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INTERNATIONAL ENERGY AGENCY

ENERGY CONSERVATION IN BUILDING AND COMMUNITY SYSTEMS

ANNEX XIII - "ENERGY MANAGEMENT IN HOSPITALS"

A GUIDE FOR ENERGY MANAGEMENT IN HOSPITALS

BOOKLET II

HEAT GENERATION AND DISTRIBUTION

COLD GENERATION AND DISTRIBUTION

March 30, 1989

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CONTENT OF THE SIX BOOKLETS

Booklet I

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:

Booklet II

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

Most of the energy flows in hospitals serve the heating and cooling systems. Generally, all this thermal energy (heat and cold) is transformed in the central heating and cooling plant.

The heating energy can be supplied to the thermal network by means of oil or gas fired boilers, gas, oil or electrical heatpumps or possibly cogeneration plants.

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

This Booklet is meant to provide help in the management of the different heat and cold generation systems, and also partly the district heating and cooling systems inside hospitals.

It does not tackle the management of the end users. This subject is treated more in detail in Booklet III.

The main objectives of this Booklet is to provide a sound base for the approach of thermal energy management. All systems are described in order to be able to understand their functioning. Then one explains how to act on them, with the main objectives to achieve energy savings, mostly with minor changes of the existing installations only.

It is divided in three parts, namely: heat generation, heat distribution and cold generation.

CHAPTER 1. HEAT GENERATION

1. Introduction

The heat generation plant and the distribution network are the heart of the energy network in the hospital. More than 2/3 of the energy consumed in a hospital flows through them in those hospitals in northern climates.

It is therefore most important to improve the heat generation and distribution efficiencies because any gain in this building system results in large amounts of energy saved.

For example, if the boiler of a 400 beds hospital consumes 1 400 000 kg of oil per year, a gain of 5 % in the heat generation efficiency would save 96 000 kg of oil per year, without any change in the heating demand.

This chapter focuses mainly on the method to save energy without modification of the demand. This chapter deals with the subsystem heat generation and distribution. Subsystems consumers are treated in Booklet III.

Modification of the demand is treated more in detail in the chapter 2 (heat distribution) and in the Booklet III (end users).

For example, the insulation of an 100 millimeter diameter valve in a steam network may save as much as the energy consumed for heating several single rooms of the hospital.

1.1 Description

The thermal energy system is composed by three main categories of subsystems:

- Heat generation (boilers, heat pumps, and cogeneration)
- Heat distribution (district heating)
- Heat consumers (end users)

The heat generation plant converts the fossil energy into heat, and the distribution network supplies the different energy consumers as their requirements. An example of thermal energy network is shown below (Figure 1.1.A).

It shows well how complex the thermal energy network can be. At each district heating substation are connected different end users networks.

It is important to notice that the energy production must be adapted to the load pattern ; it must satisfy the energy needs, but it is not necessary to keep high temperature levels in the distribution network or boilers switched on when the load does not require it.

The time pattern of the heat generation plant is determined by the energy needs, in power and temperature.

The usual energy end users in a hospital are presented on Figure 1.1.B.

They may be supplied in energy in different ways. Therefore the kinds of networks may differ for each case. Some often seen configurations are presented in Figure 1.1.C.

There are many other possible configurations.

During the process of energy transfer from the heat generation plant to the end-users through the distribution network, some losses occur (see Fig. 1.1.D).

The structure of the heat generation plant is described in the Figure 1.1.E.

There are heat generators like boilers and heat pumps, which transform the fuel or electrical energy into heat energy, which is transferred to the district heating network. The energy is supplied following the control system commands to the heat generators.

For boilers, the production losses can be diminished by a heat recovery system on the stack gases, or on water blowdown, in the case of steam boilers.

The overall efficiency of the heat generation plant, which allows to qualify its performance, is defined as the ratio of the energy supplied to the distribution network divided by the fuel energy consumed.

The most important items in heat generation plants are the heat generators themselves.

1.1.1 Heat generators

The different kinds of heat generators are designed for different temperature levels. (see Fig. 1.1.F and Fig. 1.1.G).

Apart from direct electrical heating, where the plant efficiency is practically independent of the temperature

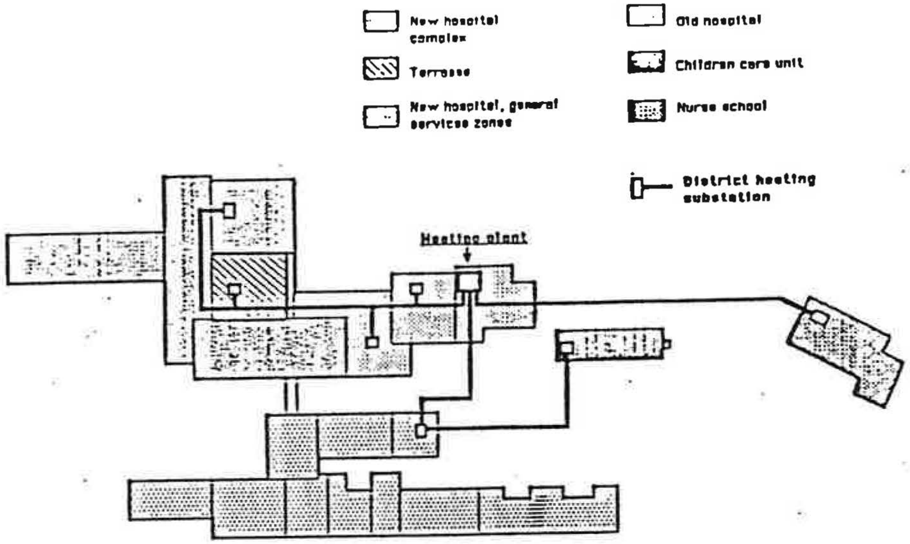


Figure : 1.1.A - Thermal Energy network

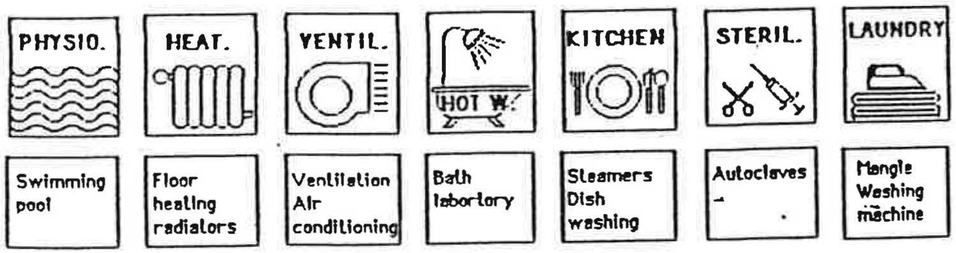
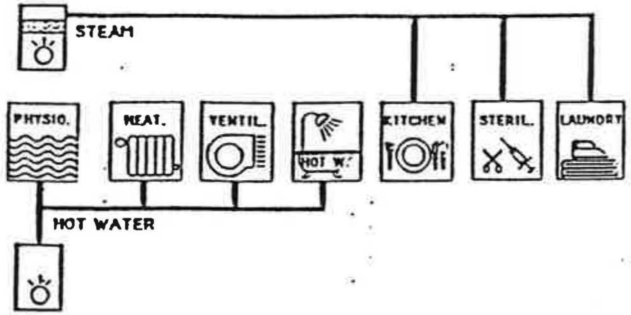
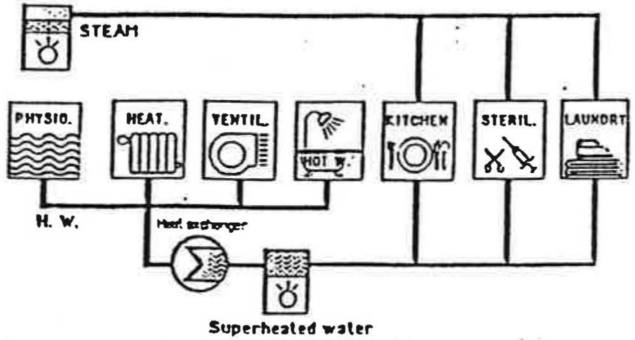


Figure : 1.1.B - Usual Energy end users in a hospital

1°) A hot water and a separated steam network



2°) A separated water network, with a subnetwork of hotwater, and a separated steam network, with the kitchen, sterilization, laundry using superheated water and steam.



3°) A main superheated water network, connected to hot water network and a steam network.

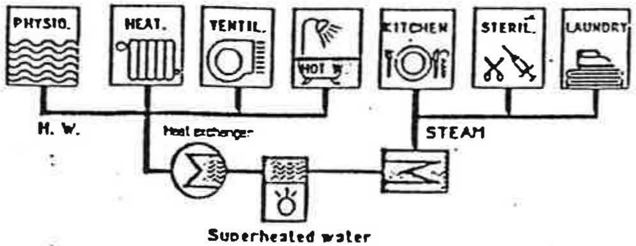
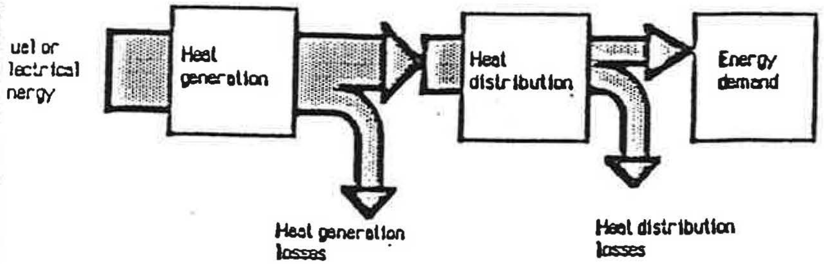


Figure : 1.1.C - Configuration of network system



gure : 1.1.D - Heat losses

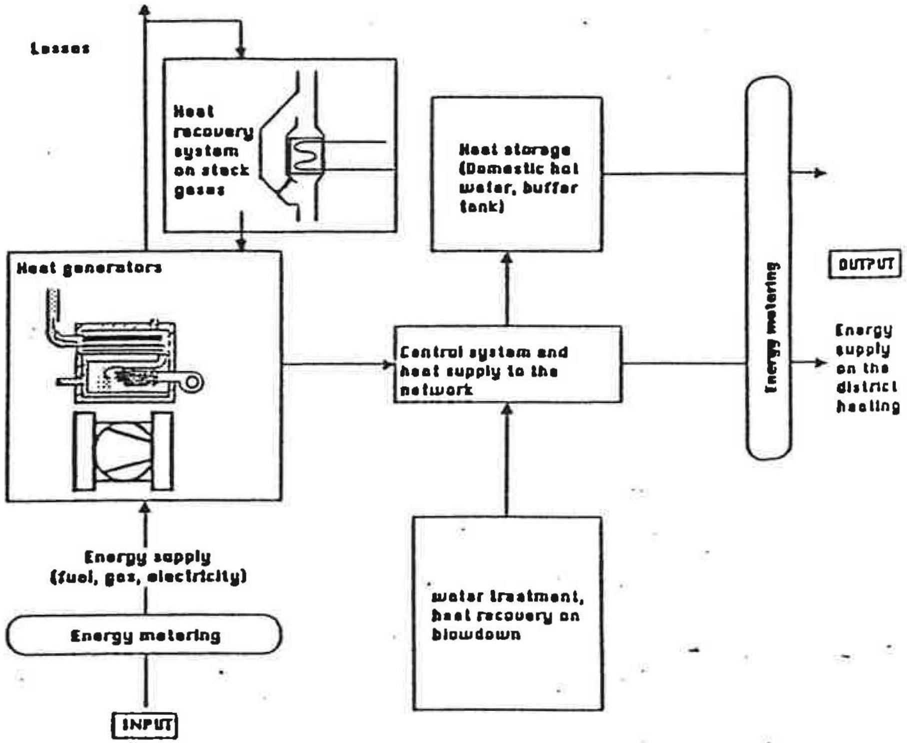


Figure : 1.1.E - Structure of the heat generation plant level, the temperature is an important factor for the energy production efficiency of all the heat generators.

Whenever as possible, one should not use high temperature heat generators to produce energy needs at a low temperature, like for example, steam boilers at high pressure producing heat for a low temperature space heating network.

The Figure 1.1.F shows an example of a middle temperature hot water system. The secondary loop (DHW, ventilation, radiators) needs water at 80 °C to be able to provide an indoor temperature of 22 °C at design conditions.

The Figure 1.1.G shows a steam system. There the mangle does need a temperature level of about 190 °C to operate. So, the steam pressure must be at 12 bar at least. During other periods, where the mangle does not operate, one could let pressure level come down to 150 °C.

