INTERNATIONAL ENERGY AGENCY

ENERGY CONSERVATION IN BUILDING AND COMMUNITY SYSTEMS

ANNEX XIII - "ENERGY MANAGEMENT IN HOSPITALS"

A GUIDE FOR ENERGY MANAGEMENT IN HOSPITALS

BOOKLET VI

BUILDING ENVELOPE

March 30, 1989

TABLE OF CONTENTS

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:

Foreword
1. Heat Generation
2. Heat Distribution
3. Cold Generation and Distribution

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:

Foreword
1. Space Heating
2. Space Cooling
3. Ventilation and HVAC
4. Domestic Hot Water

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:

Foreword
1. Introduction
2. Electrical Energy Tariffs
3. Transformers
4. Energy Distribution Network and Reactive Load Compensation
5. Electricity Consumers for the Procurement of Thermal or Mechanical Energy
6. Lighting

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:

Foreword
1. Hospital Medical Equipment
2. Laundry
3. Kitchen
4. Sterilization

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

To maintain comfortable working and nursing conditions in an hospital, it is necessary to heat, to ventilate and sometimes or somewhere to cool it.

In preceding Booklets of this manual, the concern was with energy production, energy distribution and with energy needs for specific uses, as electricity, lighting, domestic hot water, etc.

In moderate climate, heating, ventilating and air-conditioning (including cold production) represent 40 to 60 % of total energy costs.

As for other buildings, energy consumption for space heating, cooling and ventilating is mainly dependent on heat losses and gains occurring through the building envelope which includes: walls, windows, roofs, floors and fresh air intakes.

The energy consumption for cooling in fully air-conditioned hospitals can be very roughly divided into two equal parts, respectively: internal loads and external gains. This is of course a very rough estimation because it depends on latitude, glazing percentages and characteristics (including shutters), orientation, level of internal artificial illumination, etc.).

The building envelope is responsible only for external losses and gains.

In this Booklet, we will be concerned mainly by the building envelope of existing hospitals.

This Booklet is, perhaps arbitrarily, divided in three chapters:

1. Air infiltration
2. Walls, floors and roofs
3. Windows.

CHAPTER 1. AIR INFILTRATION

1. Introduction

In this chapter of Booklet VI, we are concerned with air movements in and out through the building envelope (see Fig. 1.A).

These air movements are created by:

- natural convection and stack effects inside the building (caused by the density difference between warm inside air and cold outside air),
- pressure differences between walls and openings on the windward and leeward side,
- mechanical (or forced) ventilation to provide fresh air with given flows and pressure to locations in the building or to exhaust vitiated air from the building.

1.1 Description

1.1.1 Openings

Air enters and leaves the building through a variety of openings large and small. These include:

- hall entrance for nursing staff and visitors
- emergency access for ambulances
- access doors for all sorts of materials
- exit doors for all sorts of wastes
- doors giving access to terraces and roofs
- doors between underground parking areas and ground floors or staircases
- doors between staircases and roofs
- air louvers for mechanical ventilation and air-conditioning
- small axial ventilators mounted in windows or walls
- opened, semi-opened or broken windows
- joints between fixed and mobile parts of doors and windows
- leaks between glass and frame for windows; between frame and walls for windows and doors; between fixed part of small ventilators or windows units and glass or wall
- leaks between ceiling and ventilated attics
- leaks between walls and roofs or floors
- and even porosity of walls themselves
- air paths from heated or conditioned space to non heated space and non heated space to outside. These paths are often hidden from view.
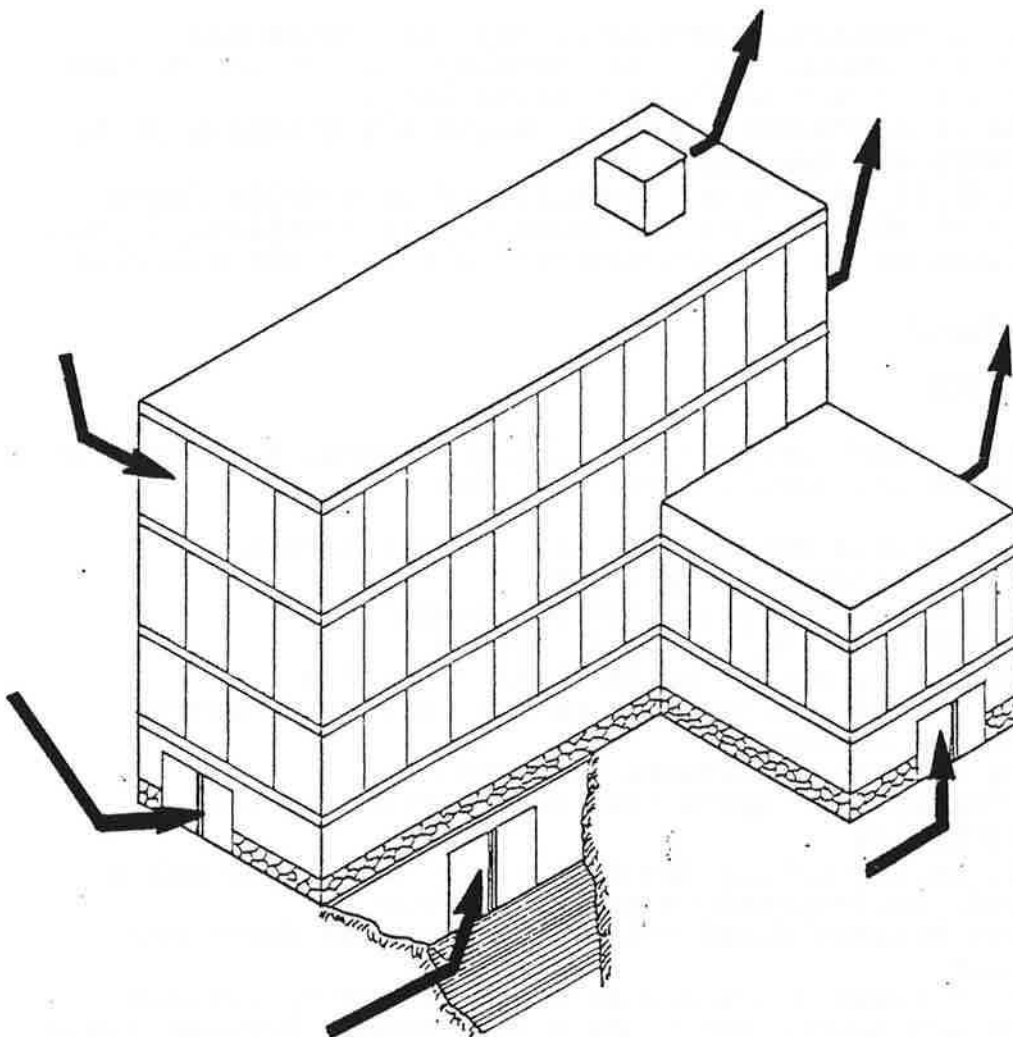
Figure 1.A. — Air movements through a building envelope

