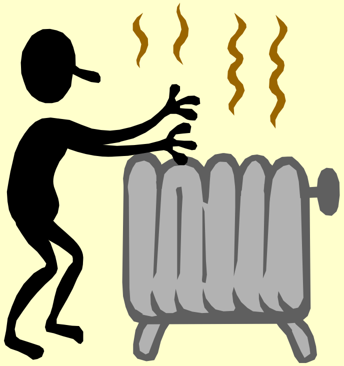

Heating

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  - Types of Heating System
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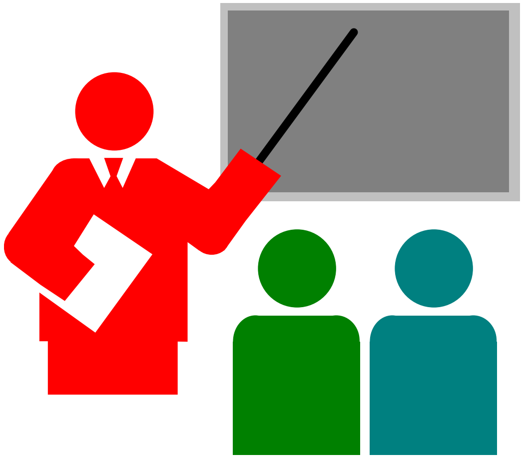


Heating Load

- **Design heating load**
  - **Max. heat energy required to maintain winter indoor design temp.**
    - Usually occurs before sunrise on the coldest days
    - Include transmission losses & infiltration/ventilation
  - **Assumptions:**
    - All heating losses are instantaneous heating loads
    - Credit for solar & internal heat gains is not included
    - Latent heat often not considered (unless w/ humidifier)
    - Thermal storage effect of building structure is ignored

Heating Load

- A simplified approach to evaluate worst-case conditions based on
  - Design interior and exterior conditions
  - Including infiltration and/or ventilation
  - No solar effect (at night or on cloudy winter days)
  - Before the presence of people, light, and appliances has an offsetting effect
- A warm-up/safety allowance of 20-25% is fairly common

The Need for Heating

Heating – Hong Kong – Meteorological Data

Green House Effect

Meterological Element	Oct 06	Nov 06	Dec 06
Mean Daily Max Air Temp	29.0°C	25.5°C	20.4°C
Mean Air Temp	26.4°C	23.3°C	18.2°C
Mean Daily Min Air Temp	24.7°C	21.6°C	16.1°C

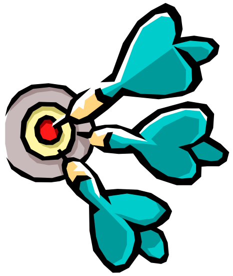
Meterological Element	Jan 07	Feb 07	Mar 07
Mean Daily Max Air Temp	18.8°C	21.9°C	22.7°C
Mean Air Temp	16.4°C	19.5°C	20.2°C
Mean Daily Min Air Temp	14.3°C	17.8°C	18.4°C

The Need for Heating

Heating – Hong Kong situation

- Office for perimeter zone
- Hospital (close temperature control needed)
- Hotel (close temperature control needed)
- Apartment (only some luxury ones)

Energy Sources for Heating



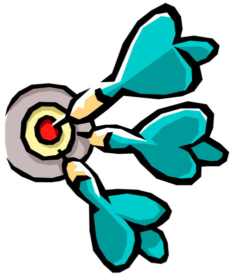
Fuel factors

- Availability, including dependability of supply
- Convenience of use and storage
- Economy
- Cleanliness

Combustion equipment factors

- Operating requirements
- Cost
- Service requirements
- Ease of control

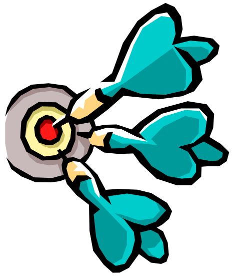
Energy Sources for Heating



Solid Fuel

- Bituminous coal, Semibituminous coal, Subbituminous coal
- Anthracite - clean, dense, hard, little dust in handling. Hard to ignite, but burns freely once started. Burns uniformly and smokelessly with a short flame.
- Lignite is woody in structure, very high in moisture when mined, of low heating value.

Energy Sources for Heating



Liquid Fuel

➢Kerosene, Gas Oil, Light Grade Oil ,Medium Grade Oil, Heavy Grade Oil

Gaseous Fuel

- ➢ Liquefied petroleum gases (LPG) - propane and butane
- ➢ Natural gas - methane (55 to 98%), higher hydrocarbons (primarily ethane) + a small proportion of noncombustible gases
- ➢ Town Gas

Electricity

- ➢ CLP, HKE

Types of Heating System

Direct systems

- The energy purchased is consumed as required within the space to be heated.

Indirect systems

- The energy purchased is consumed at some more or less central point outside the space to be heated and then transferred to equipment in that space for liberation.

Types of Heating System

- **Direct Heating**
  - Fuel directly converted to space heating
  - Solid fuel system, Convective heat system (liquid fuel, gaseous fuel, electrical), Radiant heat system (gaseous fuel, electrical)
  - Heat Pump (Reverse cycle of refrigeration cycle)
- **Indirect System**
  - A medium carries the heat generated to the space for heating
  - Furnace, Boiler plant, Steam plant, Solar plant, Heat Recovery Chiller

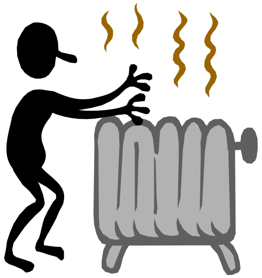
Methods of Heating

- **Convective or Radiant Heating ?**
  - Radiant Systems : minimum 50% of their output is radiant
  - Radiant heating : high air change rates or large volumes (not requiring uniform heating throughout, e.g., factories, and intermittently heated buildings with high ceilings.
  - Radiant heating can require less energy than convective heating (heat transfer at order of T^4)
  - Radiant heating is used better in situations that ventilation heat losses exceeding fabric heat losses.

Methods of Heating

- **Merits of heating by radiation**
  - Since about 45 % heat lost by the human body is radiation→ the feeling of warmth derived from radiant heating is greater than by convection.
  - Radiant heat gives a greater feeling of warmth with a lower air temperature →15 % saving in fuel costs.
  - The draughts are reduced to a minimum → dust is also kept down to a minimum.
  - Radiant heats solid objects on which it falls →floors and walls derive warmth from radiant heat rays → warm surfaces set up convection currents → heat lost from the human body by convection reduced.

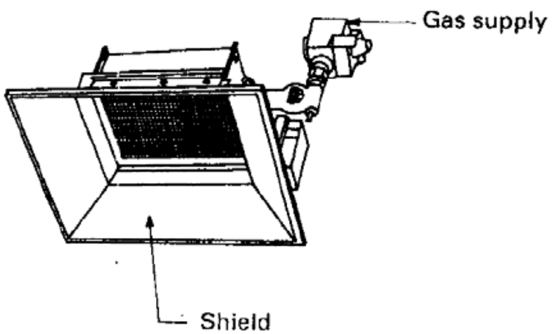
Direct Heating System



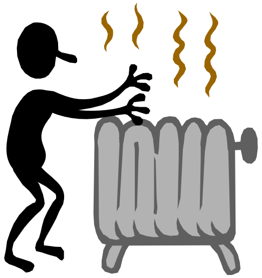
Direct systems - gaseous fuels (primarily radiant)

Infra-red heaters

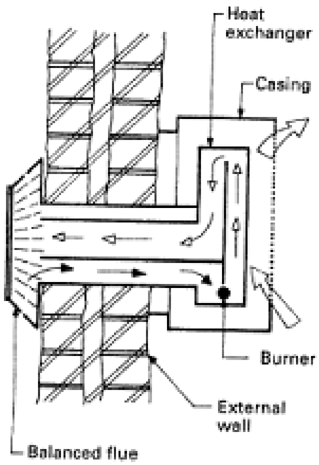
- Designed primarily for industrial applications in higher buildings
- Pipe connected to supply main or to either butane or propane cylinders.
- For permanent installations : wall mounted or suspended from a ceiling
- Rated up to 30 kW but a range between 3 and 15 kW is more common.
- Flue connections not provided for heaters but minimum rates of outside air ventilation necessary either per unit or per kW rating specified.



