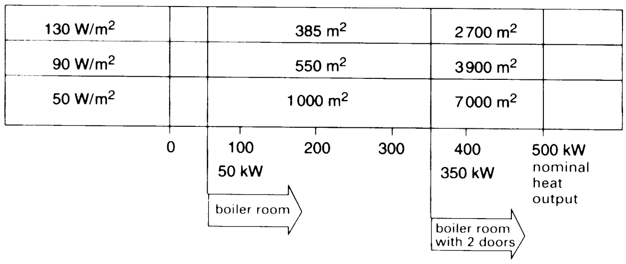
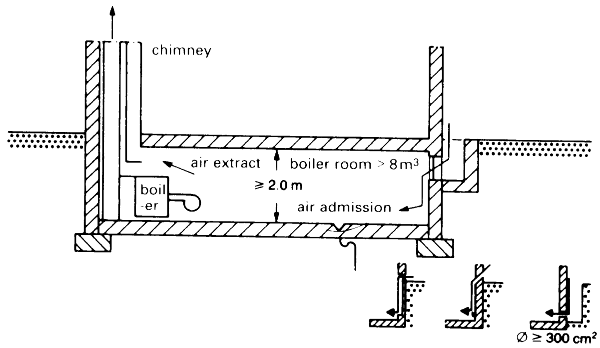
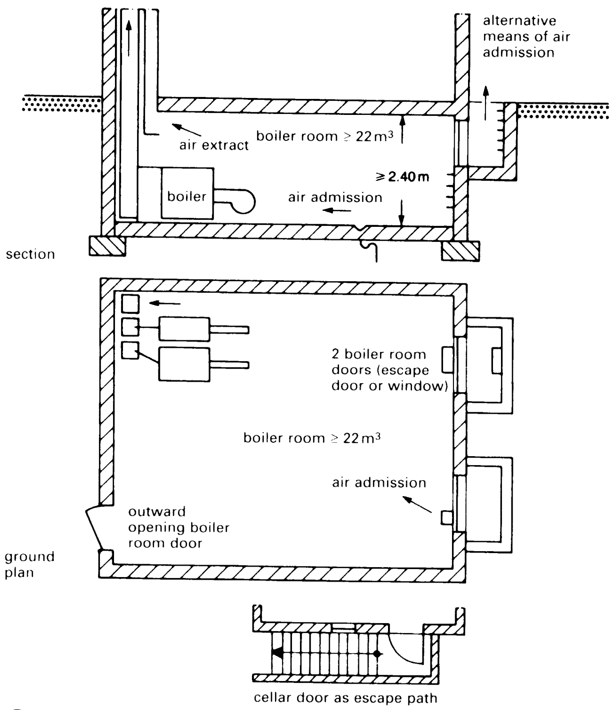


(1) **Central heating boilers with a heat output > than 50kW require individual boiler rooms**



(2) **Boiler room (min. 8m³) needed for heat output ≥ 50kW**



(3) **Boiler room with 2 doors (min. 22m³) needed for heat output > 350kW**

Heating systems are distinguished by the type of energy source and type of heating surface.

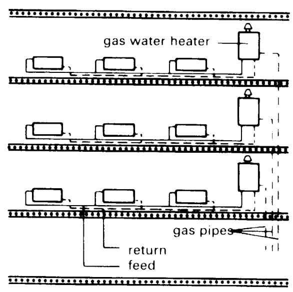
Oil firing: nowadays, light. *Advantages:* low fuel costs (relative to gas, approx. 10–25%); not dependent on public supply networks fuel oil is the most widespread source of heating energy; easy to regulate. *Disadvantages:* high costs of storage and tank facilities; in rented housing, space required for oil storage reduces rent revenue; where water protection measures apply or there is a danger of flooding, this form of heating is only possible if strict regulations are observed; fuel paid for prior to use; high environmental cost.

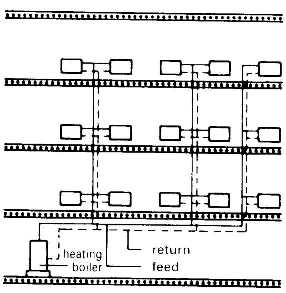
Gas firing: natural gas is increasingly being used for heating purposes. *Advantages:* no storage costs; minimal maintenance costs; payment made after usage; can be used in areas where water protection regulations apply; easy to regulate; high annual efficiency; may be used for individual flats or rooms; minimal environmental effects. *Disadvantages:* dependent on supply networks; higher energy costs; concern about gas explosions; when converting from oil to gas; chimney modifications are required.

Solid fuels such as coal (anthracite), lignite or wood, are rarely used to heat buildings. District heating stations are the exception, since this type of heating is only economical above a certain level of power output. Also, depending on the type of fuel used, large quantities of environmentally damaging substances are emitted, so that stringent requirements are laid down for the use of these fuels (protection of the environment). *Advantages:* not dependent on energy imports; low fuel costs. *Disadvantages:* high operating costs; large storage space necessary; high emission of environmentally unfriendly substances; poor controllability.

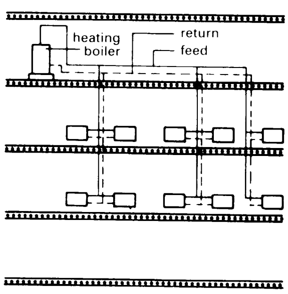
Regenerative forms of energy include solar radiation, wind power, water power, biomass (plants) and refuse (biogas). Since amortisation of the installation costs is not achieved within the lifetime of the plant required, the demand for this type of energy is correspondingly low.

Remote heating systems are indirect forms of energy supply, as opposed to the primary forms of energy discussed above. Heat is generated in district heating stations or power stations by a combined heat/power system. *Advantages:* boiler room and chimney not required; no storage costs; energy is paid for after consumption; can be used where water protection regulations apply; environmentally friendly association of power/energy coupling. *Disadvantages:* high energy costs; dependency on supply network; if the heating source is changed, a chimney must be fitted.

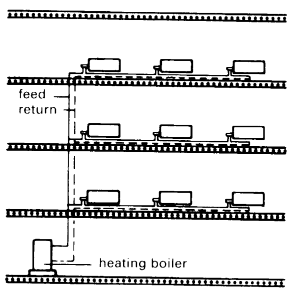




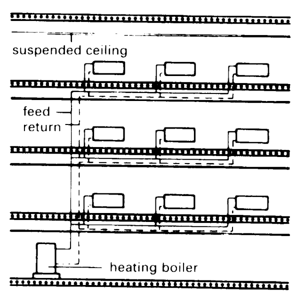
(4) **Twin-pipe system with distribution from below and vertical rising branches**



(5) **Twin-pipe system with distribution from above and vertical branches**

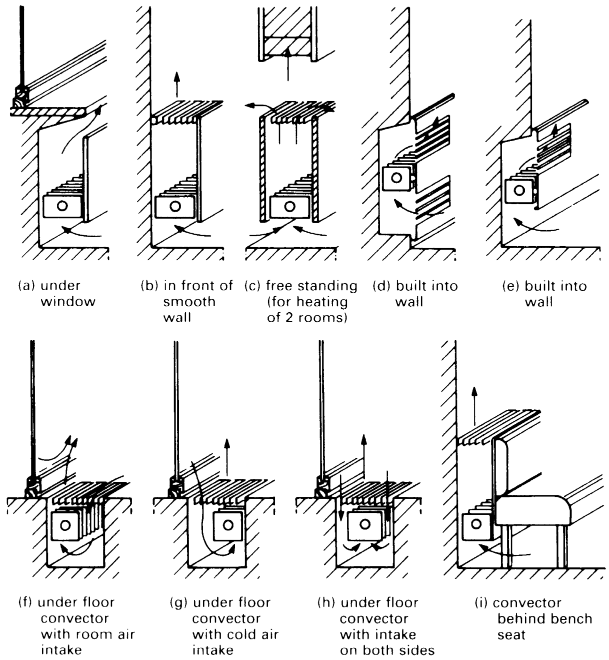


(6) **Single-pipe system with special valves and horizontal distribution**

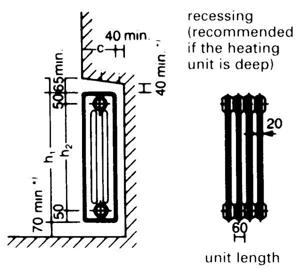


(7) **Twin-pipe system with horizontal distribution (standard construction for office buildings)**

HEATING

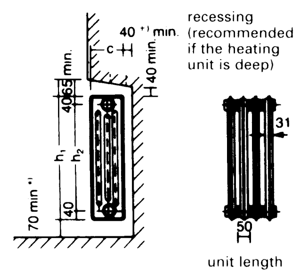


① **Various installation options for convectors**



height h^1 (mm)	distance between connections h^2 (mm)	depth c (mm)	surface area per element (m^2)
280	200	250	0.18^5
430	350	70	0.09
		110	0.12^8
		160	0.18^5
		220	0.25^5
580	500	70	0.12
		110	0.18
		160	0.25^2
		220	0.34^5
680	600	160	0.30^6
980	900	70	0.20^5
		160	0.41
		220	0.58

② **Dimensions of cast radiators**



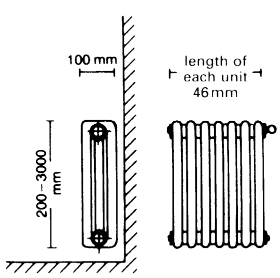
height h^1 (mm)	distance between connections h^2 (mm)	depth c (mm)	surface area per element (m^2)
300	200	250	0.16
450	350	160	0.15^5
		220	0.21
600	500	110	0.14
		160	0.20^5
		220	0.28^5
1000	900	110	0.24
		160	0.34^5
		220	0.48

③ **Dimensions of steel radiators**

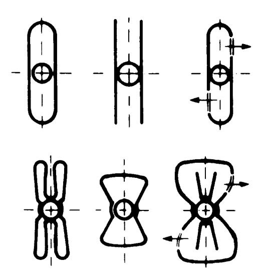
Electrical heating: Apart from night storage heating, the continuous heating of rooms by electrical current is only possible in special cases, due to the high costs of electricity. Electrical heating of rooms in temporary use may be advantageous, e.g. garages, gate keepers' lodges and churches. *Main advantages:* short heating-up period; clean operation; no fuel storage; constant availability; low initial costs.

Night storage heating is used for electrical floor heating, electrical storage heaters or for electrically heated boilers. Off-peak electricity is used to run the heaters. For electrical floor heating, the floor screed is heated overnight to provide heat during the day to the room air. Correspondingly, for electrical storage heaters and electrically heated boilers, the energy storage elements are heated during the off-peak period. However, by contrast to the floor heating system, the latter two devices can be regulated. *Advantages:* neither a boiler room nor chimney is required; no gases are generated; minimal space requirement; low servicing costs; no need to store fuel.

