through rollers or plates, heated by means of a suitable heat carrier, giving a finished smooth sheet.

For heating purposes, steam at 4 - 6 bars is generally employed. Normal calenders can process up to 500 kg/h finished linen.

- Mangles

Mangles are special ironing machines formed by a fixed hollow body, of semi-cylindrical shape, faced by a parallel rotating cylinder leaving a thin space between the two surfaces; both bodies are heated by electricity, steam, high temperature fluid, etc.

Temperature required is in the range of 150 °C.

The internal cylinder, wrapped with a cloth, is rotating at low speed, and can be pressed against the hollow body, while the linen is forced to pass through a thin space; ironing and smoothing of the linen surface is so performed.

By the use of this type of machine, up to 80 % of the total amount of linen required in a hospital can be processed.

- Folding machines

These are machines which automatically fold in the required shape the linen coming out from calenders and mangles.

Folding machines do not generally require thermal energy, and there is only a low consumption of electricity.

- Presses

Presses are machines formed by a flat heated surface which is directly applied to the linen to be pressed, laid down on a special horizontal table.

The mobile plate is heated by electricity or steam and is pressed against the table.

These types of presses are generally employed for ironing cloths such as shirts, pyjamas, albs and alike, which cannot be automatically processed in calenders and mangles.

2.1.4 Energy fluxes and index numbers

According to available recorded data, average energy consumptions referred to one kilogram of dirty linen are as shown in the following table.

hot water:		1.5			kg/kg
cold water:		1.25			kg/kg
thermal energy:	from	2.5	to	4.0	kWh/kg
low pressure steam:	from	4.0	to	6.5	kg/kg

Fig. 2.1.B

The amount of energy individually required from various operations and steps which constitute the whole washing process is largely dependent on type and characteristic of the equipment, size of the plant, degree of automation and centralization of the system.

See also Booklet II for evaluation of systems efficiency, selection of the suitable heat carrier, choice of the control philosophy.

2.1.4.1 Sterilizing machines

See Chapter 4.

2.1.4.2 Washing machines

The large variety of equipment available on the market and their continuous improvement makes it difficult to give definitive and actual figures, referring to their energy performances.

Some data are reported in table 2.1.C as an example.

Washing-centrifugal machines with electrical heating system					
Load capacity	(kg)		20		30
Total electrical power	(kW)		13		20
Washing-centrifugal machines with steam heating system					
Load capacity	(kg)	30	64	100	250
Steam pressure	(bar)		0.5÷8		4÷8
Steam consumption	(kg/h	50	60	120	280
Total electrical power	(kW)	2	3	7	8

Fig. 2.1.C

2.1.4.3 Drying and ironing machines

The vapour consumption for drying referred to the quantity of linen can have a variation from 5 kg/kg in old machines with carts to about 2 kg/kg in rotating machines. A higher efficiency can be attained in drying and ironing with mangles that can treat up to 800 kg/h of linen at a temperature of 170 °C. Some characteristics of various machines are reported in table 2.1.D.

One roller self-drying mangle			
Load capacity	(kg/h)	150	200
Steam pressure	(bar)	8÷12	8÷12
Steam consumption	(kg/h)	110	160
Total electrical power	(kW)	2	3.6
Two roller self-drying mangle			
Load capacity	(kg/h)	300	400
Steam pressure	(bar)	8÷12	8÷12
Steam consumption	(kg/h)	240	320
Total electrical power	(kW)	6	9
Electrical folders			
Total electrical power	(kW)	0.5	
Gas dryers			
Capacity	(kg/h	14	
Total thermal power	(kW)	26	
Total electrical power	(kW)	0.5	
Steam dryers			
Capacity	(kg/h)	14	
Steam pressure	(bar)	0.3÷0.5	
Steam consumption	(kg/h)	30	
Total electrical power	(kW)	0.5	

Fig. 2.1.D

2.2 Strategy

Energy saving on existing facilities is limited to eventual heat recovery of heat discharge, estimated according to working times of the laundry and management directions.

On the contrary, greater importance is attached to energy saving in the choice of new facilities such as mangle since it uses a great amount of steam, and defines the production pressure of thermal stations (often of the whole distribution network). Moreover manufacturers have considerably improved the performance standard of these plants.

It should be stressed that, at present, even under these conditions, there is a tendency towards the mechanization of a great number of operations such as sheet folding, stapling, transport.

An economy on time-cycle costs can be obtained through linen flow and the working time rationalization.

2.2.1 Washing

Washing process may be accomplished, in modern equipment, at temperature not exceeding 60°C, while in older machines the temperature was normally higher, in the range of 70-80°C.

Significant energy savings may be therefore obtained modifying the process procedure, in order to reduce the operation temperature.

The opportunity to eventually replace the old existing machines with modern equipment should also be considered.

2.2.2 Drying

We must always remember that the amount of energy required to remove water from the linen by means of heat is much greater than in the case of mechanical systems, such as centrifugal extractors.

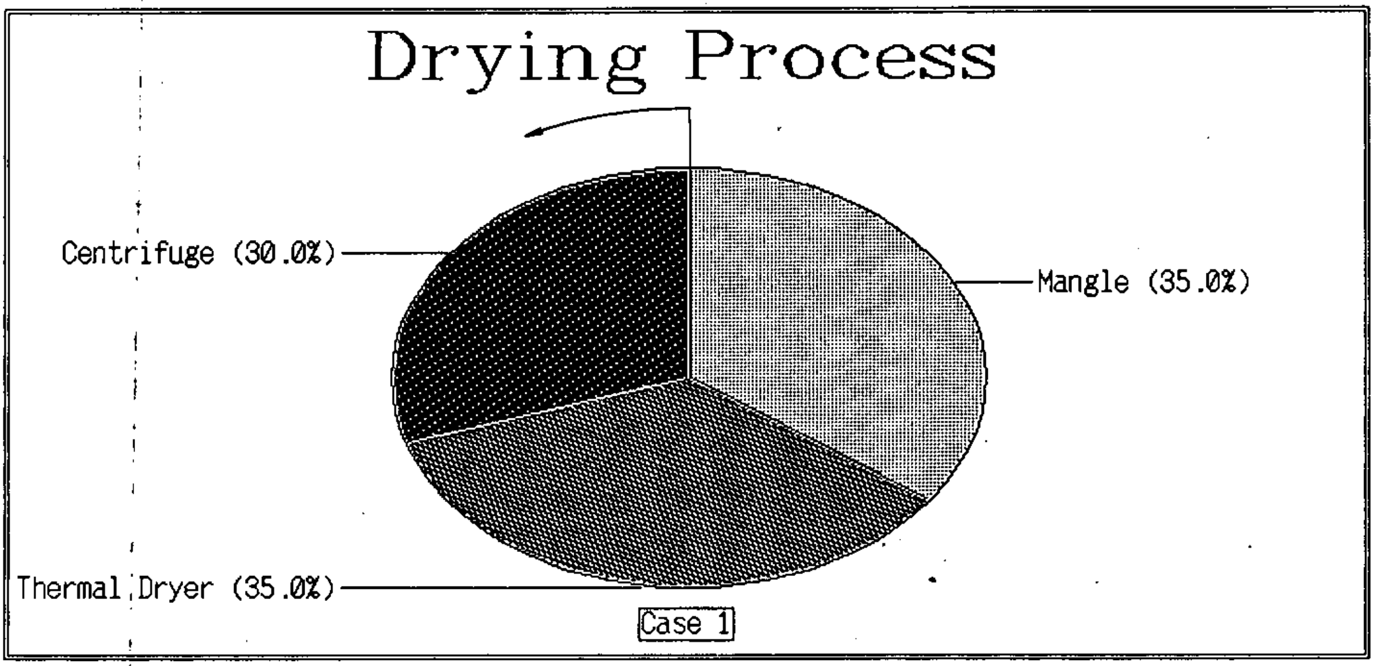
Thermal evaporation of 1 kg water may require from 0.08 to 0.12 kg fuel, depending on the type of equipment, size, mode of operation, etc.
On the contrary, mechanical extraction requires very low amount of energy.

The strategy for energy saving considers adoption of a process in which the maximum amount of water is removed in a first step by means of mechanical extraction, and the use of thermal evaporation is limited.