One can see that the temperature levels required by each system are quite different.

Of course, quite often hospitals heat systems have not been separated in two different high and low temperature systems, for example, a superheated water network at 200 °C functioning around the clock, even if 200 °C is needed only few hours a day. By changes of the operational procedure energy can be saved.

Such a configuration is shown on the Figure 1.1.C., 3°. The addition of a heat recovery system on the exhaust of a boiler, lowering the exhaust temperature allows to increase significantly the boiler efficiency.

<u>1.1.2 Cogeneration systems</u>

Cogeneration, or CHP (Combined Heat and Power) production, may be described as a method by which electricity and heat are simultaneously produced in more efficient manner than if each were produced separately.

In a CHP plant, in fact, the heat released in power production is recovered and sent to the users, via a suitable carrier medium.

Hospitals are users with simultaneous and outstanding electricity and heat requirements; moreover, because obvious safety requirements and standard regulations, hospitals must be equipped with autonomous electric energy source, in order that no interruptions may occur in the essential power supplies, even in case of external grid black-out.

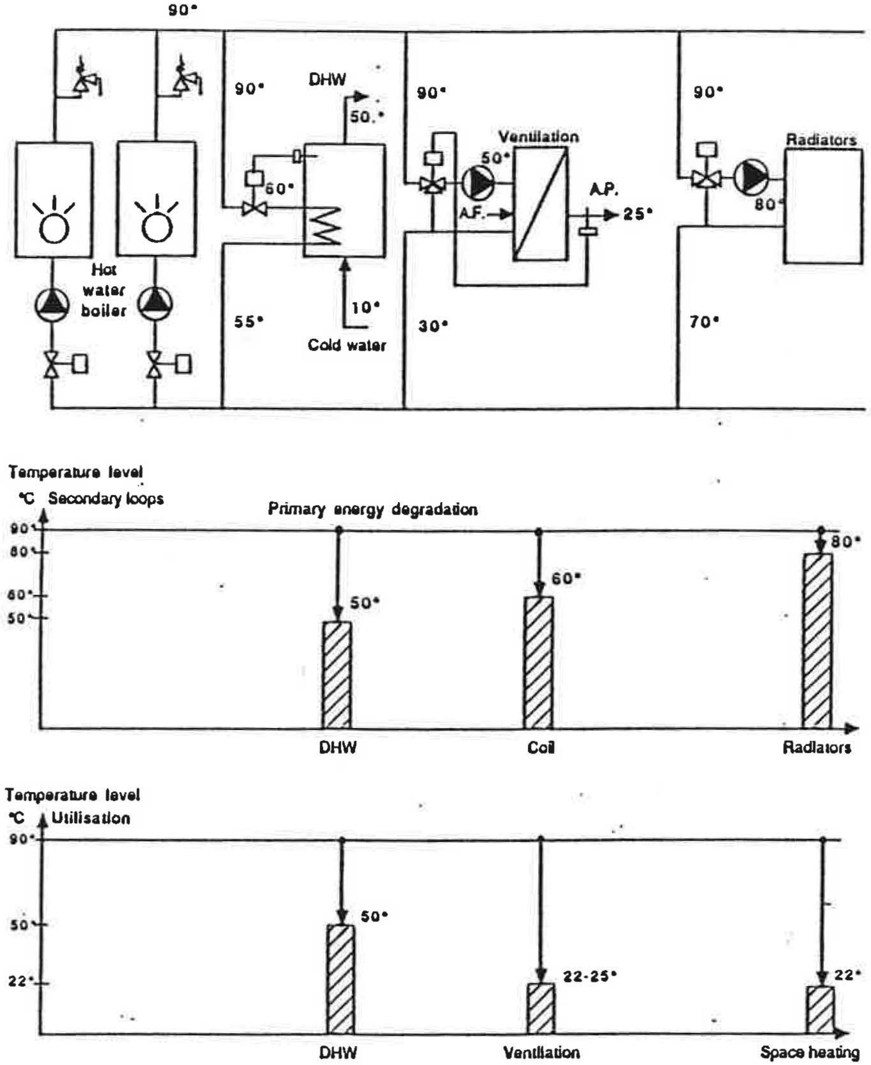


Figure 1.1.F. - Heat production and distribution at middle temperatura with hot water boiler

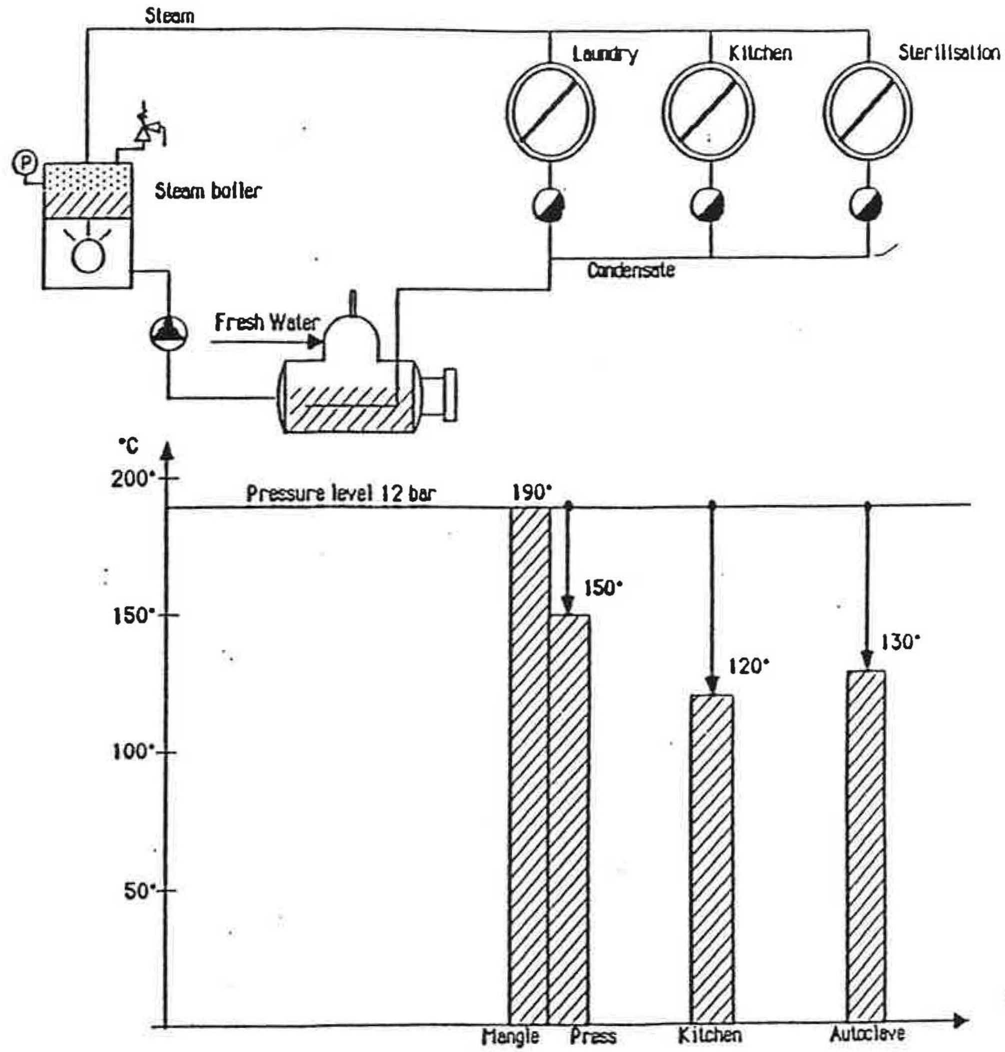


Figure : 1.1.G - Steam production and distribution, with steam boiler

From above considerations it follows, therefore, that a hospital is the typical case, where it could be convenient to make use of continuous autonomous power generation plants, with simultaneous recovery of discharged heat.

The study of cogeneration plants for hospitals is beyond the scope of this manual. Therefore, it will not be treated further. But one should keep in mind that hospitals are among the best suited users for such equipment. Therefore, when considering the replacement of old or inefficient heat generators, one should order a feasibility study for such possibility before taking any decision.

1.1.3 Control systems

These components are as important as the heat generators. The reason is that the control system must follow the actual energy demand in a hospital.

For example, the space heating and ventilation demands are primarily dependant on the outdoor temperature. The control system computes a proportional energy output based on the outdoor temperature. This computed energy output must be of the same magnitude as the actual energy demand. If it is higher, the energy supplied by the heat production system will be too high and will result in a higher temperature than required. In this Booklet, it is mainly the control of the heat generators system which is treated.

There are dedicated controls for the heat generators, which may or may not have a direct relationship to other portions of the control system. It insures a sufficient temperature or pressure level of the heating fluid to be distributed to the district heating network. Much energy can be saved with proper control because the standby losses can be reduced with the help of the right control strategy in varying the pressure or temperature time patterns.

For example, in Figure 1.1.F, a good control strategy would be that the boiler follows the temperature level required by the ventilation coils and the radiators. This would allow a reduction of the boiler losses, as it would be at a lower average temperature.

1.2 Strategy

1.2.1 Strategy at plant level

The goal of this section is to provide guidelines to reduce the energy consumption (fuels and electricity) of the heat generation plant.

The energy consumed by the heat generation plant is equal to the sum of heat furnished and of the heat generation losses.

To reduce the fuel energy consumption, one has to reduce the losses occurring during the heat production and/or to reduce the heat demand.

Emphasis is put on the reduction of the heat generation losses (Fig. 1.2.A), guidelines to reduce the heat demand by the heat are treated more in detail in the part heat distribution, and in Booklet III.

1.2.2 Efficiency, measurement, target values.

In the heat generation plant, before taking action, one has to determine its overall efficiency in order to be able to gratify its performance and compare it with target values.

1.2.2.1 Efficiencies

The overall efficiency of the heat generation plant is defined as the ratio of the heat furnished to the distribution network divided by the fuel + electrical energy consumed.

$$\eta_{pl} = \frac{Q_{pl}}{Q_f}$$

In a heat generation plant, the overall efficiency is dependant on few parameters like:

- Boilers efficiency, boiler group control system
- Efficiency of a possible heat recovery system
- Blow down losses (especially in steam systems).
- Losses of the primary network in the plant.

1.2.2.1.1 Boilers efficiency

The conversion of the fuel energy into useful heat is accomplished with some losses. For example out the 11.7 kWh of chemical energy contained in a kg of light oil, only part

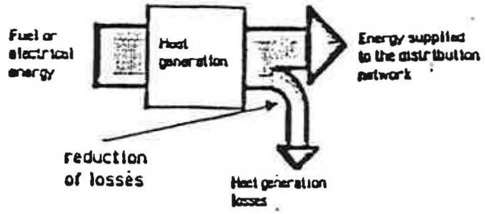


Figure : 1.2.A - Heat generation losses

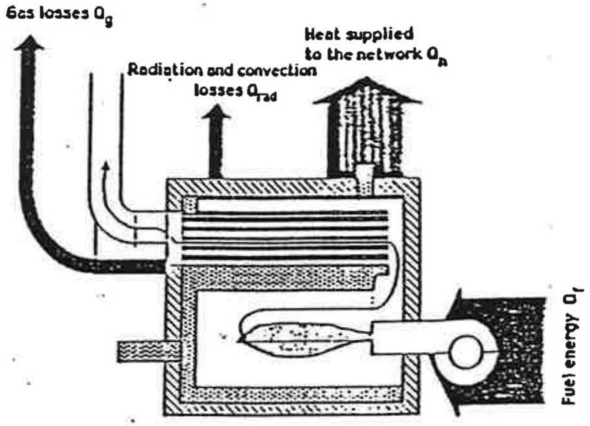


Figure: 1.2.B - Energy flux in a boiler

of it will be actually transformed into useful heat (between 8 and 10.8 kWh), the rest of it being losses (Fig. 1.2.B).

The ratio of the useful heat delivered by the boiler to the chemical energy contained in the fuel is the overall boiler efficiency.

The yearly efficiency of the boiler is equal to the ratio of the useful energy delivered to the distribution network to the chemical energy consumed (fuel consumption):

$$\eta_{pyr} = \frac{Q_n}{Q_f}$$

This value is difficult to monitor directly because of the need of special instruments like energy meters if one wants to measure accurately the energy supplied. But one can calculate the efficiency with some indirect methods.