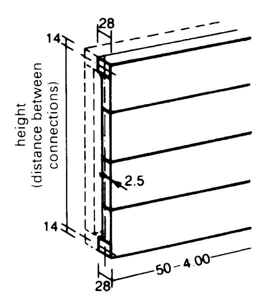
Convectors: Heat is not transferred by radiation, but by direct transmission to the air molecules. For this reason, convectors can be covered or built in, without reducing the heat output. *Disadvantages:* strong movement of air and the dust swirling effect; performance of convector depends on the height of the duct above the heated body; cross-sections of air flowing into and away from the convector must be of sufficient size. → ① For under-floor convectors → ① f – ① h, the same prerequisites apply as for above-floor convectors. The disposition of the under-floor convectors depends on the proportion of heating requirement for the windows as a fraction of the total heating requirement of the room. Arrangement → ① f should be adopted if this proportion is greater than 70%; arrangement → ① h for 20–70%; if the proportion is less than 20%, then arrangement → ① g is favoured. Convectors without fans are not suitable for low-temperature heating, since their output depends on the throughput of air and, hence, on the temperature difference between the heated body and the room. The performance of convectors with too low a duct height (e.g. floor convectors) can be increased by the incorporation of a blower. Blower convectors are of limited use in living-room areas, due to the build-up of noise. Heaters can be covered in various ways. Losses in efficiency can be considerable, and attention should be paid to adequate cleaning. For metal cladding, the radiative heat contribution is almost entirely given to the room air. For material coverings with a lower thermal conductivity, the radiative heat is damped considerably. → ① p.98 A representation is shown of the movement of air within a heated room. The air is heated by the heater, flows to the window and then to the ceiling and is cooled on the external and internal walls. The cooled air flows over the floor and back to the heater. → ② p.98 A different situation arises if the heater is on a wall which is away from the window: air cools on the window, then flows cold over the floor to the heater, where it is heated up.



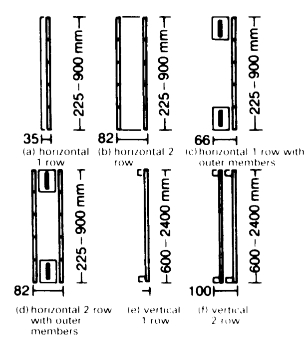
④ **Tube radiator (3 tubes)**



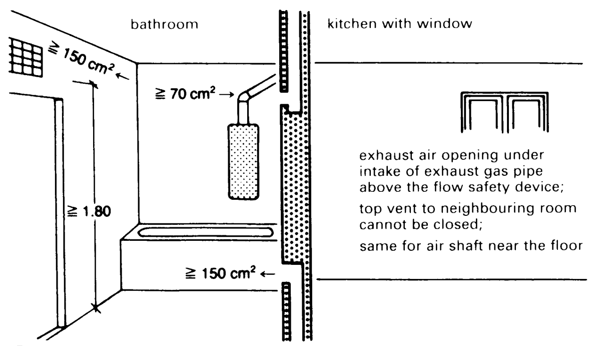
⑤ **Various rib shapes for the down tubes in tube radiators**



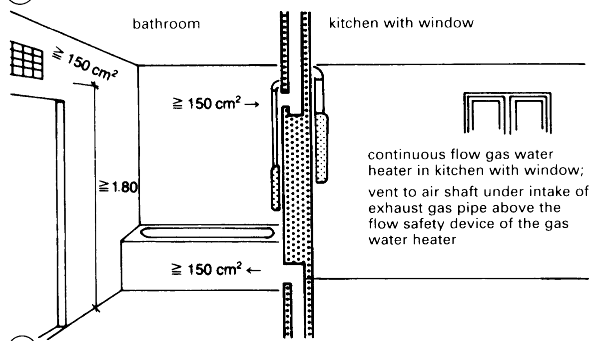
⑥ **Section through a flat panel radiator**



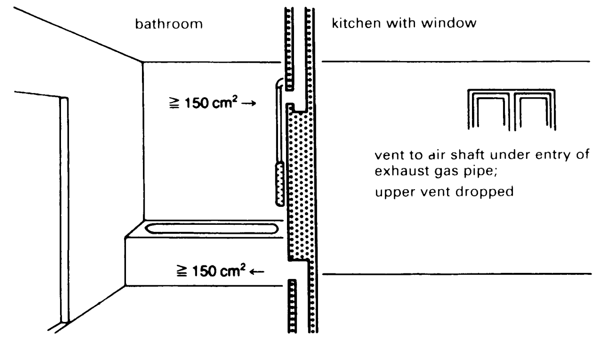
⑦ **Summary of different panel radiators**



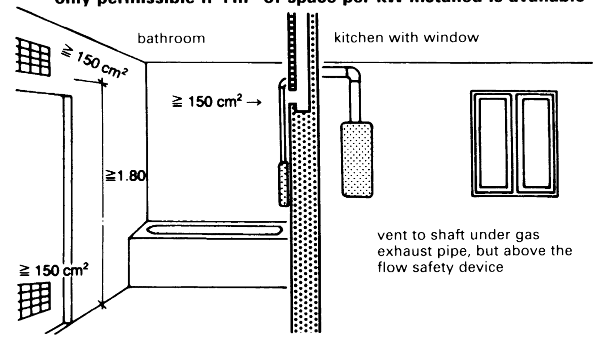
(1) Gas water heater in internal bathroom with 'Cologne' ventilation



(2) Gas space heater in internal bathroom with 'Cologne' ventilation



(3) Gas space heater in internal bathroom with 'Cologne' ventilation: only permissible if 1 m³ of space per kW installed is available



(4) Gas space heater in internal bathroom: air intake from next room

Gas heating systems

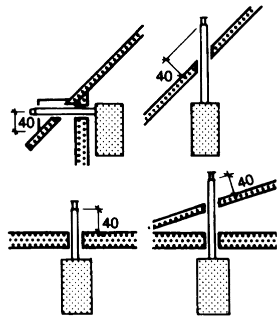
Regulations and legislation (UK): the provision of gas supply into a building in England, Wales and Scotland is controlled by the Gas Safety (Installation and Use) Regulations, 1998, which revoke and replace the 1994 and 1996 (amendment) regulations. They make provision for the installation and use of gas fittings for the purpose of protecting the public from the dangers arising from the distribution, supply or use of gas.

One of the major tasks of the architect is to make sure that the design provisions, such as locations of meters and pipe routes, do as much as possible to make it easy for the installer to comply with the regulations.

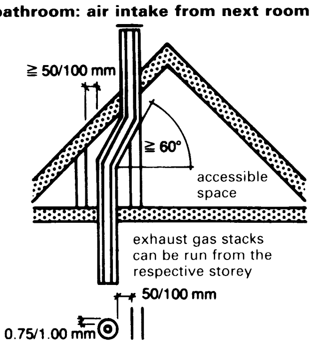
Gas fired appliances must be of an approved type and can only be installed in those spaces where no danger can arise from position, size, or construction quality of the surrounding building. Distances between components made of combustible materials and external heated parts of a gas appliance, or from any radiation protection fitted in between, must be sufficient to exclude any possibility of fire (i.e. ≥5 cm). In addition, spaces between components made of combustible materials and other external heated parts, as well as between radiation protection and gas appliances or radiation protection, must not be enclosed in such a way that a dangerous build-up of heat can occur. Heaters with an enclosed combustion chamber fitted against external walls and housed in a box-like enclosure must be vented to the room, with bottom and top vents each having ≥600 cm² free cross-section. Air vents must be arranged in accordance with details and drawings of the appliance manufacturer. The casing must have a clear space of ≥10 cm in front and at the side of the heater cladding. Heaters not mounted on external walls must be fitted as close as possible to the chimney stack.

The minimum size and ventilation of rooms containing heating appliances is determined by the output or sum of outputs of the heating appliances. For ventilated enclosed internal areas, the volume must be calculated from the internal finished measurements (i.e. measured to finished surfaces and apertures).

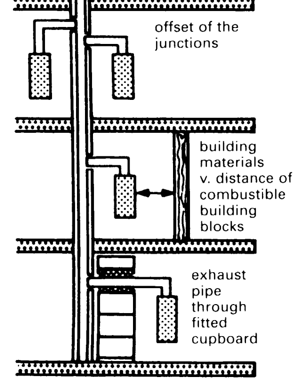
All gas appliances, apart from portable units and small water heaters, must be fitted with a flue. Flues promote air circulation and help remove the bulk of gas in case the appliance is left with the gas unlit. Cookers should be fitted with cowls and vents which should considerably help to remove fumes and reduce condensation on walls. Bathrooms equipped with gas heaters must be fitted with adequate ventilation and a flue for the heater. Flues for water heaters must include a baffle or draught diverter to prevent down-draughts.



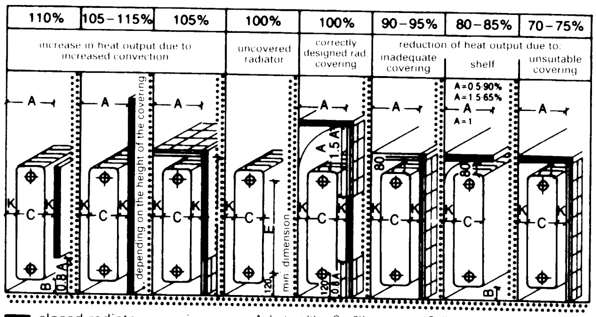
(5) Examples of burner air feed and take-off of exhaust gas to above roof height



(6) Exhaust gas stack



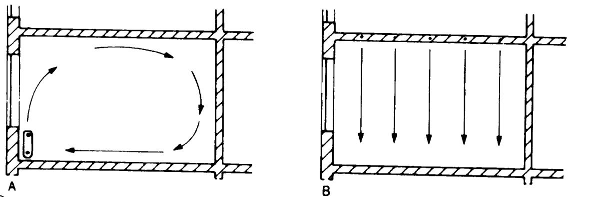
(7) Connections to the exhaust gas stack



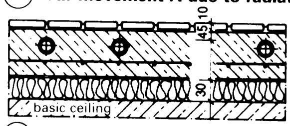
closed radiator covering
open or interrupted radiator covering

A duct width   C + 2K
B distance from floor min. 70mm (120mm better)
C heater depth
E distance between connections
H min. overall height
K separation from wall of covering (min. 50mm)

