UNIT 4

INTRODUCTION

The pattern of demand for conventional energy sectorwise in India (in terms of energy consumption as at present and as projected), is given in Table 3.1 in per cent

Table 3.1 The pattern of demand for conventional energy in percent

Year	1979-80	1984-85	1989-90	2000 A.D (Conventional)	2000 A.D. (Renewable also)
Household	15.70	13.20	14.24	22.00	36.50
Agriculture	9.40	9.80	10.36	5.60	4.25
Industry	38.20	36.40	55.00	39.00	32.10
Transport	32.30	31.40	16.80	25.60	20.4
Others	3.90	4.20	3.00	7.80	6.25
Total	100.00	100.0	100.00	100.00	100.00

The household sector is seen as having an increasing share in energy use, both as a result of population increase as well as an increase in the standard of living.

Statistical data of home equipment purchased from the market has led to the ranking of appliances listed in descending order of energy use as shown in Table 3.2.

Table 3.2 Ranking of Appliances

Type of Appliance	Percent Energy Use
Space conditioning (including Heating, cooling and air conditioning)	30
Refrigeration	25
Water Heating	15
Lighting	10
Cooking	7
Entertainment (T.V. etc.)	5

Grinding	5
Washing and Others	3

Wastage of energy is estimated to be approximately 30 per cent of the total residential energy consumption. This is because of a poor knowledge of the energy utilization efficiency of the appliances and their careless operation. Saving of energy can be achieved *by* using more efficient appliances as well as by careful operation.

HEATING OF BUILDINGS

Heating of buildings is normally required to provide comfort to the occupants. Under normal conditions, the average human body dissipates about 100 Js^{-1} and has a temperature of 37°C. Of the above quantity of heat, about 45 per cent is dissipated by radiation, 30 per cent by convection, and the remaining 25 per cent by evaporation. Radiation is governed by the temperature of the surrounding walls, convection by the air temperature, and evaporation by the humidity of the air. It is obvious that energy conservation has to be achieved while keeping comfort in mind.

The usual practice in producing comfort is to design a heating and humidity control installation to maintain an indoor temperature of 19.0°C at 60 per cent relative humidity (9.3 moisture content of air per m^3 at 19.0°C). To prevent excessive evaporation from the body, temperature and humidity are controlled.

There are various ways of producing heat. The relative costs of producing heat from electricity and other fuels can be calculated on two criteria (a) J oriented and (b) kWh oriented. Tables 3.3(a) and 3.3(b) show the relative costs based on the above criteria.

It can be seen from both the tables that electrically produced heat appears to be costlier than that produced from other sources.

Table 3.3(a) *Comparative Heating Cost (Joule Oriented)*

Type of Fuel	Gross Heat Value	Apparatus Efficiency	Net Heat Value	Cost in Paise	Cost in Paise/MJ
1. Electricity	3.6 MJ/Unit*	100 %	3.6 MJ/Unit	39.00 p/Unit	10.82
2. Oil	36.0 MJ/l	75 %	27.0 MJ/l	9.0 p/l	3.34
3. Coke	28.0 MJ/kg	65 %	18.2 MJ/kg	76.40 p/kg	4.20
4. Anthracite	33.8 MJ/kg	76 %	25.7 MJ/kg	9.0 p/kg	3.50
5. Gas	18.6 MJ/m³	75 %	13.9 MJ/m³	60.20 p/m³	4.32

Table 3.3(b) *Comparative Heating Cost (kWh Oriented)*

Type of Fuel	Gas Heat Value	Apparatus Efficiency	Net Heat Value	Cost in Paise	Cost in p/kWh
1. Electricity	1.0 kWh/Unit*	100 %	1.00 kWh/Unit	39.00 p/Unit	39.00
2. Oil	10.0 kWh/l	75 %	7.50 kWh/l	90.00 p/l	12.00
3. Coke	7.78 kWh/kg	65 %	5.04 kWh/kg	76.40 p/kg	15.14
4. Anthracite	9.38 kWh/kg	76 %	7.13 kWh/kg	90.00 p/kg	12.60
5. Gas	5.17 kWh/m³	75 %	3.88 kWh/m³	60.20 p/m³	15.52

* 1 Unit = 1 kWh = 3.6 MJ

In the choice of a particular type of heating installation, various aspects like aesthetic and hygienic considerations must be taken into account, apart from the cost. Since we are mainly interested in electric energy conservation, the advantages of electric heating are laid down-below.