Direct Heating System

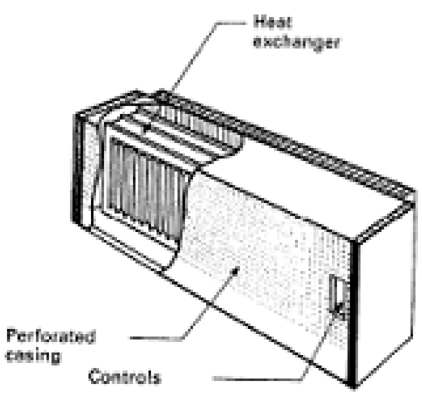


Direct systems - gaseous fuels (primarily convective)

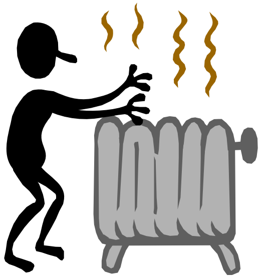


Natural convectors

- Provide means for dispersal of the products of combustion via a conventional outlet or a balanced flue arrangement.
- Heat exchanger so mounted provide a passage for the movement of convected air from a low level inlet to a top or top-front outlet.
- Some heat transfer to the front of the casing and a small radiant output may result.
- For institutional building have ratings of up to 10 kW (3 kW is common).



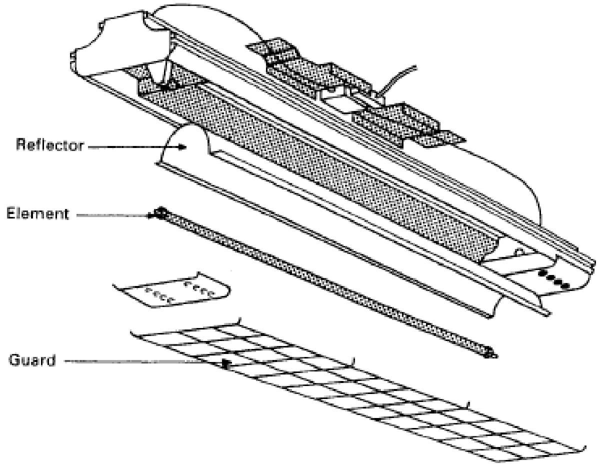
Direct Heating System



Direct systems - electrical (primarily radiant)

Infra-red heaters

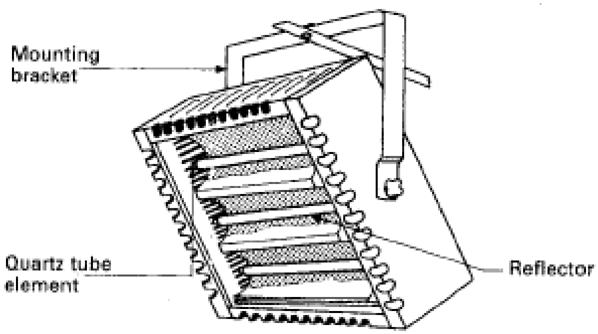
- Wall or ceiling for kitchens and bathrooms (more robust patterns for commercial or industrial).
- The elements operate at about 900 °C.
- Not for very high ceilings (e.g. churches) as it may be too high to provide effective radiant cover.
- Ratings are up to 3 kW per unit.



Direct Heating System

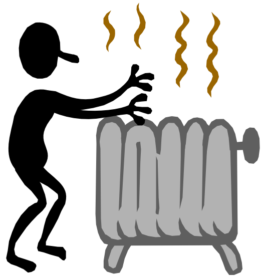
Direct systems - electrical (primarily radiant)

Quartz lamp heaters



- For large spaces requiring intermittent heating or spot heating
- Quartz lamp heaters operate over 2000 °C.
- Each element rates at about 1.5 kW.
- A tungsten wire coil sealed within a quartz tube containing gas.
- A number of elements (normally a maximum of six), each mounted in front of a polished parabolic reflector.

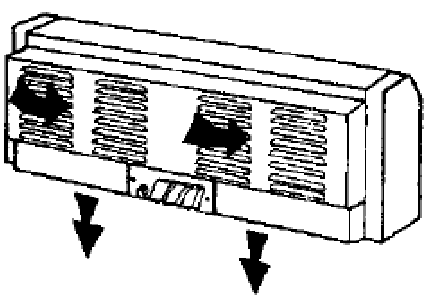
Direct Heating System

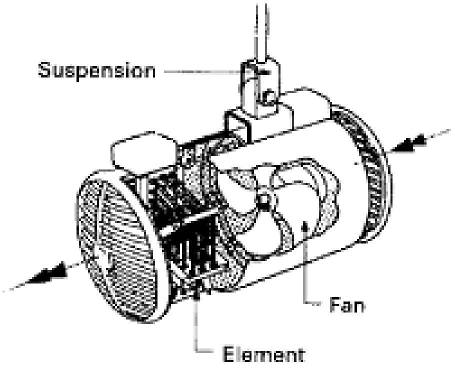


Direct systems - electrical (primarily convective)

Forced convectors

- Compact portable domestic fan heater rated at up to 3 kW.
- Commercial type heaters, fitted with axial-flow fans, having ratings of about 3-6 kW.
- Cased tangential-fan units rated at up to 18 kW for warm air curtains at building exits and entrances.
- Large industrial units rated at 30 kW or more.

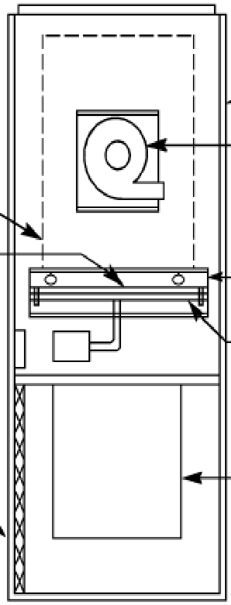




Indirect Heating System

Furnace

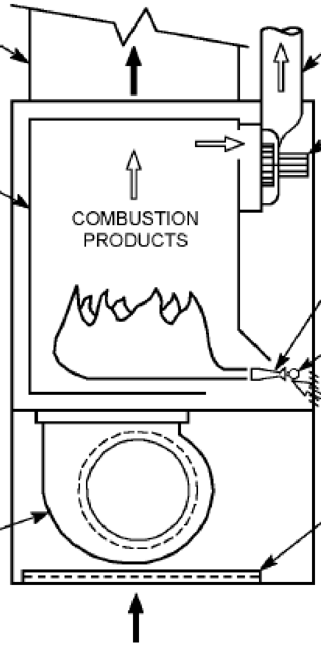
- Provides heated air through ductwork to the space.
- Fuel burning furnaces and electric furnaces.
- Fuel-Burning Furnaces
  - Combustion takes place within a combustion chamber.
  - Circulating air passes over the outside surfaces of a heat exchanger (Gas does not contact the fuel or the products of combustion).
- Electric Furnaces.
  - A resistance-type heating element heats circulating air directly