(1) **Variation of heat output for various heater/covering combinations**

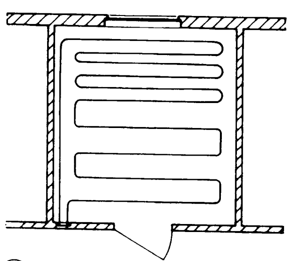


(2) **Air movement A due to radiator heating and B due to ceiling heating**

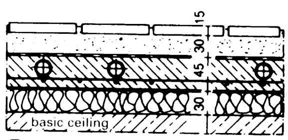


(3) **Floor heating (laid wet)**

floor construction details from the top downwards:
glued tiles 10mm
screed, min. 45mm
supporting reinforcing matting (dia. 3.5mm)
polyethylene film 0.2mm
insulation

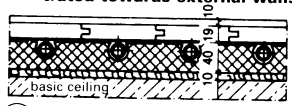


(7) **Ceiling heating pipes concentrated towards external walls**



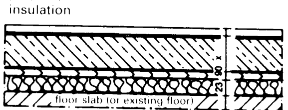
(4) **Floor heating**

floor construction details (from top down):
glued tiles 15m
in
mortar bed 30mm
slip membrane 0.3mm
floor covering 45mm
supporting mat for heating tubes
polyethylene film 0.2mm
insulation



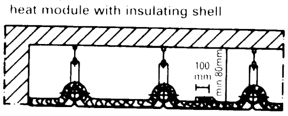
(8) **Floor heating (laid dry)**

floor construction details (from top down):
- glued tiles 10mm or carpeting
- flooring panels 19mm
- polyethylene film 0.2mm
- aluminium conducting fins
- polystyrene layer with grooves for heating tubes 40mm
- mineral fibre matting 13/10 for footfall insulation, if required

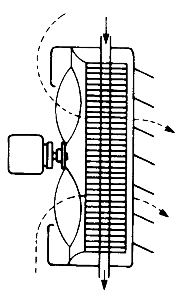


(5) **Floor heating (heat module)**

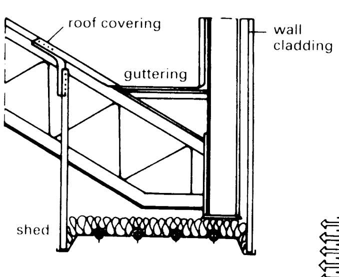
floor construction details (from top down):
floor finish with supporting layer (depth variable)
polyethylene film
heat module with insulating shell



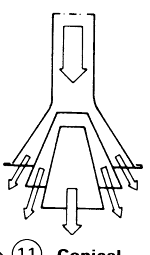
(6) **Ceiling heating using aluminium panels**



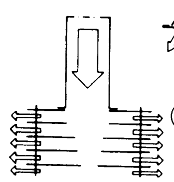
(10) **Fan heater**



(9) **Sunstrip**



(11) **Conical distributor**



(12) **Air distribution fins**

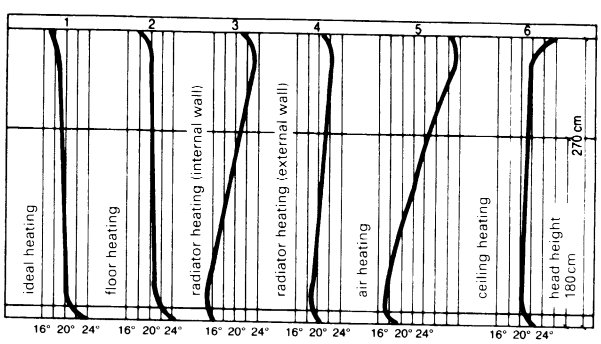
For uniform heating of the room air, convector heaters can be replaced by a floor heating system. Problems arise only where large window areas are involved, but this can be overcome by the installation of additional heating – such as floor convectors.

In general, surface heating includes large areas of surface surrounding a room and involves relatively low temperatures. Types of surface heating include floor heating, ceiling heating and wall heating. With floor heating, the heat from the floor surface is not only imparted to the room air, but also to the walls and ceiling. Heat transfer to the air occurs by convection, i. e. by air movement over the floor surface. The heat given to the walls and ceiling takes place due to radiation. The heat output can vary between 70 and 110W/m^2, depending on the floor finish and system employed. Almost any usual type of floor finish can be used – ceramics, wood or textiles. However, the diathermic resistance should not exceed 0.15m^{2}K/W.

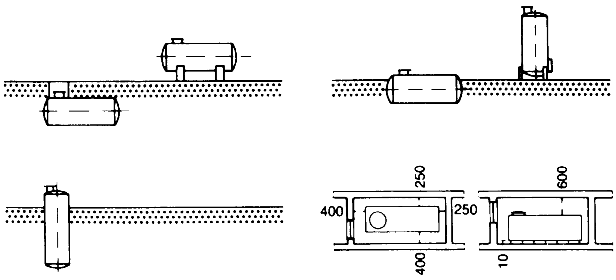
House dust allergies can be a problem in heated rooms. Previously, precautions against house dust or dust mite allergy paid no attention to the effects of heating units. Heaters cause swirling of house dust containing allergens, which can then rapidly come into contact with the mucous membranes. In addition to this, there are insoluble difficulties in cleaning heaters which have convection fins. It is therefore advantageous if heaters are designed to embody the smallest possible number of convection elements and to have straightforward cleaning procedures. These requirements are fulfilled by single-layer panels without convection fins and by radiators of unit construction.

Storage of heating oil: The quantity of heating oil stored should be sufficient for a minimum of 3 months and a maximum of one heating period. A rough estimate of the annual requirement for heating fuel is 6–10l/m^3 of room volume to be heated. A maximum volume of 5m^3 may be stored in a boiler house. The container must be within a storage tank capable of accepting the total quantity. Storage containers in the ground must be protected from leakage, e.g. through the use of double-walled tanks, or plastic inner shells. Maximum capacities and additional safety measures are prescribed for areas where water protection regulations are in force. Within buildings, either plastic battery tanks with a capacity per tank of 500–2000 litres may be installed, or steel tanks which are welded together in situ, whose capacities may be freely chosen. The tank room must be accessible.

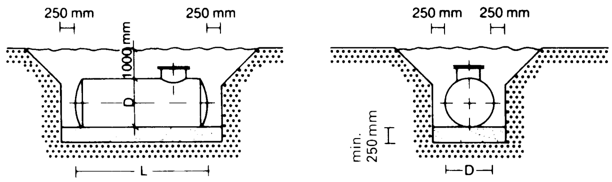
The tanks must be inspected for oil-tightness at regular intervals. In the event of an emergency, the tank room must be able to retain the full amount of oil. Tank facilities must have filling and ventilation pipe lines. Additionally, overfilling prevention must be incorporated and, depending on the type of storage, a leak warning system may be prescribed (e.g. in the case of underground tanks).



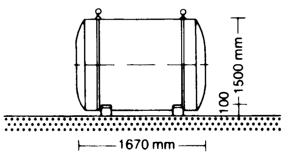
(13) **Room temperature curves for physiological evaluation of a heating system**



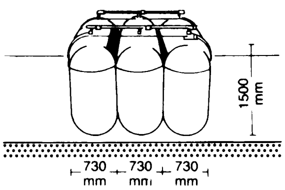
(1) **Alternative installations of standard heating oil storage tanks**



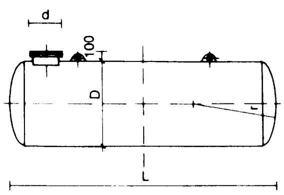
(2) **Underground installation of heating oil storage tanks**



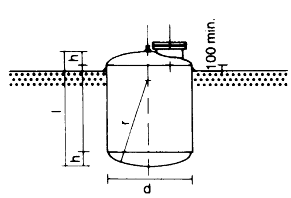
(3) **Nylon unit containers (polyamide) – side view**



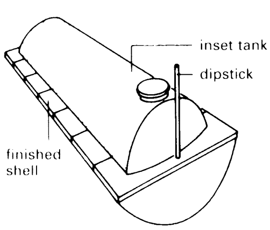
(4) **Nylon unit containers → (3) (max. 5 containers)**



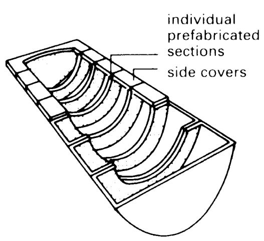
(5) **Storage tank for heating oil (side view)**



(6) **Storage tank for heating oil (front view)**



(7) **Inset tank**



(8) **Prefabricated protective concrete hull for oil tank**

The floor screed for floor heating systems must satisfy local regulations. The thickness of the screed depends on the type of covering used, its preparation and the anticipated loading. A minimum covering over the heating pipes of 45mm is prescribed when using cement floor screed and heating pipes which are directly above the thermal insulation. If there is no finish over the basic floor, then a minimum total depth of 75mm is required. The floor screed expands during use, and a temperature difference arises between the top and bottom surfaces of the screed.

Due to the differential expansion, tensile stresses occur in the upper region of the layer. In the case of ceramic floor coverings, this can only be countered by top reinforcement. On carpeted floors or parquet floors, the reinforcement can be avoided, since the temperature drop between the upper and lower surfaces of the floor covering is less than in the case of a ceramic finish. Special requirements are contained in the thermal insulation regulations with respect to the limitation of heat transfer from surface heating, irrespective of the choice of type of insulation method: 'In surface heating, the heat transfer coefficient of the component layer between the hot surface and the external air, the ground, or building section having an essentially lower internal temperature, must not exceed a value of 0.45W/m²'.

The maximum permissible floor surface temperature for a permanently occupied area is 29°C. For the boundary zone it is 35°C, where the boundary zone is not to be wider than 1m. For bathrooms, the maximum permissible floor temperature is 9°C above normal room temperature.

Under normal conditions, floor heating is possible, since the heating requirement seldom lies above 90W/m². In only a few exceptions (e.g. when there are large window areas, or when the room has more than two external walls) is there a greater heating requirement, and then additional static heating surfaces or air heating must be installed in addition to the floor heating.