The value of the annual efficiency of a boiler is mainly dependant on four parameters:

- Excess air (CO_2 content): too much combustion air leads to higher stack gas losses.
- High stack temperatures, mean an increment of the stack gas losses. This temperature is dependant upon the fluid temperature and the area of the heat exchanger of the boiler and the air and fuel flow rate.
- Load factor: the higher the load factor, the higher the annual efficiency. This factor is dependant upon the power of the boiler, and on the power demand. The design approach is to match output with heating demand, avoiding oversized units.

  It can be changed through operational changes, or such techniques as derating of the boiler.
- Standby losses: can become dominant when the boiler is oversized. There, losses are also characteristic of the boiler type and cannot be changed without a modification of the boiler or of water or steam temperature level.

<u>Calculation of the boiler efficiency</u>

To determine boiler efficiency one has to measure first stack gas losses and radiation losses.

The combustion efficiency is equal to the ratio of the fuel energy consumed, minus the gas losses divided by the fuel energy consumed.

$$\eta_c = \frac{Q_f - Q_{st}}{Q_f} = 1 - q_{st}$$

where q_{st} is the ratio $\frac{Q_{st}}{Q_f}$

The steady state boiler efficiency is equal to:

$$\eta_b = \frac{Q_f - Q_{st} - Q_{rad}}{Q_f} = 1 - q_{st} - q_{rad}$$

where q_{rad} is the ratio $\frac{Q_{rad}}{Q_f}$

Efficiency of a boiler over a period of time is as follows:

a) One-stage boiler

For this kind of boiler the efficiency is equal to:

$$\eta = \eta_b \cdot \frac{1 - q_m/w}{1 - q_m}$$

where:

q_m = standby losses
w = load factor of the boiler

q_m and w have been measured

b) Two stage boiler

The efficiency of a two stage boiler is given by the following formula:

$$\eta = \frac{\dfrac{w_1 + w_2 - q_m}{1 - q_m} + w_2 \cdot (\eta_2/\eta_1 \cdot q - 1)}{w_1 + w_2 \cdot q}$$

where:

q = ratio of the oil consumption of the second stage to the first stage
η_1 = steady state boiler efficiency of first stage
η_2 = steady state boiler efficiency of second stage
w_1 = load factor on first stage
w_2 = load factor on second stage

c) Modulating boiler

There is no simple way to determine the boiler efficiency over a given period.

1.2.2.1.2 Heat recovery system

In case there is a heat recovery system, one has to check wether its operation is optimal. The efficiency of the plant depends on it.

1.2.2.1.3 Blowdown system

In steam generation plant, blowdown is an energy consumptive process. It is important to check wether the blowdown flowrate is not too high, and then if it is not possible to save energy by a recovery system, allowing to preheat the feed water, or the DHW system (see also Booklet III, Chapter 4).

1.2.2.2 Measurement and target values

In order to be able to analyze the plant quality one must proceed to some measurements.

There are different levels of measurements:

- Short duration measurements like stack gases temperature, unburnt gas content, liters of feed water consumed per fuel unit delivered.
  These measurements will allow to find out the boilers efficiency in steady state, and the quality of the steam feed water system.

- Longer duration measurements like load factor measurement, energy metering.
  These method will allow to understand more in detail and to estimate the overall heat generation plant efficiency over a given period of time.

Consequently, one has to differentiate two levels of target values:

Short measurement	Long measurement
Results	Results
steady state boiler efficiency	overall plant efficiency
radiation losses or standby losses of the primary system	

1.2.3 Analysis, levels of actions to be taken

To be able to assess the heat production efficiency and compare it with target values, one must begin by maintenance and tune-up of the heating plant and then compare the steady-state values of the efficiency of the heat generators with the target values in § 1.3.1.2.

This comparison gives a first indication of the extent of the losses due to the heat generation plant.

Once the efficiency has been determined, the next step is to take some measurements of the operating conditions, which will also provide a basis for a change in the operating conditions.

1.2.3.1 Maintenance and tune-up

It consists in simple actions such as checking and setting the CO_2 content in the stack gases of a boiler, setting of the stack gas temperature by adjusting the fuel flow rate, soot cleaning, checking proper functions of the control system, of the valves, etc.

By these kinds of actions, energy savings can be achieved without any long analysis, or any investment. It is the first priority of action before any other.

There is no use to take measurements if the various components of the heating plant are not in good operating condition. For example, it is useless to measure the load factor of a group of boilers, if they are all not in good operating condition.

Indeed an analysis based on the results from measuring a deficient system might be misleading.

If, in the above cited group of boilers, some valves are leaking, when the heat demand is low, a measurement would lead one to believe that all the boilers are always in operation even though they are not.

This approach is explained in detail in § 1.3.2.2. Action can be taken without any delay.

The next audit action is to see whether any operational change can help save energy.

1.2.3.2 Operational change

Once the checking, maintenance and tune-up are performed, the next step is to analyze whether the heat production is matching the demand. In other words, the approach consists of measurement of the heat demand, the temperature and the pressure required: then checking if the setpoints are correctly adjusted, and if the number of boilers in operation is not too high when compared with the power demand.

Before deciding any operational change, a careful analysis must be done. At this level detailed measurements of the load factor and of the heat generators analysis of the different operating conditions, will provide the information as to what operational changes, if any, can be realized.

1.2.4 Examples

1.2.4.1 Operational changes of superheated water boilers without modification of the heat demand

In 350 bed hospitals, with 4 superheated water 2 two-stage boilers, the heat demand has been recorded on an hourly basis.

The results are shown on the Figure 1.2.C.

On this Figure, one can see that peak heating power demand never exceeds 1 850 kW.

The total power of the four boilers is 5 400 kW.

That means that only two boilers should be in operation.

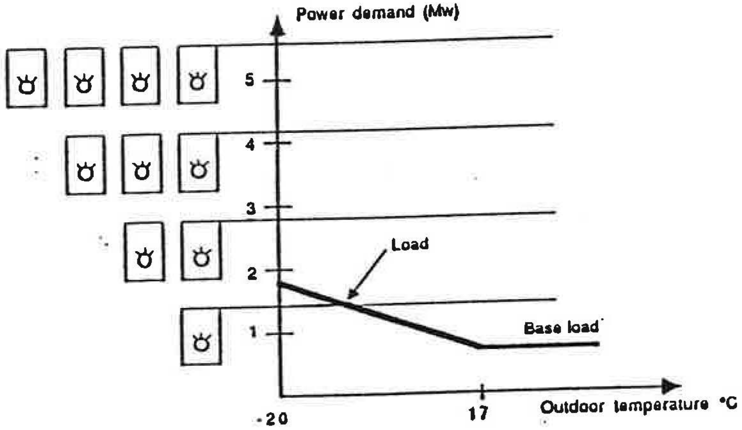


Figure: 1.2.C. - Seasonal adaptation to the load

How much energy savings can be achieved through such an operational change?

Depending on the boilers characteristics, a gain of 2 to 5 % can be achieved by this change.

In this case, the fuel gain represents 75 000 l per year.

The higher the standby losses, the higher the gain.

1.2.4.2 Energy saving in a steam generation plant

In a usual case, there are three kinds of steam consumers:
laundry, food preparation, sterilization. It is usual that the steam boiler is kept at the maximum pressure needed by only one of the consumers, i.e. laundry which usually requires 200 °C (see also Booklet V).

One can see immediately on Fig. 1.2.D that it is useless to keep the steam network at 12 bar when the laundry is not active, because the energy losses in piping, valves, boiler, and storage tanks are increased with temperature.

Example of a weekly steam consumption profile

In the case of this hospital, by measurement of the boiler load factor and by determine the steam pressure demand pattern, it could be shown that one could change the pressure set point during the period when the laundry was not in operation. This allowed one to keep the boiler pressure at a lower level most of time. In this way, the network losses were reduced, as well as the boiler losses (see Fig. 1.2.E).

The energy saving through such an operational change range between, 2 and 10 %.

That is possible without affecting the steam consumer habits.

All details about the method used to achieve these energy savings are explained in § 1.3 and § 1.4 of this chapter and partly in other chapters.

1.3 How to save energy with minor changes

1.3.1 Maintenance (Tune-up)

Very often, some components of the heat generation plant are not functioning properly.

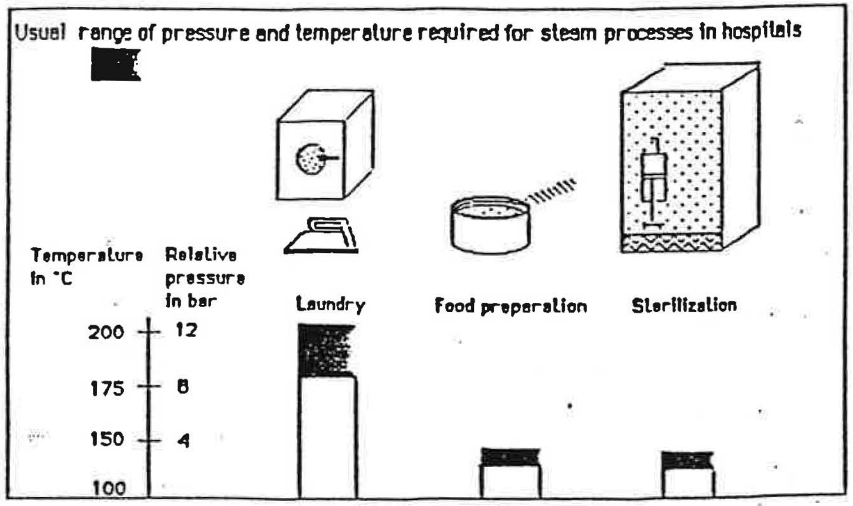


Figure : 1.2.D - Usual range of pressure and temperature required for steam processes in hospitals

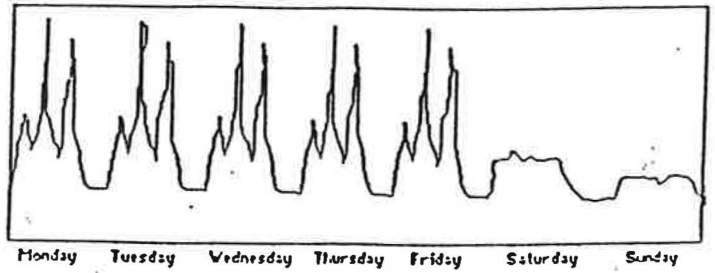


Figure : 1.2.E - Example of a weekly steam consumption profile

The reasons generally can be traced to:

- lack of maintenance
- poor tuning
- some other reasons like bad design, etc.

The following information is to provide help in the maintenance of the different components of the heat generation plant.

It is essential to follow the complete procedure, in order to avoid forgetting any important step.

After the completion of this part (§ 1.3.1) it is advisable to go on with § 1.3.2 and § 1.4.

1.3.1.1 Control system

1.3.1.1.1 What to do and how to do it

This part of the maintenance procedure is essential. It should be done carefully. If the control system does not function properly, you cannot get good efficiency from the heating plant. You must check carefully all the different operating conditions of the system, such as the first and second stage switches that control the boiler, and if the set temperatures and or pressures match the actual values observed, etc.

You must understand the different operational states that the control system should achieve. That knowledge will help you to analyze the results of the measurements (see part operational changes).

1. Switch points checking:
   Check the proper functions of the boiler control.

a) One-stage burner:

Check the on and off switching temperature control for proper functioning.
This must be done by an observation of the on-off cycles of the burner.

b) Multistage burner:

Check if the different stages of the burner operation really take place as expected, and to make certain if is not simply locked on one stage.
Try to make it work by changes in the set temperatures.

c) Modulating power:

Check the control of the modulating system. If you increase the set temperature, it should increase the fuel and air flow rate. If you decrease the set temperature, it must not switch off unless the power requirement goes down to the minimum adjustable power.

2. Set temperature:

Check if the set temperatures are not adjusted too high as compares to the set values of the distribution network.

1.3.1.2 Boilers

1.3.1.2.1 What to do and how to do it

This part applies to all kinds of boilers, and provides guidelines for:

- checking proper functions
- efficient tuning of the boilers, with a method to achieve a maximum efficiency without operational change or modification.

Even if the tuning of the boiler is often done under contract by servicing groups, this information provides arguments to convince the contractor to achieve higher efficiency.

Any improvement of performance at this stage is free of cost and may allow one to save several percent of the annual energy consumption.

The first step is to start with a general function checking;
the second step is to check the soot level;
the third step is to proceed to tune-up.

A) Proper function checking

Listed below is a checklist for oil and gas boiler maintenance.

It is recommended to install "on time" meters on each boiler for each stage (if there are more than one). In the case of variable flow rate, one has to install a fuel meter (see § 1.3.2.2.2).