1.1.2 Pressurized zones

It must be remembered that an hospital is a complex building where some rooms are pressurized or depressurized for bacteriological control purposes, thus creating a pressure difference with the other rooms (see also Booklet III - Foreword).

Air movements which are not under proper control could thus be highly dangerous in particular zones.

1.2 Strategy

The whole strategy consists of the following:

- suppressing unwanted air transfers, and
- reducing the forced air flow to their designed values.

1.2.1 Energy and air infiltration

From simple maintenance to costly retrofits, the energy manager must investigate and evaluate the energy consequences of all the points mentioned under § 1.1.1.

As stated previously in Booklet II, it is interesting to draw a diagram using the records of energy consumption per day relating to outside temperature.
Such a diagram looks like Fig. 1.2.A during the heating period.
It must be remembered that energy consumption is also increasing with cooling needs.

This diagram allows the energy manager to distinguish between energy needs for space heating and ventilation (inclined part of the curve) and energy needs for users, which are not dependent on outside temperature.

The scattering of the records in the inclined part of the curve results (apart from measuring techniques) from wind and sun effects.

For a building which is not sufficiently air-tight, wind effects are important and they could be analyzed in the following way:
When recording energy consumption/day and outside temperature, distinguish between days with high speed wind, with low or moderate wind speed, or without wind.

The corresponding records can then be plotted on the diagram with specific signs , such as:
+ : high wind speed
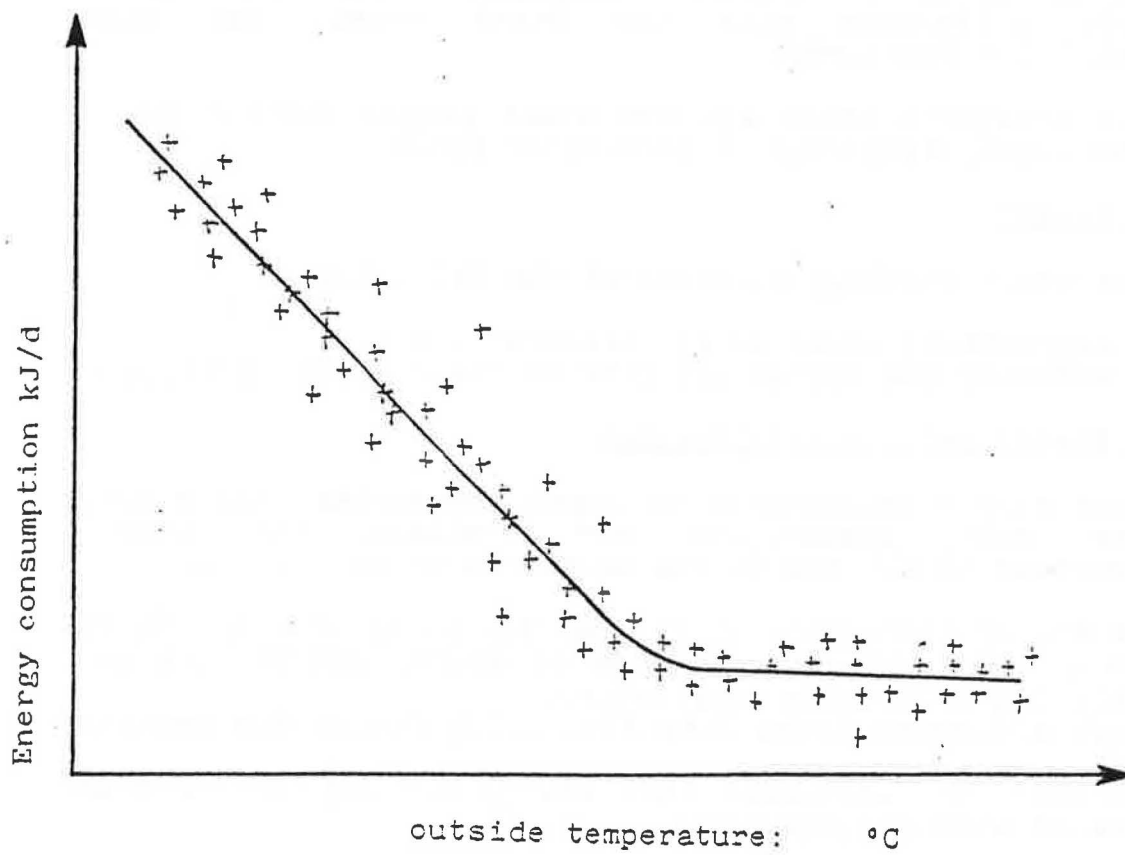^ : mean wind speed
° : no wind

3

Figure 1.2.A. – Energy consumption related to outside temperature

Fig. 1.2.B shows an enlarged part of Fig. 1.2.A.