As an example, if we plan to send the linen to the mangle with 35 % water left, so removing 65 % of the initial water content, we may consider two different solutions: a first one in which we rely more on thermal evaporation than in mechanical extraction, and a second one with opposite intention.

The above two different modes of operation are shown in the pie chart in Fig. 2.2.A.

In both cases, the goal is to obtain a product containing 35 % water after thermal drying, removing 65 % of the initial water content. In the first instance, 30 % water is removed in centrifugal extractors, and 35 % evaporated in the dryer with an energy consumption of about 0.3 kWh/kg; in



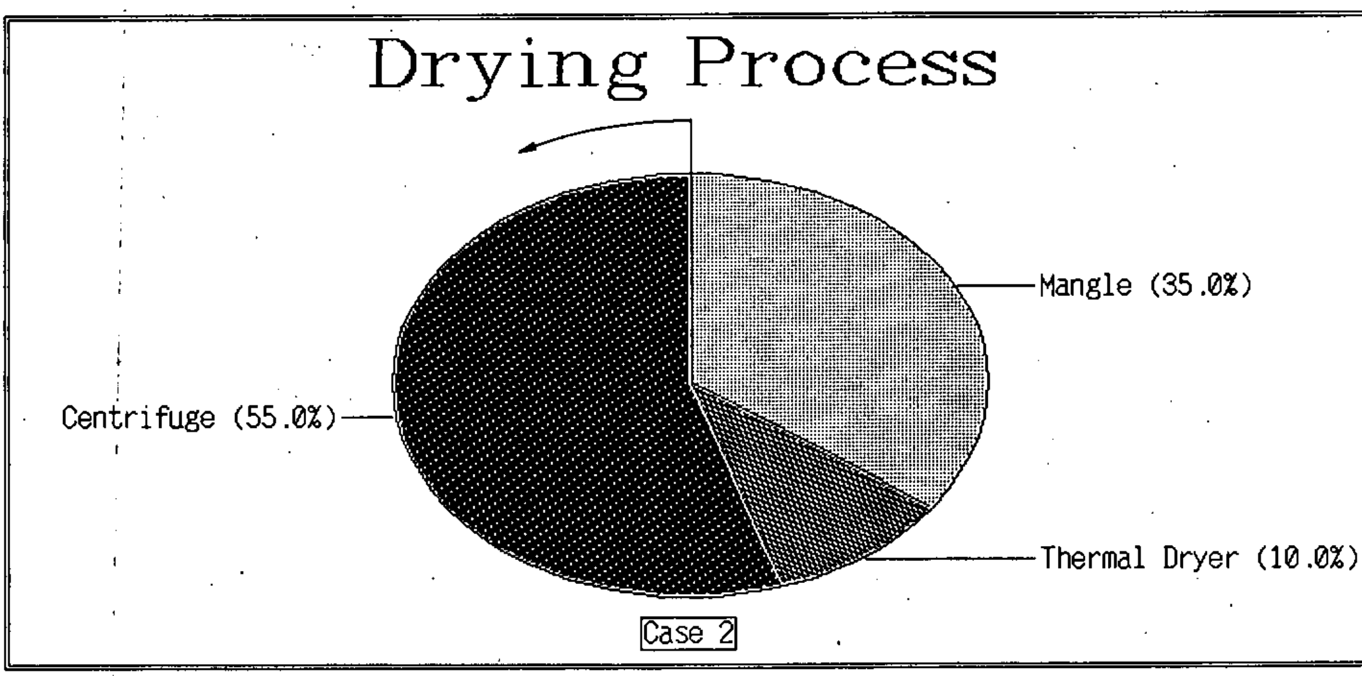


Fig. 2.2.A. - Percentage of water removed in each step of a 3 phase process

the second case, 55 % is extracted in the first step, leaving about 10 % to evaporation process: the energy demand drops to about 0.2 kWh/kg.

Partial recirculation of hot air exhausted from the dryer is another opportunity for energy saving, accomplished by means of the control of relative humidity and temperature, with installation of heat recovery facilities.

2.2.3 Pressing

Generally, about 60 to 70 % by weight of the total linen entering the washing process are treated in the ironing machines, in which a major part of the energy required in the whole process is consumed. Therefore, in the energy saving strategy, the opportunity of installation of heat recovery facilities must be considered.

The mangle is a particularly good source of cost-free heat especially because of its high steam consumption.

Figure 2.2.B shows an example of this application. Heat recovery is possible all the year round by means of a recuperator for preheating warm water for its direct use in laundries at low temperature.

2.3 How to save energy with minor changes

2.3.1 Checklist for laundry staff

2.3.1.1 General

- Arrange to do laundry during non-peak times when less equipment is being used in other areas.
- Use timers to avoid running equipment longer than necessary.
- Report any malfunction of equipment, water and steam leaks or clogged drains immediately.
- Do not leave faucets running.
- Turn off supply and exhaust fans when they aren't needed.
- Turn off lights and heating and cooling systems before leaving at the end of the work schedule.
- Cool laundry room with outside air when temperatures permit.
- Keep walls, ceilings and light fixtures clean to reflect maximum light.

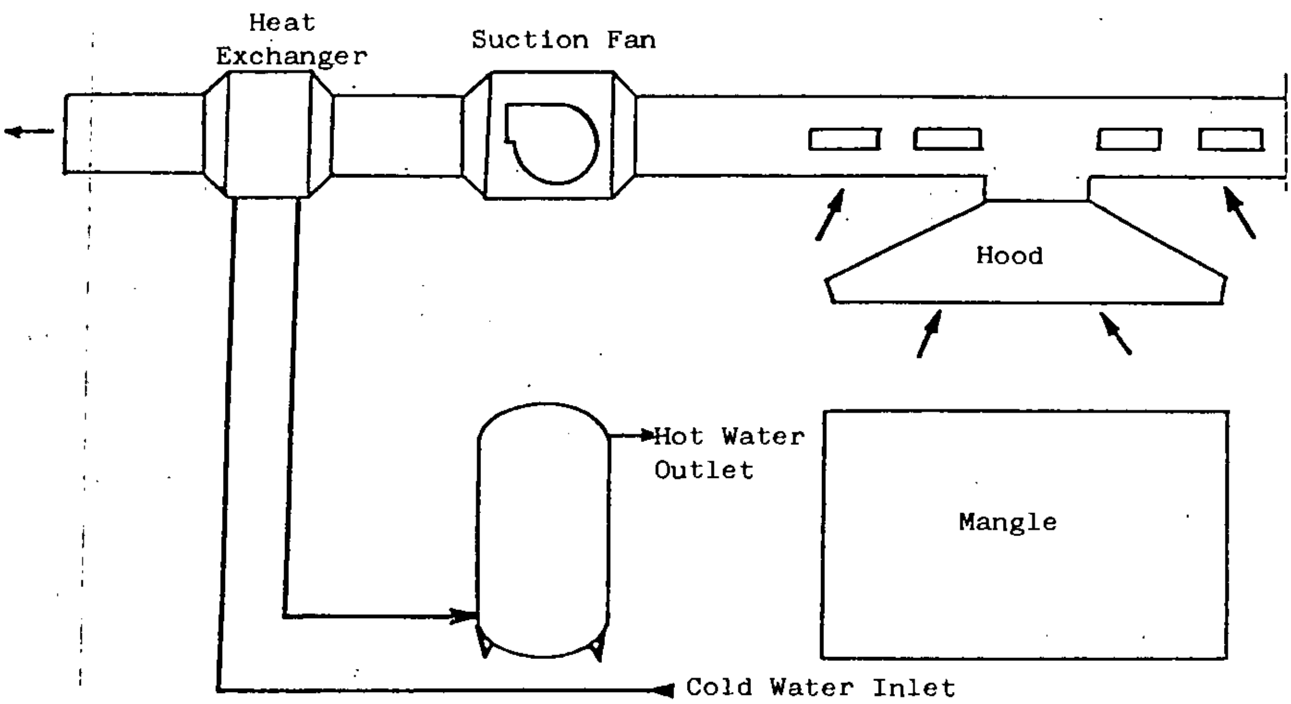


Figure 2.2.B. - Heat recovery from laundry facilities

2.3.1.2 Washers

- Sort clothes according to type and soilage. Run washers on minimum cycle necessary for type of laundry and degree of soil.
- Eliminate the recycling of clean linen to the laundry.
- Run machines with full loads. The energy requirement is the same.
- Ensure water is heated only to temperature required.
- Follow manufacturer's directions for each washer.

