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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 III

## HEATING, VENTILATING, AIR CONDITIONING

## DOMESTIC HOT WATER

March 30, 1989

INTERNATIONAL ENERGY AGENCY

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ANNEX XIII - "ENERGY MANAGEMENT IN HOSPITALS"

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**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:**

Foreword
1. Background
2. Introduction
3. Developing an Energy Management Program
4. Energy Accounting Techniques
5. Phases of the Energy Management Program
6. Energy Management Investments
7. Conclusion
8. Checklist
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**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

## FOREWORD

Each room or zone in our hospitals normally has a need for some form of space conditioning whether it be heating, ventilating, or air conditioning (HVAC). This Booklet focuses on these space conditioning requirements and how they can be met in an energy efficient way. In addition, the possibilities to reduce the energy associated with domestic hot water (DHW) supplied to many of those rooms is also covered in this Booklet.

HVAC and DHW demands directly reflect back on what must be provided from central facilities. Detailed descriptions of that heat and cold generation equipment are covered in Booklet II. It must be constantly kept in mind that the space conditions and DHW requirements in the individual rooms will directly influence the energy efficiency of that central equipment.

Space conditioning not only takes into account human needs within the hospital but also may be dictated by the energy intensive nature of the hospital functions. For example, the core of the building may require cooling for long periods during the year because of equipment heat generation. Control of internal environments, while important in every building, often requires a high degree of HVAC system sophistication in hospitals.

The acute problem of staphylococcal and other infections, which can be easily spread within any hospital, make attention to the details of the HVAC design a concern of hospital administrator and staff. High efficiency filters, in properly designed systems, can provide air that meets outdoor air quality standards, even when recirculation is employed. In some hospital areas, where the outdoor air is of marginal quality (see ASHRAE Standard 62) filtering techniques become all the more important. All medical authorities are unanimous that contamination be kept to a minimum, especially in sensitive areas such as: operating rooms, intensive care units, delivery rooms, nurseries, and burn units. The patient rooms also must be maintained at controlled ventilation rates. Contamination in these areas often results from visitors to the hospital, as well as from the patients themselves.

For these reasons, not only are ventilation rates prescribed, but isolation is often maintained by pressure differentials between zones as well as with air filtering. Each zone has a specified ventilation rate, and often a pressure to be maintained. These points will be discussed



under Standards and Recommended Practice in this introductory section.

Location of outdoor air intakes for the ventilation and air conditioning systems are critical considerations in the overall design, and in the maintenance requirements of the total system. Obtaining the best outside air source is a first step in avoiding undesirable air ingredients such as vehicle exhausts, soil bacteria (cause of gas gangrene), pesticide fumes and refuse odors. Ventilation air supplies must be located remotely from exhaust, with wind conditions considered, so as to avoid hospital exhaust air being entrained in the supply air. Potential health hazard for sensitive patients in hospitals located in industrialized, urban areas can result from long exposure to low or moderate levels of contamined and to sudden high contaminate concentrations, brought about by prevailing weather conditions, being ingested into the hospital air system.

From a design standpoint, the many different zones in the hospital, with the associated space conditioning requirements, represent a true challenge to the designer and the hospital maintenance staff. Some of the spaces have uniform loads, most require precise control. Contaminant control is always a top priority. Some systems designs meet these requirements better than others. The diversity of requirements encourages the use of combined systems where the requirements dictated by patients prescribes one system and areas used by hospital employees allows other, more energy conserving designs, to be used. These choices are described in § 3.1.

### Standards and recommended practice

Because of the critical design and operational features of the HVAC (and DHW) systems in hospital and medical facilities, special minimum requirements of construction and equipment have been mandatory in many hospitals. Figure A provides the general pressure relationships and ventilation requirements for a number of hospital areas as applied in U.S. hospitals. In the U.S. approach, hospitals are divided into areas of positive and negative pressure to avoid the spread of infection. Within these zones a range of temperatures and humidities are specified as well as a variety of ventilation levels which requires both cooling and heating capabilities for much or all of the day. These conditions must also be adjusted to the sick and elderly patients, who require higher temperatures and closer space conditioning control than other patients.

As figure A illustrates, the general hospital may be divided into zones which include: administrative, diagnostic and treatment facilities, nursery, nursing department,

Figure A

**Table General Pressure Relationships and Ventilation of Certain Hospital Areas**

| Area Designation | Pressure Relationship to Adjacent Areas | Minimum Air Changes of Outdoor Air per Hour Supplied to Room | Minimum Total Air Changes per Hour Supplied to Room | All Air Exhausted Directly to Outdoors | Recirculated within Room Units |
|---|---|---|---|---|---|
| Operating room (all-outdoor-air system) | P | 15 | 15 | Yes[c] | No |
| Operating room (recirculating-air system) | P | 5 | 25 | Optional | No[a] |
| Trauma room | P | 5 | 12 | Optional | No[a] |
| Delivery room | P | 5 | 12 | Optional | No[a] |
| Nursery unit | P | 5 | 12 | Optional | No[a] |
| Recovery room | P | 2 | 6 | Optional | No[a] |
| Intensive care | P | 2 | 6 | Optional | No[a,b] |
| Patient room | E | 2 | 2 | Optional | Optional |
| Patient room corridor | E | 2 | 4 | Optional | Optional |
| Isolation room | E | 2 | 6 | Yes | No[b] |
| Isolation room-alcove or anteroom | E | 2 | 10 | Yes | No[b] |
| Examination room | E | 2 | 6 | Optional | Optional |
| Medication room | P | 2 | 4 | Optional | Optional |
| Pharmacy | P | 2 | 4 | Optional | Optional |
| Treatment room | E | 2 | 6 | Optional | Optional |
| X-ray, fluoroscopy room | N | 2 | 6 | Yes[e] | No |
| X-ray, treatment room | E | 2 | 6 | Optional | Optional |
| Physical therapy and hydrotherapy | N | 2 | 6 | Optional | Optional |
| Soiled workroom or soiled holding | N | 2 | 10 | Yes | No |
| Clean workroom or clean holding | P | 2 | 4 | Optional | Optional |
| Autopsy | N | 2 | 12 | Yes | No |
| Darkroom | N | 2 | 10 | Optional | No |
| Nonrefrigerated body holding room | N | Optional | 10 | Yes | No |
| Toilet room | N | Optional | 10 | Yes[d] | No |
| Bedpan room | N | Optional | 10 | Yes | No |
| Bathroom | N | Optional | 10 | Optional | No |
| Janitors' closet | N | Optional | 10 | Optional | No |
| Sterilizer equipment room | N | Optional | 10 | Yes | No |
| Linen and trash chute rooms | N | Optional | 10 | Yes | No |
| Laboratory, general | N | 2 | 6 | Optional | Optional |
| Laboratory, media transfer | P | 2 | 4 | Optional | No[a] |
| Food preparation centers | E | 2 | 10 | Yes | No |
| Warewashing | N | Optional | 10 | Yes | No |
| Dietary day storage | E | Optional | 2 | Optional | No |
| Laundry, general | E | 2 | 10 | Yes | No |
| Soiled linen sorting and storage | N | Optional | 10 | Yes | No |
| Clean linen storage | P | 2(Optional) | 2 | Optional | Optional |
| Anesthesia storage | E | Optional | 8 | Yes | No |
| Central services | | | | | |
| Soiled or decontamination room | N | 2 | 6 | Yes | No |
| Clean workroom | P | 2 | 4 | Optional | Optional |
| Equipment storage | E | 2(Optional) | 2 | Optional | Optional |

P = Positive N = Negative E = Equal

[a] Recirculating room units meeting the filtering requirement for sensitive areas may be used.

[b] Isolation rooms and intensive care rooms may be ventilated by induction units if the units contain only a reheat coil and only the primary air supplied from a central system passes through the reheat coil.

[c] For operating rooms, use of 100% outside air should be limited to those cases where local codes require it, and only if heat recovery devices are utilized.

[d] Most existing governmental agency design criteria and codes require all air from toilet rooms to be exhausted directly to outdoors. This requirement appears to be based upon odor control. Practical experience has shown that health facilities, with the possible exception of nursing homes, having central toilet exhaust systems generally have sufficient dilution to render the toilet exhaust air practically odorless. For this reason, plus the need to conserve energy, it is recommended that consideration be given to recirculation of up to 50% of toilet room air where central systems with appropriate conditioning and filtration equipment are employed.

[e] Fluoroscopic rooms which are used only occasionally for this procedure or those served by large central systems may utilize recirculated air in the interest of energy conservation.

[f] Extra air must be supplied for hood exhaust so the designated pressure relationship is maintained.

General notes

[1] Table 3 does not necessarily reflect the criteria established by DHEW or any other group. If specific organizational criteria must be met, refer to that organization's literature.

[2] The outdoor air quantities for central systems using recirculation and serving more than a single area designation may be determined by summing the individual area air quantity requirements rather than by providing the maximum listed ratio of outdoor air to total air. This does not apply to sensitive areas such as operating and delivery rooms, recovery rooms, nurseries, and intensive care rooms.

[3] For maximum energy conservation, the use of a recirculated air system is preferred. If an all-outdoor-air system is used, an efficient heat recovery method is recommended.

[4] Thermal requirements of the areas may dictate a higher air change rate than those shown. The need to conserve energy may suggest consideration of greater recirculation in certain areas and locations.

[5] All air supply and exhaust systems should be mechanically operated. Exhaust fans should be located at the discharge end of each system.

[6] Recommendations for design temperatures and humidities are given in further paragraphs for specific departments and spaces. For other areas occupied by inpatients, indoor winter design temperature and humidity should be 75 F (24°C) and 30% minimum relative humidity. For all other occupied areas, the indoor winter design temperature should be 72 F (22°C).

[7] For spaces of high population density or sensible heat factors of 0.75 or less, lower dry bulb temperature results in generation of less latent heat, which may reduce the need for reheat and thus save energy. Optimum dry bulb temperature should be the subject of detailed design analyses.

[8] Room pressure relationships may be addressed by removing 10% less air than supplied for positive (P) rooms, and by removing 10% more air than supplied for negative (N) rooms. For operating rooms remove 15% less.

[9] When a room is unoccupied and unused the total air changes per hour may be reduced to 25% and outdoor air change requirement deleted provided the indicated pressure relationship is maintained.



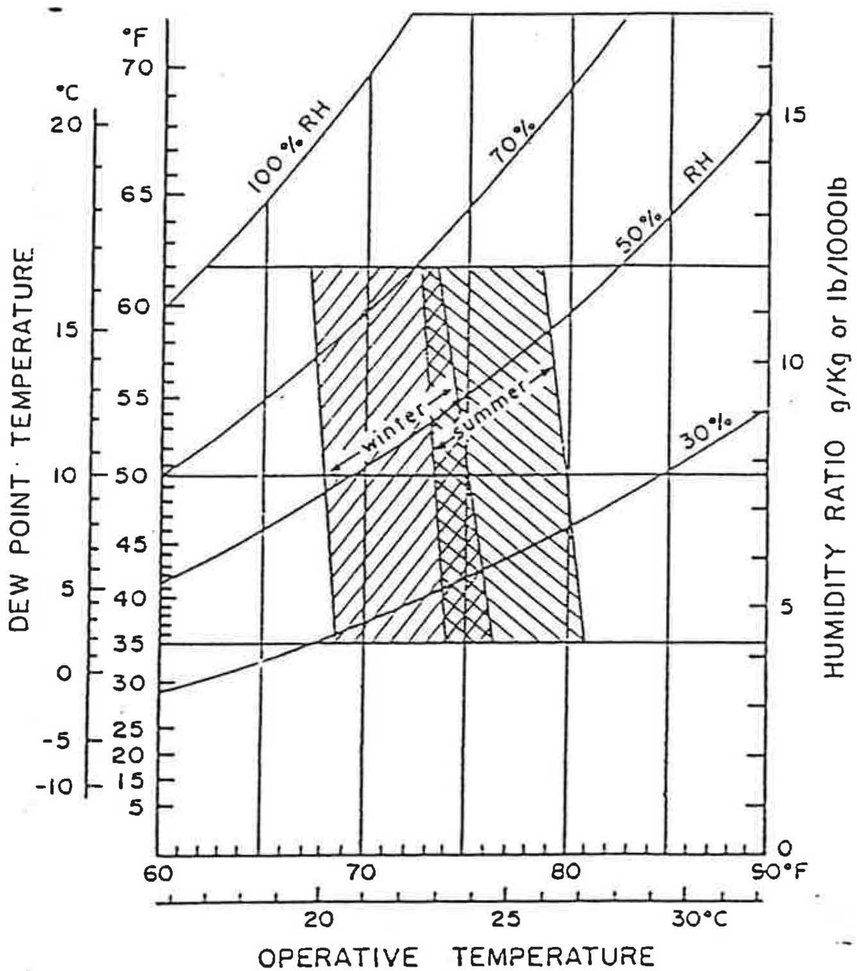


FIGURE B
ACCEPTABLE RANGES OF OPERATIVE TEMPERATURE AND HUMIDITY FOR PERSONS CLOTHED IN TYPICAL SUMMER AND WINTER CLOTHING AT LIGHT, MAINLY SEDENTARY ACTIVITY (ASHRAE 55-1981).

surgical department, obstetrical department, emergency department, services, etc. Besides the ventilation (see ASHRAE Standard 62 for more details on ventilation requirements) and pressure requirements, each of these zones have recommended temperatures to assure health and comfort. Figure B provides guidance as to what are acceptable ranges of operative temperature and relative humidity (RH) for persons clothed in typical summer and winter clothing at light, mainly sedentary activity (see ASHRAE Standard 55 for further information on comfort).

While these temperature ranges may suit the need of the areas of the hospital without patient, much more demanding standards may be applied to critical areas.

These specific conditions create some limitations for energy savings by adjustment and/or modification of the control system.

Let us see the different areas in a hospital, the priorities for energy savings and their difficulties.

**Areas without patients, and occupied during regular working hours only**

These areas are:

- laundry
- kitchen
- central sterilization (*)
- administration
- hair dresser office
- stores
- workshops
- central laboratories (*)
- bed disinfection (*)
- restaurant

In these areas, the ambient temperature can be maintained around 20°C or even less in workshops or stores.

In all these areas, one can have quite important night setback for space heating and one can stop or at least reduce the VAC systems out of working hours or during week-end in the areas not marked with a star. Such kind of operational modifications are free of cost.



**Areas with patients during day time but not in intensive care**

- Physiotherapy
- Swimming pool (hydrotherapy)
- Radiology
- Consulting rooms for diagnosis

During day time, the ambient temperature must be maintained at 22-27 °C depending on the national habits, and about 26 °C for the swimming pool. The relative humidity level in all areas equipped with electronic devices should be kept in a range of 40-60 % RH.

Out of working hours one can put a night setback on static heating and put a control for humidity build up especially in the swimming pool room, during night time, that will switch on HVAC only if humidity level becomes too high in the swimming pool.

**Areas with patients round clock, but not in intensive care**

- bedrooms, toilets
- bathrooms

During day time the ambient temperature must be maintained at 20 ÷ 24 °C depending upon the building quality. Humidity level should range between 30 to 50 % RH with the highest values in summer.

In certain cases, after a study done on the HVAC systems by specialists (consulting engineers), one can reduce the VAC system flowrates during the night and put a night setback on static heating in order to save energy.

**Areas with patients in intensive care**

- intensive care
- surgical and delivery suites
- nursery

In these areas, the maximum comfort must be ensured around the clock. The temperature level in these areas should be maintained in the range of 24 to 27°C with a humidity level of about 30 to 60 % RH for the intensive care units, and nursery, and of 20 to 24 °C with a 50 to 60 % RH in the surgical and delivery suites which require the most attention to the control for aseptic conditions.

VAC systems cannot be modified or set without the help of VAC specialist. As explained before it is essential to respect the priorities of safety and comfort for the patients in case of any adjustment of operational change aiming at energy saving.

Before starting anything you must have a complete schematic diagram of each distribution network (like hot water, steam network...).

In addition to the temperature and relative humidities of the air in each hospital room, there must also be concern for the air cleanliness which is the first priority in hospitals to control the spread of infection. Figure C indicates filter efficiencies for central ventilation systems in general hospitals. In areas such as the bacteriology unit, air movement must be carefully controlled. Ultra high efficiency ULPA filters (99.999 % efficiency) can be used at the supply air duct to the sterile transfer room to maintain the sterile environment. Outside exhaust must be sterilized to 315 °C (600 °F) or ULPA filters used in conjunction with infectious disease and virus laboratories found in our largest hospitals. Isolation units and nurseries may use high efficiency HEPA filters (99.97 % efficient) and anterooms to limit the spread of infection.