It is thus possible to draw three different curves instead of only one for the temperature - dependent part of the curve.

The vertical distance between these three lines gives an idea of the energy consumption due to wind effect.

1.2.2 Air paths

In buildings without full mechanical ventilation, thermal losses are due to air infiltration which depends on the inside to outside temperature difference, the wind conditions, the location of openings through which air enters the building.

These factors determine the ease with which air passes through the whole building and removes building energy.

This ease of air passage is often neglected, but tightened partitions between storeys and between the different zones of the building can drastically reduce the thermal losses due to air infiltration caused by wind pressure or stack effects.

1.3 How to save energy with minor changes

1.3.1 Maintenance

1. Systematic visual inspections of air tightness of windows, doors, etc. are of prime importance because a leak which is large enough to be seen by eye causes a significant energy waste, and these systematic inspections also allow one to discover broken windows; doors or windows which are kept open or semi-open in spite of orders or regulations.

2. Smaller leaks can be documented by smoke tests: these should be made wherever a leak is suspected (see § 1.1.1).

3. Measurement of air velocities in the vicinity of closed windows and doors could also be made with a hot-wire anemometer. Air velocity above 0.20 m/s is too much, and indicates a repair should be made.
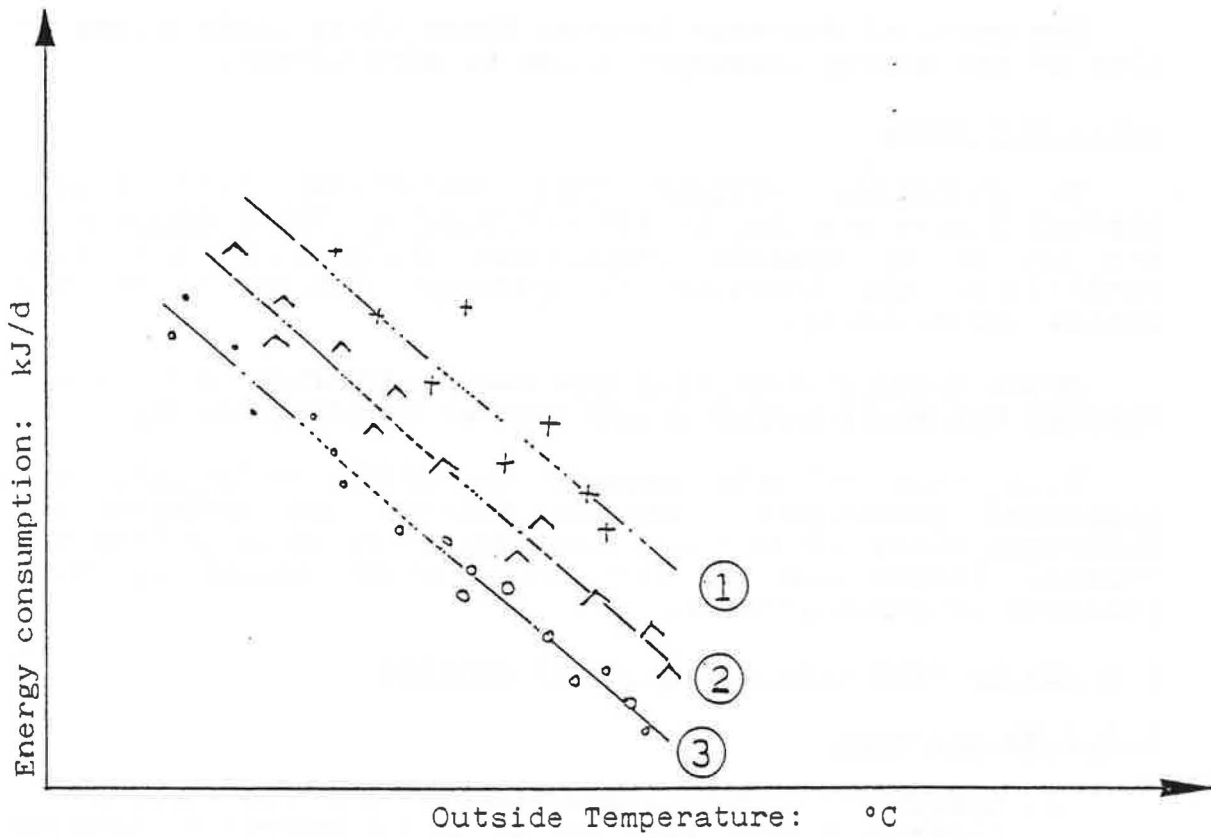
Figure 1.2.B — Energy consumption related to outside temperature
            and wind velocity

1 – high wind velocity
2 – mean wind velocity
3 – no wind

4. Immediate repair of the failures or defects detected by visual inspections or smoke tests is of prime importance:
   - replacing broken windows
   - readjusting the fastenings of windows and doors
   - filling up the cracks and fissures between windows or doors frames and walls with cement or silicon sealant
   - etc.