ADVANTANTAGES OF ELECTRIC HEATING

1. *Cleanliness*-freedom from ash, dust, grease; hence hygienic.
2. Ease of adaptation for all purposes.
3. Very little maintenance is required
4. The regulation of heat is easy, simple and accurate and can be done automatically
5. There are no products of combustion, therefore the surrounding air is not contaminated
6. Since there is no flue gas, the space that would be occupied by a chimney is saved.

TYPES OF APPLICATIONS OF ELECTRIC HEATING EQUIPMENT

The various methods of producing heat for general industrial work, heating of buildings, and for welding may conveniently be classified as follows:

1. Direct Resistance Heating: A current is passed through the body to be heated.
   e.g resistance welding, electrode-boiler type water heater.
2. Indirect resistance heating: A current is passed through a wire or High resistance material forming a heating element and the heat loss so produced is transmitted by radiation or convection to the body to be heated
   e.g. ordinary domestic radiator, immersion water heater, resistance ovens, heat treatment of metals
3. Direct Induction Heating: Currents induced by electromagnetic action in the body to be heated, such as steel and other metals which produces a high temperature to melt the metal
   e.g. Induction furnace, eddy current heating
4. Indirect Induction Heating: Eddy currents are induced in the heating element by electromagnetic action. The heat so produced is transmitted to the body to be by radiation and convection, as in the indirect resistance method
   e.g. Induction Ovens, Heat treatment of metals.
5. Dielectric Induction Heating: The electric losses set up in non metallic materials when subjected to an alternating electric field is used for heating.
   e.g. Same as title.
6. Electric Arc: An arc drawn between two electrodes has a temperature between 3000°0 and 3500°C, e.g. arc furnace, arc welding

HEAT REQUIREMENT AND HUMIDITY

The heat required to raise the temperature of the room at normal humidity can easily be calculated by multiplying the specific heat of air and its density.

Specific heat of air = 1.0 J/g°C

Density of air at 19.0°C = 1.22×10^3 g/m^3

Therefore the heat, required to raise the temperature of 1m^3 of air through 1°C is 1.22×10^3 J. This is a useful average figure although it varies slightly with variations of temperature and humidity.

The outdoor temperature in winter can be assumed to be about 5.0°C and the relative humidity 75 per cent. Under these conditions the outdoor air *has* a moisture content of 4.9 g per m^3.

In order to condition this air to an indoor temperature of 19°C and 60 per cent relative humidity (9.3 g per rn^3 moisture content), heat energy of (1.22 x 10^3 J/m^3 °C) moisture (4.4 g/m^3) must be added to condition the air.

TRANSFER OF HEAT

Before we consider the various methods of producing heat electrically, it is appropriate to briefly discuss the different processes by which heat is transferred from a hot body to a cold body.

CONDUCTION

The rate of heat transfer by conduction depends on the temperature difference between each side of the body T1 and T2 respectively, e.g. the temperatures on each side of a wall in a building of thermal conductivity *k*. Conduction of heat is an important consideration in connection with refractory and heat insulating materials when these are used for preventing the escape of heat to the outside surroundings.

$$\text{Heat dissipation by conduction} = \frac{k}{t}(T_1 - T_2)\ \text{W/m}^2 \qquad (3.1)$$

Where t = thickness of wall in in

T_1 and T_2 = inside and outside temps. in Kelvin respectively

k = thermal conductivity in W/m°C

CONVECTION

Heat transfer by convection depends on the temperature of the hot body and the temperature of the air surrounding it. Heat is dissipated by convection in immersion type water heaters and in certain low temperature heating equipment for buildings.

Natural convection takes place according to the law:

$$\text{Heat dissipation} = 3.376\,(T_1 - T_2)^{1.25}\ \text{W/m}^2 \qquad (3.2)$$

Where T_1 = temperature in Kelvin of the hot body

= 273+ temp. in °C

T2 = temperature in Kelvin of the air media

= 273 + temp. in °C

The constants are subject to variations depending on the circumstances, e.g., the shape of the heating surface, facilities for air circulation etc.

RADIATION

Heat is transmitted by radiation from a red-hot body to a low-temperature absorbing surface. It is governed by Stefan's law of radiation:

$$\text{Heat dissipation} = 5.72 \times 10 \eta \in \left[\left(\frac{T_1}{1000} \right)^4 - \left(\frac{T_2}{1000} \right)^4 \right] \text{W/m}^2$$

Where T_1 = absolute temperature in Kelvin of the radiating surface

T_2 = absolute temperature in Kelvin of the absorbing surface

η = radiating efficiency, depending on disposition of heating elements

= 1 for single element or

= 0.5 to 0.8 for several elements side by side

$\in$ = emissivity

= 1 for black body or

= 0.9 for resistance heating element.