In the operating theaters, where the surgical team supplies the greatest amount of bacteria, providing aseptic conditions means carefully conditioned air. Downward air movement from diffusers, perforated ceilings, etc., is probably the most effective air movement pattern to limit contamination levels. Ventilation rates are specified in Figure A, with high level introduction and at least two low-level exhaust (at least 80 mm from the floor). Supply air requires 90 % efficient terminal filters if acoustical duct linings have been used. More details on the conditions the hospital staff should attempt to maintain in each room may be found in ASHRAE Handbook on Applications 1982 Chapter 7, ASHRAE Handbook of Fundamentals, 1985, Chapters 2-6, 26, and Minimum Requirements for Construction and Equipment for Hospital and Medical Facilities U.S. Dept. of Health, Education and Welfare 1979 and 1985.

Discussing conditions that are required for each of the hospital rooms we should not forget that domestic hot water (DHW) is used in the majority of the hospital rooms. A prime DHW use, cleansing people (patients, as well as the medical and technical staff), helps to achieve hospital sepsis. Cleaning the facility itself, requires adequate supplies of DHW. DHW use in sterilization rooms and the laundry also helps to achieve this goal. Uses in the kitchen and other hospital zones point out other key DHW applications.

The complexity of the hospital HVAC system is highly dependent on the weather environment at the hospital site,

Figure C

**Table Filter Efficiencies for Central Ventilation and Air-Conditioning Systems in General Hospitals**

| Area Designation | Minimum Number of Filter Beds | Filter Efficiencies, % Filter Bed No. 1 | Filter Efficiencies, % Filter Bed No. 2 |
|---|---|---|---|
| Sensitive Areas[a] | 2 | 25 | 90 |
| Patient care, treatment, diagnostic, and related areas | 2 | 25 | 90[b] |
| Food preparation areas and laundries | 1 | 80 | — |
| Administrative, bulk storage and soiled holding areas | 1 | 25 | — |

[a]Includes operating rooms, delivery rooms, nurseries, recovery rooms, and intensive care units.
[b]May be reduced to 80% for systems using all-outdoor air.



and the size of the hospital. Small hospitals in cooler climates may have only a limited space conditioning system beyond the heating system, whereas the HVAC system of the larger hospital, in a warmer climate, may be dominated by the cooling and ventilation requirements. For these reasons, a wide range of systems and components may apply, depending upon the individual hospital. DHW systems, present in every hospital, may also vary in complexity depending on the methods used to generate DHW.

## CHAPTER 1. SPACE HEATING

### 1. Introduction

Space heating in hospitals is a requirement in all but the most semi-tropical locations. It is often a large fraction of hospital energy use. Various methods may be used to achieve space heating and therefore in the rooms themselves different heating terminals are present. Also one may anticipate a variety of control arrangements to regulate those terminals.

### 1.1 Description

First, considering only the heating system (as contrasted with HVAC), there are several common approaches: Centrally heating the room air, centrally heating water or generating steam to heat the room air or using individual heaters in the rooms to heat the air. Each approach will be briefly discussed.

### 1.1.1 Air heating systems

Air heating systems, in which the air is heated centrally and then is ducted to the individual rooms, date back to Roman times and still have application today. With any system that tends to mix air from individual rooms concerns must be raised as to the spread of infection. Therefore, the system may be suitable to only limited areas of the hospital. If ventilation requirements are such that there is no return flow, e.g., patient room air exhausts from attached toilet rooms, then concerns for contamination are minimized. Use of such direct air heating systems allows control of relative humidity at the same time. For example, humidity may be added to the heated air at a central location. Measurement of the zone air temperature is one common method to regulate how much heating is needed.

### 1.1.2 Warm water systems

Warm water systems are another heating approach that has been proven effective and widely used in hospitals. In these systems, water is heated up to a maximum temperature of about 90 °C (190 °F) in a central boiler and is distributed to the individual heating terminals or heating surfaces using the supply water pipe network. After heat extraction from the terminals, the water is returned to the boiler at a lower temperature level.



### 1.1.3 Steam heating systems

Steam heating systems can still be found in older hospitals. From a central steam generation boiler, that may also supply laundry and kitchen facilities, steam is led to the individual heating terminals mainly radiators, through either one or two pipe systems. From there, the condensate is returned to the steam generator. Steam as an energy carrier for the purpose of space heating can prove to be especially uneconomical because of the high system temperatures. Steam-supplied radiators are difficult to regulate and they tend to have high surface temperatures. The results of steam heating is often high dust circulation, low temperature dust carbonization, and danger of room occupants being scalded (from contact with the radiators). For these reasons, steam heating systems are no longer specified for hospitals (see also Booklet II, § 1.1 and § 1.2).

### 1.1.4 Individual room heaters

Individual room heaters are another option for hospital heating. These may take the form of electrical heaters such as: baseboard units, wall panel units, ceiling/floor electric heating cable, or approaches such as through-the-wall heat pumps.

### 1.1.5 Control

Room thermostats can be installed in combination with all the systems mentioned above, and they can take into account individual heating demands or heat sources in particular room. In addition to room thermostats, other control systems are often installed. These system are subdivided for the variety of individual demands of hospital zones, e.g., zones with different solar orientations. Often, in newer facilities, individual terminals are equipped with thermostatic valves to regulate the heat release. The influence on the space temperature due to solar radiation or internal heat sources (e.g., lighting and other hospital equipment) can be compensated by the regulation methods just described. Examples of supply temperature regulation are as follows: manual adjustment depending on the season, temperature control as a linear function of the outside temperature (a family of linear relationships may apply), and room thermostatic control of individual terminals (see also Booklet II, § 1.2 and § 1.3).

### 1.1.6 Heating Terminals

Heating terminals may take many forms and the following types are common:

- Radiators
- Convectors
- Flat-plate designs
- Floor systems
- Ceiling systems

### 1.1.7 Radiator heating

Radiator heating is one of the most widespread heating systems. With suitable choice of radiator models, the radiator can be used over a wide range of temperature levels, even with low temperature water systems (50 - 60 °C (120-140 °F) supply temperatures). Heat release takes place through both convection and radiation. Radiation contributes between 20 and 40 % of the energy, depending on the temperature level. When installed at the correct room location, the heat distributed from the radiator causes the room air to become well-mixed and leads to a comfortable condition in the room. The control action would be considered good when room temperature fluctuations are minimized, e.g., order of ±1 °C. This means adjusting the flow of hot water to the radiator in a precise way. The shape of the radiator can directly affect its ability to be kept clean. Panel or flat-plate designs are the easiest to maintain.

### 1.1.8 Convective heating

Convective heating systems are a common North American approach to space conditioning since with both hot and cold coils they can readily accommodate both heating and cooling. Supply (and return) grilles on room walls, floors or ceilings is the simplest approach for heating terminals. A common terminal version is the air-water induction system shown in Figure 1.1.A. Centrally conditioned primarily air is supplied to the unit plenum at high pressure, which induces secondary air from the room to flow over the secondary coil(s) where it is either heated or cooled depending on zone demands. Latent cooling is limited at the room but a drain pan is provided to collect condensed moisture. Primary and secondary air are discharged into the rooms as shown in Figure 1.1.A. A lint screen is necessary across the face of the secondary coil and it must be serviced regularly.

A second common approach is a fan-coil unit. Shown in Figure 1.1.B, this method has the advantages of the induction approach plus the unit can be operated with the

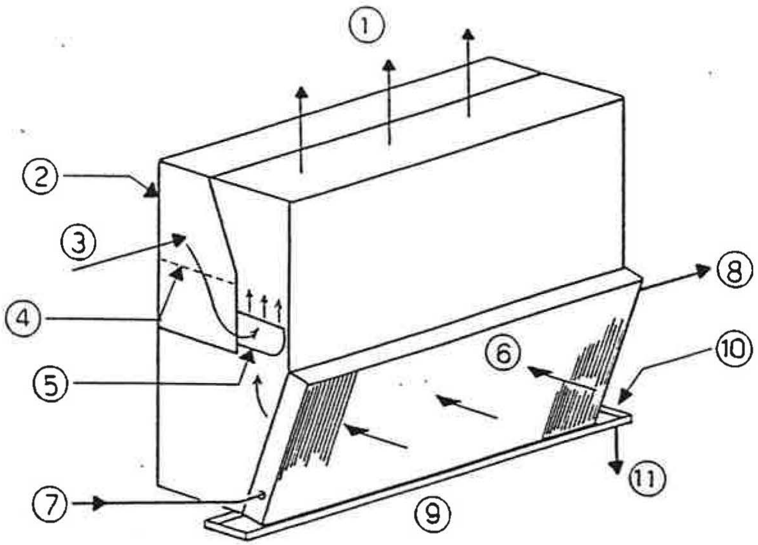


Figure 1.1.A . - Air-Water Induction Unit

1 - mixed air discarge
2 - inlet plenum
3 - primary air
4 - balancing dumper
5 - nozzles
6 - secondary water coil
7 - secondary water in
8 - secondary water out
9 - induced room air
10 - drain pan
11 - condensate drain
12 - lint screen at inlet to coil



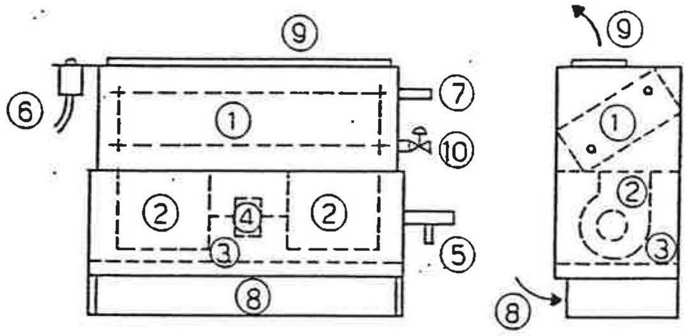


Figure 1.1.B. . - Typical Fan-Coil Unit

1 - Finned tube coil

1. Finned tube coil
2. Fan scrolls
3. Filter
4. Fan motor
5. Auxiliary condensate pan
6. Fan speed control switch
7. Coil connections
8. Return air opening
9. Discharge air opening
10. Water control valve

primary air off. The unit requires less maintenance than induction units. The primary air needs not enter the room directly through the fan-coil unit. Disadvantages are higher initial cost and the electrical consumption due to the fan. Again, cleanliness is important.

### 1.1.9 Floor heating

Floor heating systems, in general can only supplied with water temperature up to 50 °C (120 °F), and are therefore ideal for low temperature water system operation. In the past, these heating designs were much more common. Today, they are confined to special treatment facilities such as physiotherapy or hydrotherapy. The reason for this is higher costs, compared to radiator or flatplate heating. The floor surface temperatures are usually maintained between 23 and 26 °C, (73-79 °F) and in rooms with a shorter occupation time, temperatures up to 28 °C (82 °F) may be provided. The perception of comfort is increased because of the high amount of radiation, because air temperature stratification is reduced and warm feet result. However, near windows the missing exterior shielding can cause a feeling of cold radiation or of cold drafts. This can be avoided by adding radiators in window areas, which not only compensate for these effects but combines nicely with the relatively slow reacting floor heating to produce a very suitable heating system combination.

### 1.1.10 Ceiling radiant heating

Ceiling radiant heating systems in the past were sometimes installed in entrance areas, bedrooms and surgical operation rooms. Because of the high cost, maintenance and possible comfort problems, these systems were discontinued. New hospital construction is now making use of such units.

### 1.1.11 Individual unit heaters

Individual unit heaters are not widely used in hospitals. An exception is electric storage heating devices, which are sometimes installed. Question of economy, as well as the considerably high space demand for the units placed in the rooms, have limited any widespread application of these techniques.

## 1.2 Strategy. Case studies

Space conditioning and DHW are considered important energy elements of the hospital where relatively large amounts of energy can be saved by means of trouble shooting, optimized operation of the installed equipment and by modification or replacement of the system components. The extent of the energy use of these hospital components is shown in Figure 1.2.A for typical existing U.S. hospitals, hospitals designed to ASHRAE Standard 90-75 and redesigned hospitals. The heating (including DHW), cooling and ventilation (fans) consume two-thirds to three-quarters of the energy. As Figure 1.2.A points out much of the energy savings potential is to be found in these three energy components.

In order to find out how much energy can be saved and what measures have to be taken, develop a strategy for the specific hospital facility.

### 1.2.1 Organizing an effective energy management program

An effective Energy Management Program includes the following points (see also Booklet I):

- Having a good knowledge of each space conditioning and DHW system and all of its components.
- Identifying the real needs (qualities, flows and temperatures) associated with space conditioning and DHW required.
- Estimating as accurately as possible the costs of production and distribution of space conditioning and DHW.
- Reducing the unnecessary consumption, i.e., proper system operation.
- Organizing the maintenance of each system with cost in mind.
- Repairing and replacing those components which perform poorly.
- Recording the energy consumption for HVAC and DHW on a regular basis.

#### 1.2.1.1 Knowing the system

This task begins with updating the drawings of each system, working with those individuals who understand what is actually in place in the hospital. Especially important to understand is just how each system is controlled. On site inspection of critical components can prove very rewarding.

#### 1.2.1.2 Evaluating the needs

Whether it is the space conditioning or the DHW, specific needs in the hospital must be met. Are the needs being met is often most quickly determined by interviewing those familiar with that particular room or zone. Is the temperature well controlled? Is the ventilation adequate? Is the DHW to the room meeting the needs?
Measurements such as temperature and flow at these locations will prove very helpful in the evaluation.

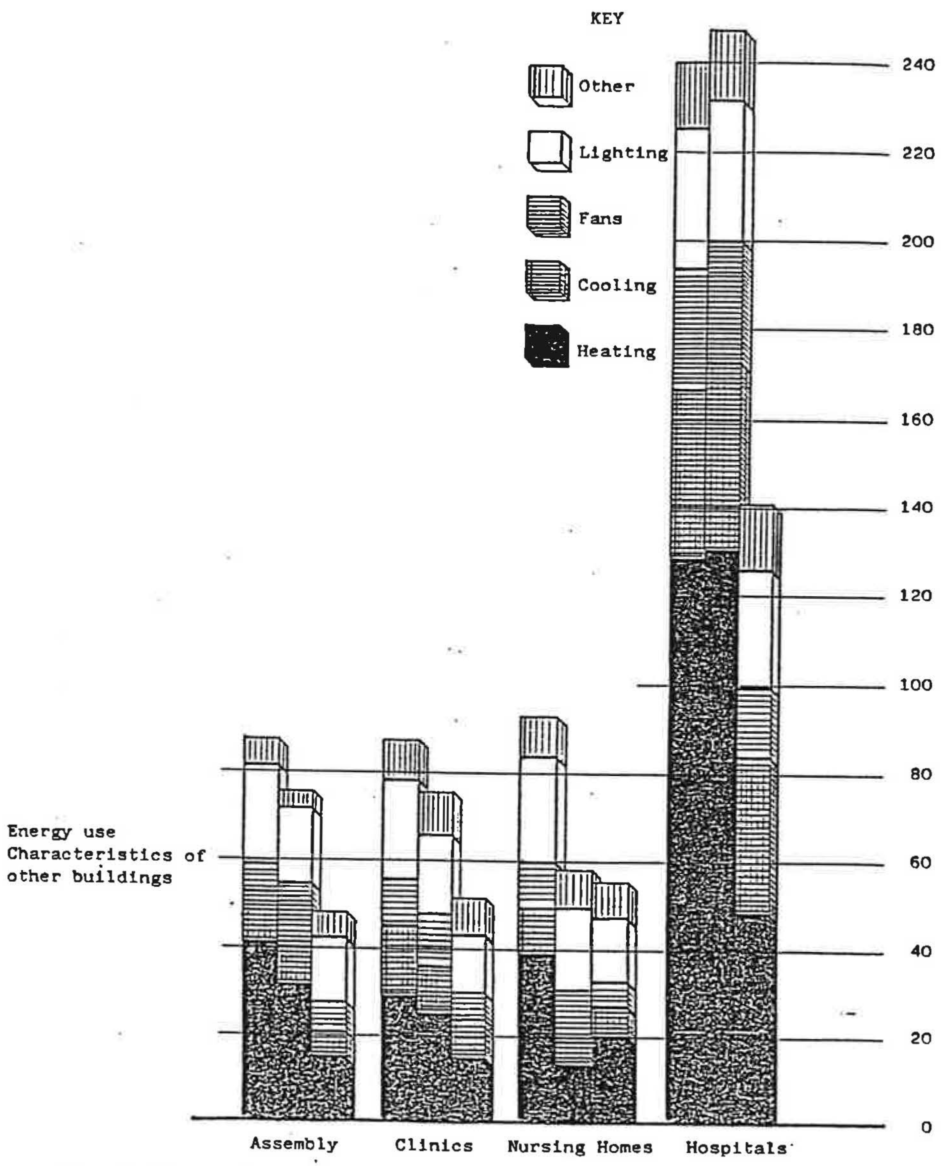


Fig. 1.2A - This figure shows the average energy use for each building type for three conditions: the original design, the ASHRAE Standard 90-75, and the redesign. Total annual energy and end use are expressed in thousands of BTU/sqft/yr for heating, cooling, fans, lighting, and other end uses, including service water, heating, elevators, escalators, and exhaust fans.