Oil system

Jobs to be done on the oil burner:

- check burner motor and ventilator
  See if the motor is rotating properly and if the ventilator is clean. In case of dirt buildup on the ventilator the air flow rate would be too low, leading to a rich combustion mixture.
- check air setting adjustment of multistage or modulating burner
  Look to see if the command system for the air setting changes its position when the power demand changes. The air damper should give a larger aperture when the second stage is switched on, or when the modulating power increases.
- check burner nozzle position setting on multistage or modulating burner
  The nozzle and/or burner component must change its position while switching on another stage. Check whether this is still in an operating condition, otherwise, the combustion efficiency can not be at its optimum value.
- check ignition and ignition control
- check fuel pressure
  Pressure control valve and oil pump are important components. Check if the pressure is as per specification, and if it remains constant while switching from one stage to another.
- check and clean pump filter if needed

Jobs to be done on the boiler:

- check switching points, function of temperature controls and safety temperature limiters
- check function of pressure control valves
- check function of low water alarm
- check refractory lining (if any) for cracks and damage
- clean boiler inside and outside. (see effect of soot cleaning)

Electrical function test:

- check contacts and relays
- check function of warning lights
- check emergency stop for function.

Gas system

Jobs on the gas burner:

- check burner motor
- check ignition and ignition control
- check burner pipe and flame pattern.

Jobs to be done on the boilers:

- check switch points and function of temperature controls, and safety temperature limiters
- check pressure relief valves
- check function of low water alarm
- clean boiler inside and outside

Jobs to be done on the fittings:

- check burner and main valve
- check any other gas valves and pressure governors; adjust, if necessary.
- check the pressure before and after the pressure regulator, and see whether it remains constant when the gas flow rate increases.
- check pressure gauge and stopcock
- check fittings for leakage

Electrical function test:

- check contacts and relays
- check pick up time of the thermal trigger
- check warning lights lamps for function
- check emergency stop for function

B) Effect of soot cleaning on efficiency of oil-fired boilers

The cleaning of an oil-fired boiler is very important, because a clean boiler has a better efficiency. The cleaner the boiler, the lower the stack gas temperature (see Fig. 1.3.A). It should be done as often as possible.

Open the boiler when it is off and cold. Check the inner surface for soot thickness.

If the soot thickness is beyond 1 mm, then it is profitable to get it cleaned.

After cleaning the oil-fired boiler a decrease of 20 to 50 °C in the flue gas temperature occurs, leading to an increase of 0.8 to 2.5 % in the boiler efficiency. Unfortunately the effect of boiler cleaning decreases with time, and after three months the gain in efficiency has been again lost. The more often the boiler is cleaned, the better will be the efficiency. For large oil-fired boilers, a cleaning every month is economically profitable.

C) Boiler Tune Up

Once you have gone through the maintenance and proper functions checklist, it is necessary to tune up the boilers in order to increase the combustion efficiency. It can be achieved by:

a) decrease the flue gas temperature (+ 1% for a 20°C decrease)

b) decrease the air excess (increase the CO_2 content of the flue gas without reaching the generation of unburnt gases)

For example, if the temperature of the flue gas is 200°C and the CO_2 content is 9 %, then etach = 88 %, by an increase from 8 to 13 % CO_2 one reaches almost 92 %, which is a 4% increase in efficiency of the boiler.
Any improvement at this level is free of cost except for the tune up labor.

As one can see in the Figure 1.3.B, the more the CO_2 content and the lower the stack temperature the higher will be the combustion efficiency. But the possible stack gas temperature are dependant of the characteristics of the system.

However, the stack gas temperature reached are dependant on:

a) the water or steam temperature in the boiler, determined by the temperature level required

b) the heat exchange coefficient between the combustion gas and the water or steam determined by the characteristic of the boiler

c) the air flow rate determined by the power level to produce

d) the fuel flow rate

Here one has to differentiate between one stage, multistage and variable flow rate burners.

Usually the difference between stack gas temperature and the water or steam temperature is 40 to 120 °C. If the difference is larger than 120 °C, then something must be done to decrease this difference.

There are mainly four kinds of heat generation systems using boilers.

For each configuration, the tune up method is different. The specifications for tune up are outlined in Fig. 1.3.C.

The reasons why the stack gas temperature are too high and when it is possible to decrease this temperature are outlined below.

There are basically four reasons why the combustion efficiency is reduced:

1. soot

   Soot cleaning is needed

2. scaling

   This problem may occur especially in steam boilers. Scaling affects the heat transfer through the boiler walls. This causes higher stack gas temperature and might lead to damage of the tubes or walls because of the high wall temperature.

   Unfortunately, scaling is almost impossible to detect before boiler disassembly, water impurities is an early warning sign.

3. air, fuel flow rate too high

   Air and fuel flow rates are too high (once points soot and scaling have been checked). In this case, one has to check whether the boiler has a high load factor.

   This can be done in winter during the early morning time when the demand is maximum or more extensively like explained in § 1.3.2.3.

   In the case of a group of boilers, with a switch on in sequence, one can reduce the fuel and air flow rate as low as possible so as to produce the temperature.

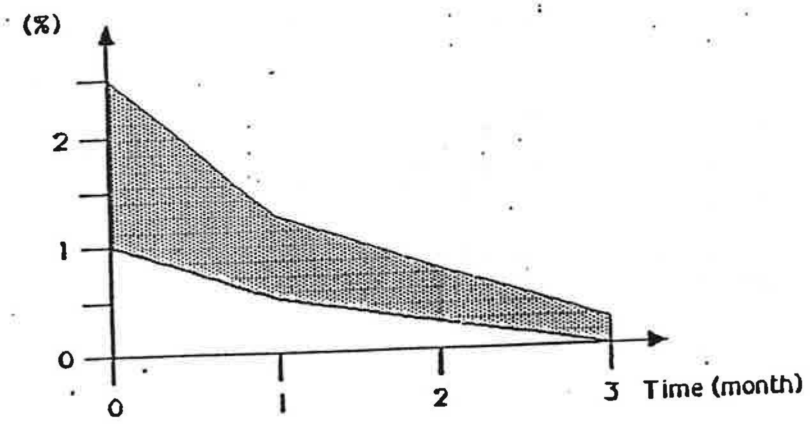


Figure: 1.3.A - Gain in efficiency after boiler cleaning

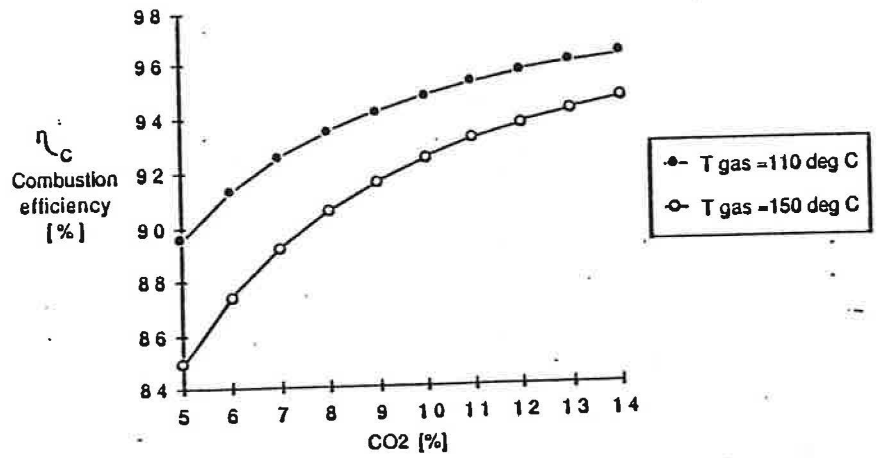


Figure: 1.3.B- Combustion efficiency as a function of the CO_2 content

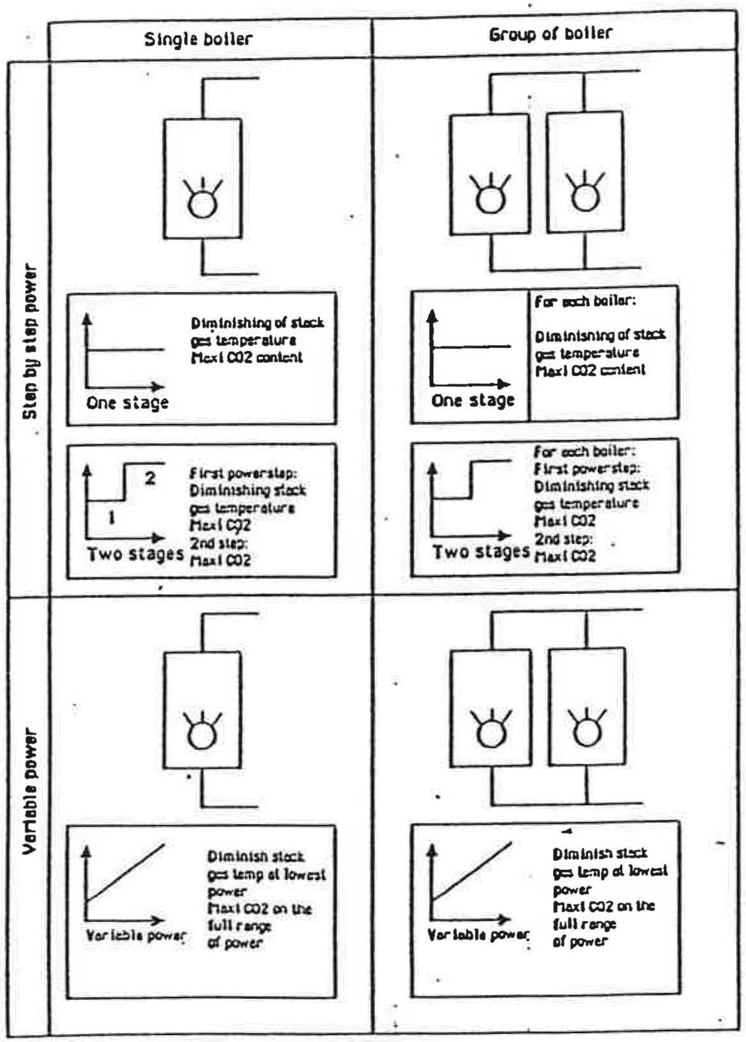


Figure: 1.3.C - Heat production configuration

If the load factor is no more then 50% during this period, one can diminish the fuel flow rate and the air flow rate.

This will decrease the stack gas temperature and increase the load factor of the boiler leading to an increase of the boiler efficiency.

4. boiler characteristics do not allow a high efficiency

If it is not possible to decrease fuel flow rate and still keep a low CO content, it is because the design it self does not allow a better efficiency.

You have to keep in mind that it is not possible to reduce drastically the stack gas temperature. The characteristics of a boiler determines the heat exchange rate and accordingly, directly influence the stack gas temperature.

The geometrical characteristics of a boiler restrains the minimum fuel flow rate below which combustion will be incomplete and the nozzle size restricts the minimum fuel flow rate where proper breakup of the fuel and mixing with the air can take place.

If after a trial following the tune-up procedure, you can not reach the range of combustion efficiency in the diagrams (see Fig. 1.3.E and 1.3.F), then try to find out whether it is really due to the boiler characteristics.

Technical data about the particular boiler will help to make rating evaluations.

For example, if the stack gas in the technical data is beyond 200 °C for the fuel flow rate you have, you will not be able to derate the burner in order to get lower stack gas temperature. If you try to derate further, it is quite likely that there would be some unburnt gas produced.