Indirect Heating System

Upflow or “Highboy” Furnace

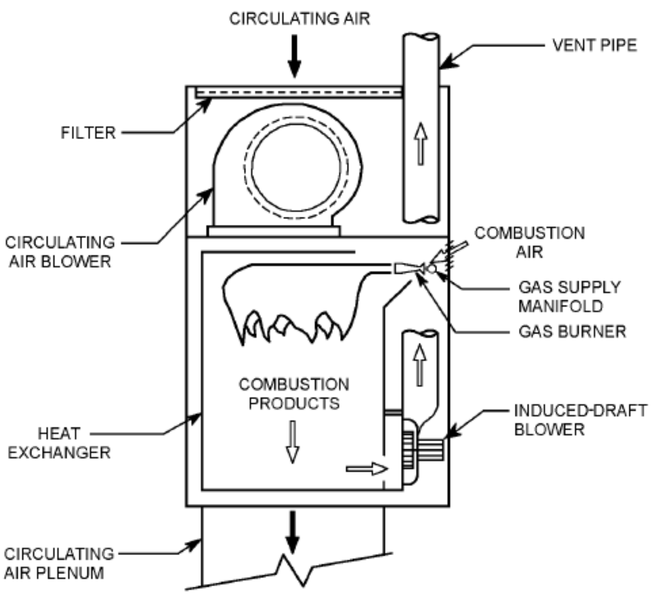
- Blower beneath the heat exchanger and discharges vertically upward.
- Air enters through the bottom or the side of the blower compartment and leaves at the top.
- Used in closets and utility rooms on the first floor or in basements



Indirect Heating System

Downflow Furnace

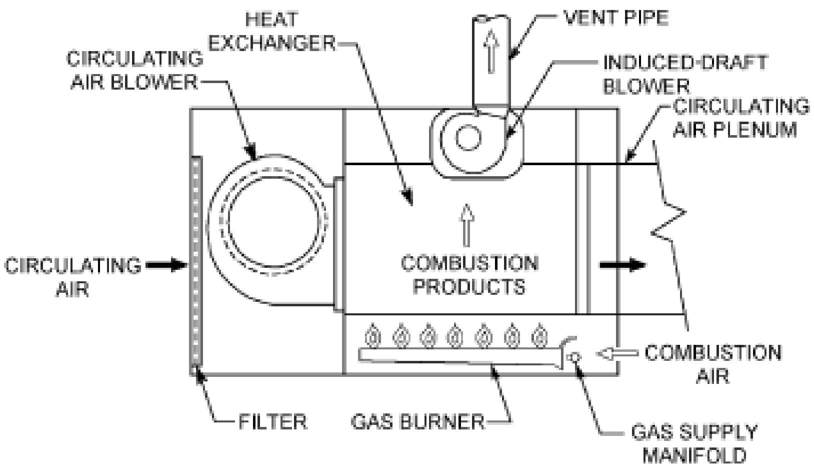
- Blower above the heat exchanger and discharges downward.
- Air enters at the top and is discharged vertically at the bottom.
- Used with a perimeter heating system in a house without a basement.
- Used in upstairs furnace closets and utility rooms supplying conditioned air to both levels of a two-storey house



Indirect Heating System

Horizontal Furnace

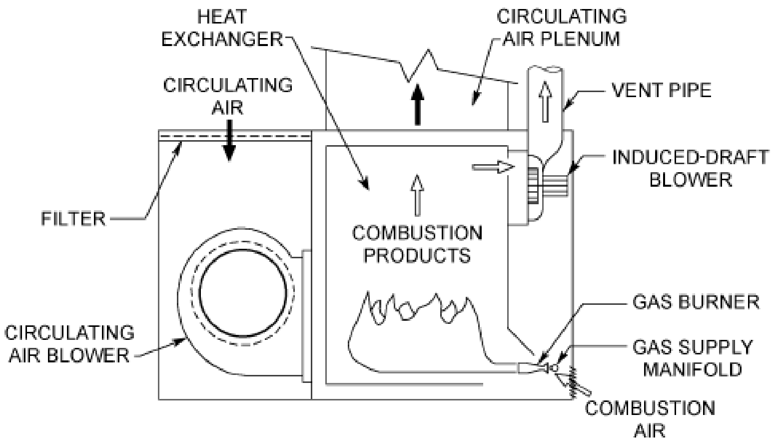
- Blower is located beside the heat exchanger
- Air enters at one end, travels horizontally through the blower and over the heat exchanger
- Use: Limited head room such as attics and crawl spaces
- Use: Suspended under a roof or placed above a suspended ceiling.



Indirect Heating System

Lowboy Furnace

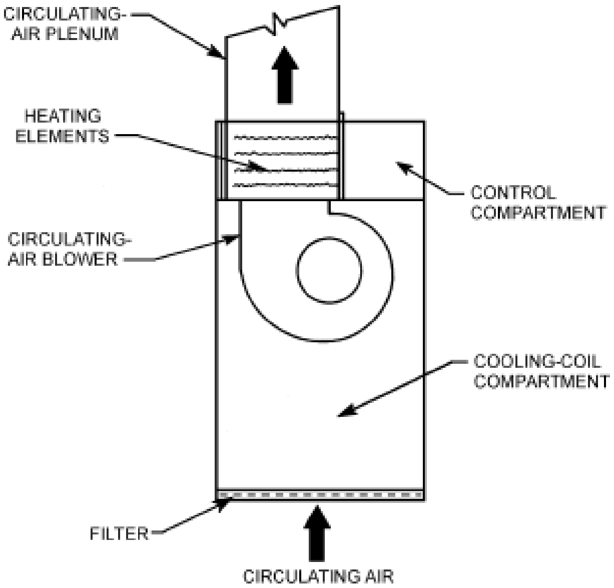
- A variation of the upflow furnace requiring less head room.
- The blower is located beside the heat exchanger at the bottom.
- Air enters the top of the cabinet, is drawn down through the blower, is discharged over the heat exchanger, and leaves vertically at the top.
- Use: Basement



Indirect Heating System

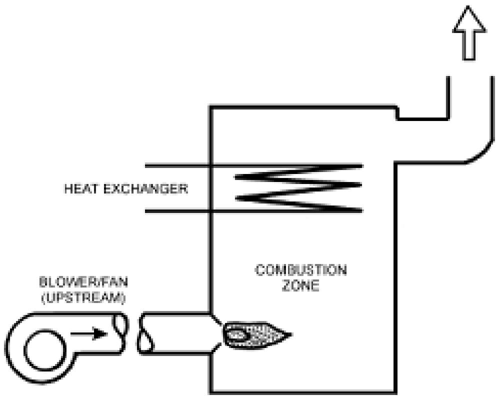
Electric Furnace

- The furnace consists of casing, air filter, and blower.
- The heating elements are made in modular form, with 5 kW capacity being typical for each module.
- Electric furnace controls include electric overload protection, contactor, limit switches and a fan control switch.
- The overload protection may be either fuses or circuit breakers.



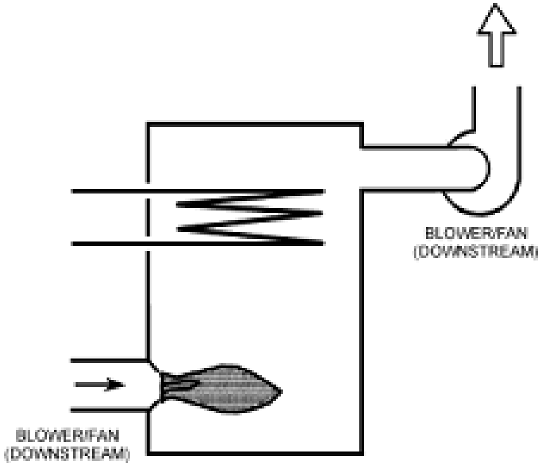
Indirect Heating System

Furnace - Combustion system variations



- Gas-fired furnaces : natural-draft or a fan-assisted combustion system.

- Natural-draft furnace
  - Buoyancy of the hot combustion products carries these products through the heat exchanger, into the draft hood, and up the chimney.



- Fan-assisted combustion furnaces
  - Forced-draft :Combustion blower at upstream, blowing the combustion air into the heat exchangers
  - Induced-draft: blower is downstream.