2.3.1.3 Extractors

- Follow manufacturer's directions for each extractor.
- Check that extractors are working correctly. Water that is removed by the extractor does not have to be evaporated by dryers; less heat is used and energy is saved.
- Check times on extractors to ensure they are working correctly.

2.3.1.4 Dryers

- Schedule drying so dryers operate continuously.
- Idle dryers waste residual heat built up during the previous load.
- When drying, sort clothes by type, use lowest temperature and set timers for shortest adequate cycle.
- Clean lint traps at least twice a day.
- Clean lint build up in other dryer parts daily.
- Follow manufacturer's directions for each dryer.
- All direct gas-fired equipment should be set at the exact firing rate recommended by the manufacturers. Firing at a higher or lower rate will waste energy.
- Check timers.

2.3.1.5 Ironers

- Permanent press linens avoid the need for ironers, which use large amounts of energy.
- Run ironers as little as possible, minimize warm-up time, heat only to minimum temperature required and turn off when not in use.

2.3.2 Checklist for technical staff

2.3.2.1 General

- Check for negative pressure in the laundry. Insufficient make-up air to satisfy the exhaust blower results in the faulty operation of tumblers and dryers. Negative pressure may also cause incomplete combustion in direct-fired units with a resulting waste of fuel.

- Take make-up air from outdoors rather than using air from air conditioned spaces.
- Clean or replace filters on ventilating units on a regular basis.
- Maintain clean fan housing in exhaust and supply systems.
- Check proper operation of waste heat recovery units and correct any leakage in water-filled or glycol-filled systems.
- Clean heat exchangers, ductwork and filters. Check drainage for icing. Verify all timers, temperature controls, damper mechanisms and valves.
- If an air-to-air waste heat recovery system is used, duct heated make-up air directly to process dryers rather than back into open laundry area.
- Develop and practice a preventive maintenance program.
- Install light switches to control lighting in unused or naturally lighted areas.
- When redecorating, use light colours to reflect light.
- Train employees regularly to:
  use equipment properly;
  develop "energy-wise" habits;
  turn it off when it is not being used.

2.3.2.2 Washers

- Check control valves to be sure they are working properly and don't leak.
- Make frequent inspections to check for possible leak points, scale formation, water stagnation; in case of failures or malfunctioning, take immediate actions to restore correct operation.
- On belt-driven models, check for tightness of belt and alignment of pulleys.
- Lubricate motor as required. Clean lint, dirt and dust from motor.
- On gas models, have gas company representative clean and adjust burners.
- Check timers on washers to make sure they are working correctly.
- Make sure that systems for water treatment are always in perfect condition and properly operating, in order to guarantee both the washing process and prevention of scale formation in the machine.

2.3.2.3 Dryers

- Have insulated covers installed on dryers to reduce heat in laundry and adjacent areas.
- Check operation of heat recovery equipment where installed. Clean waste-heat exchangers, and periodically check efficiency.
- Check level front to rear, of tumbler basket or cylinder. A small difference in level of the basket axis will result in uneven loading of materials and a substantial waste of heat energy.
- Verify rotating speed of tumbler at full load. If speed is too low, not enough of the fabric surface will be exposed to the drying air, and energy will be wasted.
- Bearings on all rotating equipment should be kept lubricated to reduce friction and the resulting waste of energy.
- Check speed of fans in tumblers and dryers. If fan is operating below its optimum speed, drying time will be longer.
- On direct gas-fired equipment see that all gas holes in the burners are clear.

2.4 Conclusion

The checklist is a guide. Many items are similar to operation of other systems. You are encouraged to develop your own checklist.

CHAPTER 3. KITCHEN

3. Introduction

A kitchen service is always present in any hospital. It is very important to have a correct design but also a good management because the average cost of this service is about 10-12 % of the total cost per patient during the period spent in the hospital, this cost being due not only to energy, but also to food, management, etc.

3.1 Description

The kitchen service generally includes several areas in order to ensure safety in the conservation of food and drinks and for adequate preparation, cooking and packaging of the meals.

In addition, such division improves safety in the washing of all the kitchenware and the storage of the carts and washing machinery.

There must also be dressing rooms and lavatories for kitchen staff.

3.1.1 System boundaries

The optimal location of the kitchen services is in a central position in respect to buildings being served.

A typical flow-chart of the principal operations that are performed is reported in Fig. 3.1.A.

Some of the indicated operations should be made in separate rooms, but many times this is not possible for space or other particular reasons.

Among operations reported in Fig. 3.1.A, the following services have significant thermal and/or electrical energy requirements:

- Storage
- Preparation
- Cooking
- Distribution
- Washing

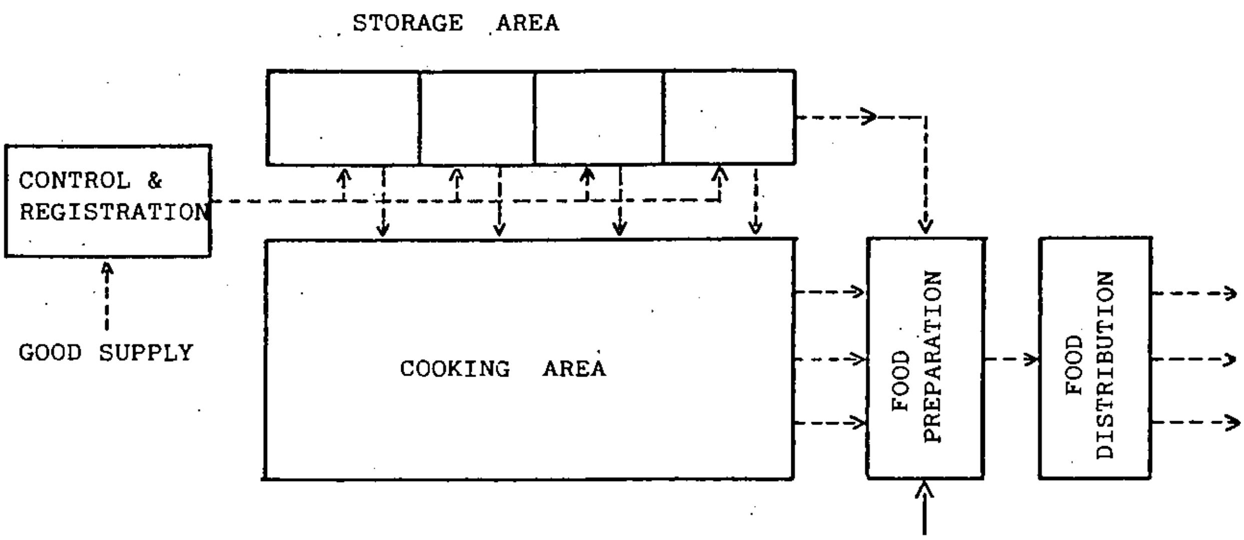

STORAGE AREA
CONTROL &
REGISTRATION
GOOD SUPPLY
COOKING AREA
FOOD
PREPARATION
FOOD
DISTRIBUTION

Figure 3.1.A.

3.1.2 Components

3.1.2.1 Stores and refrigerating rooms

Can be classified:

Rooms naturally refrigerated

A good ventilation must be guarantied and they are normally located underground.

Rooms artificially refrigerated

Many times these rooms are reached through another room refrigerated at an intermediate temperature. The conservation temperature depends on the stored goods and can vary from 0 °C to +5 °C.

In some cases there is the necessity of conservation of frozen goods for long periods at temperatures of about -40 °C.

A typical volume capacity is of 0.3 - 0.5 m^3/bed; the power of the refrigeration plant can vary from 0.3 kW for a volume of 4 m^3 to 6 kW for 200 m^3.

3.1.2.2 Preparation equipment

Employed for the pre-processing of the food before cooking. The most used are:

- Potato peelers
- Mincing machines
- Meat slicers
- Mixers

and many others that are normally electrically operated with a power up to 1-2 kW.