1.2.1.3 Estimating cost

This item is often best achieved by reviewing hospital energy consumption, and associated costs, and then trying to allocate those costs associated with space conditioning and DHW.

Submetering of systems may be necessary to make the energy/cost breakdown. Comparison with similar facilities and/or target values is very worthwhile.

1.2.1.4 Reducing unnecessary consumption; proper system operation

Over conditioned space (too much heating, cooling, or ventilation) or the wasting of DHW are indicators that energy consumption can be reduced. Improved guidance to the hospital staff and making certain that the controls are adequately marked, and functioning properly, are first steps in reducing consumption.

1.2.1.5 Organizing the maintenance of each system

Each system must be maintained properly, filters changed, valves lubricated and serviced, etc. Maintenance must be performed religiously and is vital to an energy management program.

1.2.1.6 Repair and replacement of system components

Beyond maintenance is the continual upgrading of the system; replacement of valves that are more reliable, improved filters, more efficient subsystems, etc. The systems must be considered as fully functional (see Booklet I).

1.2.1.7 Recording the energy consumption regularly

Continuous review of the hospital energy use is key to avoiding energy waste and therefore costly surprises. This recording should continue on an indefinite basis, and the information reviewed by responsible staff.

1.2.2 Guidance in energy reduction

Before describing the specific items that require our attention for achieving the desired energy reductions (Sections 3 and 4), this section provides further general guidance in where to seek the improvements. For example, one should proceed from the target values, principally the room temperatures (and energy use data), and check the hospital systematically, area by area. This means SYSTEM BALANCE, the right amount of energy to each room or zone. The desired temperature values must be compared with the actual temperatures observed. Do these values meet the standards, or if not, can they be changed to achieve better agreement? Adherence to the nominal values has to be controlled within reasonable limiting conditions. While monitoring (e.g., possibly with a data logger), one should pay attention that energy related activities of the staff, such as room airing, are limited to prevent excessive energy loss.

First and foremost, energy savings strategies for the space conditioning and DHW energy component in hospitals involves control. The control can be manual or automatic and can be based on time schedules, occupancy density or measured internal environmental conditions.

Examples of simple time scheduling opportunities include:

- For heat energy savings, setback temperature levels during unoccupied periods.
- Shut off heating to those rooms and zones that are unoccupied.
- Thermostats should be "locked" so that settings stay at energy conserving levels.

An example of the problems of excessive heating of a hospital department is shown in Figure 1.2.B. The fact that the heating demand is being met for temperatures below 0 °C, and that patient and staff complaints about underheated rooms is not a problem, means that too much heat is being used. An improved performance through reduction of the hot water loop temperature is shown in Figure 1.2.C. Here the maximum output of the system is adjusted to the minimum outdoor temperature anticipated (-10 °C) and the heating is reduced to 200 kWh/d at 18 °C). At outside temperatures above 18 °C the system is turned off.

Figure 1.2.D illustrates problems in the control settings. The characteristics of the heating system were set "too flat" and therefore rather than following the prevailing weather, the settings must be adjusted repeatedly. All operational points above the optimized characteristic represent energy waste. An "improved characteristic" is shown in Figure 1.2.E and through minor adjustments may approach the "optimum characteristic" also shown. To move to the optimized characteristic system adjustments could involve lowered water temperatures and checking that all rooms were comfortable. Windy weather, which may influence comfort in some rooms, is one reason for the difference between "improved" and "optimized" characteristics. Where space occupation patterns permit temperature setback (or setup) for certain periods,this

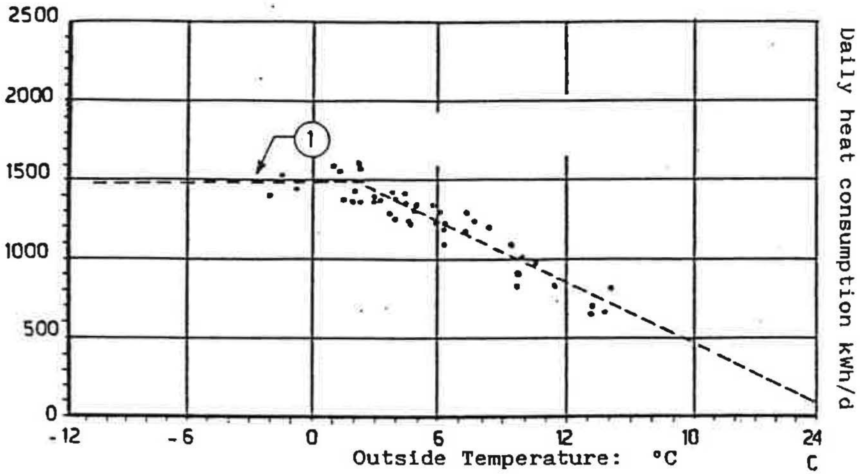


Figure 1.2.B - Daily heat consumption of one hospital department

1 - Heating consumption measured

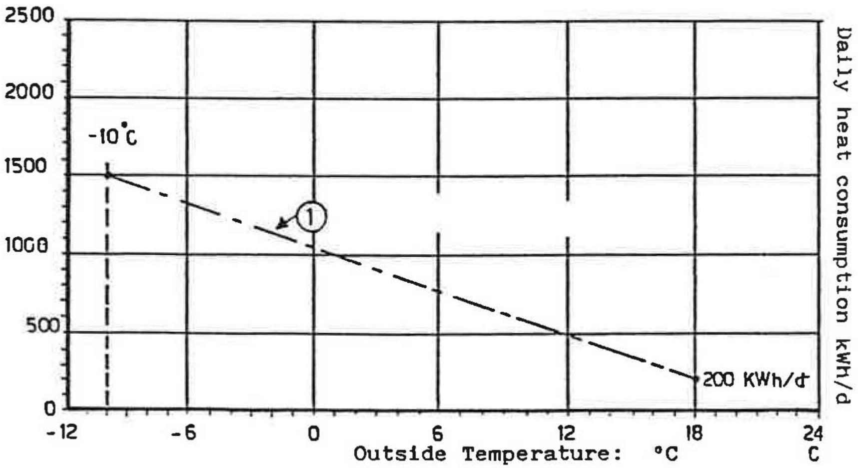


Figure 1.2.C - Improved heat consumption characteristic for the same hospital department

1 - Improved characteristic



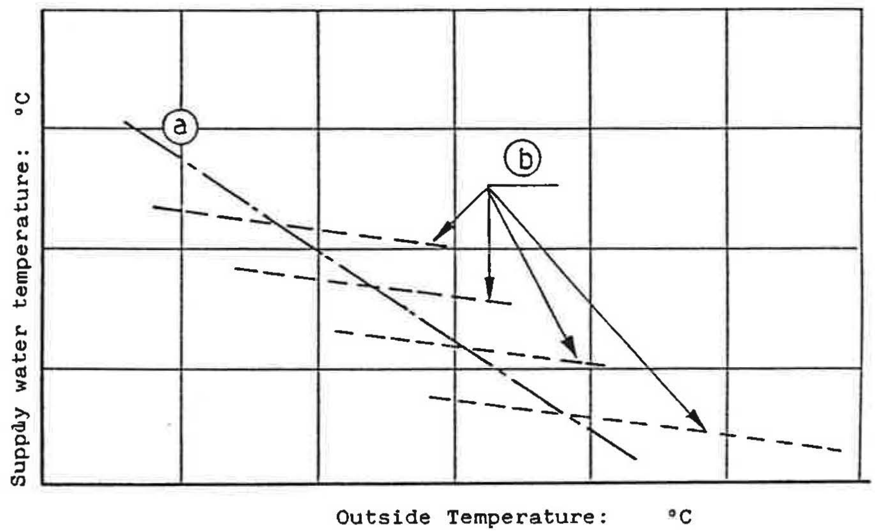


Figure 1.2.D - Sketch of adjusted control characteristics

a - Improved characteristic of the system

b - System characteristics as adjustet by Hospital personnel

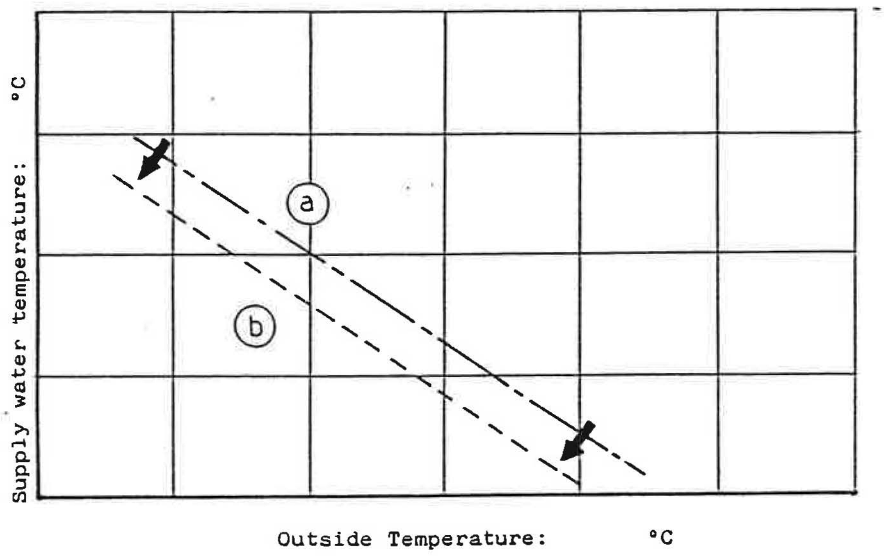


Figure 1.2.E - Relationschip between improved and optimized control characteristics

a - Improved characteristic

b - Optimized characteristic



could also move on toward an optimum characteristic with more than one setting.

## 1.3 How to save energy with minor changes

### 1.3.1 What to do and how to do it

The complete list of HVAC ECOs, found in § 3.3.1, includes ways in which to save energy associated with space heating, making use of operational and/or maintenance changes, and may include minor alternations to the system. Those items associated with the heating system are marked H.

## 1.4 How to save energy through modification

Most energy conservation measures involve some cost to the owner, if not a direct cost, then a personnel cost. Eventually, a point is reached at which a proposed change is too costly to be absorbed into normal operating budgets.

Retrofit options require additional analysis by energy auditors for the purpose of determining whether they are worthwhile investments. The time and effort expended in such an evaluation should be in proportion to the initial cost of the option since this is the extent of the risk involved.

Any retrofitting option should be carefully studied. Considerations with respect to cost effectiveness (life cycle cost) should be included in such a proposal. Approaches for analysis, measurements and methods for deciding appropriate retrofits may be found in the Source Book for Energy Auditors, Annex XI, IEA, 1987.

### 1.4.1 What to do and how to do it

The complete list of HVAC ECOs involving modifications, found in § 3.4.1, contains many suggestions as to possible heating system modifications that could lead to considerable energy savings in specific hospitals. Careful evaluation of each suggestion that applies is recommended. Again the ECO numbering is from the HVAC list which includes heating, cooling, and ventilation, and the H symbol denotes heating items.

## CHAPTER 2. SPACE COOLING

### 2. Introduction

Space cooling is required in a majority of hospitals, not only because of their geographical location, but because of the high energy intensity within many zones of the hospitals. Space cooling would normally be achieved by a central system but individual cooling units, such as window air conditioners, can also be used.

### 2.1 Description

Central chiller-based systems normally pump chilled water to each of the rooms or zones. The central equipment is described in Booklet II, Chapter 2. In this section, we are concerned with the chilled water passing through terminals such as those illustrated in Figures 1.1.A - 1.1.B.

As pointed out with the air-water induction unit, or fan-coil unit, the ability to cool the space may only require another coil (four-pipe system; hot water in, hot water out; cold water in, cold water out) or a seasonal switchover with a single coil (two-pipe system; hot or cold water in, hot or cold water out). The two coil approach is preferred for rapidly changing space conditioning circumstances and for situations where some rooms may require cooling at the same time others require heating. This commonly occurs because of equipment loads or because of local room solar loads.

An alternative approach is Direct Expansion, DX, where the refrigerant would be piped directly to the room terminals.

Wall or window units using refrigeration cooling can also be employed alone, or to supplement central cooling at critical locations.

Use of increased outside air, when outside temperature and relative humidity conditions are appropriate, the "economizer cycle" is another approach to cooling interior spaces.

Use of recirculation air to increase local air velocities, the simplest system makes use of a ceiling fan, is still another cooling method.



Each of the cooling approaches must be carefully evaluated to make certain patient and staff comfort are not compromised.

Often the cooling approach is directly linked to the ventilation requirements for the given hospital space as well as pressurization for certain spaces (see Figure A). For these cases refer to Chapter 3, where systems are described in § 3.1 and following.

### 2.2 Strategy. Case studies

In addition to the general approaches suggested in § 1.2, space cooling strategies call for such straight forward approaches as temperature setup as the appropriate action. One benefit of refrigeration cooling is the associated relative humidity reduction which can have a direct influence on occupant comfort as well as meeting hospital standards on relative humidity (see Introduction to this Booklet and Figure A).

To achieve the highest energy efficiency for the space conditioning system means that <u>control at very point in the system must be maintained by accurate sensing devices</u>. The system is only as good as its sensors, and accurate sensors are absolutely necessary to meet the exacting space conditioning standards in the various zones within any hospital.

Characteristics of a good sensor include: accuracy, interchangeability, easy installation, maintenance and compatibility within the system.

Stability of calibration over time is a key characteristic of a desirable sensor, but this doesn't mean this stability should be assumed. Therefore, one energy conservation recommendation is for regular checks on the accuracy of all key sensors.

Studies have shown that yearly energy waste due to errors in cooling system sensors can result in very large energy losses - approaching 100 % increases in the required cooling energy. The errors need only be a few degrees Celsius to cause large energy waste.

### 2.3 How to save energy with minor changes

#### 2.3.1 What to do and how to do it

The complete list of HVAC ECOs, found in § 3.3.1, contains a listing of ways in which to save energy associated with space cooling. Operational and maintenance items, or items involving minor changes for cooling systems, are denoted by the symbol C.

### 2.4 How to save energy through modification

#### 2.4.1 What to do and how to do it

Observing the same cautions as stressed in § 1.4, the list for modification ECOs, found in § 3.4.1, contains many suggestions for possible cooling system modifications, marked with the symbol C, that could result in considerable energy savings in specific hospitals. Careful evaluation of each suggestion is recommended.



# CHAPTER 3. VENTILATION AND HVAC

### 3. Introduction

Certainly in the larger hospitals, and often even the smaller ones, hospitals must comply detailed standards as to temperatures, relative humidities, ventilation levels and pressures in the various rooms and zones as discussed in the introduction to this Booklet (also see Figure A). Because of the presence of such standards and recommended practices it is important to understand what demands are being placed on the HVAC equipment and what equipment operating in the particular hospital being investigated can meet those demands while operating in an energy efficient manner.

### 3.1 Description

Often complex systems are required to handle the heating, ventilating and air conditioning needs within the hospital. Additional factors of relative humidity and zone pressure become part of that equipment plan. Eight common system designs to supply these needs are illustrated in Figures 3.1.A to 3.1.H. These systems include both all-air and air-water approaches to space conditioning.

#### 3.1.1 All-air systems

All-air systems may be classified as the single-path or dual-path designs. Single-path systems contain the cooling and heating coils in a series flow air path using a common duct distribution system operating at a common temperature to feed the individual terminals as shown in Figures 3.1.A and 3.1.B. The dual-path system, Figure 3.1.C, contains the main heating and cooling coils in a parallel flow or series-parallel flow air path, and uses either (a) separate cold and warm air duct distribution with blending at the terminal apparatus (dual-duct system), or (b) a separate supply duct to each zone with the air supplied to that zone at a discharge air temperature controlled by the main air supply fan. Single path systems include: single zone, constant volume; zoned reheat, constant volume; variable volume, multizone induction; and variable volume, reheat. The dual path systems include dual duct (and dual variable volume), see Figure 3.1.D and multizone, see Figure 3.1.E. These systems have a long list of advantages and disadvantages. These systems are further discussed in the Source Book for Energy Auditors, IEA Annex XI, 1987.

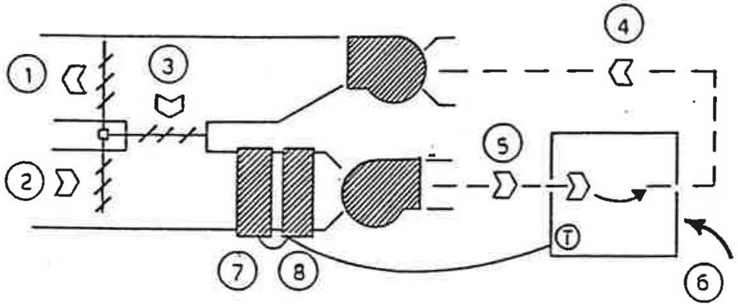


Figure 3.1.A. - single zone HVAC system

1 - Exhaust
2 - Outside air
3 - Recirculated air
4 - Return air
5 - System & zone supply air
6 - Conditioned space
7 - Heating coil
8 - Cooling coil

MODE OF OPERATION
CONSTANT OR VARIABLE VOLUME: Constant
SINGLE OR MULTIZONE: Single Zone
ZONE CONTROL: See System Supply Air Control
SYSTEM SUPPLY AIR CONTROL: By Room Thermostat
OUTSIDE AIR & ECONOMISER: Optional shown on schematic. Sequenced with heating and cooling coil for optimum energy efficiency.
TYPICAL SET-BACK OR UNOCCUPIED OPERATION: Minimum outside air allowed to go to zero, heat (or cool) coils on full output and fan cycles to maintain set-back (set-up) temperature.