This formula is used to design high-temperature heating elements.

SPACE HEATING METHODS

Heat may be transmitted from a hot source to a lower temperature by radiation (without heating the air between them), or by convection (caused by movement of the heated air). All electric heaters used for space heating transmit heat by both methods to some degree. Electric room or space heaters conveniently be divided into the following types: (1) high temperature radiator, (2) panel heater, (3) low temperature convection heaters, (4) thermal storage heater and (5) air conditioner.

HIGH TEMPERATURE RADIATOR

High temperature heaters comprise electric fins and radiators. They are made of wire-wound elements which have a working temperature of about 900°C. Some, which have polished reflectors may emit about 75 per cent of their total output as radiation and the remainder by convection.

In the fire bar 40-50 per cent of the heat may be radiated. Convection air currents tend to rise, and do not have the directional qualities of radiant heat. They can be reflected or refracted, and can be blown in any desired direction.

The principal use of radiant heaters is intermittent heating, or in conjunction with a convector. For intermittent use, a loading of 1500 W per 28.3 m^2 of room space is convenient.

It is preferable to use two or more smaller heaters instead of a big one, in a large room, to improve heat distribution and to use heaters with two elements which can be switched on independently.

PANEL HEATERS

Panel heaters have resistance elements in heat resisting material which are in the form of large panels. They are attached to the wall. Flood heaters are panels of up to 33 cm x 64 cm with a surface temperature of 205-260°C. They are usually at an angle to the wall. They are mounted at about 2.3 inches from the floor. The hot air so produced rises up due to low density and the cold air is pushed downwards and is heated up. They are suitable for buildings such as schools and factories, having a high heat loss. A high proportion of the heat produced is radiated and its direction can be controlled. Thermostatic control is available. The objection is that heat rays striking downwards are uncomfortable to some people.

LOW TEMPERATURE CONVECTION HEATER

For rooms in continuous occupation, low temperature heating by convection is preferred. If a definite temperature is to be maintained, it is necessary to calculate the heat loss through walls, windows, floors and ceilings, adding to this the heat lost by air due to ventilation, in order to arrive at the size of heaters needed. A temperature of approximately 20°C is to be maintained. Basically there are two types of convectors. (a) A metal tube about 50 mm in diameter inside which is mounted a spiral of resistance wire. Such tubes are made in lengths of between 0.6 and 4.57 in and mounted in the room to be heated. The temperature of the external surface is about 93.3°C and about 60 W per 0.3 m length of tube is necessary to maintain this. About 90 percent of the heat transferred is by convection. (b) A resistance wire operating at a low temperature inside a box provided with suitable holes to allow air to pass through the box over the elements.

THERMAL STORAGE HEATERS

Thermal storage heaters consist of a large number of pipes through which hot water is circulated. This hot water is circulated to the radiators present all over the buildings. The water is heated up using an electrode boiler or an immersion heater in the storage tank. The pipe and radiator system doesn't differ from that of the well-known central heating system employing coal or coke-fired boiler. In fact, many such

systems have been converted to electric operation by the immersion of an electric heater in the storage tank. When electric heating is employed, the tank and piping must be lagged to prevent loss of heat, which is usually not present in fuel fired systems. The efficiency of the system reduces as lot of losses occur due to lack of lagging.

VENTILATION AND AIR CONDITIONING

Air is circulated through the building by the ventilating equipment after being Preheated and treated for control of humidity. Ventilation heat loss in a building is a major factor during winter: Table 3.4 below gives the number of air changes required per hour for ventilation purposes. It is generally assumed that there is 1.5 times air changes (per volume of the room) by natural ventilation.

Type of Building	Air Changes per Hour
Dwelling houses	2–3
Offices	4–6
Factories	6–10
Cinemas, theatres and kitchens	10–20
Works with noxious fumes	30–40

Air conditioning has been defined as the simultaneous control of temperature, humidity, air movement and control of air in a given space. In air conditioners air is circulated for ventilation throughout the building mechanical1y by means of a fan, driven by an electric motor. Variation of air quantity is carried out by a multi-speed motor. Heating is generally carried out by passing the air over a resistance heater although a heat pump can be employed. Air conditioning, however, involves cooling in summer and heating in winter. Cooling is attained by a refrigeration process.