In order to reduce the stack gas temperature, two kinds of modifications are possible:

a) to add baffles in the boilers itself, ask the manufacturer whether this can be achieved

b) to add a heat recovery system (see modification section)

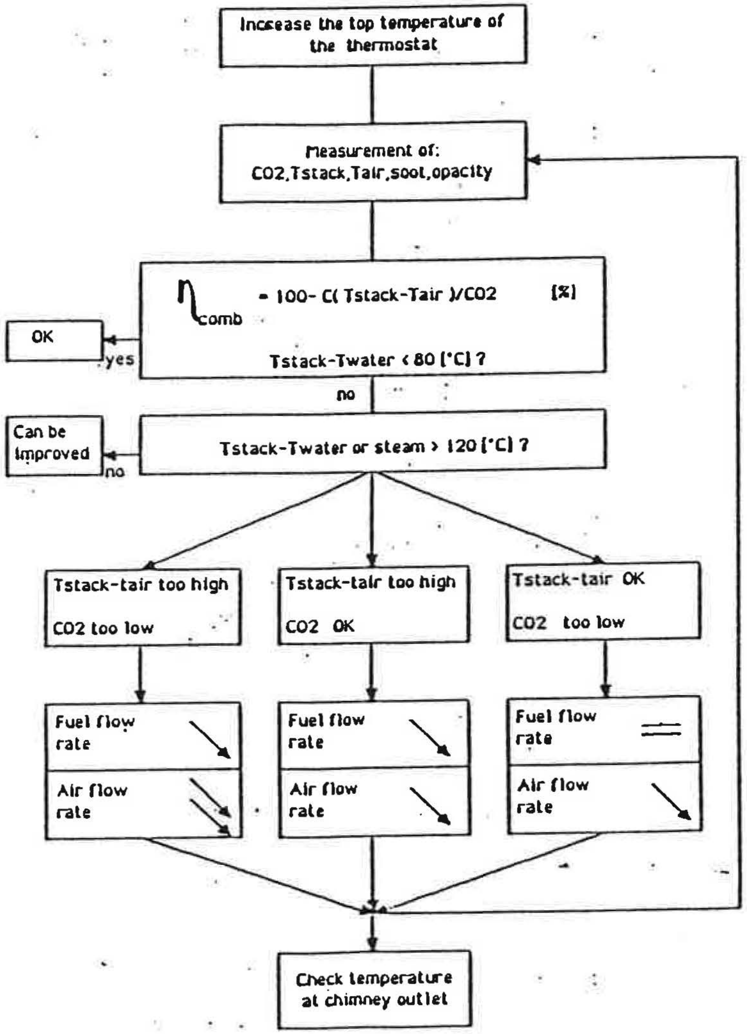


Figure: 1.3.D - Tune-up procedure

Combustion efficiency of an oil boiler producing water at 80 ° C

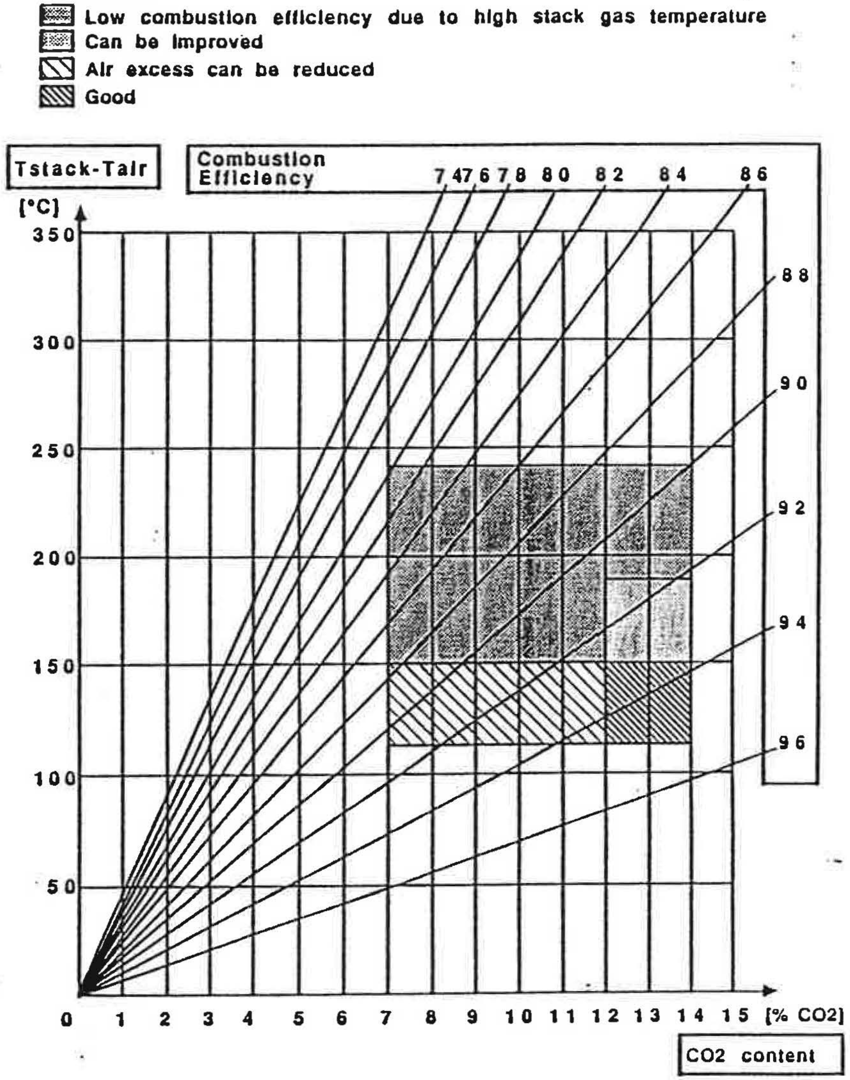


Figure 1.3.E - Combustion efficiency of an oil boiler producing hot water at 80 °C

Combustion efficiency of an oil boiler producing steam at 200 ° C

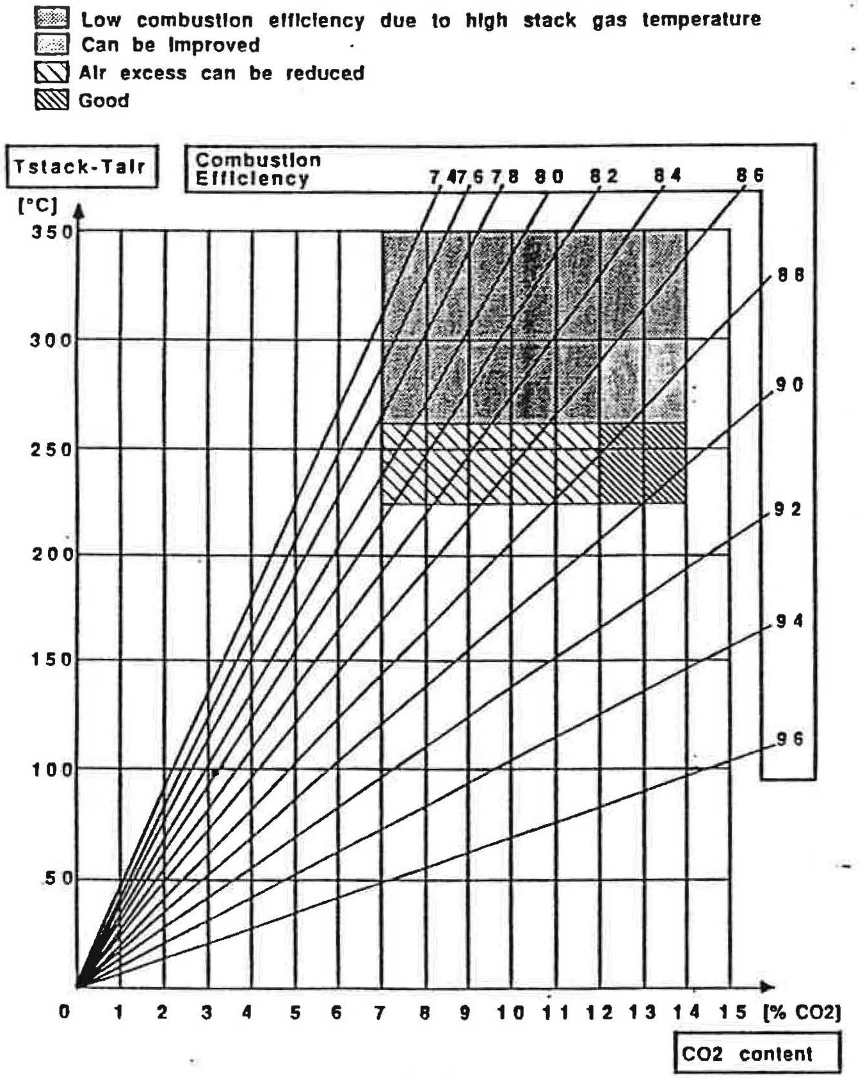


Figure 1.3.F - Combustion efficiency of an oil boiler producing steam at 200 °C

The Figure 1.3.D provided to guide the tune up procedure. Figures 1.3.E and 1.3.F give the combustion efficiency ranges for two categories of heat generators.

The first thing to do for the measurement of the stack gas temperature is to increase the difference between the switch off and on temperature if it is a one-stage burner. This is done to provide a longer measurement period. Let the boiler make a complete cycle and measure the on time.

Then proceed as per the flow sheet, but do not measure the CO_2 and temperature before half way through the burner cycle.

1.3.1.3 Heat recovery

1.3.1.3.1 Stack gas heat exchanger

Check to see that it is not dirty with soot.

In case of variable flow rate

Check the proper functioning of the control system for bypass. Does it really let the stack gas go through the bypass when there is no water flow in the heat exchange, and does it let the gas go through the heat exchanger when the water is flowing?

1.3.1.3.2 Feed tank

Check if there is any steam coming out of the feed tank exhaust pipe. If there is steam coming out in vast quantities, it means that the re-evaporated steam is not condensed in the feed tank (see § 1.4).

1.3.2 Opserational changes

There are two levels of action in a heat generation plant:

1st) Actions centered on the plant efficiency independently of the demand

2nd) Actions dependant upon the load pattern

The load patterns can be classified in two main categories: space heating, and technical heat.

1.3.2.1 Types of energy demand

1. Pure space heating
   In this case the energy demand is determined by the outdoor temperature. Knowing the thermal output of the different boilers in a group, it is possible to determine the number of boilers that have to be in operation at different periods of the year.

2. Pure technical heat
   In this case, the energy demand is not dependant upon the outdoor temperature. However, the demand varies following a definite time pattern. This data, once available, will help to improve the control strategy and the efficiency.

3. Mixed type load
   Some of the heat generation system produce for space heating as well as for technical heat. In this case both seasonal and daily variations must be taken into account.

1.3.2.2 Monitoring program and operational changes

One can divide the monitoring program into two levels.

The first level consists of a monitoring program for the boiler house and its components for each group of generators, with operational changes, and minor modifications. The different actions to be taken are the measurement of the standby losses which will allow you to determine afterwards the overall efficiency of the generators, the measurement of the water temperature in the heat generators that are not in operation and isolated by the control system , and the measurement of the preheating time and fuel consumed for it,which will allow you to determine if the boiler group losses are of importance.

The second level consists in a monitoring program of the heat demand at generators level. The actions to be taken are the measurement of the temperature and power demand, the operational changes that can be performed based on these measurements, and the monitoring after the operational changes (see also Booklet I).

1.3.2.2.1 What to do and how to do it

A) First level

Monitoring program for each group of generators, operational changes, and minor modifications.

Measurements of the boiler group characteristics.

1. Measurement of the standby losses

   This will allow you to determine afterwards the overall efficiency of the generators.

   The measurement of standby losses must be performed for each boiler at its lowest power and by isolating the boiler from the heating network. Be sure that there is enough water flowing through the boiler during the measurement period. There should always be enough recycled water circulated in order to avoid any damage to the boilers.

   a) One-stage or multistage boiler

   Leave the boiler operate in an isolated condition (not supplying energy to the network) and measure the fuel or gas consumed during this period (few hours).

   The burner on time will give you the value of standby losses.

   b) Modulation of the power

   Same as above, but you must measure the fuel flow rate.

2. Measurement of the water temperature of the heat generators that are not in operation, and isolated by the control system. Analysis, and possible modification.

   Very often the efficiency of a group of boilers is not as good as it could be, due to uncontrolled water flow through off boilers and poor control system.

   There are mainly three different kinds of boiler group arrangements :

   a) Parallel boilers without a flow control system (Figure 1.3.G).

   Water always flows through all the boilers even if only one is in operation. In this case, the losses are very high, and one should close the valves manually to isolate the boilers when their operation is not required.

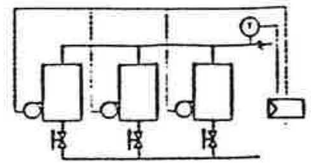


Figure: 1.3.G - Parallel boiler without flow control

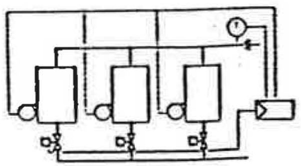


Figure: 1.3.H - Parallel boiler with flow control

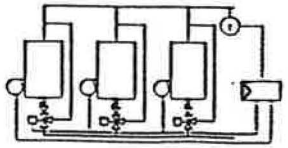


Figure:1.3.I - Parallel boilers with internal circulation pump

b) Group of boilers with one-way valves and a control system (Figure 1.3.H).

In this case, the water flows only through the boilers that are operating.
Unhappily, the check valves at the inlet of the boilers are very often leaking, leading to heat losses, and then losses in efficiency.