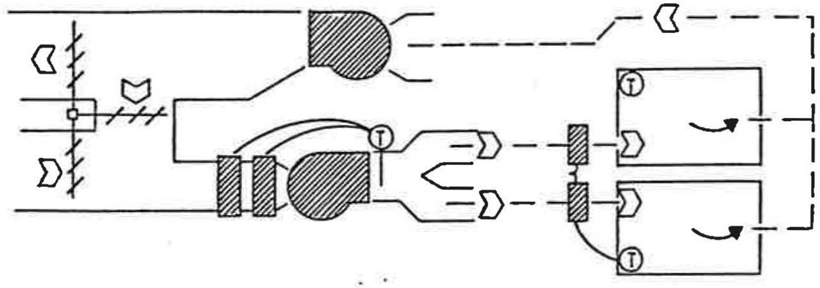


Figure 3.1.B. - Terminal Re-heat System

1 - Exhaust
2 - Outside air
3 - Recirculated air
4 - Return air
5 - System supply air
6 - Re-heat coils
7 - Supply air to zone 1
8 - Supply air to zone 2
9 - Heating coil
10 - Cooling coil
11 - Conditioned space

MODE OF OPERATION
CONSTANT OR VARIABLE VOLUME: Constant
SINGLE OR MULTIZONE: Multizone
ZONE COTNROL: By room thermostat controlling addition of re-heat. Re-heat may ve in duct heating coil or baseboard/perimeter heating.
SYSTEM SUPPLY AIR CONTROL: Fixed in basic system. Advanced strategies reschedule temperature seasonally with outside conditions or reset temperature with variations in zone demand.
OUTSIDE AIR & ECONOMISER: Optional, shown on schematic. Sequenced with system supply air controls for optimum energy performance.
TYPICAL SET-BACK OR UNOCCUPIED OPERATION: Minimum outside air allowed go to zero. Fan operates continously. Alternatively discontinue re-heat and oeprate as Type 1 System.

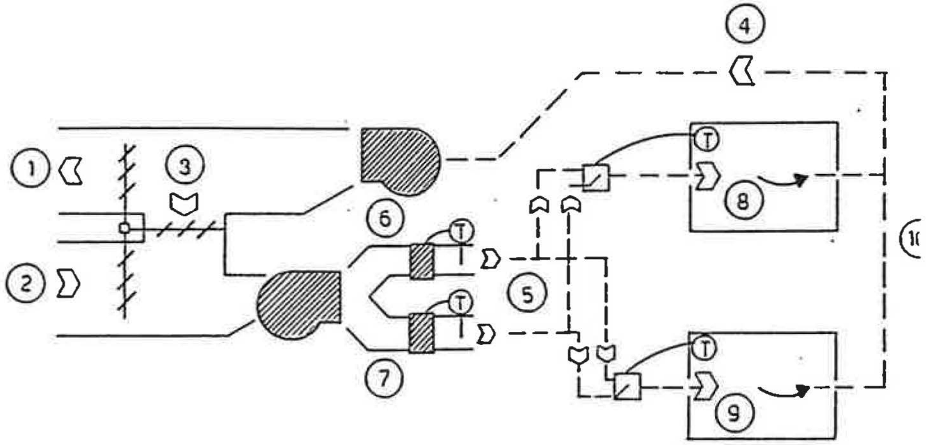


Figure 3.1.C. - dual duct system

1 - Exhaust
2 - Outside air
3 - Recirculated air
4 - Return air
5 - System supply air
6 - Hot duct
7 - Cold duct
8 - Supply air to zone 1
9 - Supply air to zone 2
10 - Conditioned space

MODE OF OPERATION
CONSTANT OR VARIABLE VOLUME: Constant or Variable
SINGLE OR MULTIZONE: Multizone
ZONE CONTROL: Similar to Type (Multizone) System except mixing occurs in a mixing box located within the control zone. In VAV systems cold duct air flow is throttled to a minimum volume before hot duct damper opened.
SYSTEM SUPPLY AIR CONTROL: Similar to type 3 (Multizone) System. (see. fig. 3.1.E)
OUTSIDE AIR & ECONOMISER: Similar to Type 3 (Multizone) System. (see. fig. 3.1.E.)
TYPICAL SET-BACK OR UNOCCUPIED OPERATION: Similar to type 3 (Multizone) System. (see. fig. 3.1.E.)



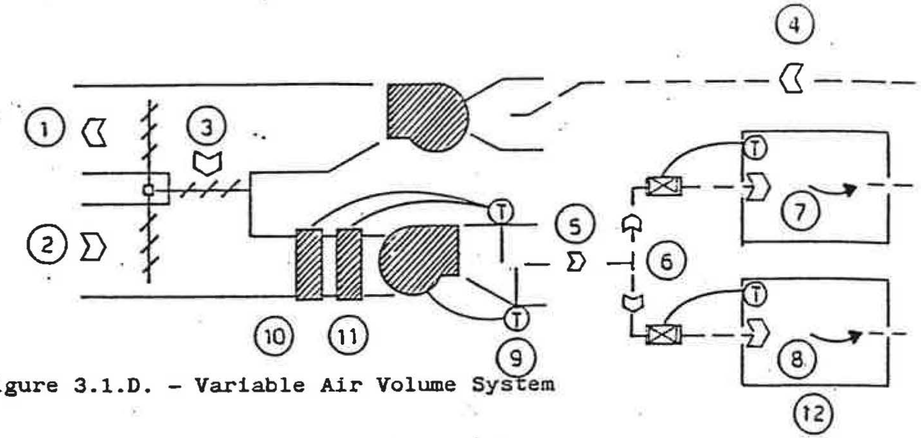


Figure 3.1.D. - Variable Air Volume System

1 - Exhaust
2 - Outside air
3 - Recirculated air
4 - Return air
5 - System aupply air
6 - VAV control boxes
7 - Supply air to zone 1
8 - Supply air to zone 2
9 - Duct pressure controller
10 - Heating coil
11 - Cooling coil
12 - Conditioned space

MODE OF OPERATION
CONSTANT OR VARIABLE VOLUME: Variable
SINGLE OR MULTIZONE: Multizone
ZONE CONTROL:Zone thermostat controls volume of air flow supplied to zone (down to some predetermined minimum acceptable flow rate). Optional zone re-heat sequenced to operate once this minimum is reached is a common feature where system used for heating as well as cooling. "Re-heat" may be in duct type or perimeter baseboard of convector heating.
SYSTEM SUPPLY AIR CONTROL: Fixed in basic system. Advanced strategies include sequencing with outside conditions or resetting with zone load variations but such a strategy will have an adverse effect on fan power consumption.
OUTSIDE AIR & ECONOMISER: Optional, shown on schematic. Sequenced with system supply air temperature control for optimum energy performance.
TYPICAL SET-BACK OR UNOCCUPIED OPERATION: Minimum outside air allowed to go to zero. Open all zone boxes and heat (cool) coil valves and operate as Type I System. Where re-heat is not dependent on system air, e.g. baseboard, shut air system off during set-back.
OHTER COMMENTS: some systems throttle the air supply thereby reducing the overall air supply fan power but increasing duct pressure. In these systems duct static pressure and fan volume control is desirable and normal.
Other systems maintain a constant system air supply by "dumping" zone air, not required in the zone, to the return duct. This is normally a simpler system but fan power savings are not realised [illegible].

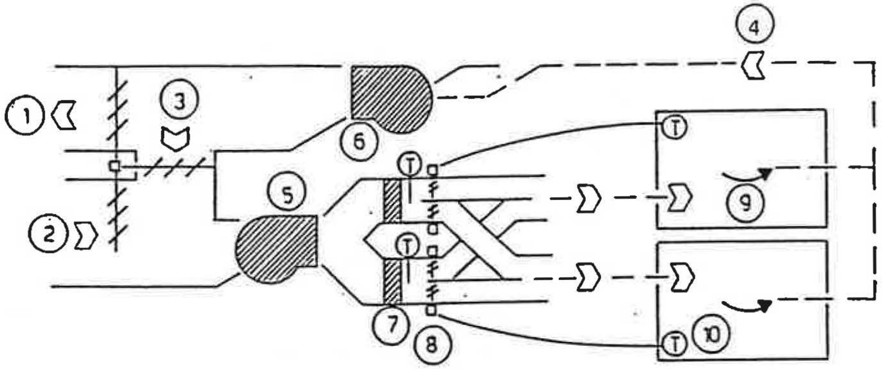


Figure 3.1.E. - Multizone System 11

1 - Exhaust
2 - Outside air
3 - Recirculated air
4 - Return air
5 - System supply air
6 - Hot deck
7 - Cold deck
8 - Zone control dampers
9 - Supply air to zone 1
10 - Supply air to zone 2
11 - Conditioned space

MODE OF OPERATION
CONSTANT OR VARIABLE VOLUME: Constant
SINGLE OR MULTIZONE: Multizone
ZONE CONTROL: Each zone thermostat control corresponding zone dampers in system to mix hot and cold air streams to provide desired zone supply air temperature.
SYSTEM SUPPLY AIR CONTROL: Individually controlled hot and cold decks in basic system. Advanced control strategies would involve scheduling of deck temperatures with outside conditions or resetting with zone load variations.
OUTSIDE AIR & ECONOMISER: Optional, shown on schematic. Sequenced with hot and/or cold deck system supply air controls for optimum and/or provide stratification guides to direct outside air, return air to hot and cold decks respectively.
TYPICAL SET-BACK OR UNOCCUPIED OPERATION: Minimum outside air allowed to go to zero. Shut off cold deck during set-back (and hot or hot deck during set-up) and operate as Type 1 System.
(sec. fig. 3.1.6.)
OTHER COMMENTS: Newer systems may have individual (zone) coils as apposed to a common heating and a common cooling coil.
Some packaged systems utilise heat from refrigerant condenser heat hot deck.

### 3.1.2 Mixed systems

Mixed systems (water and air) may be described as systems in which the energy supply in the rooms is shared between the radiators, fan-coil or induction units, and the air supply system. For instance, most of the sensible heating demand of the rooms are met by the water system, while the air system has the main function of meeting the air renewal and quality requirements and in some cases to bring supplementary energy.

An example of mixed system, with make-up air and induction units, is found in Fig. 3.1.F. Figure 3.1.G shows a mixed system with radiators and air supplied at constant temperature. Figure 3.1.H shows a system with radiators and with return air kept at constant temperature. These two last systems differ in the control strategy used for each. In the former, the radiators are sufficient to insure the required temperature with or without air supply, whereas the latter needs complementary energy supplied from the air intake in order to keep the room at the required temperature.

### 3.1.3 Interactions between different systems and areas

In complex buildings like hospitals, one has to pay a particular attention to the interactions between different systems (water, air) supplying energy to different areas with different characteristics. Modifying the control setpoints in some areas may create problems in some other areas of the hospital. Some usual configurations in hospitals are described in § 2.3, and following, of Booklet II.

### 3.2 Strategy. Case studies

Spaces within the hospital must be kept within narrow ranges of temperature and relative humidity while following closely the ventilation requirements and pressure levels that are mandated in the hospital. These goals for each space are described in the Introduction to this Booklet. Not only must the systems be balanced, it is critical that systems are designed to meet those standards without one system working against the other. A number of such conditions are outlined in the ECOs of Sections 3 and 4. For example, care should be taken not to cool the air below necessary temperatures for comfort and relative humidity requirements posed by the most demanding zone, so as to avoid unnecessary reheat.

One problem is that control characteristics are not clearly indicated on the control panels and operators don't fully understand the system.

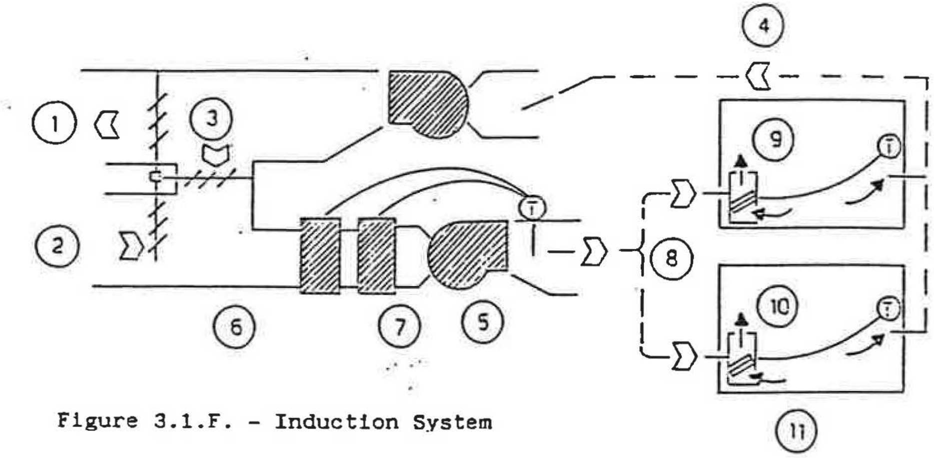


Figure 3.1.F. - Induction System

1 - Exhaust
2 - Outside air
3 - Recirculated air
4 - Return air
5 - "Primary air" system supply air
6 - Cooling coil
7 - Heating coil
8 - Induction unit
9 - Supply air to zone 1
10 - Supply air to zone 2
11 - Conditioned space

MODE OF OPERATION

CONSTANT OR VARIABLE VOLUME: Constant
SINGLE OR MULTIZONE: Multizone
ZONE CONTROL: Zone thermostat controls amount heat (or cool) added to secondary (induced air) at the zone terminal.
SYSTEM SUPPLY AIR CONTROL: Normal to schedule primary air supply temperature in winter with outside conditions and in summer supply air at a fixed temperature. Advanced control strategies reset primary air temperature with variations of zone demand.
OUTSIDE AIR & ECONOMISER: Optional, shown in schematic. Often not provided when primary air volume matches minimum ventilation rate.
TYPICAL SET-BACK OR UNOCCUPIED OPERATION: during set-back primary air can be shut off and fluid temperature to terminals raised to permit system to function like a natural convector perimeter heating system.
OTHER COMMENTS: In winter the system acts like a re-heat system with heating provided at the induction (zone) terminals and cooling achived by the "cold" primary air.
In summer the systems acts like a re-cool system with cooling provided at the induction (zone) terminals.
Terminal heating and cooling can be from a single-exchanger 2 pipe system or from a two exchanger (one heating, one cooling) 3 or 4 pipe system.



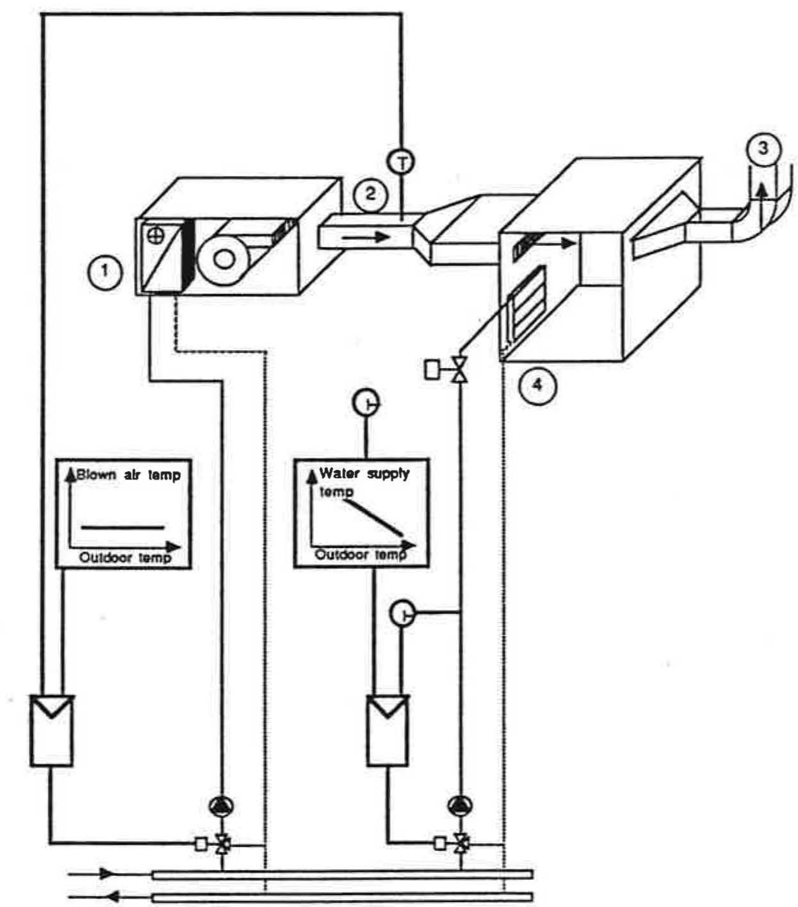


Figure 3.1.G. - Air-water system: supply air at constant temperature.