5. If simple readjusting of windows and doors fastenings is not possible because of their age or poor quality, their complete replacement must be considered.
   In that case, the replacement of simple glazed windows by double glazing could be of interest (see § 3.4).

6. Repairing the cracks and fissures in walls and their external and internal coating to restore their tightness.

7. Especially in clean zones must the leaks be repaired.

1.3.2 Operational changes

1. The operational changes relating to forced mechanical ventilation are treated in Booklet III.

2. To reduce the thermal losses due to air infiltration, some "operational" changes could be made:
   - closing doors and windows when their opening is not required for duty, comfort or exploitation purposes (check to see if overheating is not responsible for window opening)
   - if possible, systems to close doors automatically could be added to inside doors as well as for outside doors.

1.4 How to save energy through modifications

Except through the maintenance operation (see § 1.3.1 - n°4) the fight against air infiltrations can be costly because it can involve modifications to the building.

Therefore other energy conservation opportunities must be looked at first.

The modifications we could consider are:

1. Creating double doors at entrances,

2. Creating new partitions between storeys and between zones in the building,

3. Protecting entrances which are often open and exposed to prevailing winds by shielding them with walls, a curtain of trees, etc.

4. In case of severe wind exposure, curtains of trees, properly placed, could be effective for single storey building (pavillon-type hospital).

Closing or reducing air vents or shafts must never be made before answering the question "Why did they exist?" and "How were they designed?"

Besides, it must always be kept in mind that the buildings may be affected by the ambient humidity in some special department, i.e. Hydrotherapy.

CHAPTER 2. WALLS, FLOORS AND ROOFS

2. Introduction

In this chapter, we will only examine energy conservation opportunities in existing hospitals, concerning heat losses from inside to outside through walls, floors and roofs (ceilings).

2.1 Description

In the building, we have to distinguish between heated and non heated spaces (see Fig. 2.1.A).

Some spaces are normally non heated (that means that there is no terminal units such as radiators, ventilation grids, radiant floors, etc.) but it is expected that their temperature is sufficient due to heat transfer from normally heated spaces by transmission through partitions and air convection. Reduction of these sources of heat transfer would impair comfort in those zones and should not be considered. These types of "non-heated spaces" should be considered part of the heated volume of the building.

As examples of such spaces, we can give:

- halls, corridors,
- public toilets,
- lift halls,
- etc.

On the other hand, spaces which did not need any heating for comfort purposes, even though belonging to the building, are considered as being outside the loss envelope and must be thermally isolated from other spaces:

- non heated and/or ventilated attics
- underground parking lots or empty spaces
- non heated cellars
- lift shafts
- large technical shafts for air ducts, piping, etc.

2.1.1 Heat transfer

Heat transfer from one point (inside a heated space for example) to another (outside the building, for example) occurs in three different ways (see Fig. 2.1.B.):

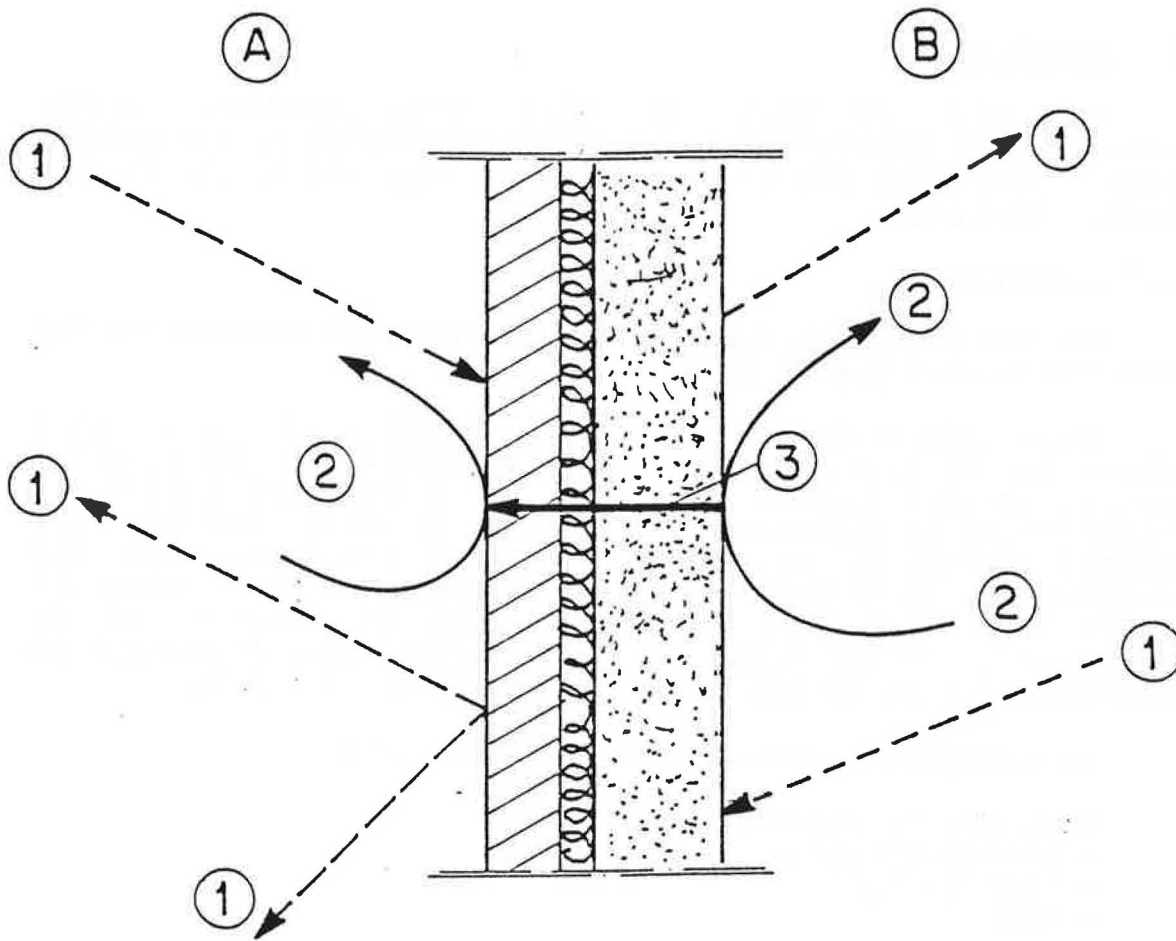- convection
- conduction, and
- radiation