Indirect Heating System

Points to be noted in the design using furnace

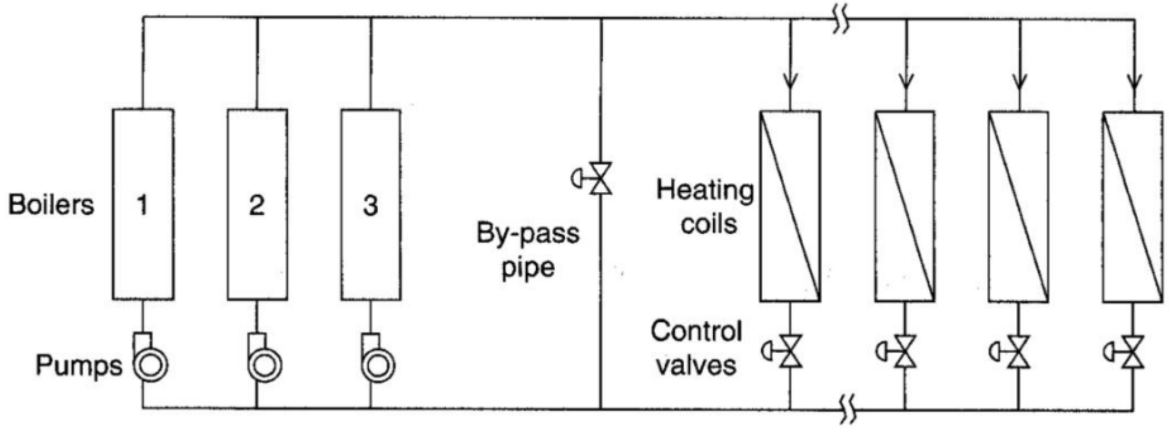
- Net heat available to heat the room/ building;
- Gross furnace output at the outlet of furnace
- Allowance of heat loss in duct and the pickup loss
- Air flow rate and pressure loss at duct

Indirect Heating System

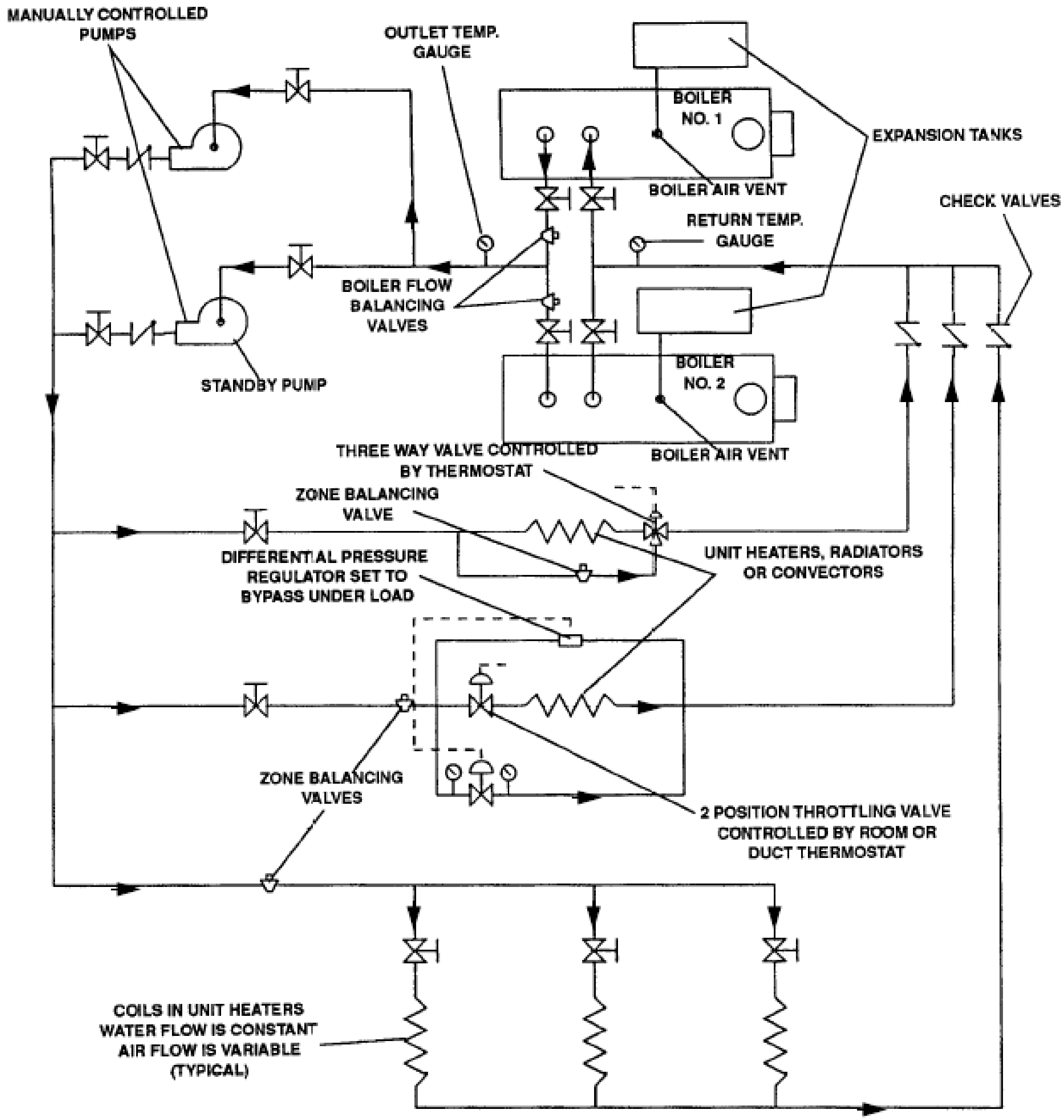
Boiler plant

A centralised hot-water heating system has three basic elements:

- Boiler.
- Heat distribution circuit.
- Heat emitter.



Typical arrangement of boiler plant used for space heating.


MANUALLY CONTROLLED PUMPS
OUTLET TEMP. GAUGE
BOILER NO. 1
EXPANSION TANKS
BOILER AIR VENT
CHECK VALVES
RETURN TEMP. GAUGE
BOILER FLOW BALANCING VALVES
BOILER NO. 2
STANDBY PUMP
THREE WAY VALVE CONTROLLED BY THERMOSTAT
BOILER AIR VENT
ZONE BALANCING VALVE
DIFFERENTIAL PRESSURE REGULATOR SET TO BYPASS UNDER LOAD
UNIT HEATERS, RADIATORS OR CONVECTORS
ZONE BALANCING VALVES
2 POSITION THROTTLING VALVE CONTROLLED BY ROOM OR DUCT THERMOSTAT
COILS IN UNIT HEATERS WATER FLOW IS CONSTANT AIR FLOW IS VARIABLE (TYPICAL)

Indirect Heating System

Low pressure hot water (LPHW)

- Output is limited by system temperatures restricted to a maximum of about 85 °C

Medium pressure hot water (MPHW)

- Permits system temperatures up to 120 °C
- Allow a greater drop in water temperature and thus smaller pipework.
- Advantage only on a large system.
- Pressurization up to 5 bar absolute.

High pressure hot water (HPHW)

- High pressure systems (up to 10 bar absolute) => greater temperature drops & smaller pipework.
- Cost-effective only for transportation of heat over long distances.