3.1.2.3 Cooking equipment

Special equipment for each method of cooking: boiling, frying, roasting, baking, flame or vapour cooking, sauce preparation.

Pots for boiling

These can be fixed or inclinable. They are heated indirectly by a fluid, hot water or steam that circulates in a cavity in the wall. The heating is by direct exposure to a flame or by steam or electric resistances. The indirect heating prevents adhesions of grease to the walls.

Other kinds of pots

There is a variety of specialized equipment for frying, roasting, milk boiling that must be heated separately for the different time schedule of use. The heating systems are various: direct flame, hot water, but more frequently steam or electric resistances.

3.1.2.4 Food carts

Special kind of trolleys heated by gas or electricity, which can be manually transported in each section of the hospital.

3.1.2.5 Washing machines

These are automatic machines that can process up to 4 000 dishes/hour in a time of approximately two minutes. The hot water, with a temperature of 60 °C to 90 °C in different times of the cycle, is obtained by electricity, gas or steam heating.

3.1.3 Energy fluxes and characteristic numbers

In the food preparation kitchen the average energy need ranges from 0.6 to 2.0 kWh/bed·day. The cost depends on the kind and on the efficiency of the heating apparatus.

The energy sources generally employed in hospitals and suitable for the operation of the kitchen equipment are the following:

- steam (pressure up to 1.0 bar)
- hot water
- liquid fuel
- gas

See also Booklet II for evaluation of systems efficiency, selection of the suitable heat carrier, choice of the control philosophy.

3.1.3.1 Milk boiling

The energy required for preheating the milk and for maintaining the temperature at boiling point in steady state, in special pots indirectly heated by low pressure steam (1.0 bar), is reported in Fig. 3.1.B.

pot capacity [l]	steam consumption preheating [kg]	steady state [kg/h]	preheating time [minutes]
100	25 ÷ 30	35	20
150	35 ÷ 40	50	25
200	45 ÷ 50	60	27
250	55 ÷ 60	70	30
300	70 ÷ 75	80	35
400	85 ÷ 90	95	40
500	105 → 110	110	45
600	125 ÷ 130	130	50

Fig. 3.1.B - Steam consumption for milk boiling

3.1.3.2 Stores and refrigerating rooms

This kind of system is not typical of hospitals and the characteristics depend on the manufacturer.

As a general information, the required capacity of refrigerating rooms is in the range of 0.3 ÷ 0.5 m^3 per person.

3.1.3.3 Cooking equipment

The characteristics and the energy demand for some cooking equipment are reported in Fig. 3.1.C.

<u>electrical-heated frying pan</u>		
- output	160 kg/h	
- installed power	45 kW	
<u>gas-fired frying pan</u>		
- output	160 kg/h	
- gas consumption	9 m^3/h	
<u>electric-heated pots</u>		
- nominal capacity	125 l	160 l
- installed power	11 kW	12 kW
<u>gas-fired pots</u>		
- nominal capacity	125 l	160 l
- gas consumption	3 m^3/h	4 m^3/h
<u>steam heated pots</u>		
- nominal capacity	100 l	200 l
- steam consumption (1.0 bar)	70 kg/h	90 kg/h

Fig. 3.1.C - Energy demand for some cooking equipment

3.1.3.4 Dish-washing machines

The characteristics and the energy demand for some dish-washing equipment are reported in Fig. 3.1.D.

electric-heated conveyor belt type		
- output	4 000	dishes/h
- total installed power	50	kW
steam heated conveyor belt type		
- output	4 000	dishes/h
- steam pressure	0.5	bar
- total steam consumption	93	kg/h
- electric power	3	kW
electric-heated basket type		
- output	2 000	dishes/h
- total installed power	26	kW
steam heated basket type		
- output	2 000	dishes/h
- steam pressure	0.5	bar
- total steam consumption	60	kg/h
- electric power	2	kW

Fig. 3.1.D - Energy demand of dish-washing machines

3.2 Strategy

The possibilities of reducing the consumption of energy used in cooking facilities are limited by the relatively short operation time of these equipment, ranging from 500 to 1 000 h/a.

The installation of energy saving devices, such as recuperators, has a low economic potential; other energy conservation opportunities may be more effective and must be considered, acting mainly on maintenance, ventilation air changes, heat distribution and use.

See also Booklet IV, Chapter 2, for updating of electric tariffs and avoiding of coïncident peak loads.

3.2.1 Ventilation air changes

A very important problem in kitchens which can also affect the energy behaviour of the whole system is the control of ventilation (see also Booklet III). This operation is mandatory for many reasons:

- Maintaining comfortable conditions for the people that work in the kitchen
- Preventing surface condensation of the water vapour, developed in the air during cooking, on the external walls, which are colder than the others
- Expulsion of exhaust air polluted by food grease that can constitute a serious fire hazard.

Use of suitably designed hoods, connected to an air exhaust system, permits to attain the above mentioned objectives, reducing at the same time the energy consumption.

3.3 How to save energy with minor changes

Often a simple list of items which can be carried out as a part of the normal practice of doing one's job can be very effective in accomplishing energy savings. Such a list of management and operation items follows.

3.3.1 Checklist for kitchen staff

3.3.1.1 General

- Follow manufacturer's suggestions. Determine a schedule of pre-heating times for ovens, grills, broilers, fryers, and other cooking equipment. Post prominently by each unit.
- Cook the largest volume possible. Most food service establishments find they can prepare some items more efficiently by cooking them partially or completely in volume and freezing them until needed.
- If you serve a large number of meals, consider the purchase of a blast freezer so you can freeze large volumes of food. This will save production time, operating time of equipment, and labour.
- Group grills, ovens and warmers as close together as possible, and keep them as far as practical from refrigerators and freezers.
- Schedule cleaning of walls and ceilings on a regular basis.
- Schedule all cleaning during daylight hours to save on heating and lighting.
- Co-ordinate deliveries to eliminate unnecessary openings of freezers and refrigeration units.

- Break the habit of turning everything on first thing every morning. Unless you plan to use a piece of equipment, leave it off until needed. Turn on fans and appliances only when required; turn them off when not in use.
- Review all cooking methods with a view to energy conservation.
- Cook at the lowest temperature that gives satisfactory results. Slow cooking retards meat shrinkage and retains nutrients and better colour in all foods. Slow cooking also means lower energy consumption; even though lower temperatures result in longer cooking times, the savings on energy losses from cooking equipment to the surrounding air are great enough to make low-temperature cooking more energy efficient.
- Cover pots and plans to keep heated air in and decrease cooking time.
- Stagger start-up times of equipment to avoid heavy electrical demand at one time.
- Immediately following rush periods, turn off all but one of each type of equipment - for instance, one burner instead of two, and one fryer instead of three. Lower the temperature of idling equipment if possible.
- Use warming tables wisely. They are not cooking appliances. You can waste energy and dry out foods with excessive heat. Learn the recommended serving temperatures of different types of foods.
- Turn on food warmers and hot plates only as needed, turn them off when not in use. Run at the lowest temperature possible for safe food handling.
- Thaw frozen food in the refrigerator (this reduces the refrigerator's demand for electricity). Large volumes of food can be thawed on racks in steamers. Thaw all foods before cooking unless prohibited by product characteristics (as with French fries and pies). Thawed foods require one third less time to cook.
- Cook with as little water as possible.
- Use cold water when it will do the job.
- Don't leave faucets running.
- Fill sinks for pot washing rather than keeping the water running; the same for cleaning vegetables.
- Use hot tap water, rather then water heated on range-top for cooking when possible.
- Turn off rotary toasters when not in use and clean regularly. Clean equipment performs more efficiently and uses less energy.

3.3.1.2 Fryers

- Drain fryers daily.
- Fryers need to be cleaned and the oil filtered at least once a day.
- Do not load fryer beyond manufacturer's stated capacity.
- Turn off fryer, or reduce to idling temperature and cover, during slack periods.
- Turn thermostat only as high as necessary to reach frying temperatures. In modern, high-speed fryers, temperatures ranging from 165 °C to 177 °C are ideal (too high temperature also causes the oil to break down).
- Preheat only as long as manufacturer's instructions recommend.
- Turn on the gas fryer no more than 20 minutes before use.
- Use fryer instead of the range top for frying, but don't turn on two fryers when one will do.
- Use a second fryer only for peak periods.
- Remove water or ice from product before frying to eliminate oil breakdown and temperature fluctuation.
- Clean heating elements at least once a week, and daily if used for high volume frying. Remove any burnt food or grease that would interfere with efficient operation.