One has to check to see if these valves are really tight.

On the other hand one has to also check to see if the water flow rate is adjusted to coincide with the number of boilers in operation.

c) Group of boilers with internal circulation pump and three-way valves (Figure 1.3.I)

In the same spirit as in case b), one has to check whether the valves are really tight and if there is any uncontrolled water flow.

<u>Detection of uncontrolled water flow through the non operating boilers</u>

With the burner switched off and the control valves closed, measure the temperature after a long time in the boiler. If it is higher than the boiler room temperature it means that water is flowing through the boiler and is heating it.

If the boiler temperature is equal to the return temperature of the network, the losses caused by the leaks through the valve are equal to the radiation losses.

You can evaluate the losses due to the leakage following this procedure:

One can estimate the radiation losses:
radiation losses = X · standby losses, where
X varies between 1.00 (new boilers) and 1.5 (old boilers)

Uncontrolled leakage losses:

$$\text{leakage losses} = \frac{T_{bOFF} - T_{air}}{T_{bON} - T_{air}} \cdot \text{rad. losses}$$

where:

T_{bON} = boiler water temperature during a normal operation
T_{bOFF} = boiler water temperature when the boiler is switched off
T_{air} = boiler house indoor air temperature.

The first thing is to check whether or not the valves can be controlled in such a way that they really close properly.

For example, in case of a butterfly valve, the motor may not be adjusted to close the valve tightly.

Ask the control company to adjust the motor valve assembly in order to make the valve seal as designed.

If there is no progress, a second item to check is an estimate if it is economically viable to change the valves, and replace it by a poppet valve (see modification and substitution section).

3. Measurements of preheating time and fuel consumed for it

a) the boiler must be isolated from the network for a long time by manually closing the appropriate valve(s).

b) a measurement system for the fuel or gas flow rate must be in operation for this particular boiler (see measurement section).

c) you can preheat the boiler until it reaches the set temperature for

d) you have to compute the energy and time for the preheating

B) <u>Second level</u>

Measurement of the temperature and power demand.

Depending on the measurements techniques and on the kind of systems, different measurement methods must be used (Figure 1.3.J).

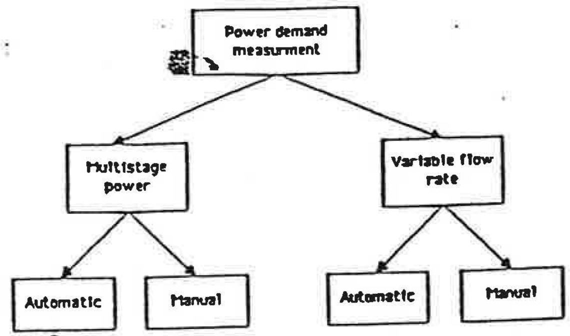


Figure: 1.3.J - Power demand Measurment

1. When should one measure?

The measurement should take place during the coldest period of winter if it is for heating and ventilation. Other periods of the year are suitable for measuring the non heating energy demands (for example, steam for kitchen, laundry, etc.)

2. How long?

To be relevant, the measurement should last at least two to three weeks.

3. Manual or automatic measurement?

If it is possible to get automatic data acquisition, it is a better way for the measurement and its analysis.

The reason is that electronic acquisition units allow one to measure every hour on a three weeks period, whereas a manual measurement can be done on a daily basis but not easily on an hour basis, because to write down every hour the readings of the energy demand personnel to be in the heating-room.

In a general way, one can say that a daily measurement applies quite well to space heating systems, because the load variations on a daily basis are not too high and are proportional to the inside-outside temperatures difference, but nevertheless, very big variations of the demand do occur with ventilation systems, especially when the control system is adjusted for different day and night operation conditions.

But for technical heat, like steam for laundry, food preparation, etc., the load variation based on a daily cycle are very high. It is most important to measure on an hourly basis in this case. Then the measurement by automatic data acquisition equipment is recommended.

A manual measurement can be done on a daily basis with the help of on time meters.

Automatic measurement involves the help of an engineering consultants but giyes much more accurate results by providing hourly information. This allows one to know exactly the peak power demand, and to take action on a sound basis.

<u>Stage-by-stage power boilers</u>

In this case, the power demand can be determined by the load factor measurement of each power stage of each boiler.

The functioning time indicated by the on time meters or the electronic data acquisition devices differs from one burner to the other.

Some of the possible 2-stage burner configurations are shown in Figure 1.3.K.

There are some other configurations, but one has to check for each case what an on time meter or electronic device will actually measure. One should pay attention to the connection of the on time meter. They are sometime connected to the switch which gives the signal for the burner but includes also the preventilation time which should not be included in the measurements. So one has to check that the on time meter measures really the time during which fuel is injected into the boiler.

<u>Manual measurement</u>

In this case, the load factor will be determined on a daily basis.

Procedure:

- Install on time meters as shown in "step by step power".
- Install a min-max thermometers on the North side far away from the building. Take care that it is not insulated at any moment of the day and for the whole year.

Week load factor:

- Write down the hours every week at the same time for each on time meter.
  The best time is around 4 p.m.
- Calculate the load factor for each boiler and for each stage as per specifications in "stage-by-stage procedure".
- Read the min and max temperatures.
  The average temperature is equal to:

$$T_{day} = (T_{min} + T_{max})/2$$

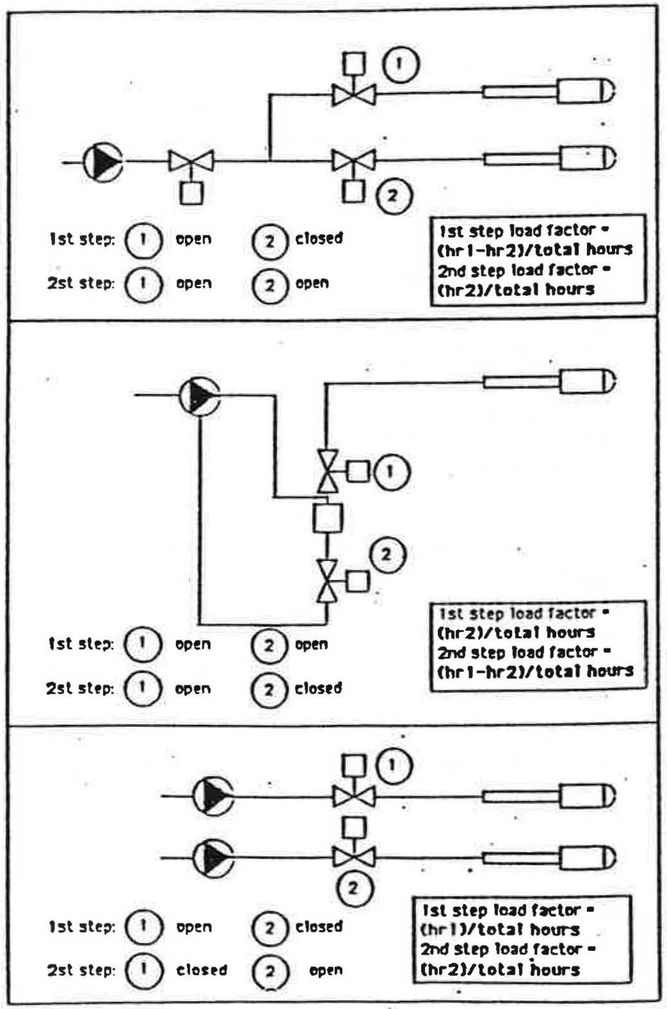


Figure: 1.3.K - Two stage burner configurations

The average weekly temperature is the average value of the daily temperatures of the week.

- Plot the point of the week in a chart (Figure 1.3.L).

Peak demand:

- On one week day, write down the load factors every hour.

- Then repeat the measurement every day for the two hours during which the load factor is maximum. Read the temperature at the same time and plot the point for each boiler and each stage, for the temperature at this time.

Automatic measurement (to be done with the help of an external consulting company)

- Connect a data acquisition units on each boiler and each power stage (see "stage-by-stage power").

- Take measurements for about three weeks, then perform the data analysis.
  Ask for daily as well as for peak demand load factor, and for overall load factor of the system.

Variable fuel flow rate boiler

In this case, one has to measure the fuel flow rate directly.

There are two kinds of burners :

a) Single oil pipe burner

   In this case one has to place one fuel meter in the oil supply line (Figure 1.3.M).

b) Double pipe burner (with by-pass)

   In this case two meters are required in oil supply and oil return (Figure 1.3.N).

   The fuel actually consumed is equal to the inlet flow minus by-pass flow.

Manual measurement

The same procedure as for step-by-step is used but the reading is in fuel volume instead of the on time.

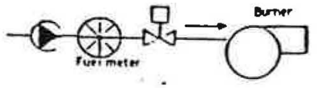


Figure: 1.3.M - Single oil pipe burner

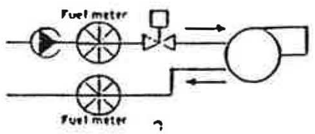


Figure: 1;3.N Double pipe burner

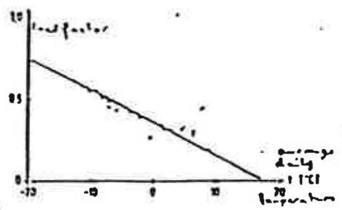


Figure: 1.3.L- Chart of the load factor

<u>Automatic measurement</u>

The fuel meters must be equipped with an impulse generator, then one can connect an electronic data acquisition unit on each fuel meter.
Then follow the same procedure as for the stage-by-stage.

<u>Operational changes in interrelationships with heat demand</u>

Once the measurement of the boiler group characteristics, and of the energy demand has been done, it is most likely possible to save energy by a decrease, or a variation of the time pattern of the energy demand.

Before starting this job, one has to go through the main distribution system.

One can separate demand into two kinds of time patterns:

- Seasonal variation related to HVAC systems
- Daily and weekly variations related to technical processes.

We first look at the HVAC type load.

<u>HVAC type load (seasonal variation, with morning peek)</u>

One can divide the actions in three categories:

- First a better management of the boiler group on a season base

  If the power demand is strongly dependant upon the outdoor temperature like for HVAC, it is beneficial to switch off the boilers which are not needed for the heat production during some periods.
  To know approximately when one has to switch the units on or off, the diagram shown in Figure 1.3.O must be plotted for each group of boilers.
  Once you know approximately when the switching time occurs, then you have a look on a min max thermometer and determine exactly the time when to do it.
  Keep a little bit of margin for safety reasons. Switch on a little bit earlier than the computed temperature.

- Secondly, a better management of the boiler group based on the fact that peak loads occur often at morning after the night set backs are switched off.

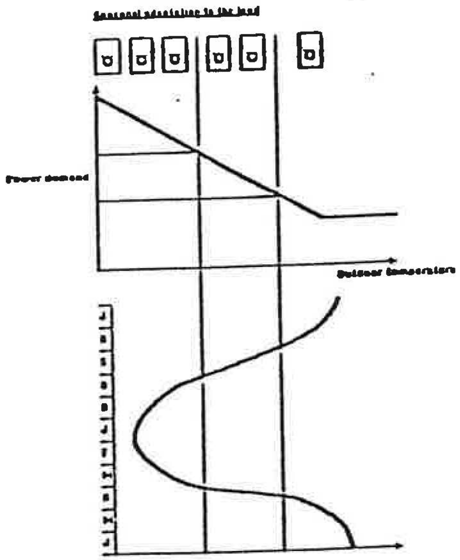


Figure: 1.3.0 – Seasonal pattern at the power demand

The first hours of the hospital day normally provide peak power demand as shown in Fig. 1.3.P. If the measurement shows that only one additional boiler is switched on at this time, it can be sound strategy to try to lower the peak loads of the different heating loops in order to avoid this boiler being put into operation for only half an hour of so (see Figure 1.3.Q).
Try to moderate the demand peak by shifting individual peaks in order to avoid to switch on a boiler only for a short time.
This outphasing is energywise profitable especially in the mid seasons.

- Thirdly, one can decrease the energy demand by an adjustment of the set temperature curves of the HVAC systems

In this case, an energy saving potential of 5 + 7 % for each °C decrease on the heating curve can be achieved (see Fig. 1.3.P).
One has to pay particular attention when changing the operating modes.
The new problem is that a temperature or pressure reduction may not be possible due to the heating network characteristics.
Indeed, if the flows in the network are not well balanced or if some heat exchangers are undersized, it might be possible that with a temperature and/or pressure reduction, the energy supplied becomes too low in certain areas of the hospital, and therefore the space temperature too low for comfort requirements.
This must be checked with a trial:

You apply the new control strategy, and measure the temperature of the fluid going to the space requiring heating or ventilation and compare it with the temperature before the reduction. Or in an easier way check the temperature level in the space where the energy is delivered with the help of a temperature and humidity recorder.