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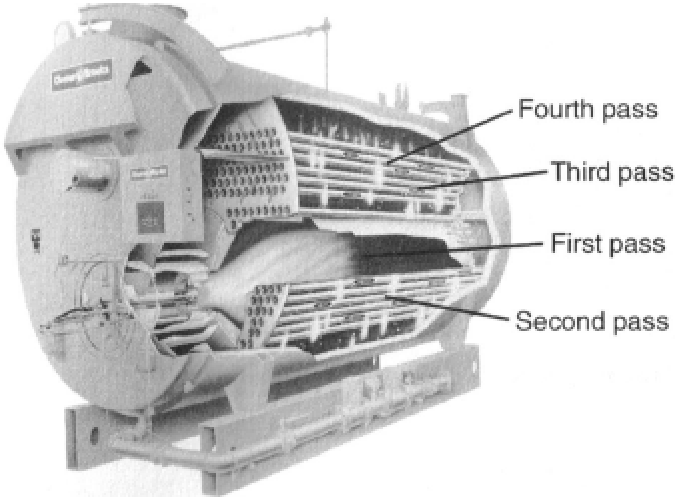
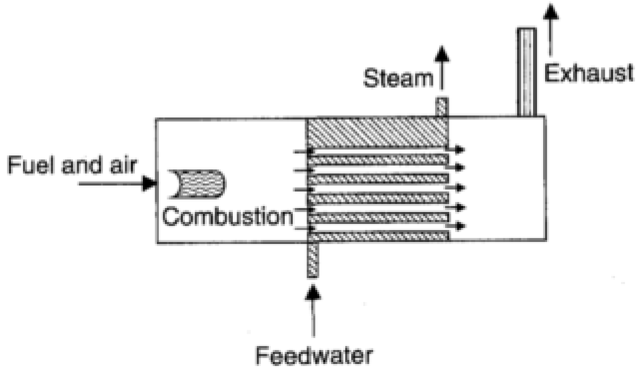
Indirect Heating System

Firetube Boiler (Scotch Marine)

- Tubes through which flue gas passing and combustion chamber are all enclosed in a shell filled with water.
- A gas, oil, or gas/ oil burner; a mechanical draft system; a combustion chamber; fire tubes; and a flue vent, outer steel shell, external insulation, controls, and wiring.
- It is a packaged boiler (a one-piece factory-assembled).
- Available in two, three and four pass designs
- Boiler efficiencies increase with the number of passes.



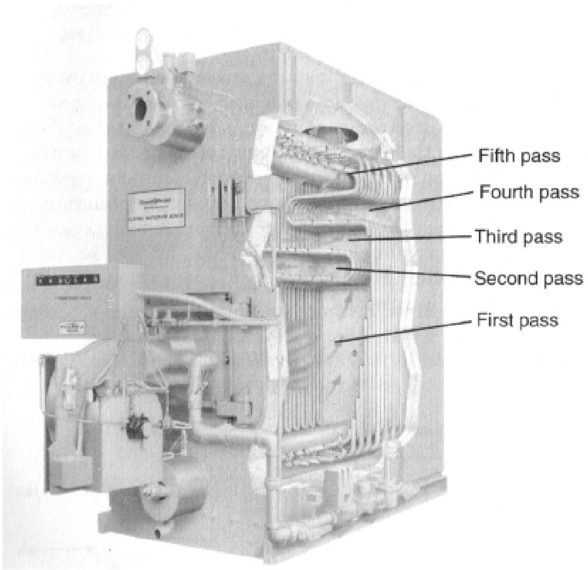


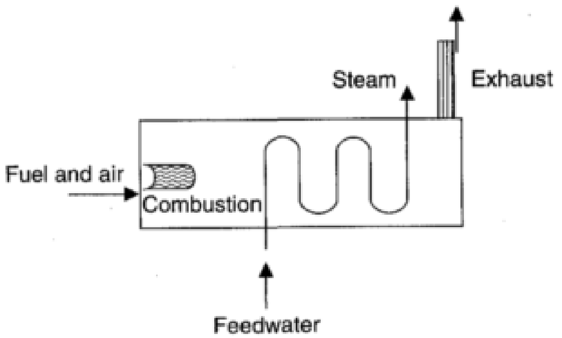
Arrangement of fire tube boilers.

Indirect Heating System

Commercial Watertube Boilers

- Produce steam or hot water for commercial applications.
- There are a wide variety of types, sizes, capacities, and design pressures available.
- Commercial watertube boilers can be straight tube, modular, etc.
- Mainly for steam at higher pressure and temperature

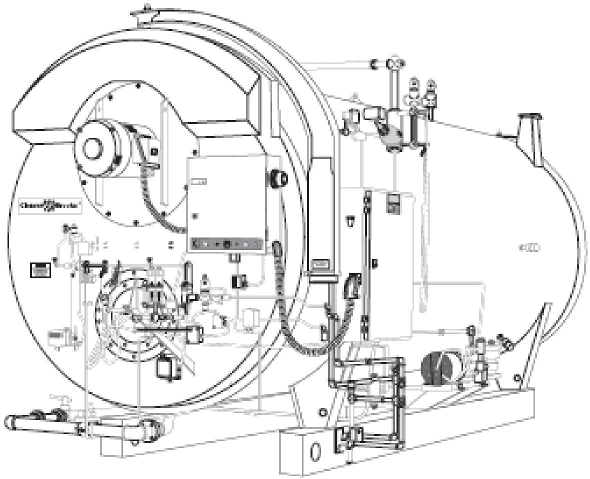




Arrangement of water tube boilers.

Indirect Heating System

Cast Iron Boilers



- Vertical cast-iron hollow sections in the shape of an inverted U filled with water.
- Limited to low-pressure steam or hot water applications
- Typically range in size from 25 to 200 horsepower.
- Modular design which includes sections for field erection.
- Slow to heat up because of its thick, heavy section.
- Large heat storage capacity.
- Thick and heavy sections preventing corrosion.
- Large combustion chamber and lower flow resistance allows a lower chimney height.

Indirect Heating System

Electric Boilers

- Electric boilers are noted for being clean, quiet, easy to install, and compact.
- Because there are no combustion considerations, an electric boiler has minimal complexity (no fuels or fuel handling equipment) with easily replaceable heating elements.
- An electric boiler may be the perfect alternative to supply low or high pressure steam or hot water where the customer is restricted by emission regulations.
- Sizes range from 9 kW to 3,375 kW output.
- Relief valve, thermal overload cutout, and high-limit switch should be provided.

Indirect Heating System

Boilers

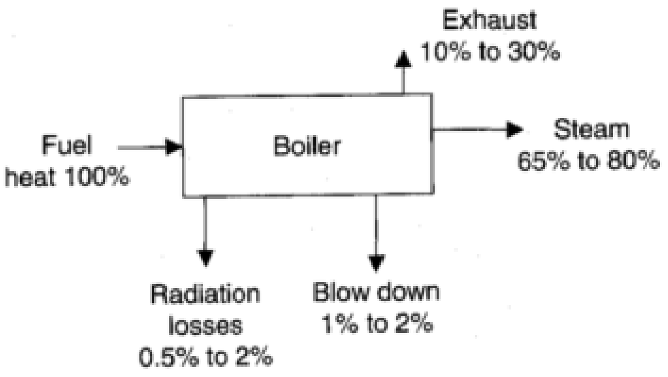
Criteria should be considered when selecting a boiler. The criteria are:

- **Codes and standards requirements** *(Manufactured according to the American Society of Mechanical Engineers (ASME) boiler and pressure vessel codes*)
- **Boiler load** *(Heating Load and Process Load, Combination Load***)**
- **Number of boilers** *(Back-Up Boilers, Type of Load, Downtime, Boiler Turndown***)**
- **Performance considerations** *(Fuels, Emissions, Combustion Efficiency, Thermal Efficiency, Boiler Efficiency, Stack Temperature and Losses, Excess Air***)**
- Special considerations in Boilers replacement *[Floor space, Access space for maintenance, Access to the boiler room, Assembled with no welding required (Cast Iron Boiler)]*

Indirect Heating System

Boiler efficiency

- Only part of the heat content of the fuel is converted into useful heat, while the rest is lost through exhaust gases, blowdown, and radiation losses.
- The efficiency of boilers is usually rated based on combustion efficiency, thermal efficiency, and overall efficiency.



Typical heat balance for a boiler.

Indirect Heating System

Combustion efficiency of Boiler

- Combustion process in boilers : Burning fuels with oxygen to generate heat.
- Amount of air for combustion depends on type of fuel.
- Excess air for combustion to ensure complete combustion of fuel.
- High efficiency is attained with formation of more CO_2 and lower flue gas temperature (more heat absorbed in heat exchanger).
- Carbon dioxide flue gas analysis and stack gas thermometer for analysis.
- Combustion efficiency can be measured directly by using a combustion analyzer (direct reading based on the fuel use).

Thermal efficiency

- A measurement on the efficiency of the heat exchanger.
- A evaluation of how well heat transfer from combustion process to water or stream.