AIR CONDITIONERS

There are three types of air conditioners

1. Unitary type
2. Central type
3. Unitary-Central type

1. UNITARY TYPE

The window type air conditioner is an example of this type. It is a factory encased self contained unit, with a compressor, a condenser, an evaporator, a filter and refrigerator piping. It is made in capacities ranging from 1/2 to 2 tons, employing motors of upto 3 hp. These units are usually fitted with an attractive frontage on the inside. It is supported on brackets and projects beyond the Wall. These units are suitable for rooms that have at least one wall exposed to the out since, as hot air from, the conditioning for large premises costs about 50 to 100 per cent more than the central type, but it has the advantage of flexible operation. The standby capacity required in the unitary type air conditioning need not be high. In case of malfunction, the unit can immediately be replaced, whereas in the central type air conditioning, this is not possible.

Also, very few structural modifications become necessary, i.e., only a wall opening of 6.4 cm X 3.4 cm is needed in the unitary type air conditioning. This type of air conditioning is suitable where only a few rooms are to be air conditioned.

2. CENTRAL TYPE

In this type of air conditioning, the plant is situated at some central place, usually in the basement, from where conditioned air is led through ducts to the rooms to be cooled. There are return ducts to carry air from these rooms back to the central plant, where it is dehumidified, cooled and recharged with fresh ventilating air. The advantages of this type of air conditioning are high efficiency and robustness of the plant. This type of air conditioning is especially suited to large buildings and rooms which do not have exposed walls. The main disadvantage of this type of air conditioning is the absence of any individual room temperature adjustments, ducting being costly and requiring a lot of space, and also the mixing of odours, cigarette smoke and bacteria present in the return air from infected rooms, and their redistribution to healthy rooms.

3. UNITARY CENTRAL TYPE.

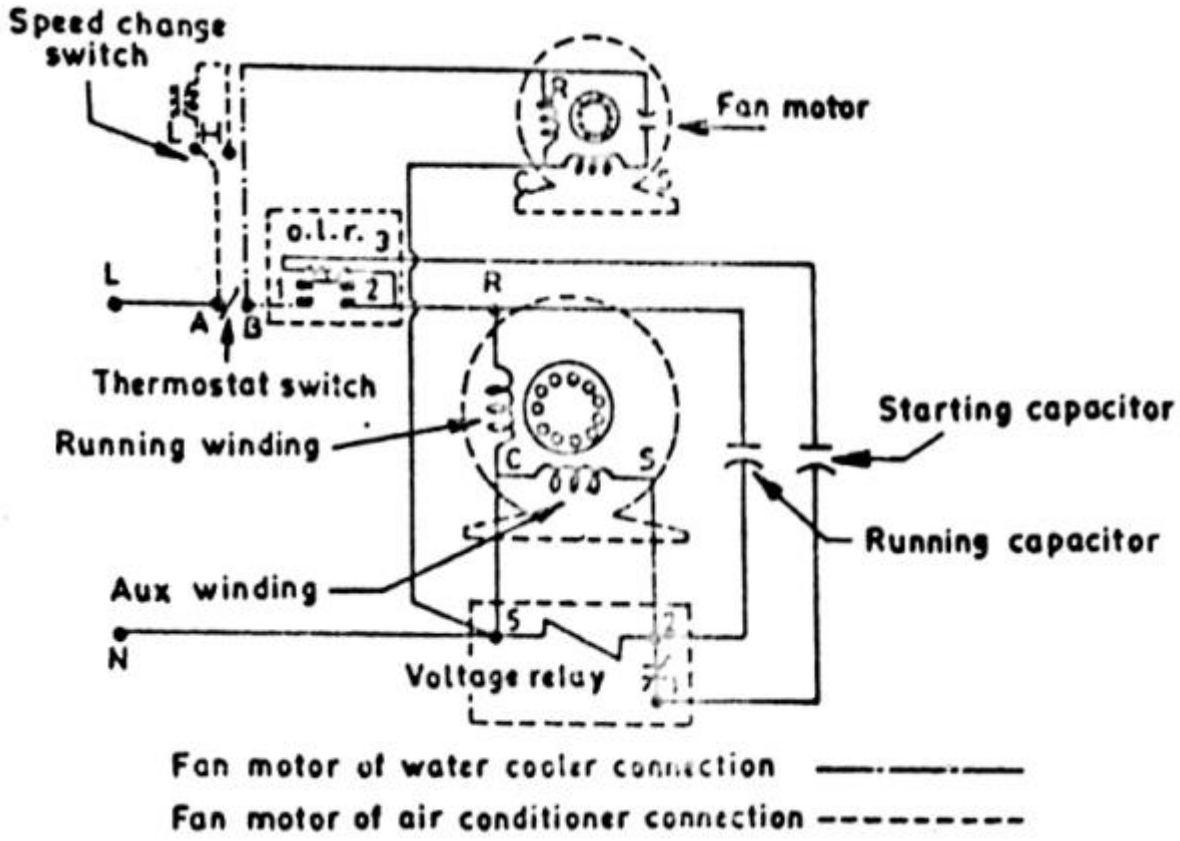
In air conditioning only 15 per cent fresh air is required, the remaining 85 per cent being re-circulated. This type of air conditioning employs both the above types with the central pipe supplying 15 percent fresh air. All the disadvantages of central type are done away with. (i) There will be no return air duct, no mixing of odours and no redistribution of bacteria, (ii) Thu fresh air duct will be very much smaller in size (iii) The temperature of each space can be controlled by a room unit. (iv) All fresh air introduced will displace a corresponding quantity of air, which will escape through openings