If it is lower than before the change, then you should see whether it is possible to increase the water flow rate from the heating plant in this particular loop, or then modify the control on the space heating network.
This is treated in Booklet III.

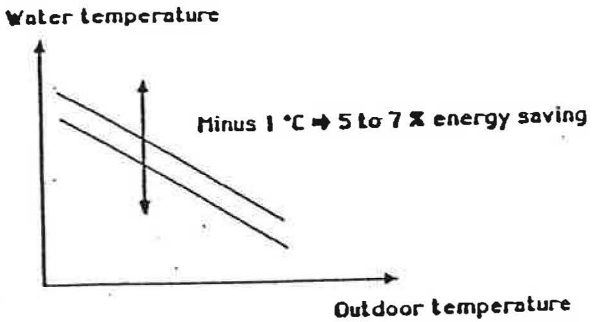


Figure: 1.3.P - Heating curve

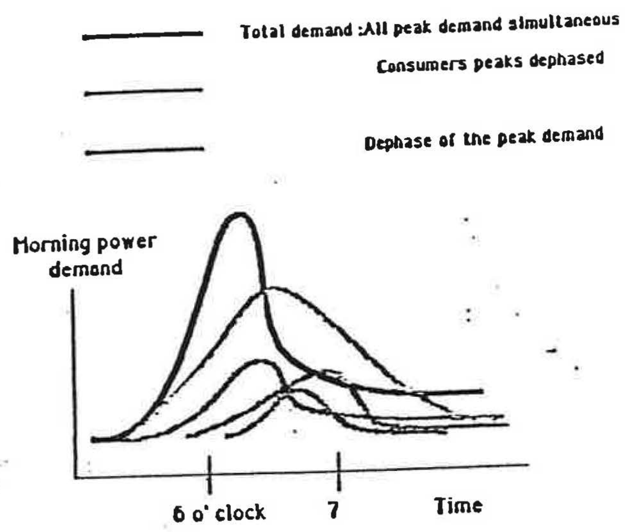


Figure: 1.3.Q- Morning peak power demand

Process heat type load (laundry, kitchen, etc.)

See also Booklet V.

When the power demand varies following a regular pattern during the day, it is possible to adjust the power, and temperature or pressure on the energy production side.

During the measurement period you have to collect some other data:
operating hours of the laundry, kitchen and sterilization, and the pressure or temperature required for them.

Based on the power demand and the operating hours of the different technical heat consumers, you can adapt the power production to the demand.

This part applies particularly to the steam and superheated water systems.

1. Plot the power demand measured on an hourly basis as in the format.

2. Plot the load factor of each boiler of a group.

   This shows how the control system drives the boiler group.
   If one of the boilers has systematically a load factor below 20 %, you must compute its efficiency for the period of measurement, based on the measurement of the standby losses, following the formula given in § 1.2.2.1.1, and

3. Plot the operating hours of the consumers and measure and ask for their temperature requirements.

4. Plot the minimum pressure or temperature required for all the consumers during a week, and then adjust the heat production to the demand with a programmable clock.

   This curve must be standardized in 3 typical days: Week days, saturdays, sundays.

   If the group of boilers produces heat for space heating as well as for technical purposes, the daily variations are combined with seasonal variations.

1.4 How to save energy with modification

1.4.1 Boilers

Even after operational changes, if you do not get good boilers efficiency, some modifications could be done:

- If you have measured very high standby losses (>2 %) you should check the boiler insulation and increase the level to limit the losses.

- If the temperature of the boilers switched off by the control system have a temperature near that of the return temperature, it may be useful to and replace the valves with poppet valves which are really tight.

- It could be economically sound to consider installing a stack gas heat exchanger if the stack temperatures are always more than 150 °C higher than the fluid temperatures. This has to be evaluated with the help of an engineering consultant because the investment is high in this case.

1.4.2 Steam plant

The peculiarity of a steam plant is that it is equipped with a feed tank:

If there is steam coming of the exhaust pipe of the feed tank, you can modify the return pipe. Instead of a single pipe, it is much more efficient to introduce re-evaporated steam in the feed tank through small holes in a manifold type arrangement (see Fig. 1.4.A).

Here again, one has to ask the help of an energy consultant, because there are some design problems (like noise in the feed tank, pressure problems,...) to be solved.

1.4.3 Substitution

If the steady state efficiency of a boiler is after proper tuning in the range of low combustion efficiency (see Fig. 1.3.E and Fig. 1.3.F), then one has to consider the possible replacement of such a boiler. Some evaluation aspects are explained hereafter.

Based on the difference in steady state efficiency between the existing boiler and a new boiler, one can compute the energy savings that would occur during a year. Then one can compute the potential money savings and estimate the payback period of a new boiler. These calculations have to be done with the help of engineering consultants.

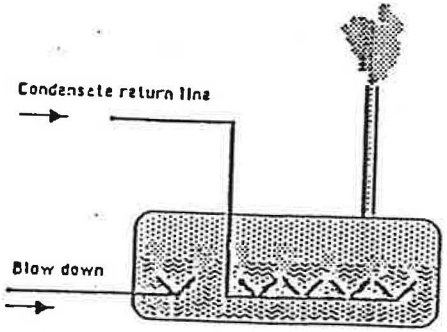


Figure: 1.4.A - Condensate return line arrangement

CHAPTER 2. HEAT DISTRIBUTION

2. Introduction

The energy produced by the heat generation plant is supplied to the consumers by the distribution network.The network must fulfill the requirements of the consumers in terms of flowrate and temperature.

The combination of these two problems makes design and control of the network a difficult task.

This part of the chapter deals with the distribution and its control system between the production and the consumption loads.

One can divide the actions in two categories:
with or without modification (see Figure 2.A).

2.1 Description

The main distribution network treated in this part is a system which does bring the energy from the heat generation plant to the different consumers. The different consumers have different time patterns, causing variation in the hydraulic and thermal conditions of the network.

In the lines some thermal losses occur. The more able the control system is to adapt the distribution network to the load, the more efficient it is (average line temperature reduced, resulting in a better energy efficiency).

The more insulated the lines, the less losses occur. The less duration of circulation the less pumping energy is consumed.

In this part, consideration is given to improve the distribution efficiency, as well as a discussion of the consumers effects on the heating plant performances, and the interactions between different energy consumers.

A detailed approach to the consumers efficiency is found in Booklets III and V.

2.1.1 Control system components

The most important items in the main distribution lines are the controller and their actuators. Valves moved by actuators under command of the control system makes the fluid in the network and the temperature vary as per the consumers requirements.

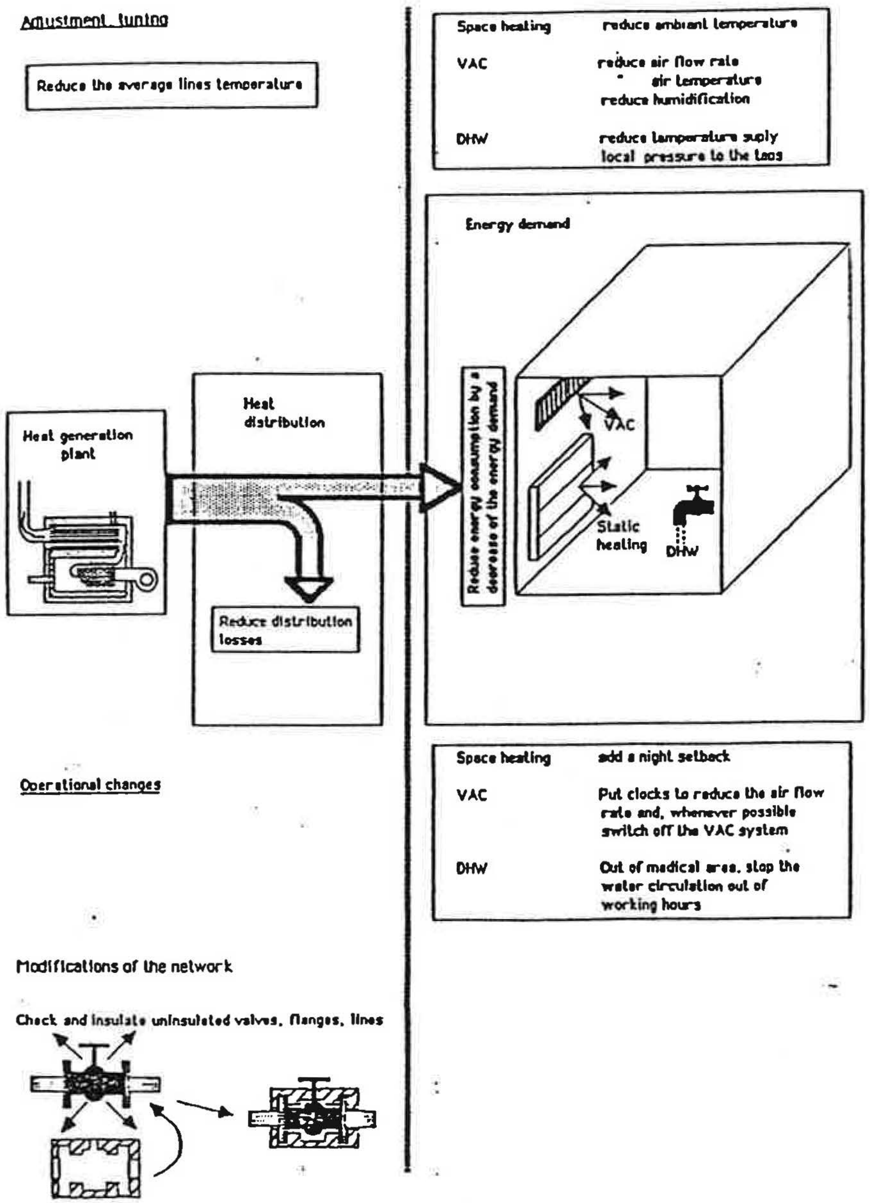


Figure 2. A. - Energy savings without modification of the distribution network

We show here only some aspects linked with operational problems.

2.1.1.1 Automatic Control Systems (principles)

Control systems are meant for the automatic maintain without human intervention of a temperature pressure or humidity at a set point whatever is the variation in the demand of energy.

How does it work?

A regulator measures pressure or temperature (the controlled variable) with a sensor, and compares it with the set point (Fig. 2.1.B).

It acts then on the control variable with a control actuator.

There are mainly two categories of control strategy in the distribution networks:

a) Fixed setpoint control systems like

- DHW temperature (Figure 2.1.C)
- steam pressure in a steam network (Figure 2.1.D)
- fixed temperature in ventilation systems (Figure 2.1.E)

b) Outdoor temperature dependant setpoints like

- space heating (Figure 2.1.F)

For some of the heat consumers, the setpoints, dependant on the outdoor temperature or not, can be changed with clocks that allows to reduce the setpoints during night time or week-end , like for example night set back in space heating (Figure 2.1.G), or night, week-end set back in steam network (Figure 2.1.H).

It might be necessary to buy a clock and an additional controller for that.

The kind of valves used are not all equivalent for their quality (i.e their leak tightness).