Figure 2.1.B.   - Heat transmission through a wall

A.   Outside
B.   Inside

1.   radiation
2.   convection
3.   conduction

a)
Convection relates to the movement of heated particles (of liquids or gases) from one point to another, which bring their own heat and transfer it to less heated particles.

This is the way by which heat is transferred by air movements from one point inside a room to the inner surface of walls, rooms, floors and windows limiting this room, or from their outer surface to outside space.

b)
Conduction is the way by which, in solids, heat is transferred from one point of the solid to another point which is at a lower temperature.

Heat is transferred by conduction through the walls, etc. from their inner surface to their outer surface.

c)
Radiation is the way by which two surfaces viewing each other exchange heat, even if pure vacuum separates these surfaces.

Heat is transferred from the surface at the higher temperature to the surface at the lower temperature.

Thermal exchanges through a wall (roof, etc.) are always composed of the three mechanisms just described, if we extend the "wall" thickness to the boundary layers of air just neighbouring the surfaces (internal and external) of the wall.

Heat transfer by convection increases with the air velocity on the surfaces of the wall and temperature difference between surface and air;

Heat transfer by conduction increases with thermal conductivity of materials composing the wall (or decreases as their thermal resistivity increases) and decreases with the thickness of the layer;

Heat transfer by radiation increases with the roughness of the surface and the emissivity of the material.

2.1.2 Thermal bridges

Thermal bridges are structural elements which connect heated spaces to nonheated spaces with materials having a much higher thermal conductivity than neighbouring materials (see Fig. 2.1.C).
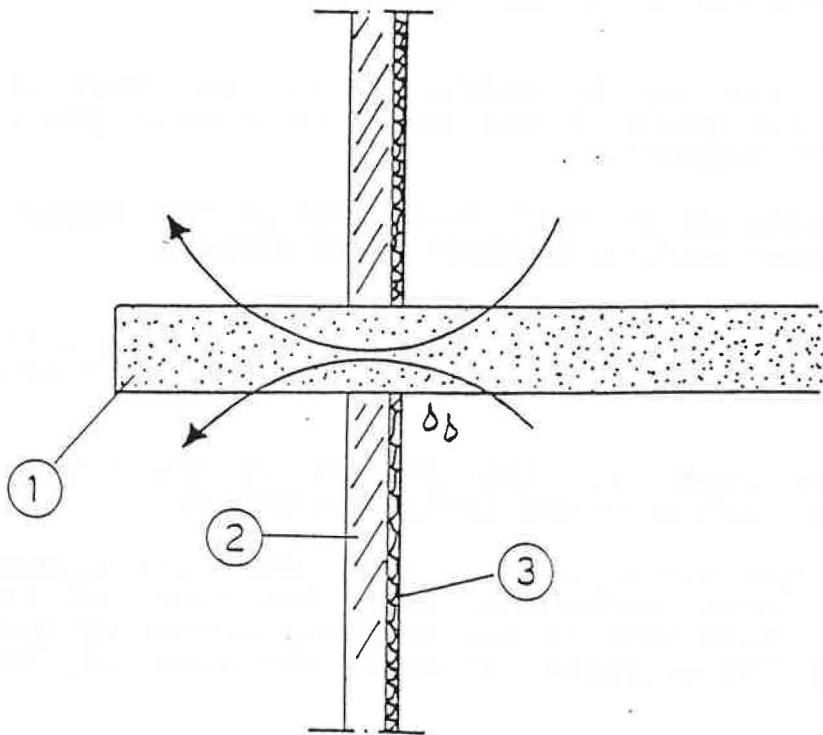
Fig. 2.1.C.   - Thermal bridges

1. Concrete slab
2. Brick wall
3. Insulation layer

For that reason, the following occurs:

- large heat transfer takes place through thermal bridges
- inner surface temperature on or near a thermal bridge is much lower than inner surface temperature of neighbouring materials, and this can cause vapour condensation on inner surfaces of thermal bridges. Mold can grow in this areas. If thermal bridges are large, comfort problems can result.

2.2 Strategy

2.2.1 Life cycle cost analysis

The only way to reduce heat losses or gains through walls, floors, roofs, etc., is to increase their thermal resistance by adding insulating material layers, suppressing thermal bridges and eliminating convective flow within the envelope components.

The payback period of such work varies (roughly speaking) from 5 to 30 years, depending on:
- the amount of energy saved
- the cost of the energy
- the cost of material and manpower to do the work
- the rate of interest of borrowed money
- the rate of inflation
- the prices increase or decrease of energy.