Indirect Heating System

Overall efficiency of Boiler

- The overall efficiency of boiler < the combustion efficiency
- (Radiative and convective losses from the boiler and other losses, such as cycle losses, passing of air through boiler during the "off" cycle).
- The overall efficiency of a boiler = combustion efficiency - stack losses - radiative losses - convective losses - other losses.
- While combustion efficiency can be measured directly by using a combustion analyzer, the stack, radiative, and convective losses can be estimated using boiler manufacturers' data.

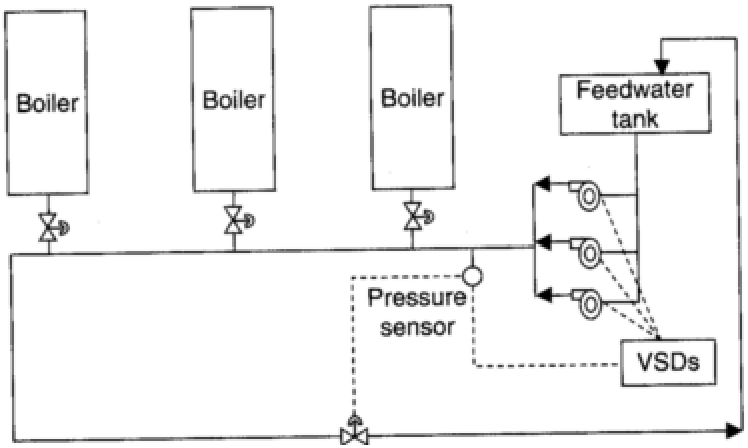
$$\text{Overall boiler efficiency} = \frac{\text{Heat output}}{\text{Heat input}}$$

Indirect Heating System

Energy Saving Measures of Boilers/ Boiler Plant

Optimizing operation of auxiliary equipment

- Operate auxiliary equipment such as feedwater pumps consume a lot of energy.
- Boiler and its own feedwater pump (to maintain the level of water in the boiler) - Interlocking between them.
- Multiple boilers by a common set of feedwater pumps - Varying the capacity (speed) of feedwater pumps.



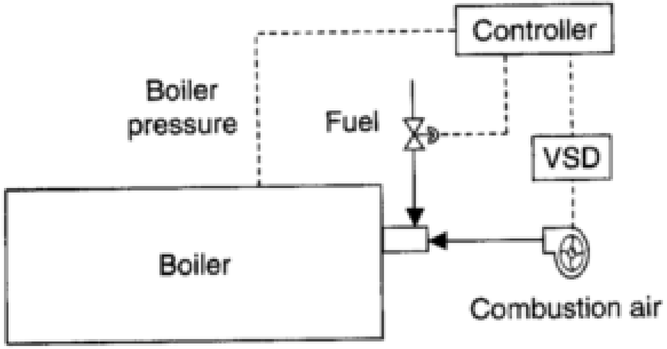
Suggested feedwater pump arrangement for a mul-tiple boiler operation.

Indirect Heating System

Energy Saving Measures of Boilers/ Boiler Plant

VSD for Boiler fans

- These fans create draft for combustion & carry flue gases through boiler.
- Constant speed fans operate at constant speed and dampers to control air flow.
- At part load, a damper throttles air flow by inducing a resistance across the path →power consumption of the fan not reduce proportionately to the air flow.
- Use of a variable speed fan, reduction in fan energy consumption would be proportional to the third power of the load. Load on the boiler reduces by 20 percent, the energy consumption of the fan will be reduced by about 50 percent.

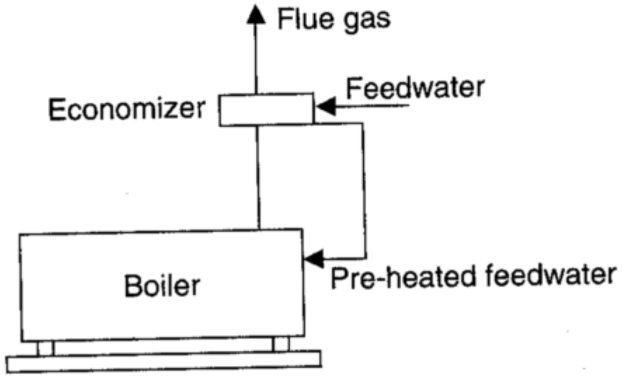


Application of VSD for boiler fan

Indirect Heating System

Energy Saving Measures of Boilers/ Boiler Plant
Heat recovery from flue gas

- Temperature of flue gas leaving a boiler typically ranges from 150 to 250°C, about 10 to 20 percent of the heat energy is lost through it.
- Heat can be recovered from the flue gas by passing it through a heat exchanger (commonly called an economizer) installed after the boiler
- The recovered heat can be used to preheat boiler feedwater, combustion air, or for other applications.



Arrangement of a typical economizer.

Indirect Heating System

Energy Saving Measures of Boilers/ Boiler Plant

Standby losses

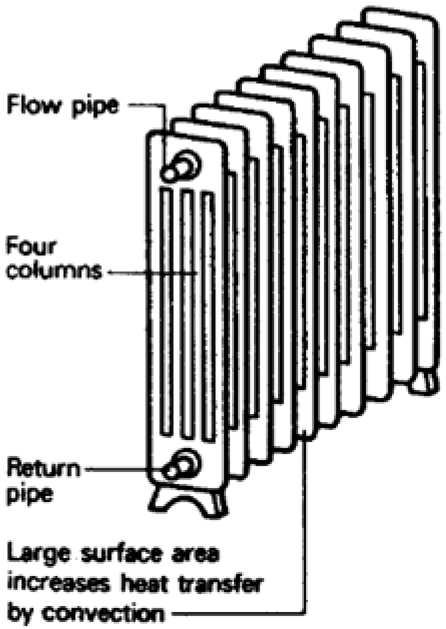
	Phenomena	Curing method
Natural convection loss	Air in the boiler gets heated (by the hot surfaces) becomes lighter and moves up the stack circulating cold air through the boiler.	Install dampers to prevent circulation of air when boiler is not being fired.
Purging loss	Boiler combustion space is purged by the fan before firing the burners to ensure that there is only air (to prevent possible explosions).	Some burner systems also follow a purging cycle when firing stops. Losses due to purging can be reduced by minimizing the on-off cycle of the burner system.

Indirect Heating System

Heat Emitter

Radiators

- Made from either steel or cast iron
- Fitted against a wall, staining of the wall above the radiator will occur due to convection currents picking up dust from the floor.
- To prevent this, a shelf should be fitted about 76 mm above the radiator
- The name 'radiator' is misleading - a greater proportion of heat is transmitted by convection, depending upon the type of radiator used.



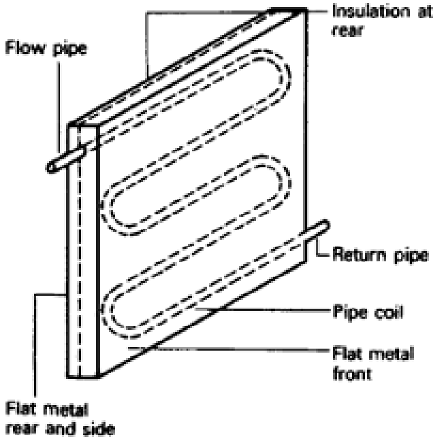
Column type radiator

Indirect Heating System

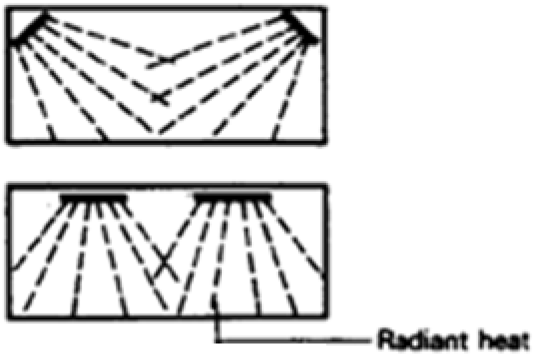
Heat Emitter

Radiant panels

- Similar to panel radiators, transmit a greater proportion of heat by radiation.
- For heating of workshops : suspended at heights from 3 to 4 m above the floor level and heat is radiated downwards.