3.3.1.3 Griddles

- Whenever possible, huddle food on griddle close together and heat only the portion of griddle being used.
- Heat griddle only to temperature required for food being cooked. A low or medium flame is best for griddling.
- Never overheat a griddle in the interest of speed. The cooking results could be disastrous and it is wasteful.
- During slack periods, turn the burner on your griddle down, and turn off some sections.
- Scrape excess food and fat particles from the surface with a flexible spatula, grill brick or other device after each cooking load.
- Clean and wipe out the grease troughs, remove any stuck-on food, and clean the surface with a soft cloth, rubbing with the grain of the metal while the surface is still warm. This should be done at least once a day, and more often if the cooking load is heavy.

3.3.1.4 Broilers

- Preheat no longer than manufacturer's instructions recommend.
- Load heated broilers to capacity when practical to utilize the entire surface area.
- Heat only as many sections as required by the cooking load.
- Turn the broiler flame to low between broiling operations and completely off during slow periods.
- When possible, use infrared broilers, which can be turned off when not in use and quickly reheated, rather than idling less efficient equipment.

3.3.1.5 Ovens

- Cook food while oven is warming. Begin the day's baking or roasting with foods that require the lowest oven temperature.
- Load oven to capacity, but maintain a 50 mm clearance in standard ovens for proper air circulation. Less clearance is required in forced-air convection ovens.
- Determine the cooking capacity of ovens. Use the smallest or most efficient one available.
- Use second oven only when cooking schedules overlap unavoidably.
- Load and unload ovens quickly, and don't open the door during operation. Every second the oven door is open, the temperature drops about 10 °C. Food cooks faster and loses less moisture if the oven door is kept closed.
- Clean interior oven walls and elements to achieve better heat transfer.
- Vacuum crumbs from oven burners each week.
- Keep lower edge of door free of food particles so door will seal properly.
- Keep microwave oven interior clean of spills and food particles. Never clean with abrasives which may damage oven surface and reduce efficiency.

3.3.1.6 Ranges

- Use the shiny side of aluminium foil under burners to reflect wasted heat, improve efficiency, and facilitate cleaning. Guard against blocking air inlets.
- There's no need to preheat an open top range; 10 to 15 minutes is all that's necessary for a solid-top range.
- Cover pots and pans when possible to reduce cooking time.
- Use black or dull finished pots since they absorb heat better than shiny pots.

- Use a pot or pan that is 25 mm larger than the burner on an electric range.
- Save gas by grouping pots and pans on solid range tops and lighting only those burners needed.
- Use flat bottom utensils on solid top ranges. Nearly any type of pot or pan can be used on an open top gas range, because the flame will tailor itself to the shape of the pan.
- When using a gas range for full heat conditions, the tip of the flame should just touch the bottom of the pan or kettle.
- Lower heat to simmer as soon as liquids begin to boil. Remember that water and water-based liquids boil at 100°C. Turning the heat higher does not cook food any faster: it only uses more energy.
- Cook at the lowest temperature that will still give satisfactory results.
- Turn off range when it isn't needed.
- Schedule routine inspections.

3.3.1.7 Steam cooking

- Fill cooking vessels according to manufacturer's recommendations, and to capacity, if possible. The amount of steam used is almost the same whether cooking a large or small amount of food.
- Turn off the steam unless actually cooking. Pre-heat times are short so the equipment should not be kept running.
- Use steam cookers for shorter cooking times.
- Use a steamer to begin cooking food whenever possible. Then finish cooking in the conventional manner.
- Thaw frozen food in steam vessels rather than in boiling water. Racks of frozen food may be thawed in volume, but food should be spaced to allow steam to circulate around each item, and once thawed should be immediately cooked through.
- Remove all deposits such as rust, lime, film and scale, from the water jacket and outside of container.

3.3.1.8 Dishwashers

- Do not use dishwasher until a full load is available. The same amount of energy is used whether or not racks are full.
- When main dishwashing rush is over, turn off booster heaters and accumulate dishes until next rush period.
- Turn water heater down to 24°C when kitchen closes, and turn back up two hours (or warm-up time required by your particular unit) before opening.
- Check that the power rinse is turning off automatically when the tray goes through the machine.
- Use a wetting agent instead of a power dryer.

3.3.1.9 Refrigerators and freezers

- Thaw frozen foods in refrigerator whenever possible. As food thaws, the surrounding air is cooled, reducing the refrigerator's energy demand.
- Do not place hot food in a cooling unit. Allow it to cool (in accordance with safe food handling practices) before refrigerating or freezing.
- Plan ahead so that when a worker enters a walk-in unit, or opens refrigerators or freezers, he or she can obtain or replace items at one time. Frequent and lengthy door openings waste energy.
- Use trays or mobile racks to reduce the time refrigerators and freezer doors need to be opened.
- Clearly label stored items; tape a diagram showing location of items, to door of refrigerator or freezer.
- Turn off lights when leaving walk-in coolers. Lights produce unwanted heat as well as wasting electricity. Units should have signal light switches to warn if lights are left on.
- Close doors immediately after items have been removed or replaced.
- Do not place items in front of refrigerator coils in a manner that will restrict air flow.
- Be sure items do not jam against closing door, which could damage door gaskets and cause leaks.
- Defrost freezers frequently; ice build-up should not exceed 3 mm on walls and shelves.
- Consolidate food where possible to reduce the numbers of refrigerators and freezers in use. Full units use energy more efficiently than partially full ones.
- Schedule food deliveries where possible to avoid overloading or under using refrigeration facilities. Store food requiring refrigeration or freezing promptly. Recooling such foods not only wastes energy, but may also affect the quality of items.
- Do not store anything within 1.2 meters of the refrigeration compressor.
- Cover all liquids stored in the refrigerator. Moisture is drawn into the air from uncovered liquid, raising the temperature of air inside the refrigerator.
- Keep refrigerator blower coil free of ice buildup, dirt, dust and grease.
- Kitchens and cafeterias are major consumers of energy. Given cooperation by your staff, and a little effort, they can be areas where a considerable amount of energy can be saved.

3.3.1.10 Food carts

- Leave open the covers for the time strictly necessary for loading and distribution.

3.3.2 Checklist for technical staff

3.3.2.1 General

- Investigate the possibility of installing side walls on existing exhaust hoods. Codes generally allow for lower exhaust rates from cubicles than from hoods.
- Size exhaust fans to meet minimum code requirements. Many exhaust systems are greatly oversized and remove far more conditioned air from the building than is necessary.
- Reduce the dishwasher temperature to the minimum allowed by health regulations.
- Position hot water boosters within 1.5 m of dishwasher and insulate pipes to avoid heat loss. Shut off when not needed.
- Consider installation of automatic shutoffs for: variable speed hood exhaust systems; dishwashers (to shut off 1-2 minutes after last rack); intermittent exhaust fans, such as used over dishwashers (to shut off 2-3 minutes after dishwasher shuts off).
- Install twist-on timer switches for lights in storerooms.
- Develop a lamping plan that gives required illumination at specific work stations: 80÷100 foot-candles in work areas; 50 foot-candles or less are adequate for storage areas.
- Install solenoids on garbage disposal units for automatic cut-off of water and electricity.
- Consider installing plastic strip freezer doors to reduce heat gain.
- Set thermostats on all cooking equipment to the lowest temperature that will still give satisfactory results, consistent with safe food handling practices.
- Do not allow fans to blow directly onto any cooking equipment or surface.

3.3.2.2 Fryers

- Lubricate gas valves.
- Inspect flue for proper draft and remove any obstructions.
- Adjust and clean pilot light.
- Inspect safety pilot and solenoid.
- Adjust and clean gas burners.
- Inspect oil container for grease leaks.
- Inspect and clean interiors of fixed-well fryers for grease or carbon deposits.
- Clean grease and food particles from exhaust hoods. Clean filters regularly.