In this type of air conditioning, each unit-cooler will be connected by means of lagged piping to the central type air conditioner, carrying either refrigerant or chilled water. The piping should be so placed that there is no direct exposure to the sun.

Window Air Conditioner

The principle of the working of an air conditioner is the same as that of a water cooler. In addition to a condenser fan, an air conditioner also has a blower, whose main job is to circulate the cooled air in a room.

In small air conditioners, a double ended shaft motor is used. At one end, a blower is mounted and at the other end a condenser fan is mounted. In large units, blower and fan may be driven *by* separate motors.



It differs from that of a water cooler, shown chain-dotted in Fig. 3.1, on the following two accounts. Firstly, the fan motor is connected at the input terminal A of the thermostat switch so that the fan motor will continue to work even though the compressor motor is off due to operation of the thermostat. Secondly, the fan motor is a double-speed motor in the case of the air conditioner, to get "Cool Lo" and "Cool Hi" conditions whereas the fan motor in the water cooler is

a single-speed motor. The air cooled condenser and the condenser fan are at the rear of the unit. Outside air is sucked in through side louvers in the unit cabinet. The fan directs air over the condenser which consists of continuous copper tubing to which aluminium fans are fitted, to increase heat transfer. Hot air is discharged to the atmosphere through the louvers at the back of the unit.A centrifugal blower sucks air from the room to be cooled through a filter and a evaporator coil, and delivers it to the upper compartment where this cooled air is mixed with fresh air obtained through a damper door, and then delivered to the room through an adjustable grill fixed on the upper part of the air conditioner.

The control panel of the air conditioner consists of (i) damper control, (ii)master control and (iii) thermostat control. Fresh air intake is regulated by a damper door inside the cabinet. When the damper control is in the vent-closed position, it closes the fresh air; when it is in the fresh-air position, the damper opens slightly and fresh air is fed. When it is in the exhaust position, the output of the blower is discharged to the atmosphere. This is done both to avoid suffocation and to remove smoke. When the master control knob is in the 'off' position, none of the motors operate. In the 'fan' position only the fan motor is working and the compressor motor is off. In the 'cool lo' position both the motors are working but the fan motor runs at slow speed. In the 'cool hi' position, both the motors are working and the fan motor runs at a high speed. A thermostat-sensing element is usually located in the return air stream, near the filter. The thermostat control On the panel adjusts the distance between the contests of the thermostat switch and hence the temperature. Some room air conditioners contain an electric-heater element which can be used to take the chill off a room in winter. This heater element is controlled by the master control switch. When the fan and heater are turned on, warm air is blown into the room through the air supply grills located at the front of the air conditioner. If the fan motor fails, heat is not distributed to the room, and a thermal switch automatically cuts off the heater at about 121°C. The fan motor may be a capacitor motor or a shaded pole, single phase, induction motor. Its speed reduction is obtained by connecting a reactor in series.

HEAT PUMPS

Heat pumps can be used instead of resistance heating to conserve energy. Basically, the heat pump is a device which utilizes heat acquired from a low temperature source (outside environment in winter) and passes it into the building. It is a reversed refrigeration process. In ordinary refrigeration, heat is abstracted from the cold storage chamber by means of an electric motor driven compressor, converted to heat at a

higher temperature, and dispatched to the surrounding atmosphere by a radiator. In the heat pump, a similar apparatus is used, but the heat is abstracted from the atmosphere which may be at quite low temperature. It is then converted, by means of a compressor, to heat at a higher temperature, to be dissipated inside the building by radiators.