Radiant panel

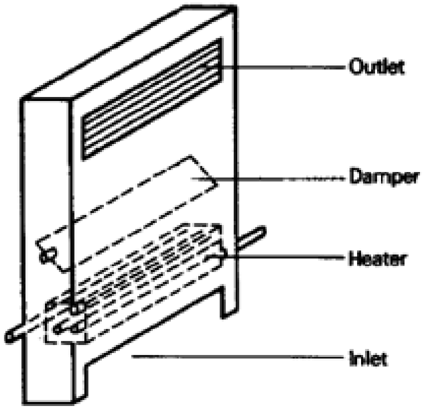


Indirect Heating System

Heat Emitter

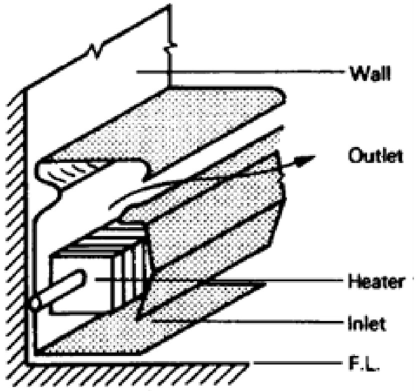
Natural convector

- Cabinet type comprises a finned tubular heating element fitted near to the bottom of the casing, so that a stack effect is created inside the cabinet.



Cabinet type convector

- Skirting types provide a good distribution of heat in a room and are very neat in appearance



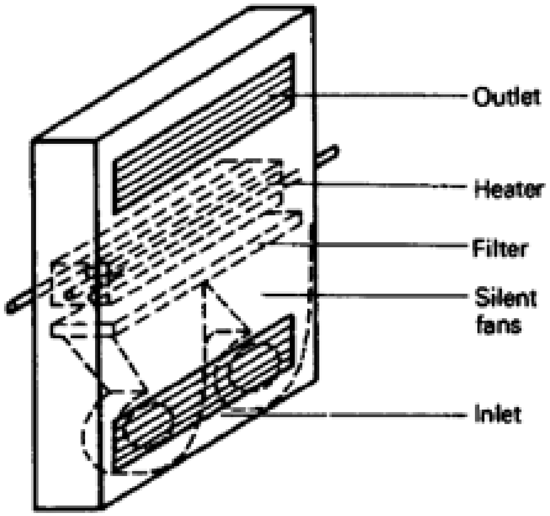
Skirting type convector

Indirect Heating System

Heat Emitter

Fan convectors

- Fans fitted below the element draw air in from the bottom of the casing,
- Air is then forced through the heating element before being discharged through the top of the cabinet.
- Air filter below the heating element
- Quickly heating the air in the room and give a good distribution of heat



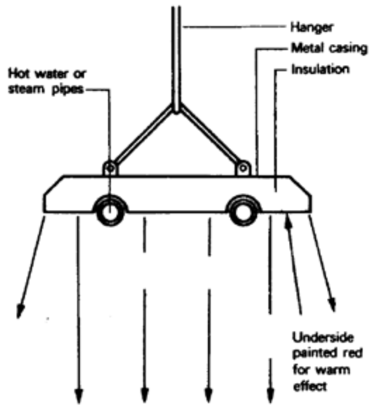
Fan convector

Indirect Heating System

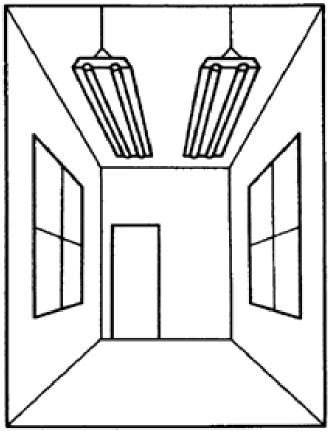
Heat Emitter

Overhead radiant strips

- Heating pipes (up to 30 m long) fixed to an insulated metal plate which also becomes heated by conduction from the pipe
- Minimum mounting height of the strips is governed by the heating system temperature and ranges from about 3 m for low temperature hot water, to about 5 m for high temperature hot water and steam



Overhead radiant strip

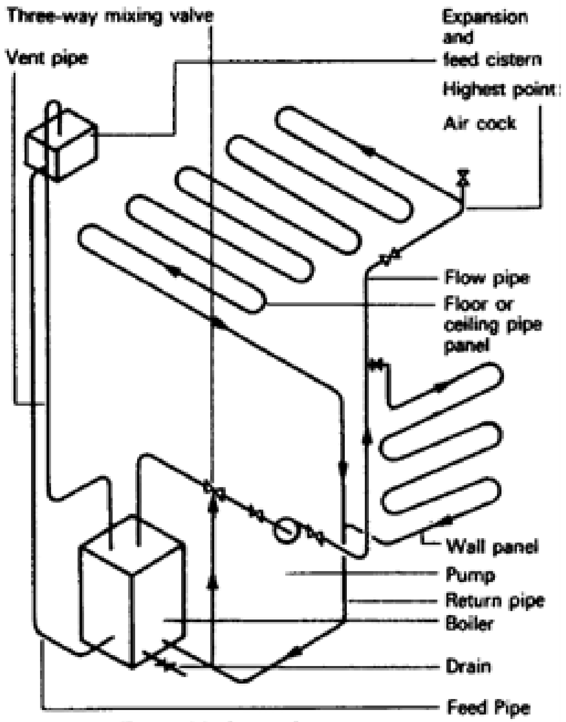

Arrangement of radiant strips

Indirect Heating System

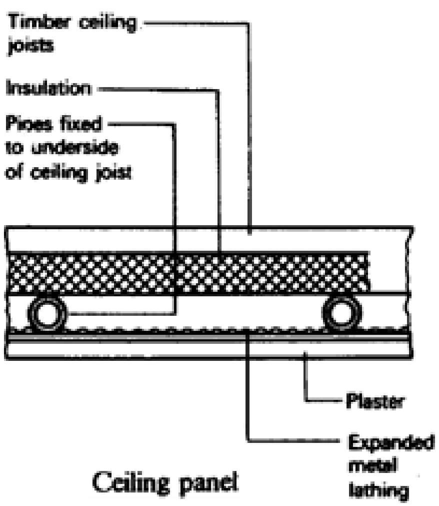
Heat Emitter

Embedded pipe panels

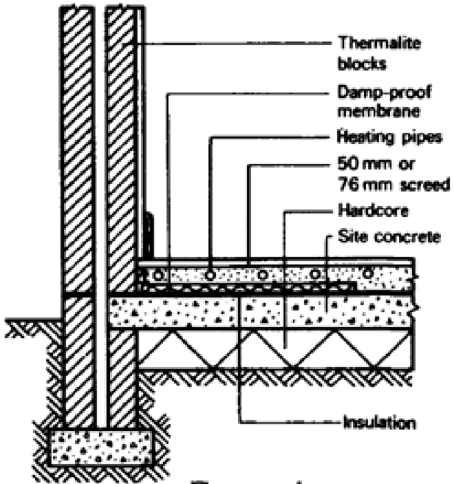
- Continuous coils of copper or steel pipes of 13 or 19mm bore at 225 to 300 mm centres embedded inside the floor or ceiling
- Recommend panel surface temperatures Floors at 26.7 °C and Ceilings at 49 °C