3.3.2.3 Griddles

- Have utility company service representatives periodically check air/gas mixture on gas griddles and adjust pilot light to lowest possible flame.
- Check surface temperature against control dial reading. Recalibrate thermostat if necessary.

3.3.2.4 Broilers

- Monitor preheat times with thermostats or timers.
- Lubricate valves.
- Check flue for proper draft and remove any obstructions.
- Periodically call in a qualified utility company service representative to check air shutters to make sure air/gas mixture is correct.
- Check and clean burner orifices on gas broilers.
- Have a service representative check gas burners every six months.
- Rearrange the ceramic material in under-fired broilers once a month to assure even heat. Replace blackened or cracked chips.

3.3.2.5 Ovens

- Check gas pressure monthly to ensure correct pressure for complete combustion.
- Every few months, have a qualified service representative calibrate thermostats, inspect burners, door closing and insulation. Have service representative adjust air/gas mixture at least annually, and adjust pilot light to lowest possible flame.
- Adjust door hinges, gaskets, and moldings for a tight fit.
- Adjust ovens and oven racks so that they are level.
- Check the flue for proper draft and remove any obstruction.
- Use a proper exhaust canopy which uses the correct mixture of exhaust and make-up air.
- Position ovens properly under exhaust canopies.
- Have a service representative check microwave ovens for radiation leaks regularly. Have safety interlock, magnetron and timer checked annually.
- Clean fan blades on convection ovens according to manufacturer's instructions. Dirt restricts the amount of air delivered. Have motor checked annually.

3.3.2.6 Ranges

- Check gas burners periodically. If the flame is yellow or uneven, clean the burner with a wire brush and make sure holes are clear. If trouble persists, have service representative adjust gas/air mixture.
- Adjust and clean pilot lights.
- Inspect automatic burner lighters and safety controls.
- Check thermostats for accuracy and calibrate if necessary.
- To clean burners and coils on open top ranges, remove encrusted matter from cool heating elements, then soak them in water and a good grease solvent. Burners should be boiled in a solution of salt and soda, or detergent.
- With closed top ranges, lift or remove the hood periodically to be certain burners are functioning properly.
- To clean closed top ranges, rub vigorously with heavy burlap or a wire brush after the top surface has cooled somewhat. Remove any cooked food lodged under burners, lid rings, or plates.
- Schedule routine inspections.
- Contact utility representative if the unit is not functioning properly.

3.3.2.7 Steam cooking

- Clouds of steam indicate unnecessarily high temperatures. Dial temperature down to reduce both the amount of energy required to operate the steam table and the load on your heating/ventilating/air conditioning system.
- Establish a firm schedule for cleaning steam cooling equipment. Follow the manufacturer's instructions, and use a non-toxic cleaner.
- Flush boilers at least weekly, following manufacturer's instructions. Use a commercial cleaning chemical occasionally, especially if your water is hard.
- Repair all steam leaks, no matter how small.
- Inspect all steam traps for steam leakage.
- Keep all seal clean and tight to prevent steam leakage to kitchen.
- Inspect the insulation on steam lines for damage. Light-gauge sheet metal may be used to protect insulation where steam lines are exposed to damage. If damaged, replace insulation promptly.
- Regularly check thermostats for accuracy, and calibrate if necessary.

3.3.2.8 Dishwashers

- Consult the owner's manual for proper maintenance instructions.
- Control frequently the gaskets for the pipes to avoid leakages.
- Check insulation of water line in recirculation loop.
- If there is no automatic fill with shut-off, provide squeeze type valve to avoid wasting water by overfilling.
- Inspect the feed and drain valves and pumps weekly for water leakage.
- Remove lime deposits from spray nozzles. Nozzles should be reamed with a wire when white deposits become visible at openings.
- Remove lime deposits from tanks and heater coils.
- Lubricate speed reducer on conveyor-type washers regularly.
- Ensure that the power rinse turns off automatically.
- Set flow controls for proper amount of rinse water.
- Adjust power dryer to deliver heated air just long enough to barely dry dishes.
- Drain and flush hot water heater at least every six months.
- Check accuracy of thermometer and recalibrate if necessary.
- Make regular checks of rinse water to avoid excessive temperatures.
- Install pressure-reducing valves to control water pressure for rinsing.
- Clean frequently the filters from garbage.

3.3.2.9 Refrigerators and freezers

- Maintain proper tension on refrigerator compressor belts and replace any that are worn or damaged.
- Inspect and service all electric motors, fans and compressors on a regular basis.
- Keep all door gaskets, seals and hinges in good condition. Try the dollar bill test. Close the door on a bill. If it falls to the floor, the gasket needs replacing.
- Control frequently the rubber lining of the doors to prevent hot air infiltration.
- Lubricate latches and hinges with good grade oil.
- Check thermostats for proper calibration.
- Feel the outside walls of refrigerators and freezers for cold spots. Any cold areas indicate insulation failure.
- Check compressor for leaks and level of refrigerant.
- Check refrigerators for loss of temperature control and short cycling problems. If the unit is not operating properly, check the refrigerant level.

- Brush clean the condenser.
- Have a service representative adjust the freezer defrost cycle so it will defrost during off peak hours.
- Level units periodically. doors should fit correctly and close automatically from an open position.

3.3.3 Heat recovery

- on waste water
- on exhaust air
- through heat exchangers
- with heat pumps

CHAPTER 4. STERILIZATION

4. Introduction

The strict requirements throughout hospital for absolutely, equipment, instruments and materials, under potentially vast contamination conditions, requires the general availability of sterilizing equipment located both in a centralized department and/or in specific locations.

4.1 Description

4.1.1 Definition

Sterilization is a process capable of rendering microorganisms on contaminated inert bodies permanently inactive without altering the body properties.

A sterilization system is considered effective when it assures a permanent contamination reduction not lower than 10^{-6} without affecting the sterilized body.

4.1.2 Sterilization methods

An item can be sterilized as effectively in three minutes at 134 °C as in several hours at 100 °C but at a different cost and energy consumption.

Items can be sterilized by the following methods:

1. Boiling
2. Conditioning in dry air
3. Conditioning in saturated steam
4. Conditioning in saturated steam and chemical mixture
5. Conditioning in a sterilizing gas or gas mixture
6. Irradiation

The choice of the sterilization method depends upon several factors, mainly the bulk of the material to process, its resistance to high temperature and humidity, and to the aggressiveness of chemical agent used.

4.1.2.1 Boiling

The oldest method of sterilization, boiling, has been abandoned in larger hospitals because it is too slow and because at the end of the process the sterilized material is wet and therefore easily contaminable.