Because the payback period could be relatively long, the last three points are important, and perhaps more than the first one, and payback period or rate of return on investment calculation must be made before making a decision.

2.2.2 Amount of energy saved

2.2.2.1 Calculation of heat losses

Calculation of heat losses before and after insulation reinforcement requires the knowledge of the characteristics of existing building envelope materials. This knowledge is achieved most easily through the drawings and specifications of the buildings. But for old buildings it is not always possible to obtain these drawings and specifications.

Other methods to determine the thermal properties of walls, floors, etc. must thus be employed:

- direct examination and measurements of thicknesses.
- taking a core through the partition (destructive test!)
- simultaneous measuring the heat flow and temperature difference between internal and external surface (which require specialized measuring apparatus).

Inner surface temperature, which can be easily measured by contact thermometer, is an important point from two different aspects:

1) In the heating period and for given outside conditions (temperature and wind velocity), the inner surface temperature decreases with decreasing thermal resistance of the wall.

For rooms normally heated at 20 or 22 °C, surface temperature less than 19 °C is an indication that insulation reinforcement could be profitable from an energy saving standpoint, and if the inner wall temperature is less than 17 °C, is a strong signal that something must be immediately done.

2) Apart from relative humidity, air velocity, activity clothing and health state, the comfort is related to "resultant" temperature which is the mean value between air temperature and temperature of all the surfaces in the room.

To obtain a same comfort level in a room with lower inner surface temperature of walls as in another room, it is thus necessary to increase the air temperature which in turn increases thermal losses by conduction as well as by air infiltration or ventilation (either natural or mechanical).

Heat losses and related energy consumptions can thus be calculated by standard methods of the country, which are developed in specialized manuals or in standards.

These measurements and calculations may seem a bit time consuming, but if the areas for which thermal improvement can be made are large, the savings can be significant.

Thermal bridges can be seen (as well as air ex-filtration) through diagnostic methods such as infrared thermography.

2.2.2.2 Conductivity coefficient

The conductivity coefficient lambda of a material is expressed in W/m·K, where

W expresses the energy flowing through the material per second
m is a length
K expresses the temperature difference between the warm and cold sides of the layers.

The lower this coefficient, the best the insulating properties of the material.

The resistance to heat transfer depends also on the thickness of insulating layer. Therefore, to compare the insulating properties of two layers differing in thickness and thermal characteristics, we have to compare the value:

t/lambda (t expressed in meter).

The higher this ratio (expressed in m^2·K/W), the better the insulation layer is in terms of energy savings.

When comparing the respective costs of two materials, their thickness must thus be also taken into account.

Example:

Material A has a lambda value of 0.028 W/m·K, and material B has a lambda value of 0.082 W/m·K. What is the necessary thickness t_B of material B to have the same insulating properties than 0.06 m of material A?

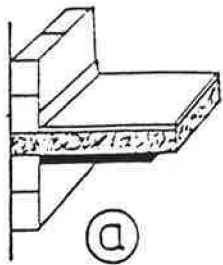t_A/lambda$_A$ = t_B/lambda$_B$

0.06/0.028 = t_B/0.082

t_B = 0.176 m

2.3 Increasing thermal resistance of walls, roofs and floors
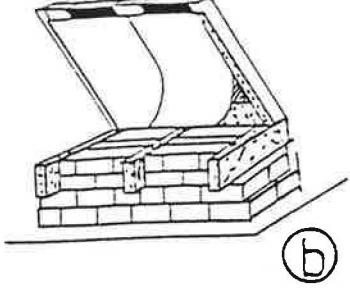
2.3.1 Techniques to be applied

Some of these techniques could be applied by hospitals maintenance staff; others need skilled outside contractors (thus increasing the cost of the operation).

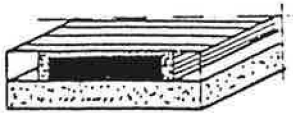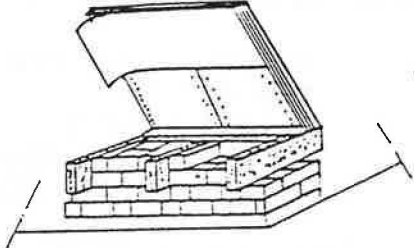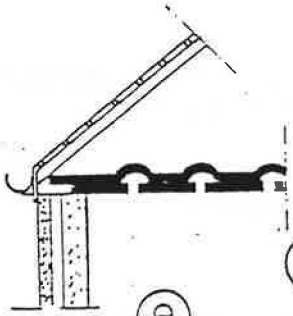Most of these techniques are illustrated in Fig. 2.3.A.
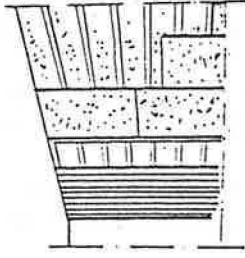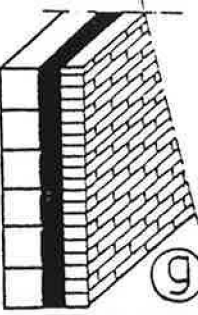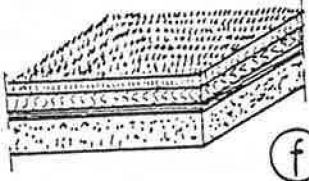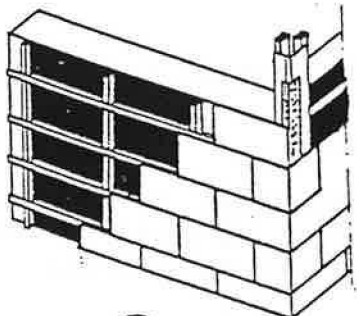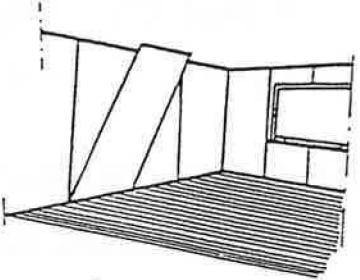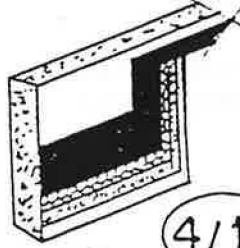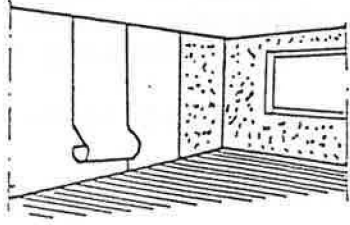
Figure 2.3.A. - Techniques for increasing thermal resistance
of Walls, Roofs and Floors