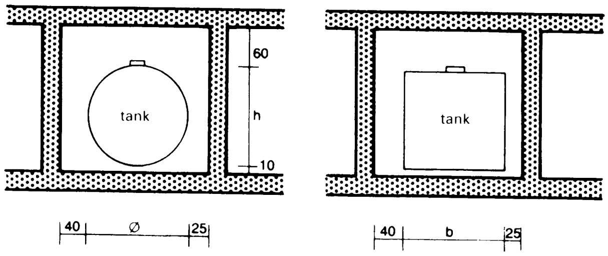
nom. contents V in litres (dm³)	max. dimensions (mm) length	depth	weight incl. accessories (kg)
1000 (1100)	1100 (1100)	720	30–50kg
1500 (1600)	1650 (1720)	720	40–60kg

(9) **Dimensions of plastic battery tanks (battery containers)**

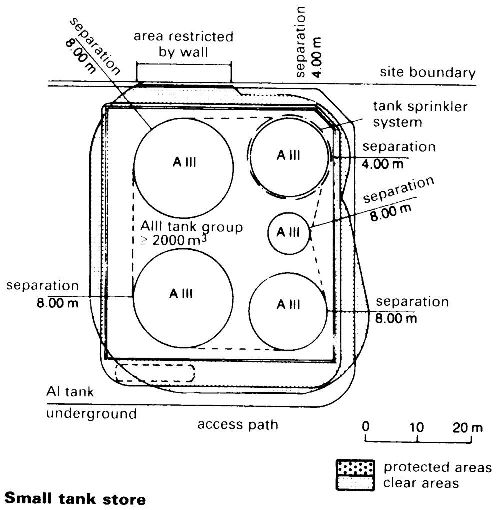
min. contents V (m³)	min. dimensions (mm) external diameter d_1	length l	sheet thickness 1 wall	2 walls	filler cap diameter	weight (kg) 1,1 1 wall	1,2 A/C	B
1	1000	1510	5	3	–	265	–	–
3	1250	2740	5	3	–	325	–	
5	1600	2820	5	3	500	700	–	
7	1600	3740	5	3	500	885	930	980
10	1600	5350	5	3	500	1200	1250	1300
16	1600	8570	5	3	500	1800	1850	1900
20	2000	6969	6	3	600	2300	2400	2450
25	2000	8540	6	3	600	2750	2850	2900
30	2000	10120	6	3	600	3300	3400	3450
40	2500	8800	7	4(5)	600	4200	4400	4450
50	2500	10800	7	4	600	5100	5300	5350
60	2500	12800	7	4	600	6100	6300	6350
						weight (kg) 1,3 A	B	2,1 2,2B
1.7	1250	1590	5	–	500	–	–	– 390
2.8	1600	1670	5	–	500	–		– 390
3.8	1600	2130	5	–	500	–	–	– 600
5	1600	2820	5	3	500	700	745	– 740
6	2000	2220	5	–	500	–	–	930
7	1600	3740	5	3	500	885	930	935
10	1600	5350	5	3	500	1250	1250	1250
16	1600	8570	5	3	500	1800	1950	1850
20	2000	6960	6	3	600	2300	2350	2350
25	2000	8540	6	3	600	2750	2800	2800
30	2000	10120	6	3	600	3300	3350	–
	2500	6665	7	–	600	–	–	3350
40	2500	8800	7	4	600	4200	4250	4250
50	2500	10800	7	4	600	5100	5150	
	2900	8400	9	–	600	–	–	6150
60	2500	12800	7	4	600	6100	6150	–
	2900	9585	9	–	600	–		6900

(10) **Dimensions of cylindrical oil tanks (containers)**

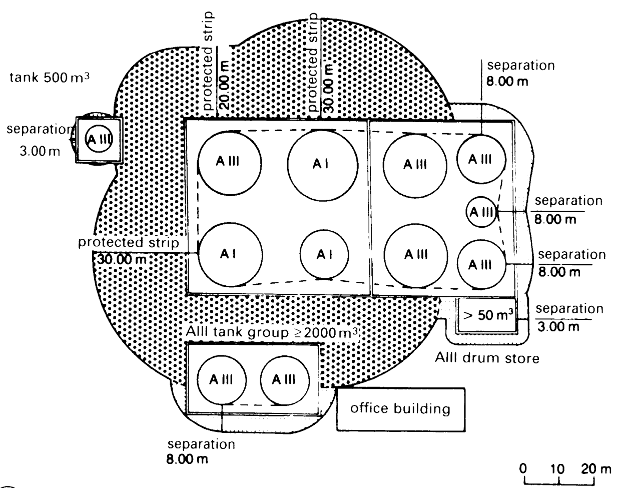
HEATING: OIL STORAGE TANKS



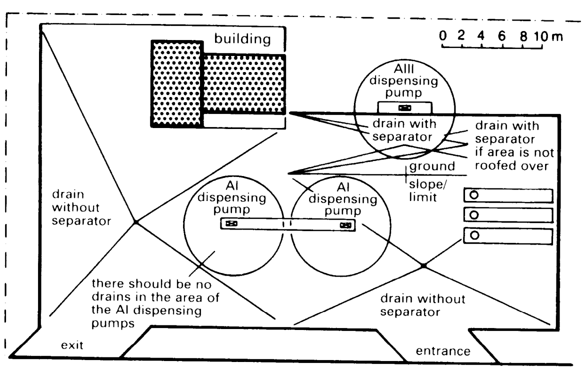
① **Heating oil storage tanks in rooms**



② **Small tank store**



③ **Large tank store**



④ **Tank facility**

→ pp. 98–9

The fuel containment enclosures must be designed so that, if fluid escapes from a storage device, it is prevented from spreading beyond the enclosure area. The enclosures must be able to safely contain at least one-tenth of the volume of all the tanks it contains, and at least the full volume of the largest tank.

Tanks in rooms: containment enclosures are required if the storage volume is ≥ 450 l, unless the storage tanks are of steel with a double wall. Tanks can have a capacity of up to 100 000 l, with leakage indicator devices, or manufactured from glass fibre reinforced plastics of an approved type of construction, or they can be metal tanks with plastic inner linings of an approved form of construction. Containment enclosures must be constructed from non-flammable fire-resistant materials of adequate strength, leakproof and stability, and must not contain any outlets. The tanks must have access on at least two sides with a minimum clearance of 400 mm from the wall, or 250 mm in other cases, and at least 100 mm from the floor and 600 mm from the ceiling → ①.

Classifications:

A	Flash point	< 100°C
AI	Flash point	< 21°C
AII	Flash point	21–55°C
AIII	Flash point	55–100°C
B	Flash point	< 21°C with water solubility at 15°C

Outside tanks, above ground: containment enclosures are required for capacity ≥ 1000 l. Otherwise, conditions are as for tanks in rooms. Storage areas can be ramparts. For tanks > 100 m^3 capacity, clearance to the ramparts, walls or ringed enclosures must be at least 1.5 m. For vertical cylindrical tanks of capacity < 2000 m^3 in square or rectangular catchment areas, clearance may be reduced to 1 m. Arrangements must be made for the removal of water and these must be capable of closure. If water can discharge by itself, then separators must be built in. Above ground facilities require protected access. A distance of at least 3 m from neighbouring facilities is required if there is a storage capacity > 500 m^3 and correspondingly more as capacity increases, to a clearance of 8 m for a storage capacity of 2000 m^3. Access routes are required for fire-fighting appliances and equipment → ② – ③.

Underground tanks: > 0.4 m clearance of tanks from boundaries; > 1 m from buildings. Underground anchorage of the tanks is required to prevent movement of empty tanks in the presence of ground water or flooding. Backfilling is required to a depth of 0.3–1 m above the tanks. Also, 600 mm diameter access openings into the tanks are needed, serviced by a watertight shaft with a clear width of at least 1 m, and 0.2 m wider than the tank access opening lid. The shaft cover must be able to withstand a test proof loading of 100 kN where vehicular access is to take place. Filling points are subject to approval for combustible fluids in hazard classes AI, AII or B. They must be immediately accessible, with protected access. The ground surface must be impermeable and constructed of bitumen, concrete or paving with sealed joints. Drainage outlets with separators, overfilling protection, and emptying and washing facilities for tanker vehicles are required.

Tankage facilities for the fuelling of all vehicles with combustible fluids in hazard classes AIII (e.g. heating oil and diesel fuel) must not be stored together with those in hazard classes AI, AII or B. Neither must the effective regions of separators and operating surfaces of such storage areas overlap → ④.

Requirements for all tanks: Ventilation and venting facilities must be sited at least 500 mm above the access cap, or above ground level in the case of underground tanks, and be protected from the ingress of rain water. Devices must be provided to determine the filling levels in the tanks. Access openings must have a clearance diameter of at least 600 mm and visual inspection openings, 120 mm diameter. Protection must be provided against lightning and electrostatic discharge. Additional provisions cover flame spread resistance, internal and external corrosion, and fire extinguishers of the appropriate type. Tanks for diesel fuel or heating oil EL with a capacity over 1000 l, must have fill meters and overfill protection.

SOLAR ARCHITECTURE

Components

Essentially, economic considerations led architects and building developers to seek alternatives to the conventional fossil fuel sources of energy. Today, equal emphasis is placed on the ecological necessity for change. By means of energy conscious construction, the energy requirements of living accommodation can be reduced by around 50% in comparison to older buildings.

Energy balance of buildings

Solar energy is available free of charge to every building. Unfortunately, in many climatic areas, solar radiation is very low, so that other forms of energy must be used for room heating, hot water, lighting and for the operation of electrical appliances.

The greatest energy losses from a building arise due to the conduction of heat through windows, walls, ceilings and roofs.

Considerations of energy conscious construction

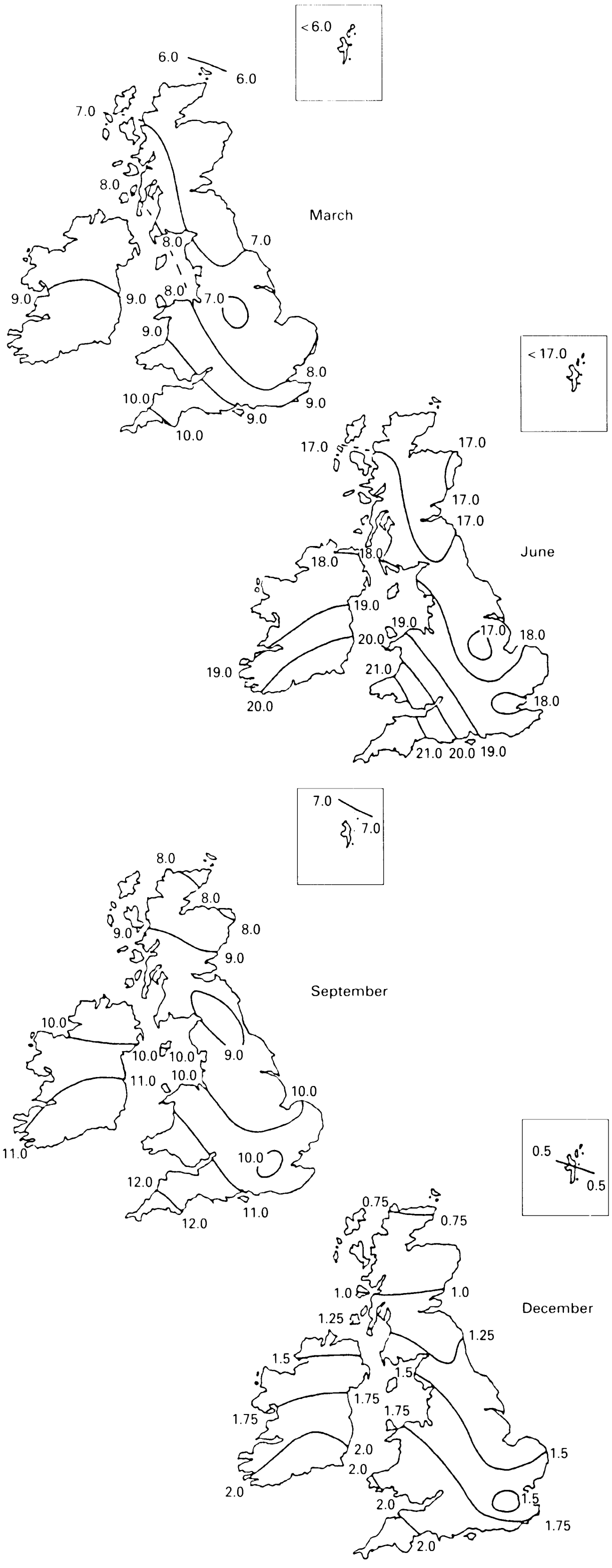
There are three fundamental points which lead to a considerable reduction in the energy requirement of a domestic building:

(1) Reduction of heat losses
(2) Increase in energy saving through the use of solar radiation
(3) Conscious efforts by users to improve the energy balance

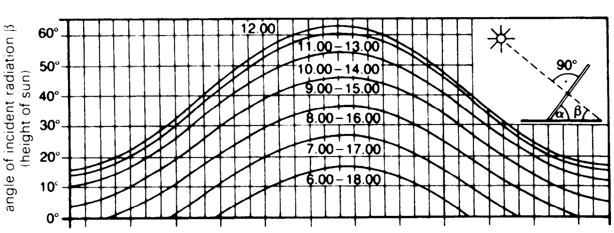
The choice of building location itself can reduce the heat losses from a building. Within a small area in a region, conditions will vary; e.g. wind and temperature conditions vary with the altitude of a building site.

Relatively favourable microclimatic conditions result on south-facing slopes when the area of ground is situated on the upper third of the slope but away from the crest of the hill.

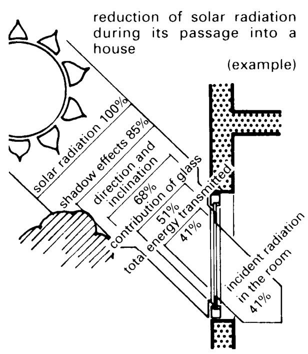
The shape of the building plays an important role in terms of energy conscious construction. The outer surface of the building is in direct contact with the external climate and gives up valuable energy to the outside air. The design of the building should ensure that the smallest possible external surface is presented to the outside air in relation to the volume of the building. The shape to be aimed for is a cube, although a hemisphere in the ideal case. However, this ideal assumption applies only to a detached house.



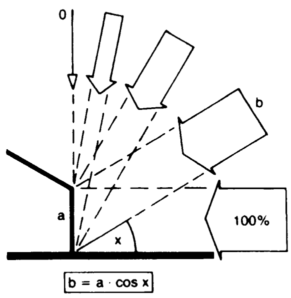
(1) Average daily totals of solar radiation (MJ/m²)



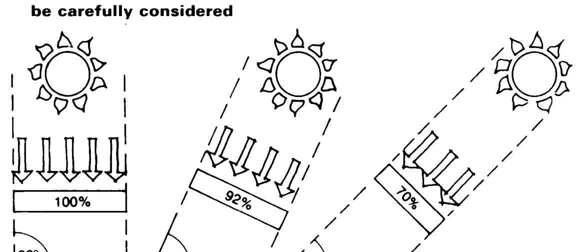
(2) Incident radiation angle β (height of sun at the geographical latitude 50°N at various times, over the course of a year)



(3) To keep the reduction in radiation as small as possible, each individual influencing factor should be carefully considered

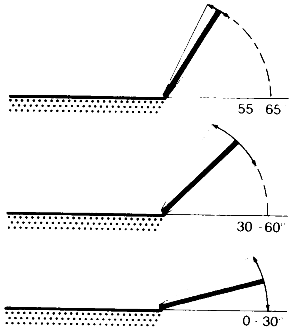


(4) The dependency of the level of incident radiation on a surface on the angle of incidence



(5) Both effects act simultaneously in two dimensions – height and azimuth angle variation

SOLAR ARCHITECTURE

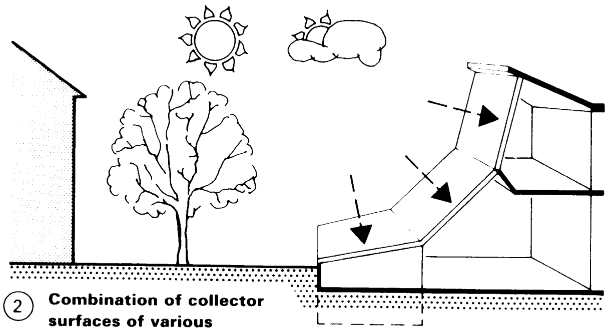


South-facing surfaces inclined at an angle of 55–65° provide optimum utilisation of solar energy during the cold winter months

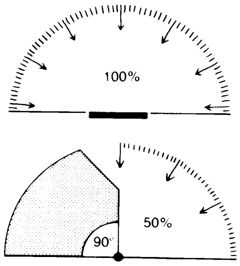
South-facing surfaces inclined at 30–60° are suited to good solar energy usage during the transition periods (these periods of the year are decisive for solar house optimisation)

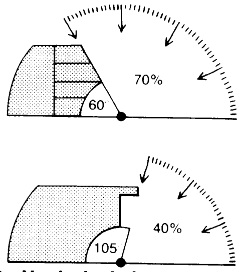
South-facing surfaces inclined at 0–30° are typical for summer use (e.g. for solar panels for domestic water heating), this being the optimum range for the collection of diffuse radiation

(1) **Solar energy usage as a function of the inclination**



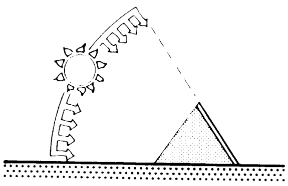
(2) **Combination of collector surfaces of various inclinations**



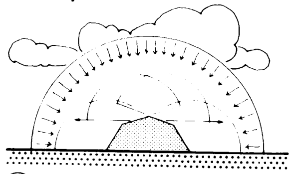


(3) **Flat horizontal and inclined surfaces are well suited for the collection of diffuse radiation**

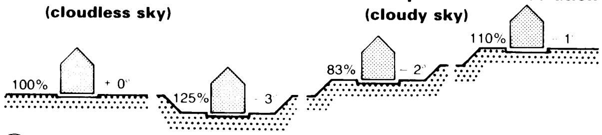
(4) **Vertical windows receive only up to 50% of the diffuse radiation when the sky is clouded**



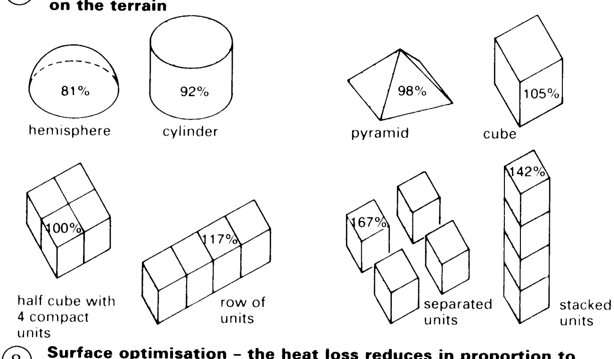
(5) **Cross-section of a house planned only for the gain of direct radiation (cloudless sky)**



(6) **Cross-section of a house planned only for the receipt of diffuse radiation (cloudy sky)**



(7) **Heat losses and temperature differences as a function of position on the terrain**



(8) **Surface optimisation – the heat loss reduces in proportion to the reduction in surface area**

Organisation of the ground plan

In the passive utilisation of solar energy, the heat is utilised through direct incident radiation and heat storage in specific structural components such as walls and floors.

Because of the conditions under which solar energy is used passively, the arrangement of the ground plan necessarily follows a particular logical layout. The continuously used living and sleeping accommodation should be south-facing and provided with large window areas. It is useful to provide glazed structures in these living and sleeping areas. There are three important reasons for this:

(1) Extension of the living area
(2) Gain in solar energy
(3) Provision of a thermal buffer zone

The little-used low-temperature unheated rooms, with low natural light requirements should be north-facing. They act as a buffer zone between the warm living area and the cold outside climate.

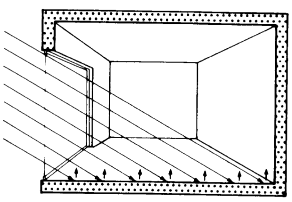
Use of solar energy

In the use of solar energy, a distinction is drawn between the active and passive use of solar energy.

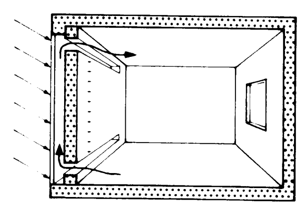
The active use of solar energy necessitates the application of equipment such as solar collectors, pipework, collector vessels circulation pumps for the transfer of the solar energy. This system entails large investment and maintenance costs which must be recovered solely by saving in the cost of energy. As a result, such systems cannot be operated economically in single family houses.