The amount of heat produced is 2 to 3 times corresponding to the electrical input, i.e.,2 to 3 times as much as would be produced by a resistance heater of the same input. This is called the coefficient of performance of the heat pump (COP), which is essentially the first law efficiency.

$$\text{COP} = \frac{Q}{V} \approx 2 \text{ to } 3 \qquad (3.4)$$

where Q=Heat injected inside the building in J (1 = 4.186 J)

W=electrical energy input (Work input to the heat pump, J)

The second law efficiency of a heat pump is defined as

$$= COP\left[1 - \frac{T_0}{T_1}\right] < 1 \qquad (3.5)$$

Where T_0 =ambient temperature of outside atmosphere in K

T_1 =Temperature inside the building in K

Under certain circumstances, the first law and second law efficiencies can differ dramatically. For example a furnace providing hot air at $43\,^0C$ to a house, when the outside air temperature is $0\ ^0C$, has second law efficiency=0.082 if its first law efficiency(COP) is 0.6. On the other hand, for a power generator the first lawand second law efficiencies are nearly the same

INSULATION

This is a very important aspect for energy conservation in buildings. Generally buildings should be well insulated in order to minimize heat losses.

U=Value ($J / m^2\,^0C\ h$) *(Compare with* $\frac{k}{t}$ in eq.3.1)

which is the heat transfer coefficient of construction. It has relationship with the rate of heat loss of a structure, and decreases inversely with respect to insulation thickness. In theory,

therefore it is possible to reduce heat losses to any chosen values by increasing the thickness of insulation. The most important deterrent on this increase in thickness is capital cost, as insulating materials are rather expensive. Thus, it is essential to fix an economic limit for energy conservation. U-value can be converted to J/m^2 °C per h by multiplying the numerator and denominator of W/m^2 °C 3600. Table 3.5 gives U-values of the different parts of a building.

Type of Wall or Ceiling	*U-Value, J/m² °C h*
Corrugated asbestos roof	20.8×10^3
Brick, Walls, with plaster and air cavity in between two courses	5.286×10^3
Windows	20.52×10^3
Wooden Floor	5.04×10^3

COOLING LOAD

The heating load calculation is made assuming steady-state heat transfer, which is the usual procedure, and this gives a reasonably accurate estimate of the heat necessary to maintain indoor conditions, when outside air conditions are stable. The transient nature of the heat loss due to the variation of outdoor air conditions is neglected. The results obtained are normally quite adequate.

The cooling load, however, presents a much more complex problem because of the larger number of variables involved, and also the transient nature of the heat gain must be considered. The instantaneous heat gain into a given space is variable with the time of day, day of the month, and season of the year, because of the transient nature of the solar radiation. There may be an appreciable difference between the instantaneous heat gain to a space and the actual instantaneous heat removal rate. The reason for this is the heat storage effect of a structure.

In an air conditioning design, it is important to differentiate between three related, but distinct, heat flow rates, each of which varies with time, such as

1. Space heat gain
2. Space cooling load (heat removal rate)
3. Cooling coil load in central air conditioning system.

ELECTRIC WATER HEATING SYSTEMS

For domestic purposes, there are advantages in combining electrical heating with some form of central heating (e.g., a small coke burning boiler). For maximum efficiency hot

water cisterns should be lagged with cork or some other material of low heat conductivity. For central heating, it may be advisable to also lay the pi: earn purchase ac power, if there is surplus during off-peak periods (late night), and a thermal storage system of hot water enables such powers to he utilized and the heating effects of the power to be stored.

Table 3.6 gives the temperature of hot water required for various purposes, and also the hot water storage temperatures.

Type of Use	*Temp. °C*
Wash basin	43.3 minimum
Kitchen sink	60.0 minimum
Laundry work	100.0 maximum
Boiling point	100.0
Scalding temperatures	65.5
Hot bath	40.5
Warm bath	36.6
Tepid bath	29.4

Recommended storage temperatures

Soft water	71.0
Hard water	60.0

There are three types of electric hot water systems described below.

1. Immersion heaters
2. Self contained water heater (geyser)
3. Electrode boilers

IMMERSION HEATERS

These are principally for water heating, but special types are available for heating oil, wax and bituministic materials. Immersion heaters have a high efficiency; loading is from 100 W to about 10 kW and banks of several large heaters be employed for industrial purposes.