11a

1. Placing an insulating and reflecting layer on the walls behind the radiators: due to overheating, radiation and convection, the overall heat transmission coefficient of the wall is much higher behind radiator than elsewhere. Placing that layer on the wall, with an aluminium foil surface facing the radiator decreases sharply the heat transfer coefficient.
   That kind of material can be bought in super-markets and easily glued on the wall if the radiator is placed 8 or 10 cm from the wall.
   This is a highly profitable opportunity which needs no cost analysis.

   If the radiators are placed too close to the wall and need to be disconnected to install the insulating material, the cost of the operation must be analyzed.

2. Placing an insulating layer underneath the floor separating heated rooms from underground and non heated spaces is also easy to do by clamping or nailing. This can be very profitable if the non heated space is naturally highly ventilated. (see Fig. 2.3.A, detail a).

3. For ventilated roofs, it is obviously useless to place an insulating layer above the ventilated space.
   In that case, insulation reinforcement sometimes needs complementary works to support the insulating material and vapour barrier (see Figure 2.3.A, detail b).

4. If the attic is unoccupied but accessible, different simple techniques could be used:
   - placing a vapour barrier on the attic floor and then pouring balls of expanded polystyrene, foamglass, mineral wool, or cellulose
   - covering the attic floor with insulating materials of bat or roll type
   (Don't forget to insulate access door or hatch)

5. If the attic temperature is no problem but it is an area used for storage purposes, it is necessary, after proceeding as in 4. to create a new floor, and this could be expensive (see Fig. 2.3.A, detail c).

6. If the material stored in the attic needs some moderate temperature, the roof of the attic has to be insulated instead of the attic floors (see Fig. 2.3.A, detail d).

7. If the attic isn't accessible, the insulation of the roof becomes more difficult and the work must be done through the ceiling of the room situated beneath although access can be made through the roof or gables (see Fig. 2.3.A, detail e).
This project may cause problems due to activity in that room.

8. For flat roofs, insulation reinforcement is usually made by placing rigid panels of cellular insulating material on the existing watertight layer and covering the insulating panels with ballast (see Fig. 2.3.A, detail f).

    For walls, insulation improvement to the cavity can be made from inside or from outside, by filling the air cavity with insulating materials like foam glass balls, fiber glass or cellulose (see Fig. 2.3.A, detail g).

    When adding a new insulating layer to the inside of a room, all appliances placed on the walls (electricity switches or plugs, radiators, plugs for medical gases...) as well as mouldings must be removed and replaced.

    Furthermore, if the floor constitutes a thermal bridge, insulation of the wall from inside may actually increase the effects.

9. Insulation from inside can be made with rigid panels made with insulating material glued on plaster panels or by a supple insulating coating which is glued on the wall (see Fig. 2.3.A, detail h).

10. Insulation from outside is usually made by placing new rigid material on the existing wall; then a grid of fiberglass and finally a finishing coating (Fig. 2.3.A, detail i).

11. Another way to do external insulation is to nail or glue isolating materials on the wall, then to add lathing and cover the walls with tiles (Fig. 2.3.A, detail j).

12. In old hospitals, and particularly in hospitals made from converted buildings, some rooms can have very high ceilings.
The corresponding outside wall also cover too large an area. This heat transmitting area can be decreased by reducing the height of the rooms through the addition of a false ceiling.

This false ceiling must be air-tight so that the space between it and the ceiling becomes a non-heated space.

A side benefit can be better lighting efficiency if the fixtures can be lowered.

For fully air-conditioned hospitals situated in very hot, sunny countries, heat gains through roofs (and, in lesser extent, through external walls) induce additional heat load into the building and thus additional electricity consumption related to the cooling equipment.

14. In these countries, you can also spray the roof with water. The evaporation of the water cools the roof, thus reducing the cooling load.

2.3.2 Profitability

These operations could be classified in terms of profitability by two ways:

- in terms of energy savings per square meter or
- in terms of energy savings per square meter per cost unit.

On each figure above, these operations were classified in order of interest.

The first value is the place in the classification based on energy savings only; the second value is the place in the classification based on the ratio of energy/cost (profitability or cost benefit).

The lower the cost benefit values, the more interesting is the opportunity.

2.3.3 Insulating materials and cautions

The thermal properties of insulating materials result from the high quantity of air which embedded in these.