1 unit heating coil
2 supply air
3 exhaust air
4 radiator

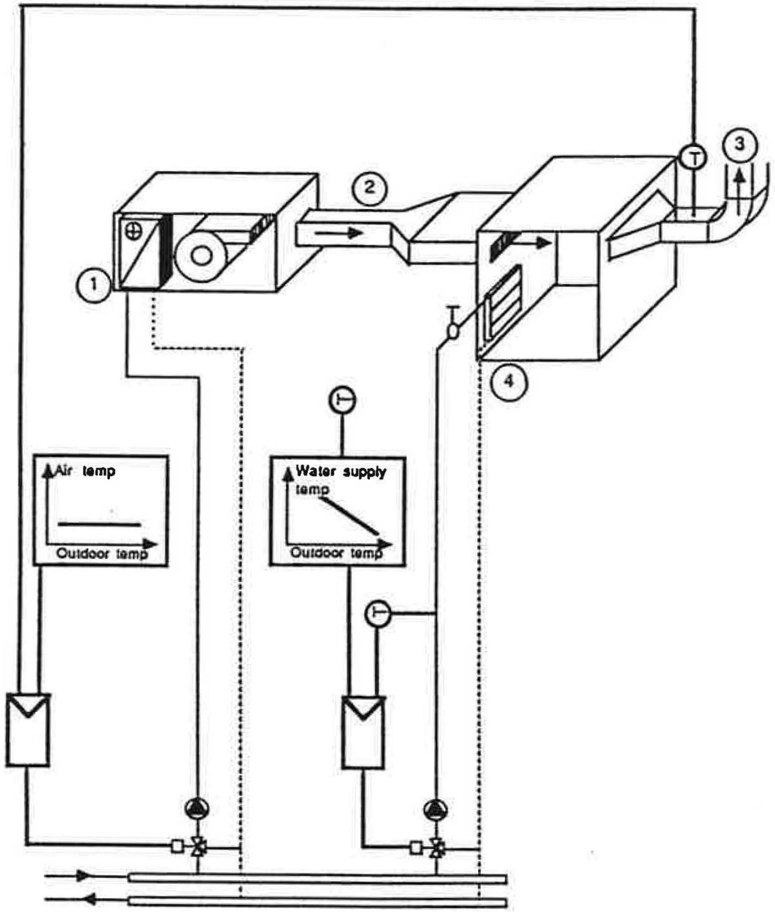


Figure 3.1.H. - Air-water system: exhaust air at constant temperature.

1 unit heating coil

2 supply air

3 exhaust air

4 radiator



Strategies on how to achieve energy savings while maintaining control are discussed in more detail throughout this section.

Another strategy to achieve saving in HVAC energy is to never ignore the duct system. The duct system is a vital element needed in the distribution of conditioned ventilating air throughout many of the hospitals. Although this strategy primarily concerns new hospitals (or hospital additions) its importance deserves discussion. Balance throughout the duct system is difficult or impossible to achieve if the air distribution system isn't correct, and modification to existing poorly performing systems should be considered.

Another design feature, present in each of the various systems is the choice and maintenance of coils. The coils cool the air, heat the air, and dehumidify the air. Where the coils are placed and how they are maintained are key ingredients to achieving high system efficiency. The air-side coils in patient rooms, using air-water systems, require proper maintenance of the filter, otherwise lint and other dirt buildup will quickly degrade performance. This dirt may even be a breeding ground for undesirable molds and bacteria. Drainage of any water from the coils is also a requirement to make certain there is no buildup of microbial slime, which has been identified as a health problem.

The standards associated with the local environments throughout the hospital also offer opportunities for energy savings. The American Hospital Association, in Energy Strategies, points out feasible energy-saving code changes such as: relaxing humidity requirements in recovery areas to 30 percent RH; reducing hospital operating room outdoor air exchange rates from five to four, and total air exchange rates from 25 to 20; night shutdown of fan systems, using relaxed standards for air pressure in nonsensitive patient rooms; reduced outside air ventilation at night, that is proportional to occupancy levels (sensitive patient areas excluded); and conversion of air systems to VAV systems. The projected energy savings from such changes are shown in Figure 3.2.A.

Returning to the important subject of control strategies, for optimum efficiency of energy usage it is desirable to tailor the standard for the environment with that of hospital occupancy in the various zones. Such a tailoring of conditions is normally achieved through some HVAC system scheduling or control strategy which can take one or more of a number of specific forms. The control can be manual or automatic and can be based on time schedules, occupancy density or measured internal environmental conditions. Similar examples of simple time scheduling

| Reference for table Hospitals | No. of beds |
|---|---|
| C | 50 |
| G | 630 |
| H | 279 |
| I | 268 |
| M | 39 |
| S | 505 |
| T | 535 |
| W | 364 |

Figure 3.2A

## Projected Energy Savings Attributable to Proposed Changes in HHS Construction and Equipment Standards

| Degree-Days | | Hospital | Total No. of Air Systems Analyzed | Total Supply CFM | Avg. % O.A. | Total Site Energy Savings | | | | Savings per 1000 CFM (MMBTU) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Elec. | | Gas | | | |
| Htg. | Clg. | | | | | MMBTU | % | MMBTU | % | Elec. | Gas |
| **Relaxed humidity requirement** | | | | | | | | | | | |
| 8310 | 527 | M | 3 | 7,091 | 43 | 6.44 | .4 | 282.78 | 6.3 | .91 | 39.88 |
| 6132 | 490 | H | 5 | 76,700 | 33 | 52.01 | .4 | 2417.51 | 7.7 | .68 | 31.52 |
| 1507 | 722 | C | 2 | 10,106 | 34 | 11.43 | .6 | 207.64 | 5.9 | 1.13 | 20.55 |
| **Reduced total and outdoor air changes** | | | | | | | | | | | |
| 8310 | 527 | M | 1 | 4,491 | 35 | 12.80 | .7 | 53.00 | 1.1 | 2.85 | 11.80 |
| 6132 | 490 | H | 2 | 30,050 | 33 | 329.95 | 2.4 | 829.36 | 2.6 | 10.98 | 27.60 |
| 6127 | 925 | I | 1 | 14,500 | 37 | 239.96 | .6 | 320.80 | .6 | 16.55 | 22.12 |
| 4650 | 162 | W | 4 | 74,875 | 20 | 523.69 | 1.1 | −15.32 | – | 6.99 | −.20 |
| 3478 | 1569 | T | 2 | 81,785 | 23 | 918.33 | 2.7 | 1490.87 | 7.5 | 11.23 | 18.23 |
| 3095 | 1589 | G | 3 | 80,495 | 20 | 433.38 | .8 | 176.24 | .1 | 5.38 | 2.19 |
| 1507 | 722 | C | 1 | 8,606 | 22 | 14.60 | 1.4 | 25.54 | 6.6 | 1.72 | 2.97 |
| **Night shutdown due to relaxed pressurization** | | | | | | | | | | | |
| 4650 | 172 | W | 1 | 9,950 | 20 | 294.01 | .6 | −3,01 | – | 29.55 | −.30 |
| 3478 | 1569 | T | 2 | 33,085 | 21 | 65.60 | .2 | 124.33 | .6 | 2.01 | 3.76 |
| 3080 | 39 | S | 5 | 155,650 | 100 | 1746.76 | 5.6 | 5357.07 | 4.4 | 11.22 | 34.48 |
| **Reduced ventilation in accordance with occupancy** | | | | | | | | | | | |
| 6127 | 925 | I | 1 | 51,000 | 51 | 63.48 | .2 | 155.98 | .3 | 1.24 | 3.06 |
| 4650 | 152 | W | 2 | 31,485 | 20. | 297.26 | .6 | 230.44 | .2 | 9.44 | 7.32 |
| 3478 | 1569 | T | 1 | 5,950 | 22 | 582.00 | 1.7 | 66.33 | .3 | 97.82 | 11.15 |
| 3095 | 1589 | G | 2 | 42,810 | 79 | 476.84 | .9 | 1951.71 | 1.4 | 11.14 | 45.62 |
| **Variable air volume conversion** | | | | | | | | | | | |
| 6132 | 490 | H | 4 | 67,960 | 33 | 1651.20 | 16.7 | 3165.20 | .9 | 24.30 | 46.57 |
| 6127 | 925 | I | 3 | 167,000 | 51 | 8020.53 | 19.0 | 5867.00 | 11.8 | 48.03 | 35.13 |
| 3478 | 1565 | T | 3 | 139,429 | 10 | 5144.92 | 15.4 | 1346.53 | 6.8 | 36.90 | 9.66 |
| **Composite** | | | | | | | | | | | |
| 8310 | 527 | M | 3 | 7,091 | 43 | 18.89 | 1.1 | 321.14 | 8.4 | 2.56 | 45.29 |
| 6132 | 490 | H | 6 | 98,010 | 33 | 1651.20 | 23.1 | 3165.20 | 10.1 | 16.85 | 32.29 |
| 6127 | 925 | I | 4 | 181,500 | 50 | 8309.77 | 19.7 | 7181.25 | 14.5 | 45.78 | 39.57 |
| 4650 | 162 | W | 7 | 116,310 | 20 | 702.42 | 1.5 | 196.46 | .2 | 6.04 | 1.69 |
| 3478 | 1569 | T | 7 | 234,964 | 15 | 5316.83 | 15.9 | 2791.60 | 14.1 | 22.63 | 11.68 |
| 3095 | 1589 | G | 5 | 123,305 | 40 | 894.55 | 1.6 | 2106.64 | 1.5 | 7.25 | 17.08 |
| 3080 | 39 | S | 5 | 155,650 | 100 | 1746.76 | 5.6 | 5367.07 | 4.4 | 11.22 | 34.48 |
| 1507 | 722 | C | 2 | 10,106 | 34 | 26.14 | 1.4 | 231.67 | 6.6 | 2.59 | 22.92 |

Σ American Hospital Association. *Interim Report: Energy Impact Analysis of Proposed Changes to the Minimum Requirements.* Chicago: AHA Hospital Energy Task Force, January 1984.

opportunities as discussed under heating (§ 1.2) and cooling (§ 2.2) apply to HVAC systems with the added complications of maintaining required pressures and ventilation rates necessary for the occupants and activities within the hospital.

Measures involving some form of space monitoring include varying ventilation rate based on measured $CO_2$ levels, humidistat control of therapy areas ventilation rates, and CO control of parking garage ventilation. There are also some compound control strategies such as optimum start of heating and cooling plant which rely on two or more inputs. In the case of optimum start (outside temperature and occupancy period are considered), the start of the heating or cooling plant is delayed until there is just sufficient time to bring the space to comfort or design conditions in time for occupancy. This means that as outside conditions become less extreme, the preconditioning period becomes shortened. This is also true for ventilation as noted in ASHRAE Standard 62.

In some cases it may not be possible to obtain the desired conditions with the environmental conditioning system as installed. Beside the obviously undersized equipment which cannot meet loads, system design often limits the ability to provide the required conditions in all zones at all times. More often than not, areas of a building are overheated or overcooled in order to satisfy the requirements of some other areas and this obviously results in energy wastage. This is particularly so, for instance, where occupants respond to overheating by opening windows. The most common cause of such problems are the use of "feed forward" (open loop) control strategies and poor zoning.

In <u>feed forward control systems</u> there is no information feedback from the space that is being conditioned to the heating and/or cooling system controller, and thus it is not possible to directly correct for deviations in space conditions from those desired. With such systems, control of heating or cooling to the space is controlled according to some measurement value <u>outside of the conditioned space</u>, typically this is outside temperature, although some systems allow compensation for solar radiation and wind speed variations.

Feed forward control systems can be replaced by <u>feedback (closed loop) systems</u> for improved control and generally improved efficiency. In a feedback system the control of the conditioned air supply to the space would be regulated by a device installed in the space. In patient rooms, where patients are very lightly clothed and hospital staff are more heavily clothed, desired temperature conditions may not satisfy both groups. Thermostats should be "locked" so that



temperatures stay set at energy efficient levels for cooling (and heating). Zoning may be improved in a variety of ways from simple measures such as correcting balancing deficiencies, to the installation of additional terminal control devices, and finally one may consider system replacement.

### <u>3.3 How to save energy with minor changes</u>

First, a note of caution. Because of the inherent code regulations under which hospital facilities are governed (such as those outlined in Figure A), engineering expertise and evaluation are required prior to implementing any change that could affect patient care. In these cases, an outside engineer should be consulted to evaluate a proposed change.

<u>Revisions to any air-handling or exhaust system must be regarded with respect to required pressure relationships that are intended to minimize contamination and infection</u>. Temperature, humidity, and air filtration requirements must be considered to be, along with smoke removal and other secondary functions of HVAC equipment, as important as other primary functions. Tampering with the system without care could be fatal in case of fire, or could spread infections.

#### <u>3.3.1 What to do and how to do it</u>

The following are a list of possible actions that can be taken to save energy in the HVAC systems in the hospital. These are maintenance and operational items in which little or no cost other than the time of hospital staff would be involved or items with minor expenditure.

HVAC 1. Check to be sure that outside air ventilation quantities are consistent with current code requirements. In some cases, outside air requirements will have decreased, while air filtration efficiencies requirements will have increased. Outside air quantities should be measured for each air handling unit. Check air balancing and correct if required.

HVAC 2. Maintain proper space setpoints by checking settings and calibration proper space setpoint by checking settings and calibration of all space thermostats and humidistats. Adjusting the anticipator setting where appropriate.

HVAC 3. Operate shades, drapes and shutters for proper balance of daylighting; consider heating and cooling needs.

HVAC 4. Inspect air heating, cooling and dehumidification coils for cleanliness. Coils can be kept clean by using a mixture of detergent and water in a high pressure (35 bar) portable cleaning unit. Remember that in addition to energy efficiency cleanliness is necessary to avoid the spread of infection.

HVAC 5. Post signs next to all operable windows, instructing occupants not to open them while the building is being heated or cooled. Indicate the months included in heating and cooling seasons.

HVAC 6. Clean or replace air filters on a regular basis. Consider installing manometers across the filters so that replacement is based on performance (pressure drop), not on appearance.

HVAC 7. Check and calibrate all temperature controls and temperature readout devices at least every two years. Proper set points for each control and acceptable ranges for each readout should be clearly marked next to, or directly on, each item.

HVAC 8. Check the accuracy of all recording instruments used to monitor pressure, temperature, steam flow, etc. Obtain maintenance and calibration data from manufacturers.

HVAC 9. Develop guidelines for the operation of laboratory exhaust hoods, and post them in the vicinity of the switches that operate the fans. Hoods should be run only as long as is necessary to implement a particular procedure. Sliding doors on the fronts of enclosed hoods should be closed as far as possible. Consider installing timers on the fan switches.

HVAC 10. Check to see whether exhaust air from various areas is used to ventilate storage area, equipment rooms, etc. This is basically free space conditioning for these areas which have low ventilation requirements.

HVAC 11. Check all accessible air ducts for leakage. Tape and caulk joints as needed. Use materials that ensure long life. Standard duct tape often cannot withstand temperature cycling and becomes loose. Better caulking stays flexible and continues to seal.



HVAC 12. Inspect all fans for excessive noise and vibration. Lubricate bearings and check alignments and tension of drive belts on a regular basis. Clean fan casing and impeller.

HVAC 13. Examine the locations of zone thermostats to see that they are in areas representative of zone conditions. Poor location is often the result of remodelling or of a change in the use of the space.

HVAC 14. Check thermostat settings on a regular basis and calibrate thermostats with tamper-proof settings every two years. Thermostats with external set points that are frequently adjusted should be calibrate once a year. Thermostats can easily be off several degrees and calibration is an important energy saving.

HVAC 15. Keep thermostats and humidistat settings for inpatient areas within the limits required by ASHRAE. Considerable latitude exist for settings in offices, laboratories, and other nonpatient areas. However, the type of air handling system and the way it is controlled should be examined before determining the best summer and winter room temperatures. A typical reheat system will use more energy if thermostats are set higher in the summer, while the opposite is true for most systems.

HVAC 16. Consider the use of locking plastic covers on thermostats that can be reset by occupants, or replace the thermostats with tamper-proof models. Because of clothing differences between staff and patients there is a tendency to readjust thermostats from energy conserving settings.

HVAC 17. Examine the possibility of shutting down air-handling systems or reducing outside air quantities during evenings and weekends in areas with little or no occupancy. Color-code one set of floor plans to indicate coverage of air system. Code other sets having different occupancy patterns.