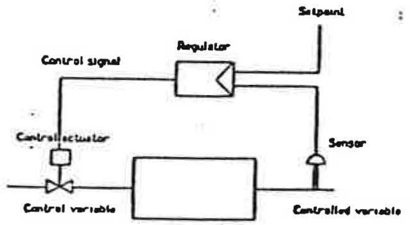


Figure: 2.1.B - Control system diagram

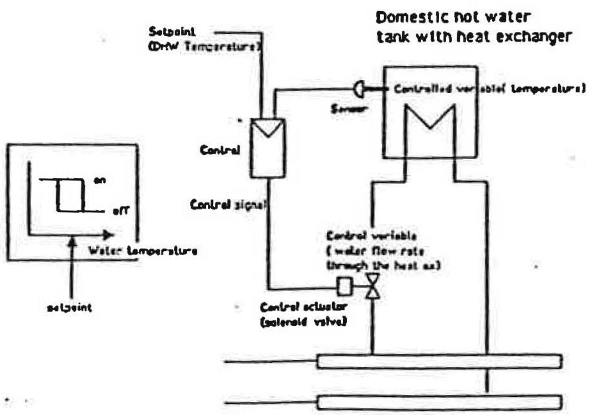


Figure: 2.1.C - Fixed Setpoint Control Systems for domestic hot water

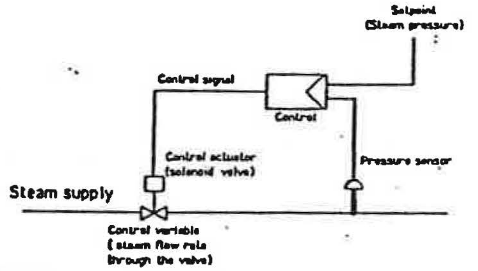


Figure: 2.1.D - Steam pressure control

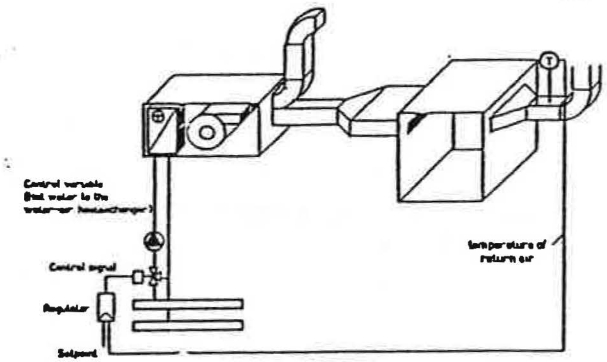


Figure: 2.1.E - Fixed temperature

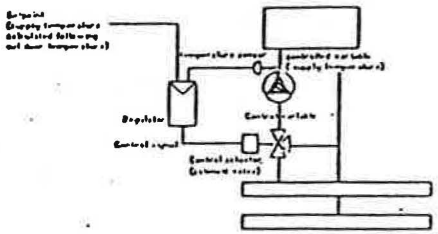


Figure: 2.1.F' - Supply temperature in function of outdoor temperature

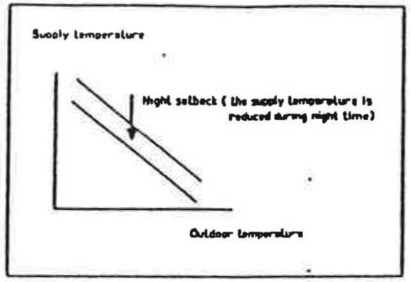


Figure: 2.1.G - Might set back

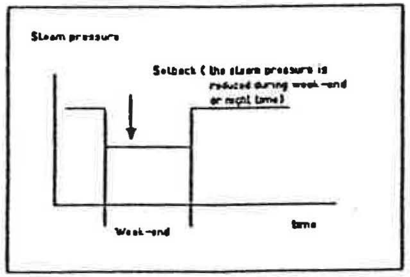


Figure: 2.1.H- Relet, week-end set back

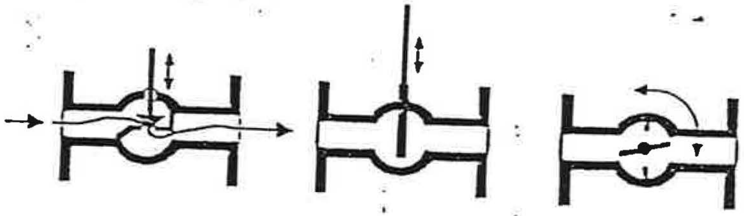


Figure: 2.1.I. - Kinds of Valves

One can identify three distinct kinds of valves (Figure 2.1.I): Poppet valves, Sliding vane valves and Butterfly valves. Their tightness can be classified as shown below.

Poppet valves	Sliding vane valves	Butterfly valves
they are usually tight	slight leakage increasing with time	hard to seal tightly

Depending on the desired control quality, some of these valves are inadequate, and can cause parasitic flows in the hydraulic network even when they are closed.

One should know that even with 1 % of its nominal flow rate, a coil supplies approximately 10 % of its nominal power.

This can happen very easily with butterfly valves which may allow parasitic thermosyphon flows during summer in the radiators network.

2.2 Strategy

Even though the goal of this manual is to provide guidelines for energy savings, never forget that the most important thing in a hospital is to provide safety and comfort at any time to the patients and the working staff.

Nevertheless you must operate the heating system as efficiently as possible, in order to reduce the energy consumption (Figure 2.2.A).

2.2.1 Information about the distribution network

In order to be able to achieve energy savings without affecting the comfort and services in the hospital, you must have a good knowledge of the heat distribution network.

That will help you in the analyze of the energy problems.

The first step is to identify the different lines of each network (steam, water).

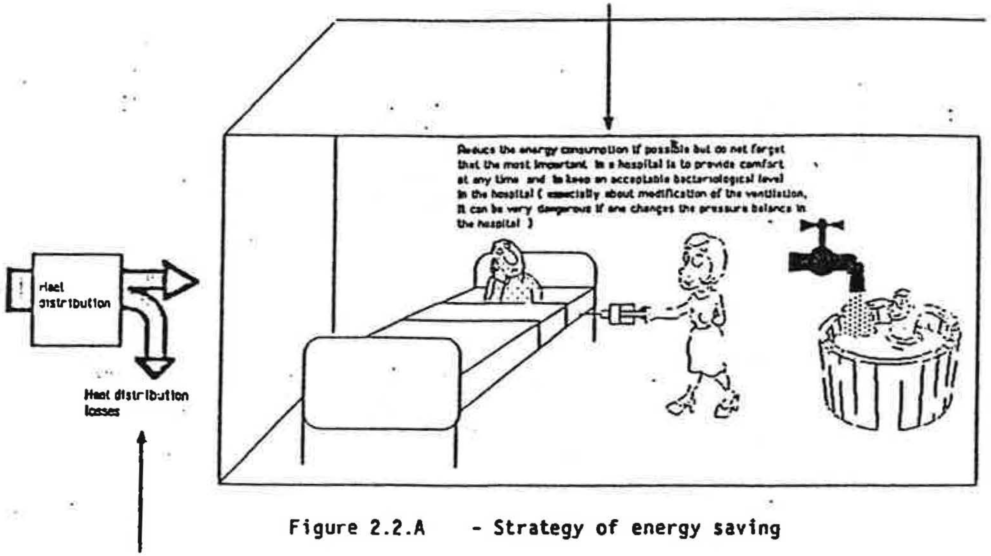


Figure 2.2.A - Strategy of energy saving

A schematic diagram will assist in the identification of the different lines. Lacking a diagram, one should be constructed.

An example of a schematic diagram is shown in Figure 2.2.B.

You must also identify the geographic area deserved by each subloop or substation.

Once you have identified the energy flows, you must understand how the these flows and temperatures are controlled.

You will add to the schematic diagram the control functions of the primary loops, and also of some important secondary loops, and describe how the regulators command the valves or command devices (Figure 2.2.B).

If you do not find the information on the control system, ask to the control supplier, the functions of each control device.

Once you have a schematic diagram with the main hydraulic control system characteristics, and that it has been carefully described, geographically and technically you can start the work on the heat distribution system.

2.2.2 Levels of intervention

There are two levels of intervention :

- Tuning, operational changes
- Modification, substitution

2.2.2.1 Tuning, operational changes

1. Reduction of the energy consumed by an adjustment of the control system of the end-users.

2. Reduction of the heat losses by a reduction of distribution temperature of the main distribution lines.

The part 2.3.1 gives guidelines for a reduction of the energy consumption by an adjustment of the control systems of the different heat consumers and the district heating.

The part 2.3.1.3 goes a little bit further and guides for operational changes of heat distribution. It has to be performed once the control functions have been checked and properly tuned.

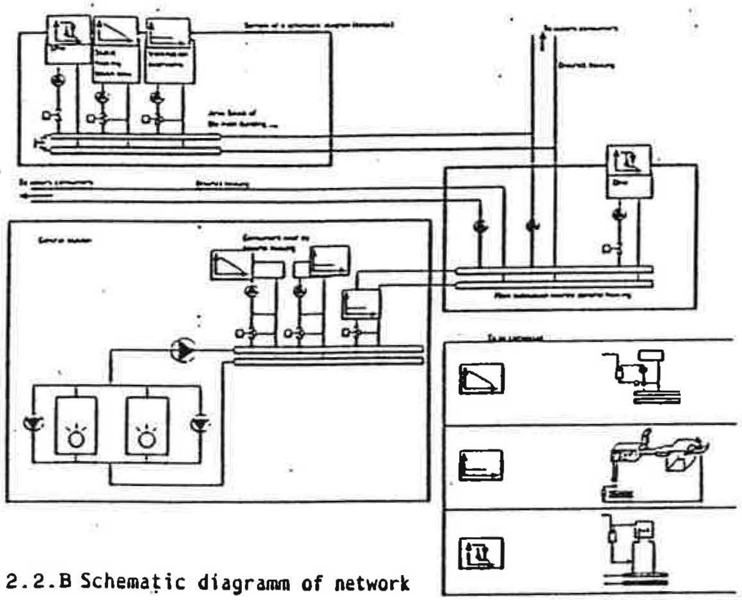


Figure 2.2.B Schematic diagramm of network

The part 2.3.1 and following require a good knowledge of the distribution network in its different functions.

Before any action, remember always that the patient comfort and security are the most important thing in a hospital and therefore be careful in your actions.

2.2.2.2 Modification, substitution

1. Reduction of the energy consumption by a reduction of the distribution losses (insulation or reinsulation of uninsulated parts).

2. Reduction of the energy consumption by a reduction of the lines length, by decentralizing some remote energy consumer.

Part 2.4.1 provides information for the improvement of the thermal properties of the network, that is to minimize the losses thanks to a better insulation.

2.2.3 Geographical approach

The best strategy is to decrease the energy consumption of each subsystem at its minimum by a fine tuning at the end-users level, then to reduce the temperature or pressure level at the primary level, taking into account the need of each consumer (Figure 2.2.C).

2.2.4 Kinds of consumers served by the distribution network

There are two different kinds of heat consumers:

- temperature dependant, like HVAC

- temperature independent, like DHW, processes (kitchen, laundry, sterilization)

2.2.4.1 Temperature dependant consumers

The power consumed is varying with the outdoor temperature (Figure 2.2.D).

For each substation you must correlate the outdoor temperature and the ambient temperature, there should not be any dependance between them, but in summer (Figure 2.2.E).

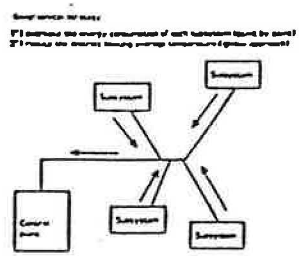


Figure: 2.2.C. - Geographical strategy

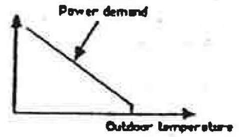


Figure: 2.2.D - Power demand

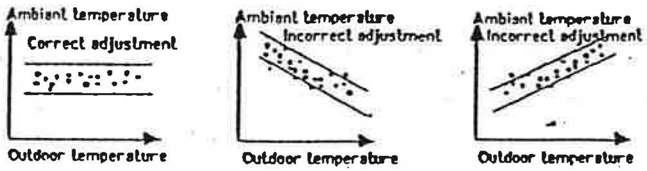


Figure:2.2.E - Correlation of outdoor and ambiant temperature

These figures represent three different cases:

a) Correct adjustment:

It shows that the indoor temperature at a given time of the day should be the same or less if the outdoor temperature remains below 12 °C

b) In that case the indoor temperature remains too high when the outdoor temperature is very low and to low when the outdoor temperature is around 8-12 °C. This is due to the fact that supply temperature is increasing too fast with a decrease of the outdoor temperature (see Fig. 2.2.F).

c) Similar as b) but in that case the supply temperature does not increase sufficiently with a decrease in outdoor temperature.

To measure that, you need a thermohygrograph that you keep in a room (always the same) to measure the ambient temperature.

In the case of a supply temperature dependant on the outdoor temperature, the measured supply temperature would be accordingly looking like that shown in Fig. 2.2.F.

By an action on the control you can adjust the supply temperature at its proper level for any outdoor temperature, keeping a constant ambient temperature.
(Detailed explanation is found in § 2.3.2).

In the case of an ambiance temperature control system, you must adjust the set temperature if it is too high.

2.2.5 Process consumers (laundry, kitchen, sterilization)

These consumers require a temperature or pressure level that is independent of the outdoor temperature, but changes during the day and the week.

You have to try to reduce the temperature and pressure level as much as possible and adapt the distribution network to it.

Once you have adjusted all these control systems, you can work on the primary loops.

Then one can reduce the primary loop temperature at its lower level to be able to still ensure that the process will work in good conditions (see also Booklet V).