Embedded panel system



Ceiling panel

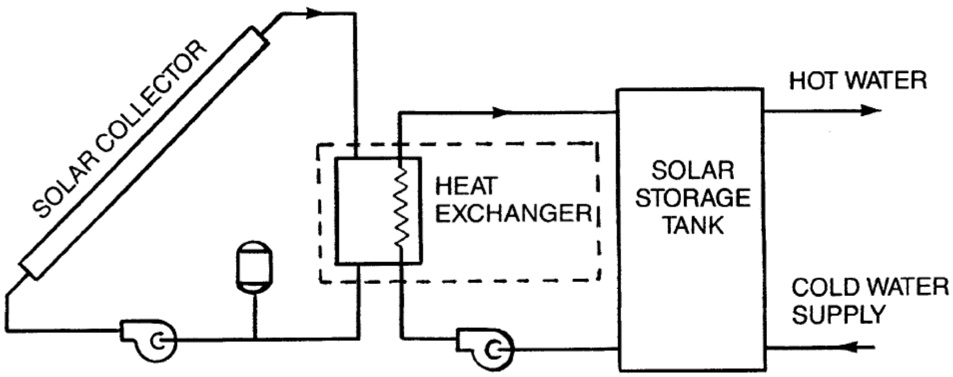


Floor panel

Indirect Heating System

Solar plant

- Collectors
- Controls

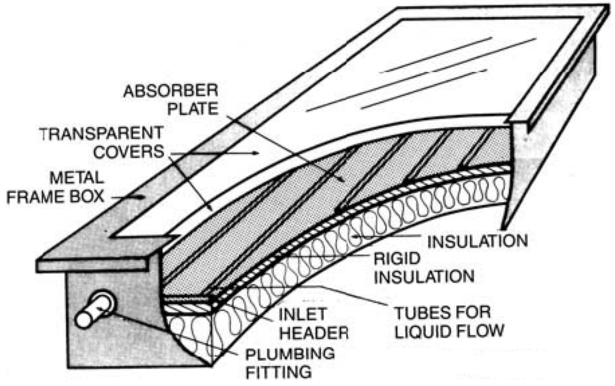


Indirect Heating System

Solar Hot Water System

A flat-plate collector

- Contains an absorber plate covered with a black surface coating and transparent covers.
- Covers are transparent to incoming solar radiation and relatively opaque to outgoing (long-wave) radiation
- Supply hot water at temperatures up to 95°C
- Also absorb diffuse radiation (important in cloudy climates).



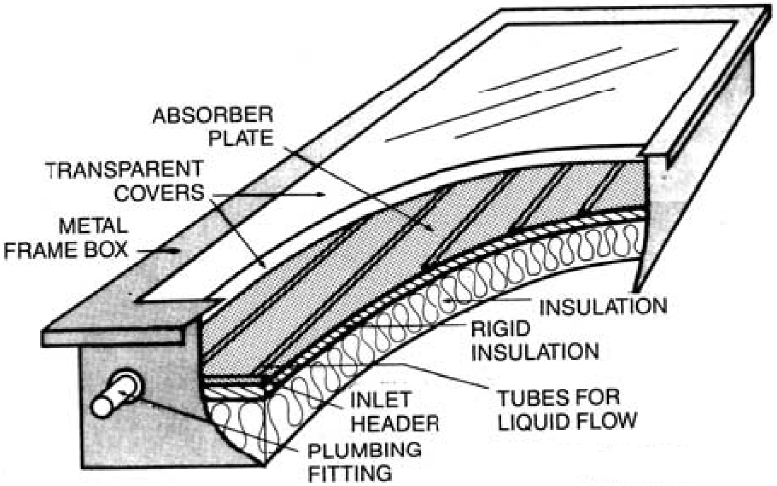
Indirect Heating System

Solar Hot Water System

A flat-plate collector

Collector Performance

$$q_u = A_c[I_t \tau\alpha - U_L(\bar{t}_p - t_a)]$$



q_u = useful energy delivered by collector, W
A_c = total aperture collector area, m^2
I_t = total (direct plus diffuse) solar energy incident on upper surface of sloping collector structure, W/m^2
τ = fraction of incoming solar radiation that reaches absorbing surface, transmissivity (dimensionless)
α = fraction of solar energy reaching surface that is absorbed, absorptivity (dimensionless)
U_L = overall heat loss coefficient, $W/(m^2 \cdot K)$
$\bar{t}_p$ = average temperature of absorbing surface of absorber plate, °C
t_a = atmospheric temperature, °C

Indirect Heating System

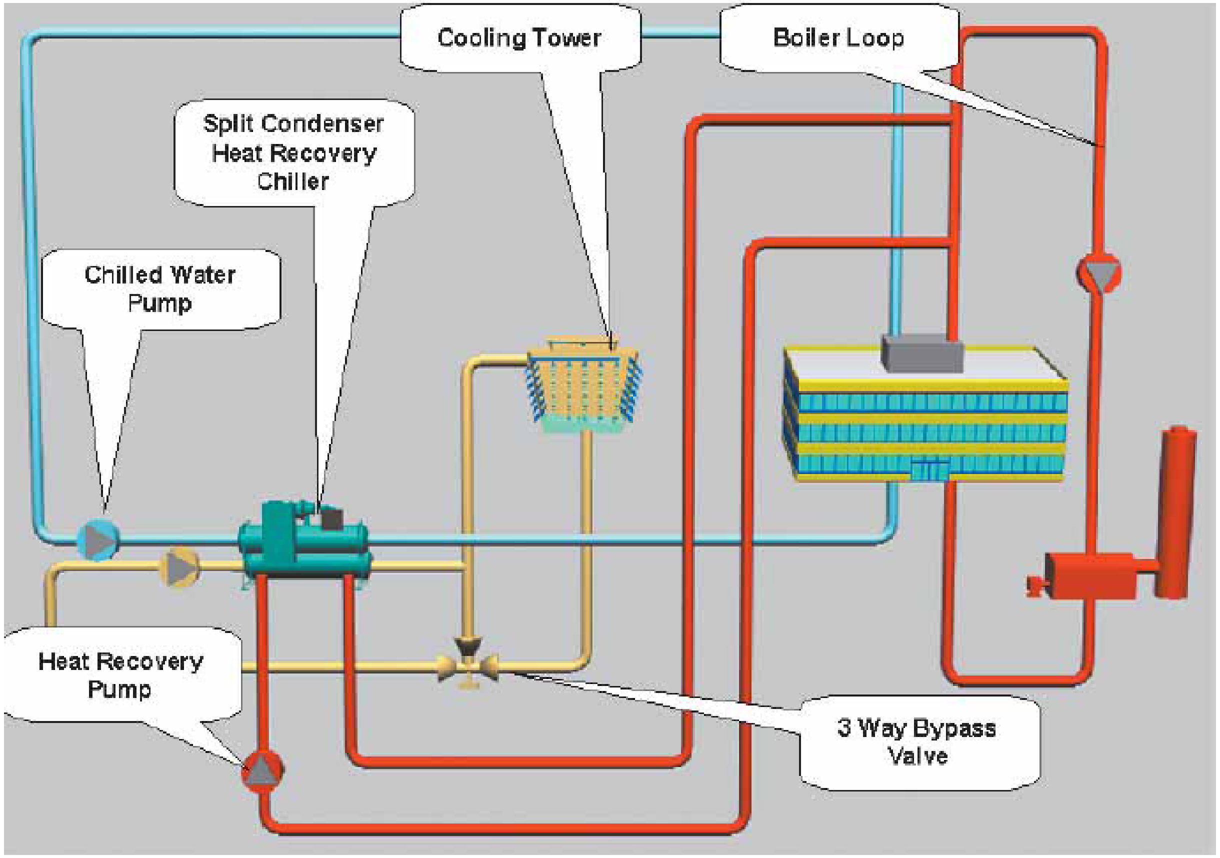
Solar Hot Water System

Controls

- Collector sensor location/selection
- Storage sensor location
- Over-temperature sensor location
- On-off controller characteristics
- Reliable solid-state devices, sensors, controllers, etc
- Alarm indicators for pump failure, low temperatures

Indirect Heating System

Heat Recovery Chiller



Indirect Heating System

Heat Recovery Chiller

- Heat recovery chillers produce 44 °C to 48 °C hot water for heating the building.
- Most heating systems are designed to operate at 84 °C supply water.
- As the chillers produce hotter condenser water, their performance drops when compared to conventional chilled water production.

Q & A