HVAC 18. Determine whether existing steam valves can be used to isolate sections of steam piping used only for heating. These can be shut off in the spring and re-opened in the fall, thus reducing heat loss from pipes and from leakage through control valves. Verify that expansion joints and anchors are operable before closing valves.

HVAC 19. Shut off coil circulators when not required using a three-way mixing valve, maximum benefit will be obtained where system operates with full coil flow and intermittent fan operation.

HVAC 20. Shut off air handlers for induction systems during winter periods when areas served have little or no occupancy. Raise the secondary hot-water temperature to the induction units, as required, and allow them to operate simply as convectors. A similar approach can be used, to a limited extent, on fan coil systems, but these will not function as convectors as effectively as induction units due to the more restricted air flow.

HVAC 21. Consider closing down outside air dampers in proportion to occupancy level if air handling systems must remain on during evenings and weekends. If less than 15 or 20 per cent of the normal daytime occupancy is anticipated, the leakage through fully closed dampers will usually provide sufficient ventilation. This should only be done during periods when the temperature is such that additional outside air will result in additional cooling or heating loads. Where outside air will prove beneficial these flow should be encouraged.

HVAC 22. Consider cutting off direct air supply to toilet rooms and other potentially "odorous" areas. Permit air from other areas to migrate into such areas through door grilles and then be exhausted from those rooms.

HVAC 23. Operate central exhaust systems serving laboratory, laundry, or kitchen exhaust hoods only during the hours they are needed. Other air systems serving these areas should be evaluated to determine whether the exhaust system is a necessary part of the air systems operation from the standpoint of air balance and required pressure relationships.

HVAC 24. Be sure that air dampers are closed tightly when heating and cooling systems are shut down. An inspection should be made, followed by repairs or replacement of any dampers that cannot be sealed. Felt strips should be



securely fastened to the edges of the blades to ensure a tight seal.

HVAC 25. Manually open the outside air dampers on air handling systems that do not have economizer (mixed air) control, when temperatures are below 21 °C (70 °F) and cooling is required. In many cases, this may permit shutting down refrigeration equipment.

HVAC 26. Prohibit the use of portable electric space heaters, unless they are authorized by the hospital engineer. Many times these devices are used when minor adjustments in the heating system would correct the problem.

HVAC 27. Investigate the possibility of installing a vestibule arrangement at receiving doors, if space permits. Making the vestibule large enough for dollies or hand trucks will also permit interlocking of the inner door to delay its opening until the outer door has been closed. Not only will this reduce the loss of space conditioning but drafts often extending beyond the receiving areas will be minimized.

HVAC 28. Investigate the possibility of adding personnel access doors at loading docks. This will reduce unnecessary opening of larger delivery doors. Not only will this reduce the loss of space conditioning but drafts often extending beyond the receiving areas will be minimized.

HVAC 29. Consider installing power-assisted door operators on main receiving doors, if none presently exist. Convenient location of actuating controls minimize the amount of time doors remain open. Not only will this reduce the loss of space conditioning but drafts often extending beyond the receiving areas will be minimized.

HVAC 30. Where a separate unit heater or air handler is used for a receiving area, install an automatic switch or interlock with the door operator, to lock out fan operation when the door is up. In addition to cutting down on winter heat losses, this will encourage personnel to close the door as soon as possible.

HVAC 31. Cover all window and through-the-wall cooling units when they are not in use. Specially designed covers can be obtained at relatively low cost. Drafts, if the units aren't properly sealed, will result in higher heating use and occupant discomfort.

HVAC 32. Turn off HVAC systems serving areas that are used only periodically, such as conference rooms, auditoriums, tending classrooms, and food service areas. Through the use of time clocks, signs should be posted instructing occupants to notify engineering if the space is going to be used other than during normal periods. The systems can remain off if rooms will be used for a short period of time or by a small number of people. In the case of heating equipment use a thermostat to maintain setpoints, e.g., 13 °C or 16 °C (55 °F or 60 °F).

HVAC 33. Discontinue heating and cooling of storage areas and unused rooms by closing local valves and dampers. The rooms should be checked out occasionally to make certain temperatures have moved closer to ambient. Temperatures below freezing should be avoided because of possible water pipe freeze up.

HVAC 34. Post signs next to unitary equipment, e.g., window or through-the-wall air-conditioners, fan coil units, portable heaters and fans, instructing occupants to turn them off unless they are absolutely needed (or interconnected with light switch).

HVAC 35. Monitor perimeter radiation closely to ensure that it does not create artificial loading of cooling systems. Local radiation excess means local discomfort, where additional cooling may cause overcooling elsewhere.

HVAC 36. Check perimeter radiation units for blockage of air passages. This happens when objects are placed on top or in front of radiation covers.

HVAC 37. Consider using night flushing to cool down space with night air in buildings of heavy mass where nighttime temperatures are much lower than daytime setpoint. Care must be taken not to overcool the space.



HVAC 38. Consider using a preoccupancy cycle to pre-heat and/or precool without introducing outside air, where the outside air would impose an additional load. Provides more rapid conditioning of space prior to ventilation needs with occupants.

HVAC 39. Maintain proper ventilation and exhaust rates by adjusting outside air or return damper setpoints (if fixed ratio) or minimum position on economizer air equipment. Alternative action is to change throttle fan discharge, changing fan, changing fan speed (new sheaves or motor speed control or by cycling fan).

HVAC 40. Sequence, heating and cooling to ensure that the final desired temperature of the air is first obtained by mixing and then only adding sufficient heating or cooling. Evaporative cooling applications or use of economizer should be considered.

HVAC 41. Reset deck temperatures in reheating system upwards so that the zone with the highest cooling load is met without reheat. In dual duct and multizone systems, reset cold deck temperature as above and reset hot deck as low as possible while still satisfying zone with greatest heating. For induction systems reset primary air temperature down during heating season to satisfy zone with minimum heating and in summer as high as possible to satisfy zone with least cooling. Not applicable to fan-coils.

HVAC 42. Evaluate present instrumentation to determine whether additional thermometers, pressure gauges and flow meters are required to obtain adequate information on system performance. Make a list of instruments, indicating how frequently each should be read.

HVAC 43. Evaluate air handling unit controls to determine whether economizer (mixed air) controls should be added. Economizer controls are most beneficial on units serving interior zones.

HVAC 44. Consult the manufacturer of any in-house computer system the hospital might have to determine temperature and humidity ranges for most efficient HVAC system operation. Adjusting controls of computer-supported HVAC equipment to provide those conditions that are acceptable and that will result in the minimum expenditure of heating/cooling/humidification/ energy.

HVAC 45. Maintain proper system control setpoints for all systems with automatic controls. Ensure correct setpoints, calibration & location of control sensors & operators; correct control operations, i.e., check that controls are capable of doing what they are supposed to do. Examples include:

a) Throttling range.
On many commercial controllers, the adjustment of throttling range is a simple field adjustment.
Too short a range can cause control instability, too wide can waste energy; for example reducing the throttling range on dual duct and multizone air temperature controllers effectively reduces mixing losses, going below 2 %, however, can cause control instability.

b) Increasing room to supply air temperature differentials can permit lower air volumes to be utilized with potential for fan power savings.

c) Check for overlap in valve (or damper) operation especially where separate controllers used to sequence heating and cooling. E.g., 4 pipe induction units.

d) Set pre-heat as low as possible consistent with precautions against freezing.

e) Minimizing the temperature difference in dual duct and multizone systems by setting the hot deck temperature as low as possible and the cold deck as high as possible while still satisfying comfort.

f) Setting the discharge air temperature in re-heat system as high as possible to minimize re-heat.

g) Check minimum damper position for ventilation air. Ideally the fresh air volume should be measured since setpoint indicator cannot be relied upon for accuracy.

h) Check for appropriate economizer setpoints.



i) Set preheat times of fixed start preheat systems to minimum possible consistent with preheating needs.

j) Set VAV box minimum setpoint as low as possible consistent with diffuser and air movement performance and minimum ventilation requirements.

k) For two pipe induction systems check correct settings for primary air reset schedule (winter operation) and fixed summer air temperature. The aim is in winter to have the air temperature as high as possible while still satisfying the zone with the greatest cooling load. (In winter the systems act like a reheat system and so doing this will minimize "reheat" energy). In summer, to minimize re-cool energy, when the system functions as a re-cool system, the primary air temperature should be set as low as possible, consistent with not overcooling with space with the least cooling demand. (Note there may be some tradeoff required in summer with a free-cooling cycle).

l) For four pipe systems it might be worthwhile to re-evaluate the primary air setpoint temperature if this is to remain fixed.

m) Check locations of sensors to ensure that they are measuring representative conditions.

n) Check appropriateness of flow water temperature schedule in those systems with outside air temperature reset controls.

HVAC 46. Use exhaust hoods in food preparation areas only while operations are underway.

HVAC 47. If a food preparation area exhaust hood is oversized, adjust it so that no more air than necessary is exhausted. Such an adjustment can be made by blocking off a portion of the hood, reducing fan speed, lowering the hood, or by utilizing a combination of these techniques in compliance with applicable health regulations.

HVAC 48. Cook with lids on pots and kettles in place. This will allow less energy to be used in food preparation and reduce the local humidity generation.

HVAC 49. Consider the application of Mylar plastic coating to windows, or the installation of louvered screens outside windows, on sections of the building which are subject to heat loss and solar heat gain. This reduces heating and cooling loads.

HVAC 50. Air distribution in the laundry: Supply air to all areas should be directed toward personnel before passing on towards warm equipment and into exhaust grilles and hoods.

HVAC 51. Instruct workers to keep lint filters in dryers and exhaust hoods clean. Perform spot check to ensure that this is done regularly. This insures that the lint is captured at the source and does not become a problem elsewhere in the hospital.

### 3.4 How to save energy through modification

#### 3.4.1 What to do and how to do it

Observing the same cautions as stressed in § 1.4, the following list contains many suggestions as to possible HVAC system modifications that could lead to considerable energy savings in specific hospitals. Careful evaluation of each suggestion that applies is recommended. This list is complete in that it incorporates the heating and cooling system recommendations as well as those that apply to complete HVAC systems.

HVAC 1. Add automatic systems to adjusting shades, drapes and shutters to properly balance daylighting, heating, and cooling needs.

HVAC 2. Replace existing space thermostats with deadband type or set existing heat and cool setpoints with deadband. This is a specific form of sequencing.

HVAC 3. Improve zone control by treating those areas with different thermal requirements as separate control zones, and/or correctly balance flow of heating and cooling fluids to respective zones. In single pipe steam best control is with thermostatic valves in series with air vent.

HVAC 4. Modify the HVAC system to permit independent conditioning of air in areas such as computer rooms, which require special conditions. Independent conditioning will prevent the



running of unnecessary air handling equipment during off hours. Close control of temperature and humidity should be restricted to those areas requiring it.

HVAC 5. Vary ventilation rate with occupancy by adjusting of outside air and mixing dampers, throttling fan flow, motor, speed control, mechanical speed control, variable pitch blades (vane axial fans) or inlet guide vanes (centrifugal fans).

HVAC 6. Replace worn nozzles in induction system to improve air induction performance and reduce fan power by reducing primary air volume and associated conditioning.

HVAC 7. Minimize room stratification by using fans, tubes, or air jet entrainment to mix the high temperature room air that collects at the ceiling. Application is in room higher than five meters. Under cooling conditions stratification can reduce the cooling load.

HVAC 8. Consider adding automatic control valves on two-pipe steam radiators and uncontrolled hot water radiation to prevent the common "overheat/open window" syndrome.

HVAC 9. Try to minimize the use of lights and other heat-producing appliances in areas of the hospital that are air-conditioned. These devices represent an expensive source of heat in the winter, even in perimeter rooms, since other sources of heating will provide heat at lower cost.

HVAC 10. Consider replacing incandescent luminaries with fluorescent or H.I.D. luminaries where applicable. This action will make a noticeable reduction in the cooling load and increase the heating load but at a lower energy cost.

HVAC 11. Use lighter colors on surface finishes of ceilings, walls, floors, and furnishings. Light finishes increase the use of available light. By repainting ceilings, walls, and floors, and by using lighter-colored furniture, the average illumination level of the room, using the same light sources, can be increased by as much as 30 foot-candles. This better use of light can reduce the cooling load. The color choice can also make the room appear cooler.

HVAC 12. Consider runaround type heat recovery systems for larger 100 % outside air systems, where recirculation is not feasible. Rotary heat wheels or enthalpy wheels are also possibilities, depending on the orientation of exhaust and intake ducts.

HVAC 13. Use air-to-air heat recovery to precondition make-up air; options include heat wheels, plate, run around, heat pump or heat pipes.

HVAC 14. Consider operating heat recovery systems automatically to provide precooling as well as preheating. Add necessary controls.

HVAC 15. Supply exhaust make-up from other zones to replace the need of fresh air make-up. It may be necessary to install smoke sensors to shut off ventilation in case of fire.

HVAC 16. Add variable air volume controls to existing fume hoods to maintain nominally constant sash opening velocity over a range of sash opening positions. Alternate, replace old fume hood with new VAV hood.

HVAC 17. Install localized exhaust/make-up air systems to replace large central systems. Especially effective where there are a number of exhaust stations and they require intermittent use.

HVAC 18. Locate make-up air at exhaust hoods. This make-up air replaces conditioned air in the space. Applications are in the kitchen and laundry where large amounts of exhaust air are needed.

HVAC 19. Modify existing exhaust hood to high velocity type with extract located around the perimeter. Capture efficiency can be improved with lower air volumes saving fan power and space conditioning.

HVAC 20. Examine the possibility of ducting exhaust air to cooling towers, with associated dampers and controls. When outdoor ambient temperatures are higher than exhaust air, cooling tower efficiency will be improved.



HVAC 21. Consider using evaporative cooling to replace or supplement mechanical cooling in those site locations where low humidities are prevalent and adequate water supplies are available. Requires careful analysis to justify costs.

HVAC 22. Consider the use of an evaporative cooling roof spray to lower roof temperatures and thereby reduce cooling loads.

HVAC 23. Convert to variable air volume systems in those areas of the hospital where fixed ventilation rates are not required. Replace reheat coils with or add VAV control boxes to reheat systems. Convert dual boxes to two motor operation.

HVAC 24. Consider mechanical dehumidification in hydro-therapy rooms. Reduce ventilation to satisfy occupancy levels and control humidity using heat pump dehumidifier. Rejected heat may be used to preheat DHW.

HVAC 25. Consider the use of adsorption filters to recycle vitiated air to the space. Activated charcoal filters and other special materials are used to remove undesired air contaminants. Careful choice of exhaust locations is necessary.

HVAC 26. Consider subdividing existing hot water (or duct system) in smaller zones (additional loop in water grid) to take into account local conditions, i.e., solar loads, local equip-ment, heat generation, etc.

HVAC 27. Install an energy management system to schedule equipment operation. The more sophisticated EMS equipment provides actual control capabilities such as direct digital control. System is highly dependent on sensor inputs, properly trained personnel and a computer program that matches the particular hospital facility.

HVAC 28. Install more efficient HVAC system. Normally only considered near the end of existing equipment lifetime and when hospital is undergoing major renovation and/or there are significant operation, comfort or maintenance problems.

HVAC 29. Consider changing a constant flow water heating system to a variable flow system, so that the return water temperature can be minimized and transmission heat losses reduced.



# CHAPTER 4. DOMESTIC HOT WATER

## 4. Introduction

Domestic hot water (DHW) is used nearly everywhere in a hospital.

Its general use is washing people (patients as well as medical, technical and administrative staff), but DHW is also broadly used in the kitchen, in the laundry, in sterilization rooms, etc...

## 4.1 Description

### 4.1.1 DHW production, storage and distribution

Schematically, a plant for production and distribution of DHW can be represented by the block diagram shown in Fig. 4.1.A.

The primary fluid can be:

- steam or condensate
- hot water
- frigorific fluid condensing at a condenser of a heat pump or other frigorific compressors.

There can be (pre)heating of cold water by different sources of heat recovery:

- cooling water of internal combustion engines
- exhaust gases of boilers or engines
- heat recovery, heat pumps or heat exchangers from sewage water
- etc...

There can be also a reheating and/or storage just before some particular use if this one needs a higher temperature than supplied.

The fuel can be oil, gas...

The hot water storage can be combined with, or separate from, the heat or energy exchanger, or nonexistant.

The return pipe (recirculation) can be nonexistant.

### 4.1.2 General D.H.W. system

This 4th Chapter of Booklet III deals with the general system as illustrated above; particular users as laundry, kitchen, etc... are dealt with in Booklet V.

Primary fluid distribution or production is dealt with in Booklet II.

### 4.1.3 Energy flows

The energy flows associated with each subsystem can be visualized in a Sankey diagram of the type shown in Fig. 4.1.B.

The diagram represents the energy balance of the system; the arrows pointing down indicate the energy losses that should be reduced to a minimum.