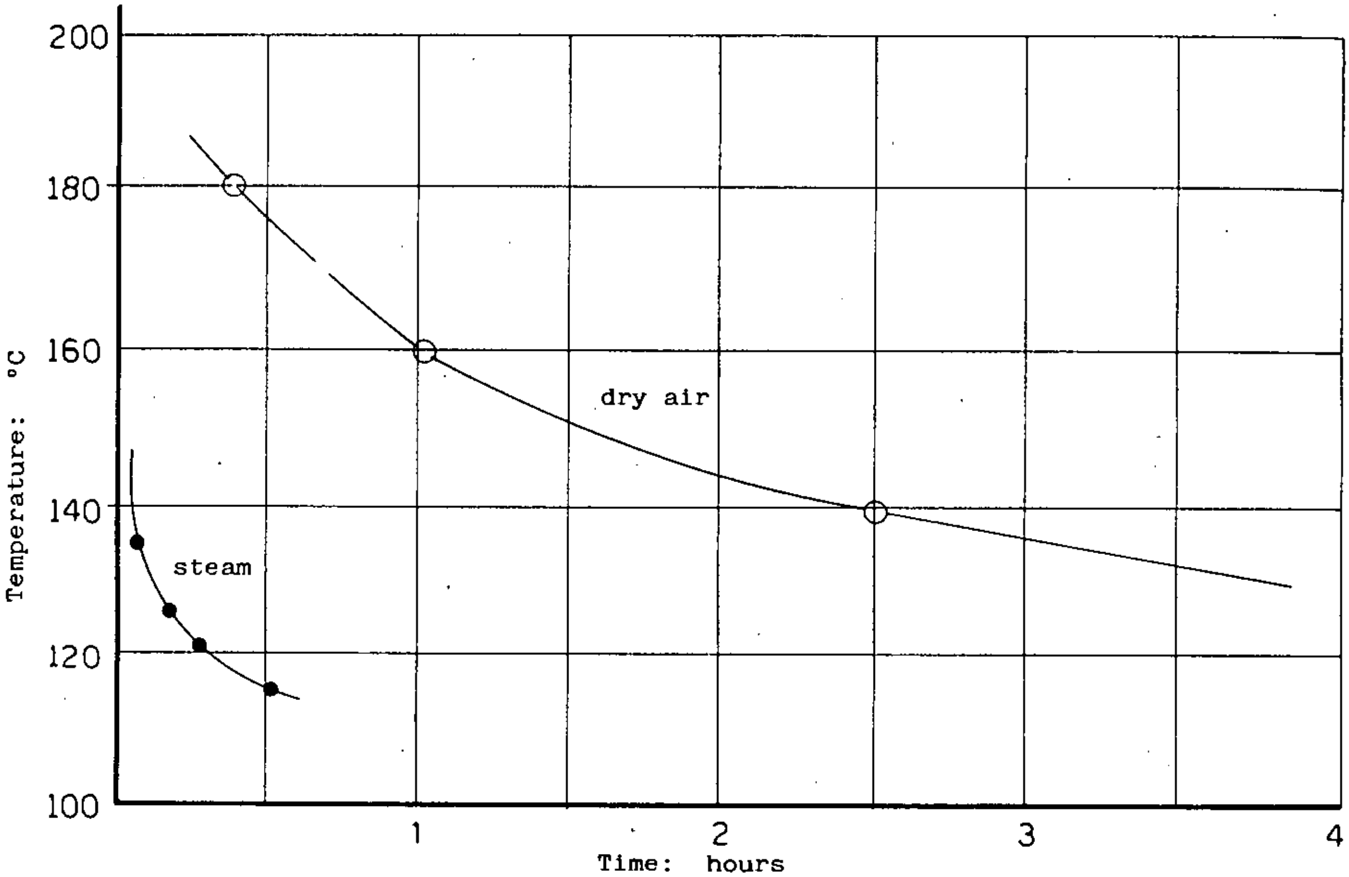


Figure 4.1.A. - Mortality curve of Bacyllus Stearothermophylus in steam and in dry air

4.1.2.2 Conditioning in dry air

The use of dry air in sterilization is limited by its low thermal conductivity since this lengthens the process time. Furthermore microorganisms have a higher resistance to dry hot air than to steam, as shown in Figure 4.1.A.

4.1.2.3 Conditioning in saturated steam

Saturated steam is the most common sterilizing agent in use.

For good results it's essential for the steam to contact all body surfaces and, if the surface is porous, to penetrate into it. It is also essential that the contact temperature between steam and material be controlled properly and maintained for the correct time.

The air inside the sterilization chamber must be removed before steam is introduced because air reduces the sterilizing effect of steam by lowering the local temperature at constant pressure and by opposing its diffusion inside the material (see table in Fig. 4.1.B).

Air-steam mixture temperature

Overpressure	bar 0.4	0.6	1.0	2.1	% Air
In situ	72	90	100	121	50
°C	96	105	112	121	25
temperature	109	115	121	135	0

Fig. 4.1.B

The process consists of a succession of air suctions and steam introductions, at pressures which depend on the type of equipment used.

4.1.2.4 Conditioning in a steam and sterilizing agent mixture

This method is used to sterilize poor heat resisting materials.

Formaldehyde is usually the sterilizing agent added to low pressure steam in equipment similar to that used in saturated steam sterilization.

The method can sometimes be incorporated as an extra feature of specially adapted steam sterilization units.

The process is concluded after rinsing with steam and hot air to eliminate mechanically any residues of formaldehyde.

4.1.2.5 Conditioning in a sterilizing gas or gas mixture

Ethylene oxide can be used as a sterilizing agent alone or in a mixture with carbon dioxide or freon. The equipment differs accordingly.

In both cases, vacuum is first induced in the sterilization chamber. When ethylene oxide is used alone, it's fed into the chamber at subnormal pressure. When mixed with carbon dioxide or with freon, the mixture is fed at higher than normal pressure. In both cases after evacuation of the gas, or gas mixture, the process is completed by a degassification phase in order to eliminate all residues of absorbed gases.

As ethylene oxide is toxic and explosive, great care should be taken in handling the equipment (gas cylinders, sterilization unit, etc.) and in assuring the proper evacuation of gases after use.

4.1.2.6 Irradiation

Irradiation by gamma rays is not used because the capacity of the equipment is too high compared to hospital quantity requirements.

4.1.3 Location of sterilization equipment

Sterilization equipment is located mainly in four areas:
- Surgery and special departments
- Central sterilization department.
- Pharmacy
- Laboratories

Sterilization covers the following classes of items:
- Instruments and utensils
- Linen and porous material
- Termolab materials

All three classes of items are treated in surgeries and special departments (such as Dialysis, X-ray, First aid, Out patients, etc.) and in the central sterilization department.

Pharmacies usually treat bottles, solutions and drugs.

Hospital laboratories generally sterilize glassware, culture fields (before + after testing), etc.

4.2 Strategy

Sterilizing equipment do not generally constitute an energy intensive system. The energy requirements are low, in the order of less than 1 kW for decentralized equipment and some kW for larger central systems.

Consequently, the possibility to attain important energy savings are limited. As already explained in Chapter 1 of this Booklet, great attention should be paid in the purchasing phase and in the installation phase of such equipment.

The goal of this section is to provide guidelines to reduce the steam and electricity consumption of the sterilization system through the following steps:

- Establish target values
- Monitoring
- Periodic comparison with target values
- Action definition and implementation
- Control of results

4.2.1 Establish target value

Equipment capacity is generally built to handle multiples of standard sterilization unit loads, one unit being a two cubic foot volume.

Energy consumption for dry heat sterilizers, usually electric powered, is 30 - 40 kW/m^3: the higher consumption figure applies to the smaller units.

Due to their low efficiency, dry heat sterilizers should be considered obsolete.

Steam sterilizers draw their energy from electric power, direct steam and indirect steam (superheated water or heating oil).

In electric powered sterilizers, energy consumption is proportional to this capacity as shown in Fig. 4.2.A.

In direct steam sterilizing units, steam is drawn from a centralized generator. In both methods, however, some electric power is required to operate the ancillary equipment, such as pumps and controls.

Energy consumption, steam and power, are proportional to the sterilizer chamber capacity as shown in Fig. 4.2.B.

4.2.2 Monitoring

The second step of an energy saving program is to keep track of the operating conditions of the sterilizing units installed in the hospital and of their energy consumption.

The actual consumption values should be compared periodically with the single and overall target values.

In case of ascertained differences, check the record sheets for quantity and type of material treated. If the differences are not explainable, steps should be taken in order to modify and improve the situation.

4.3 How to save energy with minor changes

Energy saving actions may be taken in two different areas and the savings differ accordingly:
- maintenance and/or operation
- modification and/or replacement

How to save energy through actions affecting maintenance and operation

Very often sterilizer efficiency is low due to poor maintenance of the equipment and/or non optimized operations.

Insulation of piping and equipment must be checked, and repaired when necessary. Heat loss from such equipment may affect the operation of air conditioning system, and should be prevented.

Actions without operational changes

Proper maintenance should be performed unit by unit in accordance with the manufacturers instructions. A preventive maintenance program should be scheduled for year round operation. Check for proper temperatures, pressures and time control, and for vacuum pump operation.