The passive use of solar energy necessitates the use of specific structural components as heat stores, such as walls, ceilings and glazed units. The efficiency of this system depends on specific factors:

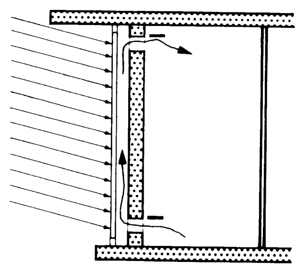
(1) Climatic conditions – mean monthly temperature, solar geometry and incident solar radiation, hours of sunshine and level of incident energy radiation
(2) Method of using the solar energy – indirect usage, direct usage
(3) Choice of materials – absorption capability of the surface and heat storage capability of the materials



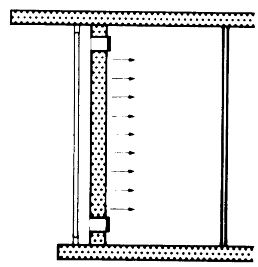
(9) **Direct usage of solar energy through glazed surfaces**



(10) **Indirect use of solar energy through a Trombé wall**

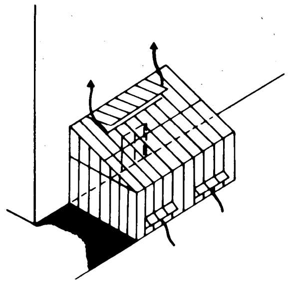


(11) **Winter day: incident solar radiation heats the air between the pane and the Trombé wall; room air is circulated through the lower and upper flaps and thus heated**

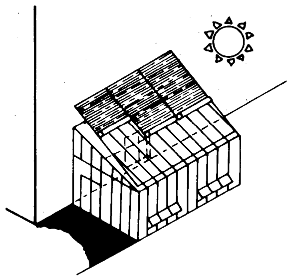


(12) **Winter night: thoroughly warmed wall acts as a radiant heat surface in the room; with the upper and lower flaps closed, the stationary layer of air between the external glazing and the Trombé wall helps to reduce the heat loss**

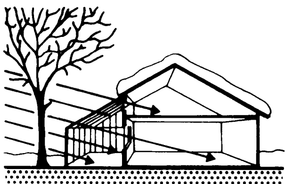
SOLAR ARCHITECTURE



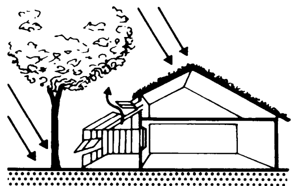
(1) **Large ventilation openings are important for climate regulation of glass structures during summer**



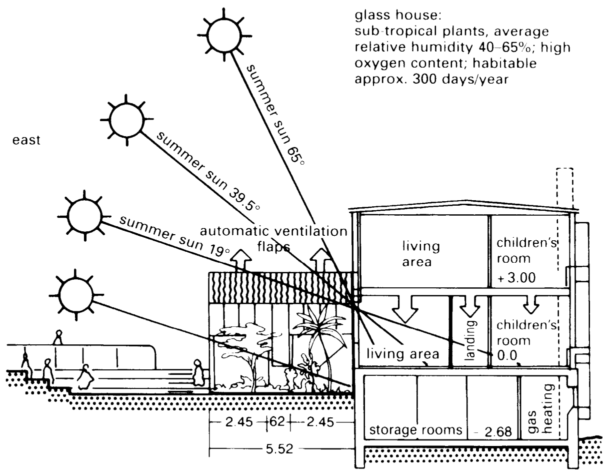
(2) **External sun shades are effective in preventing solar radiation from entering the structure, but weather quickly**



(3) **Building extensions: maximum sun required in winter; shade from neighbouring buildings is a disadvantage**

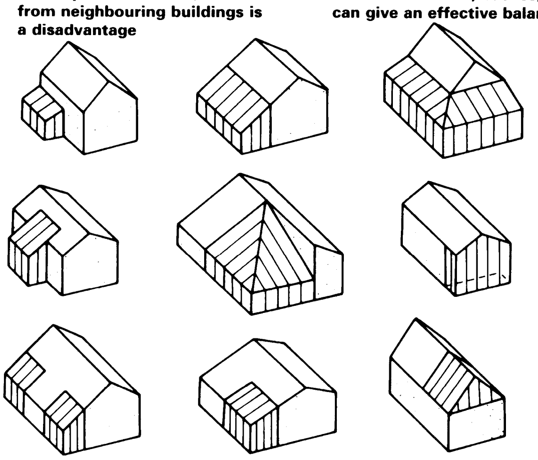


(4) **In summer, a degree of shading is desirable: trees, bushes, etc., can give an effective balance**

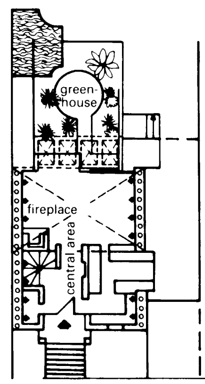


Architect: LOG

(5) **Solar town house with winter gardens for two storeys**

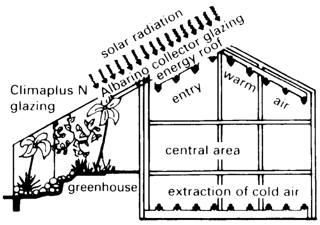


(6) **Alternative ways of adding glass structures to existing buildings**



Architect: Béla Bambek, Aichwald

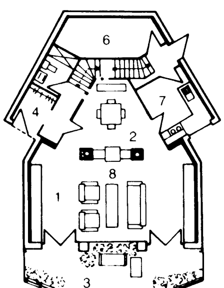
(7) **Single family house with glazed extension**



(8) **The function of hypocaustic gable wall heating**

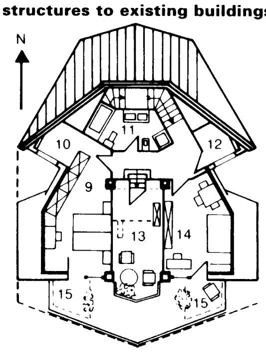
(9) – (10)

1 living room
2 dining room
3 glazed extension
4 entrance
5 guest room
6 domestic room
7 kitchen
8 fireplace
9 bedroom
10 dressing room
11 bathroom
12 store room
13 guest room
14 children's room
15 balcony

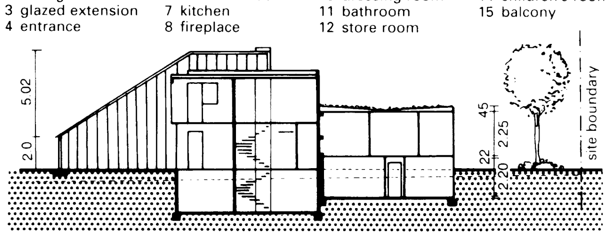


Architect: Berndt

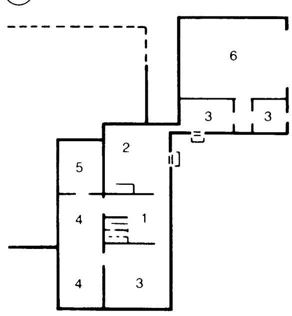
(9) **Plan view – ground floor**



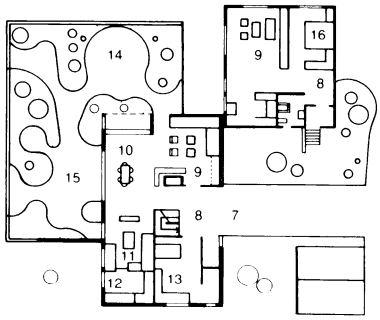
(10) **Plan view – upper floor**



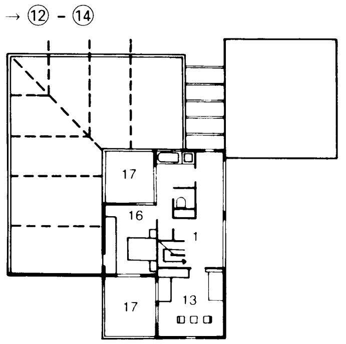
(11) **Section** → (12) – (14)



(12) **Basement** → (11)



(13) **Ground floor**



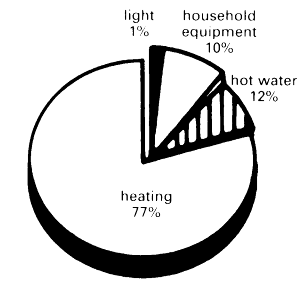
Architect: Planning team LOG

(14) **Upper floor**

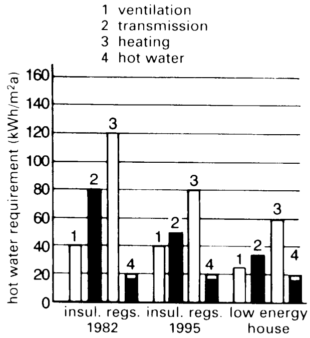
plan

1 corridor
2 domestic systems
3 storage room
4 cellar
5 wet storage cellar
6 double garage
7 wind trap
8 vestibule
9 living room
10 dining room
11 kitchen
12 hot water system room
13 children's room
14 energy greenhouse
15 storage surface
16 bedroom
17 balcony

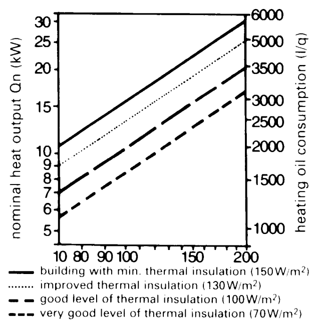
SOLAR ENERGY



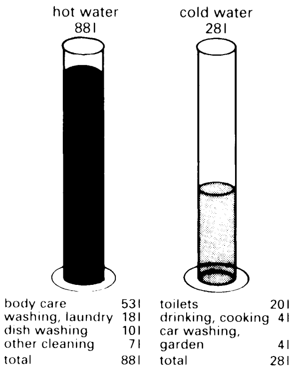
(1) **Energy use in a household**



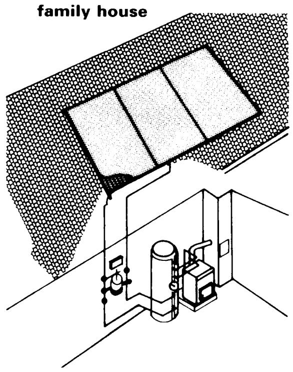
(2) **Heating and hot water requirements of a single family house**



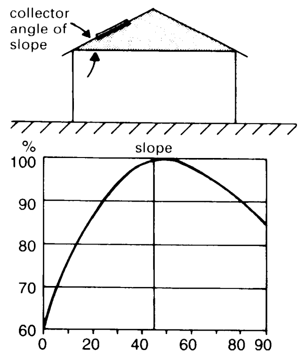
(3) **Heating and fuel requirements of houses in relation to insulation levels**