## 4.2 Strategy

### 4.2.1 Organizing an effective energy management program

An effective Energy Management program includes the following points:

- Having a good knowledge of the system in all of it parts;
- Identifying the real needs (quantity, flow and temperature of DHW needed for each different use);
- Estimating as accurately as possible the costs of production and distribution of DHW;
- Reducing the unnecessary consumptions;
- Reducing the cost of DHW;
- Organizing the maintenance;
- Recording regularly the energy consumption for DHW. (See Fig. 4.2.A)

### 4.2.2 Knowing the system and the costs

This work begins by establishing (or updating) the drawings of the system, to have a good understanding of how it works and what sort of actions could be the more effective to save energy.

In § 4.3.2, we explain how to determine the energy flows, depending on the type of system installed.

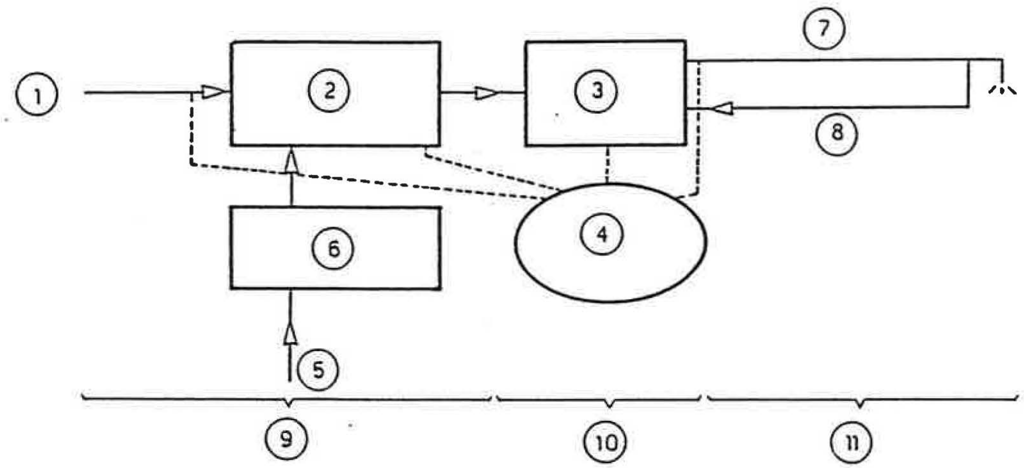


Figure 4.1.A - DHW production, storage, distribution

1- primary fluid, fuel, or electricity
2- heat or energy exchanger
3- hot water storage
4- control system
5- cold water supply
6- water treatment
7- hot water supply to consumers
8- recirculation or return
9- production
10- storage
11- distribution

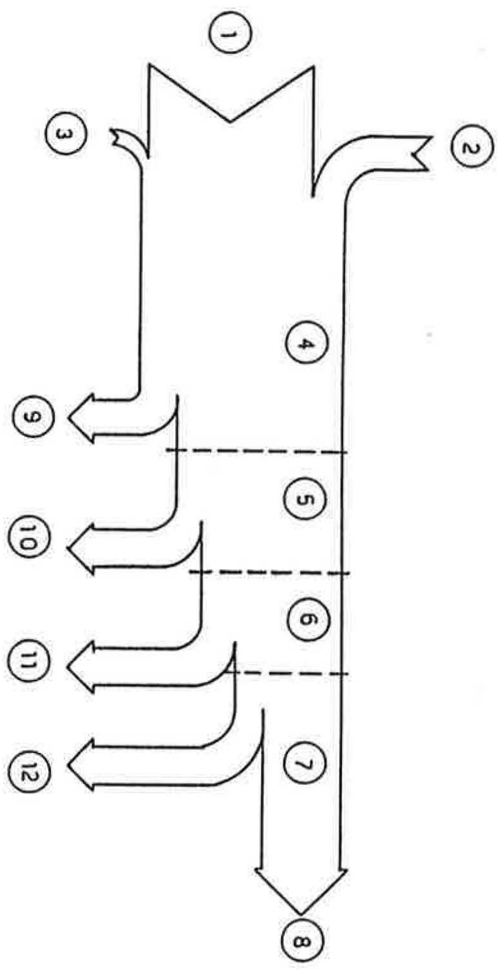


Figure 4.1.B . - Energy flows in a DHW system

1- input energy, from fuel or electricity
2- input energy, from "free" sources (solar, heat recovery, etc.)
3- pumping input energy
4- production
5- storage
6- distribution
7- utilization
8- useful energy
9- boiler losses
10- storage losses
11- distribution losses
12- utilization losses



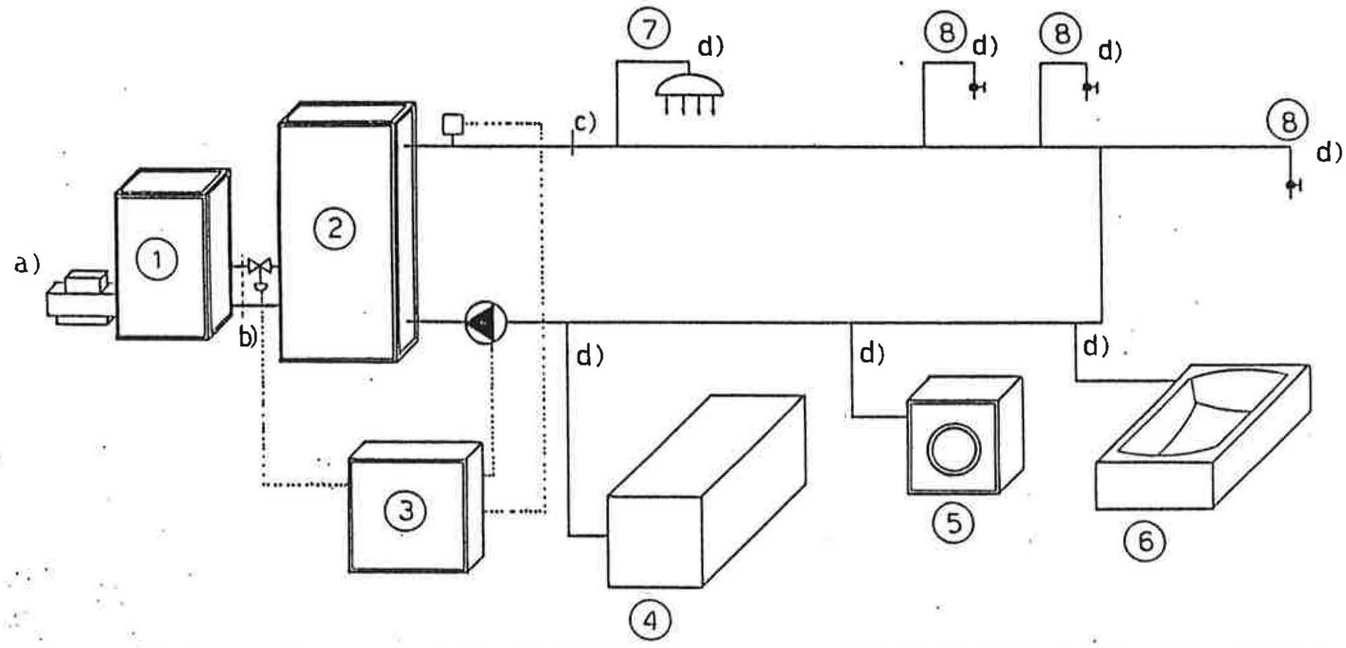


Figure 4.2. A - Recording energy consumption for DHW systems

1 - boiler
2 - storage
3 - control
4 - kitchen
5 - laundry
6 - hydrotherapy
7 - shower
8 - consumers

Points of interest for the measuring and recording system:

a)- flow-rate, cost of fuel
b)- flow-rate, temperature of primary fluid
c)- flow-rate, temperature of DHW; cost of energy; cost of DHW for several temperature levels (40 °C, 50 °C, ...)
d)- flow-rate, temperature of DHW delivered to consumers

The cost of DHW for a given quantity of water and a given temperature depends on:

- cost of primary fluid, fuel or electricity;
- efficiency of heat or energy exchanger;
- heat losses of hot water storage;
- heat losses of supply and return pipes[1];
- electrical consumption of pumps, heat recovery heat pumps, etc...;
- cold water treatment;
- maintenance costs.

Knowing these "primary" energy consumptions and their corresponding costs, adding the cost of pumping on primary and secondary side, it is possible to establish monthly and yearly reports on:

- quantity of DHW used
- energy content of DHW used
- "primary" energy consumption
- total cost for DHW
- specific cost per $m^3$ and GJ of DHW

These reports allow the energy manager to notice anomalies in use or in the operation of the system, as well as to establish some objectives and to check how they are reached.

They allow also to distinguish between heat produced for heating purpose only and heat produced for DHW.

### 4.2.3 Target values

In Figure 4.2.B are the estimated values which are more design values than actual ones.

Target values for consumption would thus be lower than those given in the table.

---

[1] These losses are approximately 20-60 %, rather than about 10 %

Figure 4.2.B

**Hot water demand per fixtures, following ASHRAE HANDBOOK "SYSTEM" Chap. 37. (at 60 °C, [140 °F]; in $10^{-3}$ $m^3/h$ [gal/h])**

| | S.I. | I.P. |
|---|---|---|
| - basins, private lavatory | 7.5 | [2] |
| - basins, public lavatory | 22 | [6] |
| - bathtubs | 75 | [20] |
| - dishwashers[2] | 185/565 | [50/150] |
| - foot basins | 12 | [3] |
| - kitchen sink | 75 | [20] |
| - laundry, stationary tubs | 105 | [28] |
| - pantry sink | 38 | [10] |
| - showers | 280 | [75] |
| - slop sink | 75 | [20] |
| - hydrotherapeutic showers | 1 500 | [400] |
| - leg baths | 380 | [100] |
| - hubbard baths | 2 250 | [600] |
| - arm baths | 130 | [35] |
| - sitz baths | 120 | [30] |
| - continuous flow baths | 625 | [165] |
| - circular wash sinks | 75 | [20] |
| - semi-circular wash sinks | 38 | [10] |

3

[2] Dishwasher requirements should be taken from manufacturers'data

[3] A simultaneity factor of 0.25 shall be applied to the sum of hot water demand of all fixtures.



Other data found in litterature (S.I. Handbook) are:

- Service temperature 60 to 65 °C [140 to 150 °F]

- Consumption without laundry in $10^{-3}$ $m^3$/pers.·day [gal/pers.·day]

| | | |
|---|---|---|
| min | : 40 to 60 | [11 to 16] |
| mean | : 60 to 80 | [16 to 21] |
| max | : 80 to 120 | [21 to 32] |

From Canadian enquiries, we can also give values of 33 to 75 kWh/year.$m^2$ for general hospitals and of 21.5 to 64.5 kWh/year.$m^2$ for long-term care facilities.

It is also estimated in Canada that DHW energy consumption represents about 13 % the total energy consumption of the hospital.

In a paper from Ellis (Beyond the nucleus, Building Services, June 1982) the percentage of energy for DHW is about 18 % in a hospital specially designed for low energy consumption.
The same percentage is given by Cundall (Energy Target: 68 % cut: Building Services, Sept. 1984).

### 4.2.4 Actions

The actions to be undertaken are the same for DHW installations as for other services:

- recording the consumptions
- establishing a maintenance schedule
- looking for improvements in operation or materials
- checking the results.

Here too, it is necessary to be attentive to the comfort of patients and staff and to carefully examine the economic profitability of modifications and/or replacements.

The energy manager should have the responsibility and the means to act rapidly when low investment cost decisions have to be taken (for instance to repair failures or replace old materials).

## 4.3 How to save energy with minor changes

### 4.3.1 Maintenance

(see Fig. 4.3.A)

The maintenance operations are:

a) Control of the quality of DHW:

- Water which is too hard causes scaling. The scale reduces heat transfer coefficients of exchangers. To obtain the desirable temperature of DHW and the same heating time, it is thus necessary to increase the primary temperature and this decreases the efficiency of DHW production. Scaling reduces also the net internal section of pipes, increases friction losses of circulating water and costs of pumping. Finally, scaling reduces the flow through fixtures, which increases the duration of drawing up water and maintenance costs.

- Water which is too soft can cause corrosion and leaks. A hardness between 5 and 7 °F (1 °F = 10 mg/l $CaCO_3$ or 4 mg/l MgO) is usual.

b) Control of the control system, to see if the temperatures prescribed for storage and supply are really obtained and not overstepped.

c) Control of the cleanliness of filters:

Dirty filters increase friction losses of circulating water and pumping costs.

d) Control of leaks:

A leak, even a small one, is a place of continuous consumption (24 h a day, 365 days a year). It is necessary to replace seals wherever a leak appears.

e) Control of presence of air in the pipes:

Air in pipes causes scaling, noise and "water hammer" when opening the taps. Dead end pipes (part of networks which are no longer used) are sources of air and scaling and should be completely isolated.

f) Control of insulation

Every failure or misfunctionning must be immediately corrected.

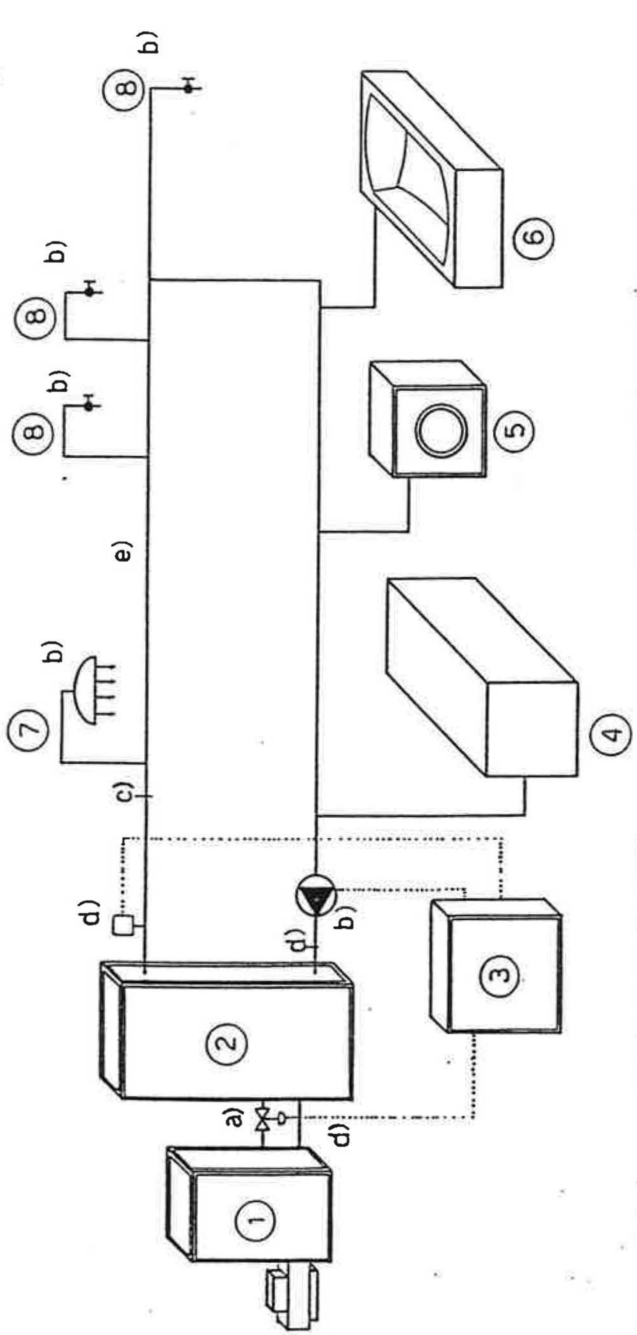


Figure 4.3.A . . - Maintenance for DHW systems

1 - boiler
2 - storage
3 - control
4 - kitchen
5 - laundry
6 - hydrotherapy
7 - shower
8 - consumers

Points of interest for maintenance operations:

a)- control of tightness
b)- control of leaks
c)- control of hardness of DHW
d)- control of temperatures
e)- control of insulation



4.3.2 Operational changes

Two major operational changes can induce energy savings: lowering the temperatures and lowering the drawing up of water.

a) Lowering the temperature should be very carefully examined:

At first, it is necessary to measure the temperature of DHW at taps. If it is high enough at each point and necessitates local mixing with cold water, supply temperature can be progressively and slowly decreased. (See 7. in § 4.4.2) for recommended values).

After this lowering of supply temperature to a value which doesn't reduce the comfort, storage temperature can be also progressively and slowly decreased to the point where supply temperature can always be maintained to its new value, but no lower than 60 °C to avoid possible microbial growth.

These temperature lowerings, not only decrease heat losses of storage and distribution but also increase the efficiency of DHW production.

If the same quantity of DHW is used at 45 °C instead of 50 °C, the energy saving is 12.5 %.

b) Reducing the quantity

The quantity of DHW used can be reduced in some places, for instance where it is used to wash hands without filling the sink (free flowing water).

Reducing the pressure by adjusting valve setting which will be progressively lowered to reduce the flow and thus the quantity used.