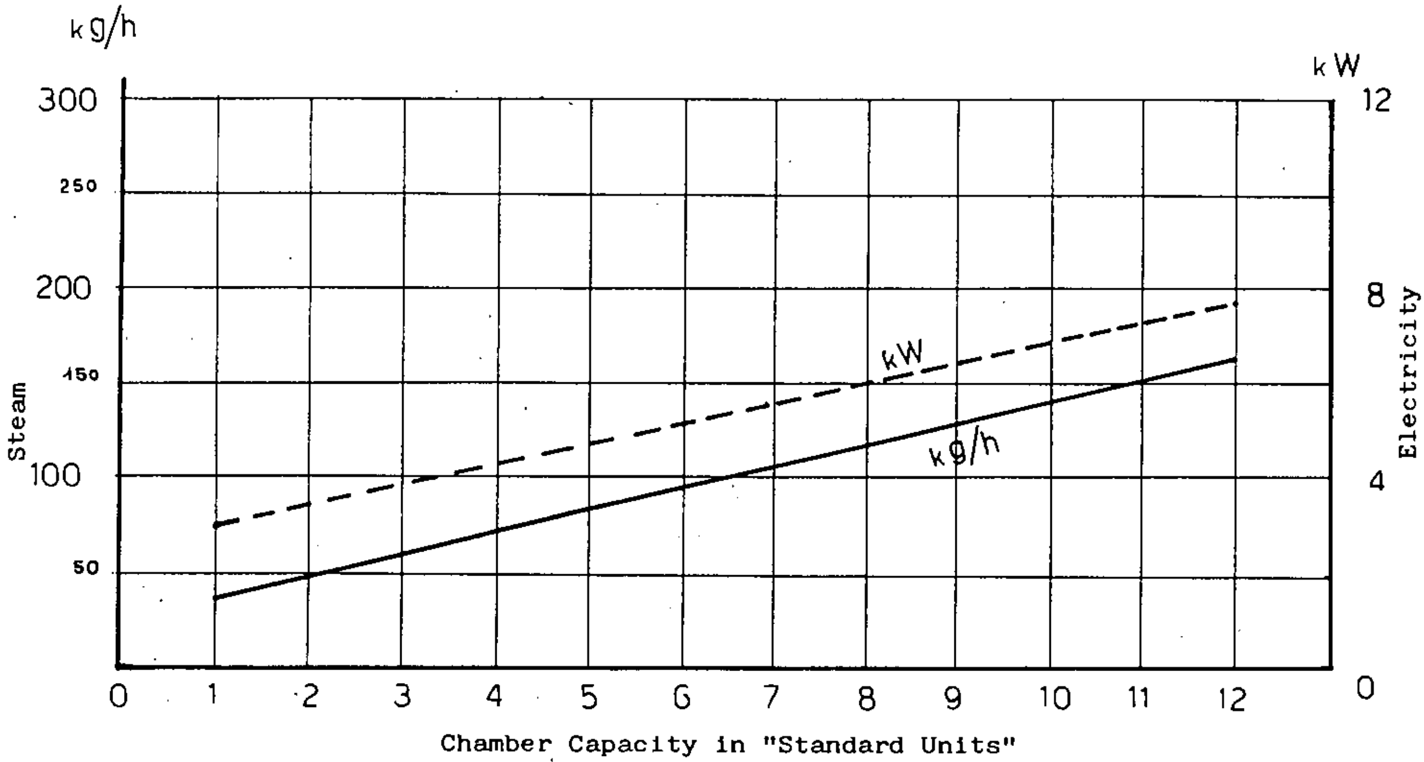


Figure 4.2.A. - Energy consumption in electric and/or steam powered sterilizers

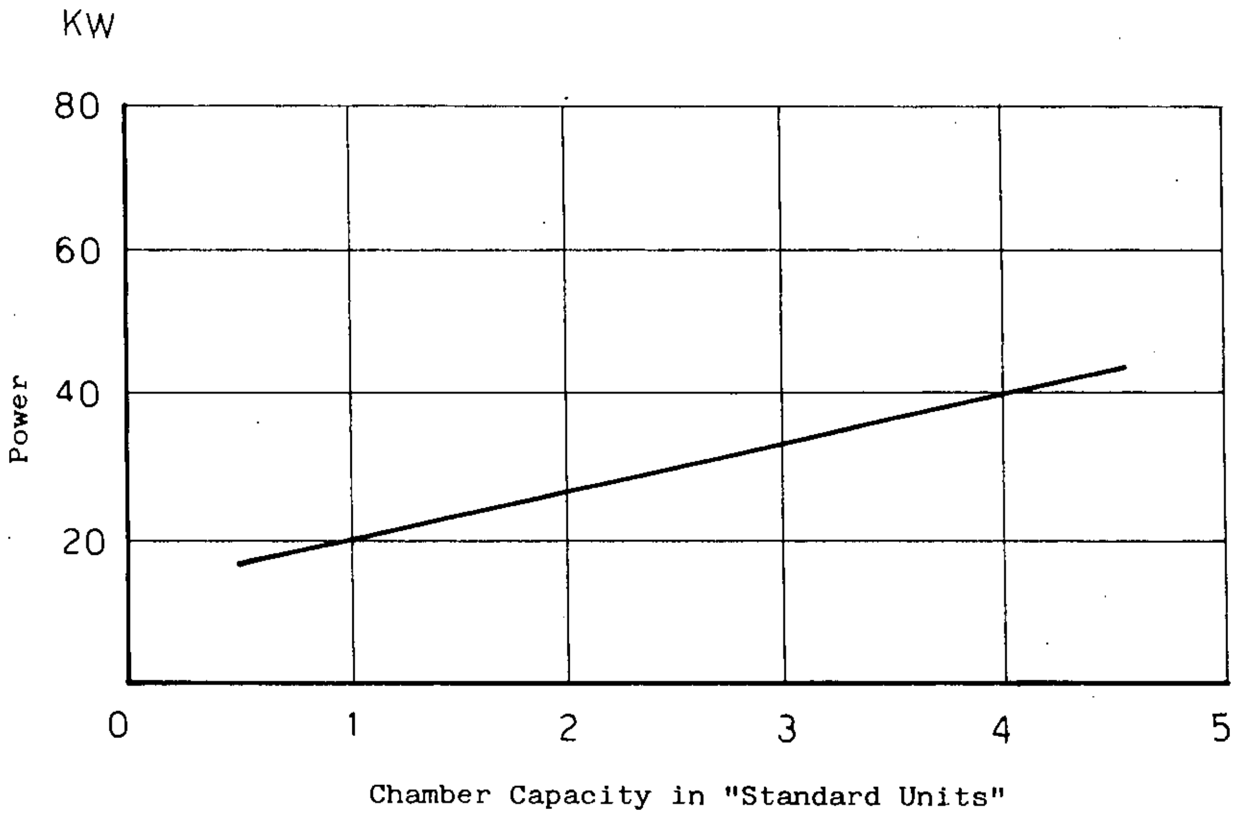


Figure 4.2.B. - Energy consumption in electric powered sterilizers

Actions with operational changes

To optimize operations and save energy it is advisable to:

- Select the best temperature-time cycle for the material to be treated;
- Sort the material to be treated in homogeneous classes;
- Use the sterilizers to their full capacity;
- Run the sterilizing cycles consecutively to avoid unnecessary cooling and heating.

4.4 How to save energy through modification

Energy savings can be attained by concentrating as far as possible all sterilization operations in a central department. Bigger equipment with higher efficiency can be used and fed by the hospital central steam generator. The system allows a fuller and better use of the equipment and a limited reduction of personnel. The system requires, however, an increase of the quantity of linen, surgical instruments, glassware, etc. to allow for the processing time.

It is advisable to have a standby steam generator to face breakdowns of the central generator.

A number of sterilizers will still be located throughout the hospital. To reduce their energy consumption it is advisable to

- replace the older units;
- draw steam from the centralized steam system;
- reduce the number of decentralized units;
- install electronic programming to allow full time use multipurpose equipment.

Control of results

Steps should be taken to ensure that the improved results attained from the corrective actions undertaken on the single sterilizing units or on the sterilization system will last for a long time.

They include, but are not necessarily limited to, the following:

- auditing the monitoring system
- auditing maintenance operations and procedures
- periodical energy consumption determinations.

4.5 Washing and disinfection

Many items such as carts, beds and instruments need to be washed and/or disinfected often with hot water or steam or chemicals.

This can be carried out in a wash room, or utensil washer, or a cart/bed washer, often adjoined to Sterilizing Dept.

The main aspects to be considered for energy conservation are:

a) time of day - system load
b) consumption and operating efficiency
c) temperature
d) pressure of water-steam