Insulating materials are either fibrous (or with open structure) or cellular; either organic or inert.

a) Fibrous material as mineral or glass wool, heraclith, etc. have to be protected from humidity and vapour diffusion.
It is highly recommended not to use them if they can be exposed to outside conditions (water can penetrate through all holes made by nails for ex., and diffuse through all the material).

b) Unlike inorganic materials as mineral wool, foamglass, organic materials as polyurethane, polystyrene etc., can age and lose some of their initial properties with time.
Some organic materials, as polyurethane or polystyrene foams, can be destroyed by small animals (mouses).

c) One of the most important problems occurring with insulating is water vapour condensation.
Because of their thermal properties, there is a high decrease of temperature within the material when going from inner side to outer side.

If humid air is allowed to diffuse through the insulation, the decrease of temperature causes condensation of water.
This water soon replaces the air normally imbedded in the material, and the material loses its insulation properties.
In addition, the increase of water content increases the weight of the material and that can cause the insulation material to compress and cause structural problems.

It is thus of prime importance to place vapour barrier between the heated space (where humidity is usually higher than outside) and the insulating material, especially if they are of fibrous nature.

For the same reason, it is better to have no vapour barrier on the cold side although wind or air barriers can reduce air penetration into the insulation thereby maintaining the design thermal resistance.

CHAPTER 3. WINDOWS

3. Introduction

We treat of windows apart from walls, roofs and floors, because windows are not only responsible for heat losses, but also for natural lighting during the day and for heat gains during the sunny days or from indirect radiation.

These heat gains are obviously beneficial during the heating season but can present overtreading problems for the shoulder seasons and in summer for conditioned spaces.

In this chapter, we will not consider air infiltration, which is treated in chapter 1 of this Booklet.

3.1 Description

As every one knows, a window is composed of one or more frames each holding one or more glazings.

3.1.1 Frames

The frames holding the glazing can be rigidly fixed to the aperture of the wall, (non-opening or fixed windows) or articulated on another frame to allow the window to be opened and closed. The opening can be made by rotating (around a vertical or an horizontal axis, or both) or by lifting the mobile frame holding the glazing, or by sliding the frame horizontally.

The frames can be made out of wood, steel, aluminium, PVC, composite materials, etc.
Wood and plastic can be considered as relatively insulating; steel and aluminium, on the other hand, are highly conductive. However, modern aluminium frames are made with a "thermal brake" so that the heat transmission is greatly reduced.

3.1.2 Glazing

Apart from steel and aluminium frames without thermal brakes (and obviously air infiltration gaps), the glazing is the most heat transmitting part of the building envelope.

The glass industry has made great progress in the field of windows glazing and new products are appearing each year.

It is thus impossible to provide a complete description of all the various existing glazing and of their properties.

The different categories of glazing are:

- simple glazing
- double glazing (with space filled with air or with inert gas)
- triple glazing
- tinted glazing
- coated glazing
- reflecting glazing
- etc.

The properties of glazing which are of interest from our energy saving point of view are:

- heat transmission coefficient, and
- radiation transmission coefficient

3.2 Strategy

In terms of energy savings/sq meter, replacing old single glazed windows by modern double glazing windows is more profitable than increasing the insulating properties of walls, roofs and floors.

In terms of costs savings, it is exactly the opposite.

The strategy in this building envelope component is to look at modification of windows only if they have to be replaced for other reasons; for example excess of air infiltration due to age, wood decay, warping, etc.

The strategy could be different with a new increase of energy prices, but the life cycle cost analysis (see § 2.2.1) must be applied.

3.3 How to save energy with minor changes

It is necessary to emphasize the need to clean the glazing, and to maintain the mechanism of closing and opening the windows, the curtains and the shutters.

Although considered routine maintenance these items are required if window systems are to function as designed.

Some operational changes can reduce the energy consumption relating to windows:

3.3.1 During the heating season

1. Closing the curtains and the shutters at night greatly reduces the radiative and convective heat losses through windows.

2. Closing transparent curtains during day is important too, but the curtains should not hinder the emission of heat from the room radiators.

3. If it is necessary to ventilate a room by window opening, it is better to open windows widely during a short period than letting them remain semi-opened during the whole day and night.
Any window opening must take into account the comfort of patients and staff.

3.3.2 When airconditioning is on

1. For airconditioned rooms, providing window shading or closing external shutters during sunny days in summer and during shoulder seasons reduces the external load due to sun.

2. The closing of internal curtains or venetian blinds is effective too, but much less than the closing of external shutters or shading devices.

3.4 How to save energy through modification

The possible modifications often involve costly retrofits to buildings, and the profitability must be studied before deciding upon any action.

1. Nevertheless, if some radiators are placed in front of glazed surfaces, it is highly profitable to place an insulation material in place of glazing behind the radiators.

2. For windows not facing south, and if it doesn't impair natural lighting, it may also be useful to reduce glazed area by replacing some of it by opaque and insulating material.

   If it is seen by experience that, in some places, artificial lighting is very widely used, that indicates that some reduction of natural lighting is not a big problem.

3. Replacing simple glazing by double or triple glazing must be evaluated to determine if there is simultaneously a window replacement necessity for other reasons.

4. When replacement of old windows is reviewed, it is sometimes profitable to make certain the new windows have higher air tightness and thermal brakes.

5. Overglazing, the addition of storm windows, requires less work inside the room than the complete replacement of the window.

   Additional glazing should be looked at if existing are still in a good state and need no replacement for the next 10 or more years and is now single glazed.

6. Properties of existing glazing can be improved by low-cost films coverings.

Two types of films are available: <u>summer solar reflective</u>, which reduce room overheating, thus preventing excess window opening, and <u>winter heat retaining</u>, which reduces the radiative loss from the room to the outside.