For showers also, a slow reduction of flow can greatly reduce the quantity of water used, even if there is a small increase in the duration of use.

As stated above (§ 4.2.1), it is necessary to fully understand the operating characteristics of the system. This is essential before looking at operational changes.

After updating the drawings of the system, it is often necessary to verify the balancing of the whole system of DHW distribution network. A bad balancing is the source of over- or under-pressure at taps.

Looking at Fig. 4.3.B, we can see that, depending on the control system, different data have to be gathered or recorded to estimate the energy corresponding to the consumption of DHW.

The useful energy produced by the DHW production plant is:

$$E = F_3 \cdot T_3 - (F_2 \cdot T_2 + F_1 \cdot T_1) \qquad (1)$$

where F and T are respectively the flow and temperature of water at points 1, 2 or 3.

The flows of water are related by

$$F_3 = F_1 + F_2 \qquad (2)$$

Generally, $F_2$ and $(T_3 - T_2)$ are kept constant and $T_1$ can be, in first approximation, considered constant too, except if the cold water supply pipe go through place where temperature varies broadly through the year.

Thus, if the temperature of supplied DHW is kept constant too, it is enough to measure $F_2$, $T_2$ and $T_1$ from time to time and to record $F_3$ or $F_1$ to determine E through relations (1) and (2).

The same procedure applies if there are more than one supply and return circuit.

Cheap water flowmeters allow for a good knowledge of the energy associated with DHW use.

If $T_3$ varies, it is necessary to record simultaneously the flows $F_3$ or $F_1$ and the temperatures $T_3$ and $T_2$. A more sophisticated - and thus costly - heatmeter is necessary to record the energy.

Looking at Fig. 4.3.C, C and D we see the corresponding situation on the primary side.

In the case of Fig. 4.3.C, where the heat is brought in by a primary fluid through a heat exchanger, the flow of energy is the product of the flow of primary fluid by

- the difference of temperature IN and OUT and by the specific heat of this fluid if no change of state occurs
- or the latent heat of condensation if condensation occurs
- or a combination of both.

If there is no condensation of primary fluid, a heat meter which integrates the product of flow and the difference of temperature is necessary; but if primary flow

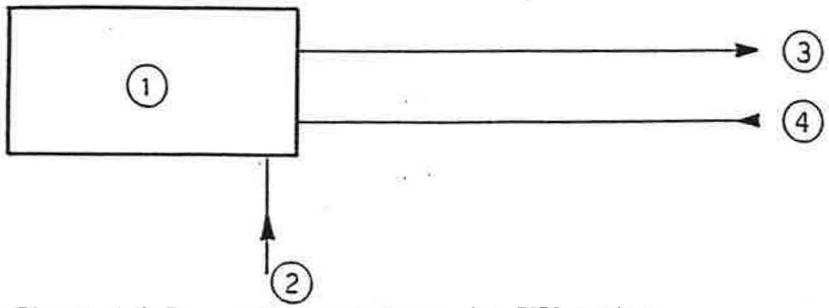


Figure 4.3.B - Energy balance for DHW system

1 - DHWproduction and/or storage
2 - Cold water in
3 - DHW out
4 - DHW return

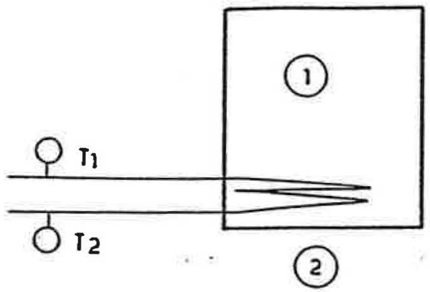


Figure 4.3.C - DHW production by means of a primary fluid

1 - DHW production system
2 - primary fluid heating coil



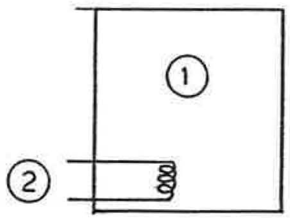


Figure 4.3.D - DHW production by means of electricity

1 - DHW production system
2 - electricity heating coil

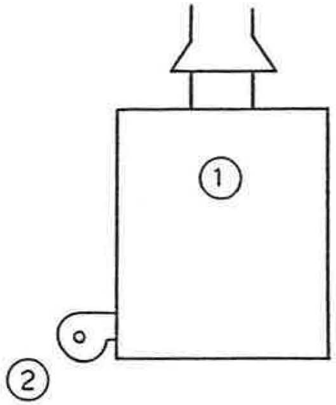


Figure 4.3.E - DHW production by means of a fuel

1 - DHW production system
2 - fuel or gas burner

is kept constant (by use of a local pump running continuously), recording the difference of $T_1$ and $T_2$ is enough.

For a condensing primary fluid, if the temperature (or pressure) is kept constant, it is only necessary to record and integrate the flow of liquid by a simple flow meter.

In all these cases, it is necessary to add to the energy calculated or recorded by this way, the heat losses (distribution losses) of the pipes of primary fluid between the boiler, incinerator, etc. and the heat exchanger.

In the case of Fig. 4.3.D, a simple wattmeter indicates the electric consumption. It is necessary to distinguish between day and night periods if there is a difference in cost per kWh.

In the case of Fig. 4.3.E, the energy consumption is easily recorded by a flowmeter on fuel or gas, or an hour meter on the burners'ventilator if the flow of fuel is constant.

## 4.4 How to save energy through modification

### 4.4.1 Long and short term energy savings

Improvements at low or moderate costs can be realized without life cycle cost analysis but others should be also seriously considered.

In all cases, when looking for modifications in DHW production and/or distribution system, the following points must be taken into account:

- cost of modification
- present cost of DHW at point of use
- future cost of DHW at point of use
- increase or decrease of heating plant efficiency
- present and future maintenance costs
- costs of water treatment
- present and future costs of auxiliary electric consumptions (pumping).

### 4.4.2 What to do and how to do it

1. The suppression of DHW supply where it is not really necessary is the first source of savings.

2. For distribution pipes supplying some specific non continuous use (kitchen, laundry, hydrotherapy, showers for technical staff, etc...), the installation of a clock to control the circulating

pumps on the return pipe and to stop it during off hours reduces heat losses together with pumping costs.

3. The individual control of showers by push-buttons instead of group control reduces greatly the quantity of water used.

4. The insulation of pipes (supply and return) in non heated spaces can be economically interesting if supply and return temperatures are relatively high. In normally heated zones, this is not the case because the heat losses of DHW pipes reduces heating needs.

5. In small hospitals where there is no heating during summer time, an oversized boiler used only for heating DHW decreases the mean annual production efficiency.
It is thus highly profitable to examine the feasibility of a specific DHW heating plant.

6. Large quantities of DHW are used at low or moderate temperatures.
This can induce a profitable use of solar heating systems or heat pumps. These can recover heat from exhaust air or sewage water.

   In this latter case, plate heat exchangers with large interdistance between plates reduce fouling problems; leakage between primary and secondary sides must be guaranteed to be zero.

   When estimating the profitability of heat pumps or solar heating installations, the auxiliary costs for pumping must not be neglected.

   With heat pumps driven by internal combustion engine, heat can also be recovered from exhaust gases and cooling water from the engine. For that type of heat pump, the cost of maintenance and repair must be taken into account.

   A treatment plant for sewage water is a very interesting cold source for heat pumps if the plant is not too far from storage or use of DHW.



7. DHW is used at different temperatures:

| | | |
|---|---|---|
| Lavatory hand washing | 40 °C | (104 °F) |
| Showers and tubs | 43 °C | (109 °F) |
| Therapeutic bath | 43 °C | (109 °F) |
| Surgical scrubbing | 43 °C | (109 °F) |
| Dishwashing wash | 60 °C | (140 °F) |
| Sanitizing rinse | 82 °C | (180 °F) |
| Laundry | 82 °C | (180 °F) |

   If it is not the case, it is profitable to have separate supply pipes for the different uses, by mixing with return or cold water after a high temperature storage to supply uses at low or moderate temperature, or to have general supply at moderate temperature with local reheat and storage for high temperature use.

8. Modify size of storage tank to adjust to storage. Optimized tank requires careful assessment of DHW demand. (See Fig. 4.4.A, 4.4.B).

9. Local production of DHW for specific uses can decrease distribution heat losses and pumping costs, but maintenance and water treatment costs can increase and production efficiency decrease.

10. Install or improve water temperature regulation to improve temperature control: install flow mixers in place of existing taps. Adopt modulating rather than on-off burner. Install a mixing valve to obtain stable supply temperature.

11. Install water heater timers. Control heater operation (boiler or resistive heater) to match DHW demand, thereby saving on standby losses.

12. Replace pilot flame with automatic electronic ignition system in gas DHW systems. Consider particularly if DHW replacement is advisable.

13. Replacing one source of energy by another should be examined (see particularly § 4.4.1, in that case).-

<u>4.4.3 DHW check list</u>

The following is a summary of many of the ECOs previously discussed in this section as a review of what changes may be made to save energy.

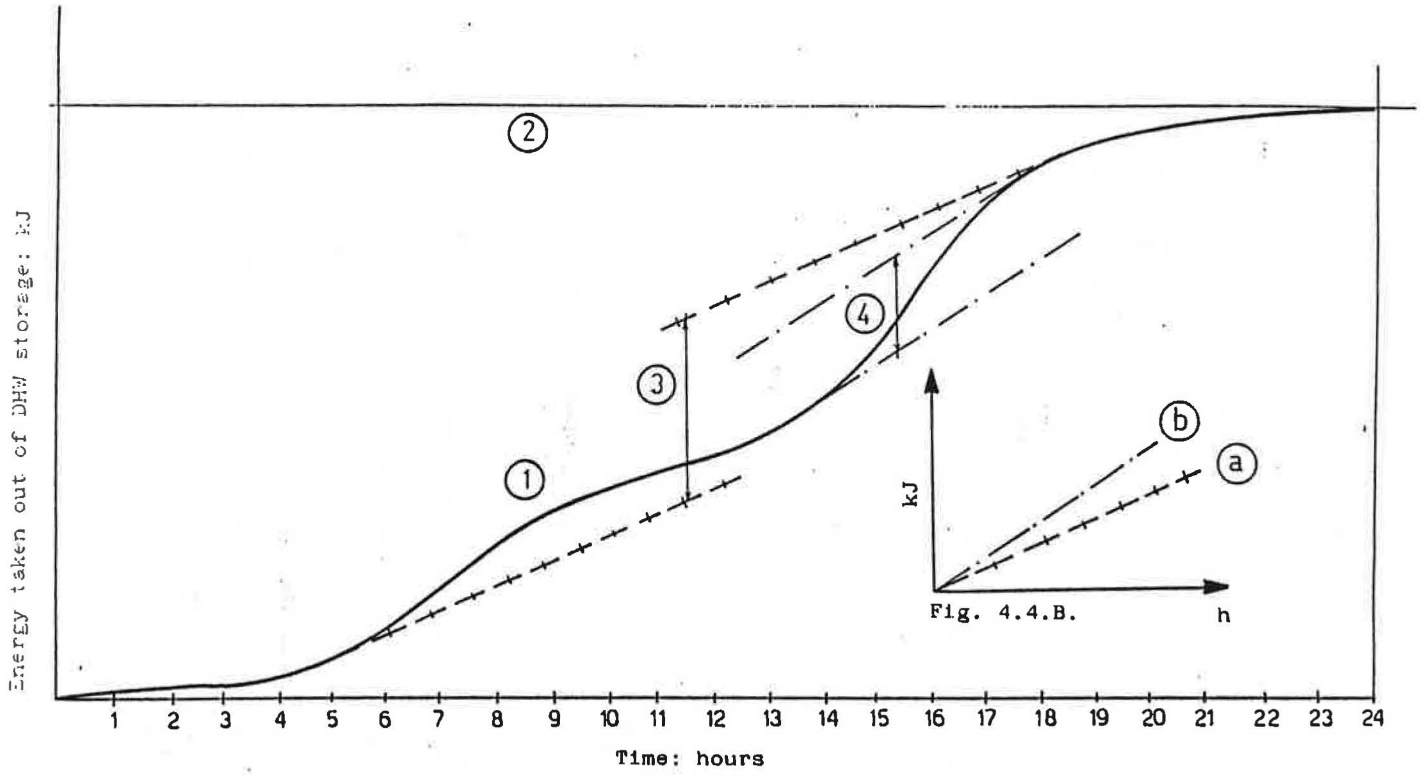


Figure 4.4.A. - Energy provided by DHW Storage

1. curve (cumulative) of DHW consumption during a whole day (to be recorded)
2. maximum daily hot water requirements
3. energy storage needed when primary heat input is like curve (a) in fig. 4.4.B.
4. energy storage needed when primary heat input is like curve (b) in fig. 4.4.B.

Figure 4.4.B.

The slope kJ/h = kW of the curve indicates the available power on the primary side of the heat exchanger

### 4.4.3.1 Items involving minor changes to the DHW systems

1. Lowering the temperature of the water must be considered with great care. Temperatures of storage should be maintained no lower than 60 °C (140 °F) to avoid possible microbial growth. Measurements of DHW at individual taps indicates whether local demands are being met. Major savings may be possible, e.g., if the same quantity of DHW is used at 45 °C instead of 50 °C the energy savings is more than 12 %.

2. Use lower temperature water in laundry. Select appropriate washing and rinsing programs (if possible) to use coldest water that is still suitable. Applicable to laundry machines and dishwasher having reduced temperature washing programs. Use appropriate detergents for lowered temperatures.

3. Maintain the cleanliness of filters. Dirty filters increase friction losses of circulating water as well as pumping costs.

4. Install flow restrictors at suitable points, e.g., in piping, low-flow shower heads, aerated faucets, etc., to conserve DHW. Make sure supply flow rate is not reduced below minimum, and the action is accepted by patients and staff. May cause mixing problems, particularly with non-modulating gas burners.

5. Avoid/control leaks in DHW system. Inspect seals, gaskets, pipe fittings, storage tanks for possible DHW leaks. Prevents damage to insulation and building materials. Reduces water consumption since leaks represent continuous undesirable DHW waste, 365 days a year.

6. Control of presence of air in the pipes. Air in pipes causes scaling noise and "water hammer" when opening the taps. Dead end pipes (part of networks which are no longer used) are sources of air and scaling and should be completely isolated.

### Items involving modification of the DHW system

1. Modify size of storage tank to adjust to storage. Optimized tank requires careful assessment of DHW demand.



2. Substitute ordinary taps automatically operated by photocells, infrared sensors, or mechanical means to minimize DHW use. Advisable for hygienic reasons also.

3. Install or improve water temperature regulation to improve temperature control: install flow mixers in place of existing taps. Adopt modulating rather than on-off burner. Install a mixing valve to obtain stable supply temperature.

4. The individual control of showers by push-buttons instead of group control substantially reduces the quantity of water used.

5. Control of DHW loop flow. For distribution pipes supplying some specific noncontinuous use (kitchen, laundry, hydrotherapy, showers for technical staff etc.), the installation of a clock to control the circulating pumps on the return pipe and to stop it during off hours reduces heat losses together with pumping cost.

6. Install water heater timers. Control heater operation (boiler or resistive heater) to match DHW demand, thereby saving on standby losses.

7. Install a water softener to limit water hardness or condition for acidity, etc. This action will help to reduce water circulation problems and increase life of system components. Can prove very effective in saving on soaps and detergents. Reduction of scaling keeps water flowing properly. Avoid water conditioning that may cause corrosion and leaks.

8. Replace pilot flame with automatic electronic ignition system in gas DHW systems. Consider particularly if DHW replacement is advisable.

9. Dedicated summer DHW system. In small hospitals where there is no heating during summer time, an oversized boiler used only for heating DHW decreases the mean annual production efficiency. It is thus highly profitable to examine the feasibility of a smaller DHW heating plant.

10. Consider local production of DHW for specific uses. This approach can decrease distribution heat losses and pumping costs, but maintenance and water treatment costs can increase and production efficiency decrease.

11. Add an instantaneous boost heater to raise water temperature from storage to desired level. Useful concept if DHW temperature needs vary widely throughout the hospital.

12. Install heat pump water heater or solar water heating. Possible combinations that may used to lower heating DHW costs are: a) heat pump only b) solar only c) solar-assisted heat pump. All features of systems must be evaluated such as corrosion, weather effects etc. May prove suitable for certain locations. Evaluate carefully.

13. Decentralize DHW production to minimize distribution losses. Replace centralized system with individual units to minimize distribution losses. Most effective if existing system has low distribution efficiency.

14. Switch energy sources. Changes from electric to gas heater to accomplish DHW goals at lower energy costs. Recovery time of gas/oil DHW systems greatly reduces storage needs associated with electric water heating.

15. Install a heat exchanger on waste water collector to preheat supply water in buildings with significant waste water heat content and with centralized DHW production. Leakage between water systems must be guaranteed to be zero. Plate heat exchangers with large spacing between plates reduces fouling problems.