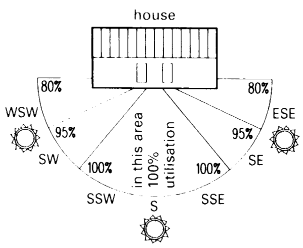
(4) **Use of water in a household**



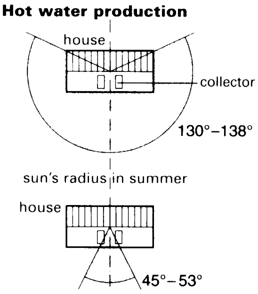
(5) **Hot water production**



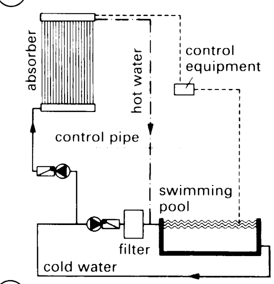
(6) **Angle of slope of collector**



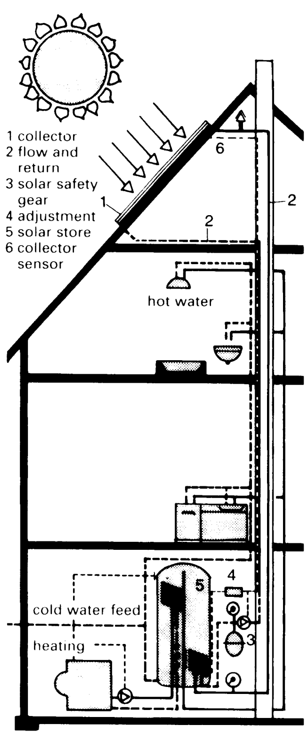
(7) **Use of sun's radiation**



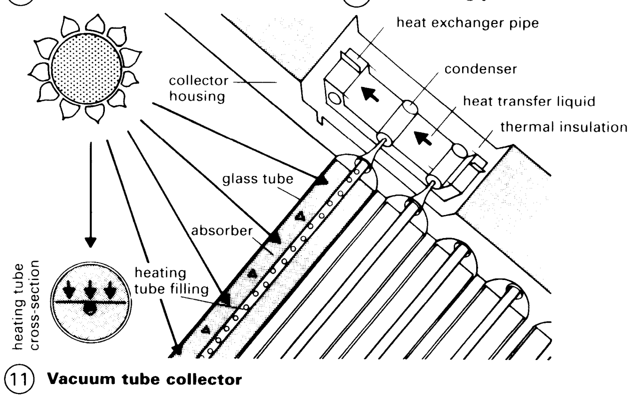
(8) **Sun's radius in winter**



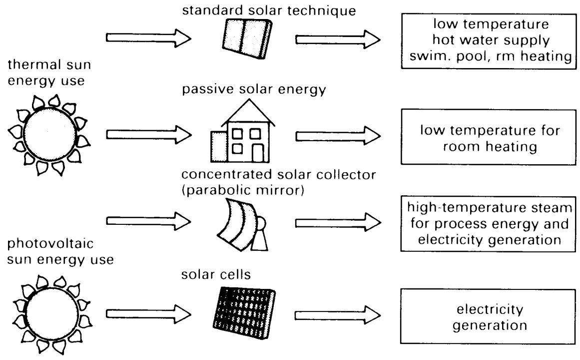
(9) **Swimming pool absorber**



(10) **Hot water supply solar installation**



(11) **Vacuum tube collector**



(12) **Solar techniques (diagrammatic representation)**

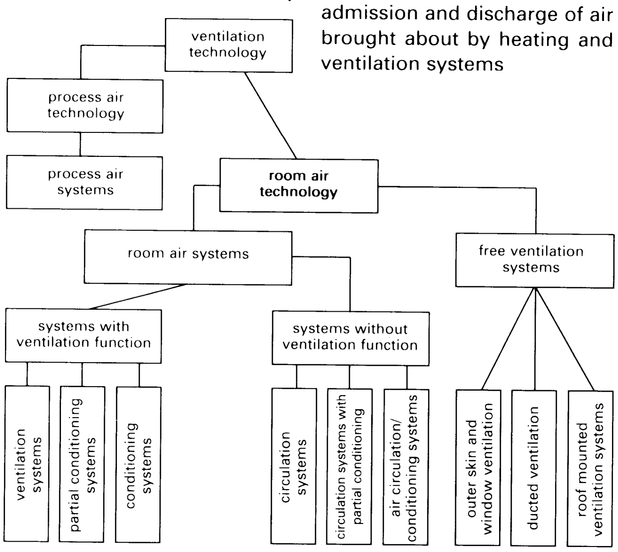
About 1.5 m^2 of collector area and about 100 l volume of water in the storage tank is needed per person in the household. → (1) A 30-pipe solar collector with an absorption surface of 3 m^2 is needed to produce hot water for a 4-person household. The collector will produce about 8.5–14.0 kWh solar heat per day, depending on the amount of sunshine, i.e. enough to heat 200–280 l of water. → (5) Within the foreseeable future, the sun cannot provide enough power for heating, so solar heating installations still require a conventional heating system.

There are two different technologies. Solar heat: thermal collection of solar energy using collectors (equipment which catches and accumulates solar thermal energy). Thermal energy is used to heat water. Solar electricity: photovoltaics is the direct conversion of the sun's rays into electrical energy (direct current) with the help of solar cells.

VENTILATION AND AIR CONDITIONING

Air movement is caused by pressure differences, i.e., disturbances to the state of equilibrium, resulting from:

(1) temperature differences } 'natural ventilation' – windows, doors, ventilation shafts
(2) natural wind }
(3) ventilators. } 'mechanical ventilation' – admission and discharge of air brought about by heating and ventilation systems



(1) **Arrangement of ventilation and air conditioning systems**

Room ventilation systems are used to guarantee a specific room climate. In fulfilling this objective, the following requirements must be satisfied, depending on the application:

(a) Removal from rooms of impurities in the air including smoke and other harmful substances, and suspended particles
(b) Removal of perceptible heat from rooms: unwanted quantities of both hot and cold air
(c) Removal of latent heat from rooms: enthalpy flows of humidifying air and dehumidifying air
(d) Protective pressure maintenance: pressure maintenance in buildings for protection against unwanted air exchange.

Most of the requirements under (a) are solved through continuous replacement of air (ventilation) and/or suitable air treatment (filtering). Requirements of type (b) and (c) are usually met by appropriate thermodynamic treatment of the air, and, to a limited degree, by air replacement. Requirements of type (d) are solved by various types of mechanical control of supply and extraction air.

Natural ventilation

Uncontrolled air is admitted through joints and gaps in window frames, doors and shutters (as a result of the effects of wind) rather than through the walls. However, the increased use of thermal insulation measures in buildings means that the natural sources of ventilation through gaps in windows and doors may no longer be adequate. It may therefore be necessary to provide controlled ventilation in living accommodation, using mechanical ventilation systems and, if necessary, to replace the heat lost as a consequence.

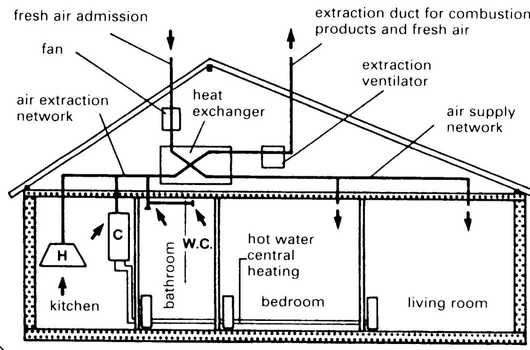
Window ventilation → (5)–(8) p.179 is generally adequate for living rooms. Sash windows are favourable, where the outside air is admitted at the bottom and internal air flows out above.

Intensive ventilation is brought about by mechanical ventilation systems. In accordance with the building regulations, this is a requirement for windowless bathrooms and WCs, with the removal of air to the outside via ducting. Allowance should be made for the requirement of a flow of replenishment air through ventilator grills, windows and/or gaps in the fabric of the building. Furthermore, as far as is possible, draught-free admission of the outside air must be provided.

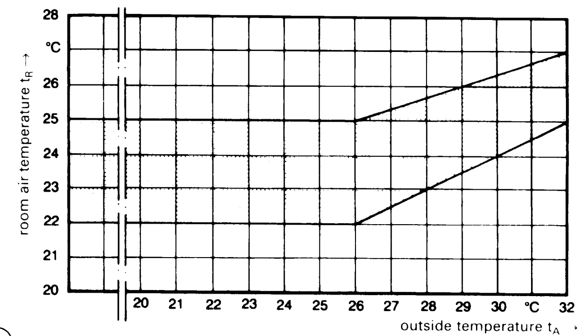
The installation of simple ventilator grills in outside walls for inflow and outflow of air leads to the danger of draughts in the winter. Mechanical ventilation systems are better.

Humidity of room air

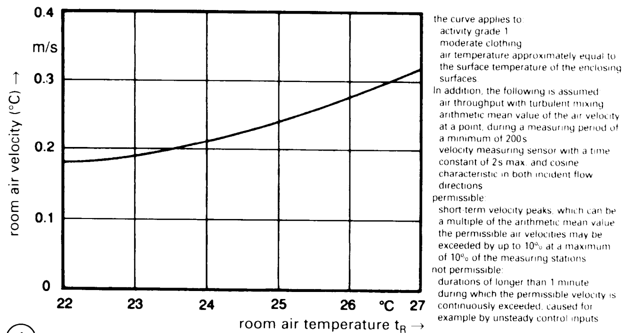
For comfort, the upper limit for the moisture content of the air is 11.5kg of water per kg of dry air. A relative humidity of 65% should not be exceeded. The minimum flow of fresh air per person for cinemas, banqueting halls, reading rooms, exhibition halls, sale rooms, museums and sports halls is $20\,m^3/h$. The value for individual offices, canteens, conference rooms, rest rooms, lecture halls and hotel rooms is $30\,m^3/h$; it is $40\,m^3/h$ for restaurants, and $50\,m^3/h$ for open plan offices.



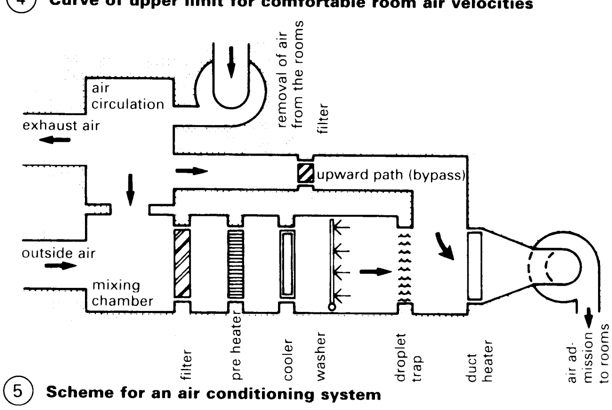
(2) **Scheme for an installation incorporating a 'twin-flow gas system'**



(3) **Comfortable room air temperature range**



(4) **Curve of upper limit for comfortable room air velocities**



(5) **Scheme for an air conditioning system**

VENTILATION AND AIR CONDITIONING

Several handling stages are usually involved in ventilation and air conditioning. Filtering; air heating; air cooling; and washing, humidifying and evaporative cooling are discussed on this page. For ventilation and damping → p. 107.

Filtering

Air cleaning to eliminate coarse dust particles:

(a) Oiled metal filter plates in air filter chambers or automatic circulation filters; used particularly for the ventilation of industrial premises. Disadvantage: entrainment of oil mist.

(b) Dry layer filter mats made of textile or glass fibre in metal frames; not recoverable; also as roll tape filter with automatic cleaning.

Fine cleaning and separation of fine soot

(c) Electrostatic air filter; the dust is ionised and deposited on negatively charged metal plates. Very low air resistance. Disadvantages: large filter chambers; cleaning with warm water.

(d) Fine filtering through filter media of paper, or glass fibre. Advantages: cheap to manufacture; no corrosion from air containing harmful substances; high operating safety. Disadvantage: greater air resistance than electro filters, which increases as the filter is soiled, leading to disruption of the air flow.