The tubular type has one, two, or three tubes or blades in which the elements of nickel-chrome are embedded in refractory materials. These elements cannot be replaced in the heater. The removable core type has sections of ceramic material wound with the element wire in a tinned copper sheath, and has the advantage of replaceable element. Loading may be upto 6.0 W/sq.cm. with 1.5 to 3.0 W for the removable core type.

Horizontally fitted elements cause good circulation in the tank with little difference in temperature between top and bottom. The element should be as low as possib1e, due to the low heat conductivity of water, the water below the- heater will remain at a comparatively low temperature. Vertically fitted elements with top entry, should be long enough to reach the lower layers of the water for the same reason. This system gives less circulation, but is quick in heating a volume of water.

Thermostatic control is convenient., and gives good results if the hot water system is correctly planned and the surfaces well lagged. The thermostat for an immersion heater consists of a tube and rod of different metals, which expand at different rates when heated, the difference in movement at the free ends being used to operate the switch. The contacts have a micro gap and are large, so that the arc is cooled below ignition temperature after being extinguished, when the ac current wave passes through the zero value. A quick break may be obtained by a magnet or a similar device.

SELF CONTAINED WATER HEATERS

These are factory made vessels which contain a heating element and thermostat, and are insulated for high efficiency. Heaters of 6.8,13.6 and 22.71 are suitable for sink heaters;54.5,68,91.1 and larger sizes being good for general household purposes. Table 3.7 shows the approximate time required for the various heaters to raise the contents from room temperature to $76.66^{0}C$. Standby losses may vary from about 4kWh per week for the 6.8 size, to about 16 kWh per week for the 91 1 size.

Table 3.7 Approximate Time Required

Size of Heater (litres)	Rating (kW)	Time taken to reach 76.66°C (h)
6.8	0.75	1
13.6	1.0	$1\frac{1}{2}$
22.7	1.0	$2\frac{1}{2}$
54.5	1.2	4
68.0	1.5	4
91.0	2	4

ELECTRODE BOILER

These are suitable for supplying large central heating systems. They have capacities of 25-5000kW and voltages upto 11kV. Three-phase, small boilers of this type have a large capacity. When alternating electric current is passed between electrodes, most of the power is utilized in heating the water due to its resistance. The power used in electrolysis may be as low as 0.1 per cent of the input. The resistivity of the water varies considerably in different parts of the country, it maybe 50-100W per cube of the purer glacial and rainwater supplies.

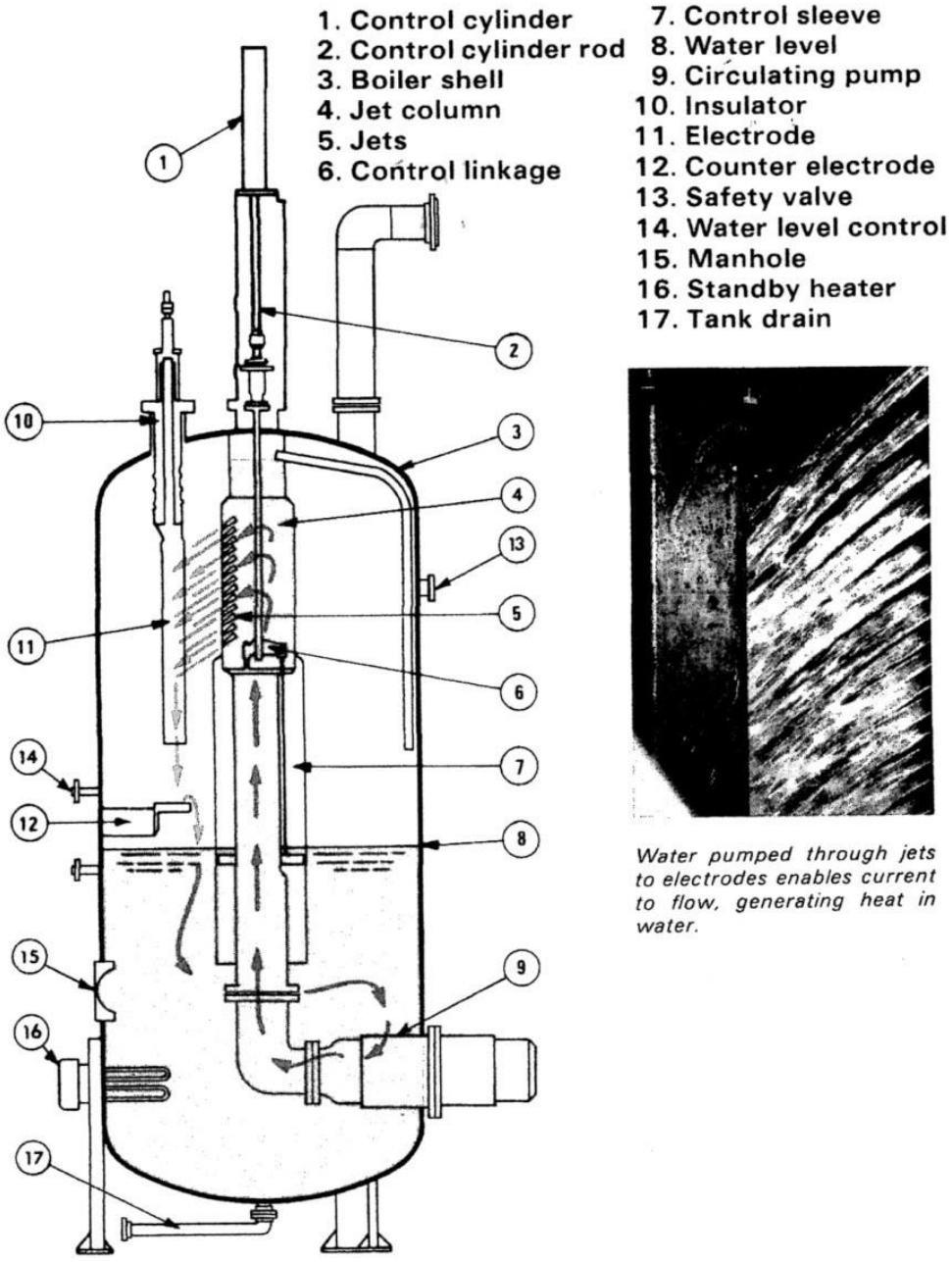
Various controlling and safety devices are fitted for the following purposes:

1. Switching on the current, usually by a time switch set to coincide with `off-peak' periods. Usually the current is switched on when the electrodes are in the minimum current position
2. Switching off by thermostat when the storage temperature has been reached, the electrodes then being automatically returned to the minimum current position.
3. Starting the boiler if the temperature falls below the preset temperature before the end of the `off-peak' load period.
4. Switching off, under minimum current conditions, at the end of the `off-peak' periods.
5. Switching off by remote control from the supply station to correspond with load conditions, in an alternative method.
6. Safety switches to switch off if the water supply fails, if 'out of balance' of the three-phase loud occurs, if excess current flows due to insulation failure, if the water temperature exceeds a safe value, or if there is a sudden loss of water from the system. In any of these events an alarm may be sounded and the electrodes moved to the minimum current position. To ensure this, the gear is so designed that the

main switch cannot be shut off until the pilot motor, or electrically operated water valves controlling a hydraulic piston, have moved the electrodes to the starting position.

7. Alternatively the control gear may be designed so as to keep the current within certain limits, irrespective of the water temperature.

With electrode boilers, storage is usually effected in a separate vessel, and primary pumps circulate the water between the lagged boiler and lagged tank, while secondary pumps circulate the water between the tank and heating radiators.



Water pumped through jets to electrodes enables current to flow, generating heat in water.

ELECTRIC ENERGY CONSERVATION METHODS

Conservation of electric energy in domestic buildings can be achieved in the following ways:

- Efficiency of various appliances varies a great deal. It is important that the type of appliance used should be given adequate consideration as regards its efficiency, before adoption.
- Heating appliances rn7 be used at the lowest acceptable level of heat emission.
- All cooling systems should be maintained in a clean condition and also kept in good working order.
- The use of heat emitting appliances could be minimized in areas where a cooling system is in operation.
- Appliances should be turned off when buildings are not occupied, provided this does not affect the functional use of the building and appliances, such as refrigerators.
- ON/OFF controls of water heaters and air conditioners must be adopted since these are high current-drain devices.
- The thermostat and humidity control settings could be raised in summer, and lowered in winter. For example, for summer cooling it is possible to save up to 15 per cent of energy by having a thermostat temperature setting of 27°C, and 60 per cent relative humility.
- Heat pumps could be used for space heating instead of electric heating.
- Fan speed regulators (resistance type) should be replaced by electronic regulators to mitigate the lenses in the resistance.
- Chilled water systems should be considered for space cooling.