(e) Air washing: removes dust or aerosols and acid fumes, but not soot, and therefore should not be used in areas with many oil-fired heating installations.

filter class	mean level of particle separation A_m relative to synthetic dust (%)	mean efficiency E_m relative to atmospheric dust (%)
EU 1	$A_m < 65$	–
EU 2	$65 \leq A_m < 80$	–
EU 3	$80 \leq A_m < 90$	
EU 4	$90 \leq A_m <$	–
EU 5		$40 \leq E_m < 60$
EU 6		$60 \leq E_m < 80$
EU 7		$80 < E_m < 90$
EU 8		$90 \leq E_m < 95$
EU 9[1]		$95 \leq E_m$

[1] air filters having a high mean efficiency may already satisfy the classification requirements for suspended material filter class

1 **Air filter classes**

Air heating

(a) Controllability is limited with simple gravity-circulation solid-fuel heating installations.

(b) Controllability is good with natural gas and heating oil, and with electrically heated equipment.

(c) Heating with low-pressure steam, warm and hot water, using finned tube radiators made from galvanised steel or copper tube with copper or aluminium fins. Good, simple controllability. No need for local chimneys and flues.

Air cooling

Used principally for industry when constant temperature and humidity must be maintained over the whole year, also for commercial buildings and office blocks, theatres and cinemas in summer.

(a) Cooling of the air with mains water or spring water. At a temperature of 13°C, spring water should be allowed to drain back again as much as possible on account of the ground water table level. In most towns, the use of mains water for cooling is not permitted and is uneconomical anyway, due to the high price of water. Spring water systems require the approval of the water authorities.

(b) Compression cooling systems for room air conditioning must accord with strict regulations and must use non-poisonous refrigerants such as Freon 12 or Freon 22 (F12, F22), etc. If the cooling plant is in the direct vicinity of the central air conditioning area, direct evaporation of the refrigerant should take place in the cooling radiators of the air conditioning plant. Since 1995, substances containing CFCs are prohibited.

(c) In large installations, cooling of the water takes place within a closed circuit, with distribution by pumps. Advantages: the central cooling plant can be in an area where noise and vibration are not troublesome; very safe in operation. Today, compact cold water systems and prefabricated air conditioning/cooling units are available.

For large cooling installations

(d) Compression of the refrigerant in a sealed unit turbo compressor (complete machine installation with compressor, water-cooler and condenser), low vibration and very low noise levels.

(e) Absorption cooling facility with lithium bromide and water. Due to the vaporisation of the water, heat is extracted from the water to be cooled; water vapour is absorbed by the lithium bromide and continuously evaporated in the cyclic process, then condensed again and passed to the first vaporisation process. Very low noise levels; vibration-free system requiring little space.

(f) Steam jet cooling: A high velocity steam jet induces a negative pressure in a vessel. Circulating cooling water becomes atomised and vaporised, with simultaneous cooling. The cold water is transferred to the air coolers of the air conditioning plant. This method of cooling is employed in industrial applications.

The condenser heat must be disposed of in all mechanical cooling systems. Various means are employed for this purpose, e.g. water cooled condensers, which are cooled by spring water or circulating water, and air cooled condensers. On water-cooled condensers, the spring water installation requires approval by the local water authorities. Also, careful checks should be made as to whether the spring water contains any aggressive substances which would damage the condensers in the cooling installation. If appropriate, sea water resistant condensers must be used (cost factors).

A return cooling system is necessary on circulating water installations (cooling tower). In the cooling tower, circulating water is sprayed by jets. The water then flows over layers of granular material and is blown through with air (evaporative cooling). The cooling towers should be sited away from buildings or, better still, be sited on the roofs of buildings, due to the level of noise generated. The same applies to air cooled condensers.

Washing, humidifying, evaporative cooling

Air washers provide humidification for dry air (when correctly set) and, to a certain degree, they can also provide air cleaning. By means of saturation, i.e. increasing the absolute water content of the air in the washer, 'evaporative cooling' can take place at the same time; this provides the possibility of cheap cooling for industrial air conditioning facilities in areas where the outside air is of low humidity. The water is very finely atomised in the air washer, through the use of pumps and jet sprays. The sprays are housed in galvanised steel sheeting or watertight masonry or concrete. An air rectifier or water-control sheeting prevents the escape of water into the conditioning chamber.

Other humidifying devices

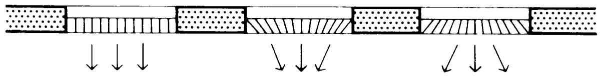
(a) Evaporation vessels on heating elements or atomisers.

(b) Centralised device with steam or electrically heated evaporation vessels (disadvantage is scaling).

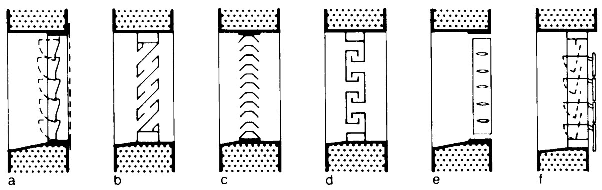
(c) Rotating atomisers (aerosol apparatus) – only usable where low volumes of air are involved

VENTILATION AND AIR CONDITIONING

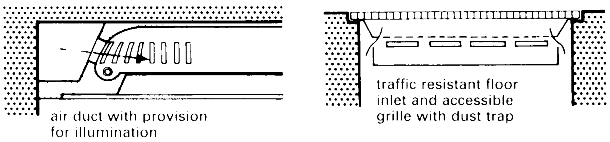
The efficiency of a good ventilation design can be 80–90%, depending on the application. Both radial and axial fans produce the same noise levels up to a total delivery pressure of approx. 40mm head of water. Above this level, axial fans are louder and they are used particularly in industrial construction. Special foundations are provided with damping elements to isolate vibration levels.



(1) **Air admission grilles showing flow directions**



(2) **Ventilation openings: a = self opening; b,c,d,e = non-moving; d = for dark rooms; f = manually operated**



(3) **Air inlet and outlet grilles**

Sound damping

Sound dampers are provided in air ducts to reduce noise from installed machinery into the air-conditioned rooms. The length of these in the direction of air flow is 1.5–3m, depending on the damping to be achieved. The design may embody baffles made from non-combustible material, e.g. moulded fibre boards or from sheeting with a rockwool filling. The requirements for sound insulation in building construction should be observed.

Ducts and air outlets and inlets are in galvanised steel sheet, high-grade steel or fire-resistant fibre board or similar. Ideally, the cross-section should be square or round, or rectangular with an aspect ratio of 1:3. Regular servicing is necessary, and the requirements for fire protection of ventilation systems must be observed.

Masonry or concrete built ducts are more economical than sheet construction for large floor or rising ducts. Masonry ducts dampen noise better than concrete. The insides should be smoothly plastered and have a washable surface coating. Air entry ducts should be provided with lightweight insulation only, so that heat retention is avoided. The duct cross-sections should be large enough for cleaning (soiling impairs the condition of the air). So, the floor air-exhaust ducts should be equipped with drainage pipes or channels with sealed screwed connections and the air ducting should have adequate access openings for cleaning purposes.

Cement fibre ducts (asbestos-free) are suitable for moist, non-acid containing air and plastic ducts for aggressive, gaseous media. Inlet and outlet gratings should not be sited in accessible floor areas (except in industrial construction and electronic data processing rooms). Air outlets are crucial for the distribution of air in rooms; the flow should be directed horizontally and vertically. Grilles for air inlets and outlets should be designed from an air conditioning standpoint, but should also be easy to clean – ideally made from stove enamelled sheet. → (1) – (3)

The introduction of air into offices should, when possible, be at a window (point of most pronounced passage of cold and heat). Air removal should be on the corridor side. For theatres, cinemas and lecture rooms, admit air under the seats, and remove through the ceiling. This method depends on the shape and usage of the room.

Plant rooms

Air conditioning and ventilation systems should be considered during preliminary planning, as they have a major influence on building design and construction. Plant rooms should be as near as possible to the rooms to be air-conditioned, provided this is acoustically acceptable, and have good accessibility. The walls should be of masonry, plastered, with a washable coating, preferably tiled.

Floor drainage should be provided in all compartments, and have traps and airtight removable covers. Where plant rooms are above other rooms, watertight floors should be provided. External walls need insulation and vapour barriers, to avoid damage by condensation. The extra floor loading for machinery in a plant room can be 750–1500kg/m^2, plus the weight of the walling of the air ducting. In situations where there are extremely high requirements for noise and vibration reduction, consideration should be given to flexible mounting and isolating a plant room as a 'room within a room'.

Space requirements for air conditioning equipment are very much dependent on the demand for air filtering and sound damping. In narrow, long floor shapes, the compartments can be arranged in sequence, one after the other.

- Simple industrial conditioning systems: approx. 12m long
- For full air conditioning systems: approx. 16–22m long
- For air extract systems: approx. 4–6m long.

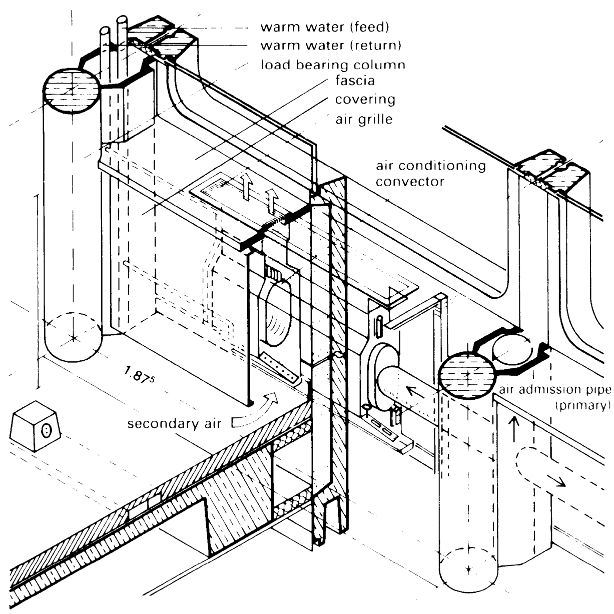
Width and height (clear space) for industrial and full air conditioning system plant rooms:

air supply m^3/h	width (m)	height (m)	
< 20000	3.0	3.0	room centre
20–40000	4.0	3.5	
40–70000	4.75	4.0	

An additional 1.5–2m should be allowed for assembly and maintenance access. In the case of large installations, for heating and air conditioning distribution systems, allowance should be made for common maintenance access and space for the control panel.

Air conditioning systems for large offices

It is useful to use several conditioning systems for large and open planned rooms. An isolated conditioning zone can be installed in the façade area (high-velocity systems) and a separate area for the internal zone, with low pressure or high velocity systems → (4).



Construction management: Dyckerhoff Zement AG

(4) **Example of a high pressure air conditioning system (System LTG).**

High-pressure air conditioning systems

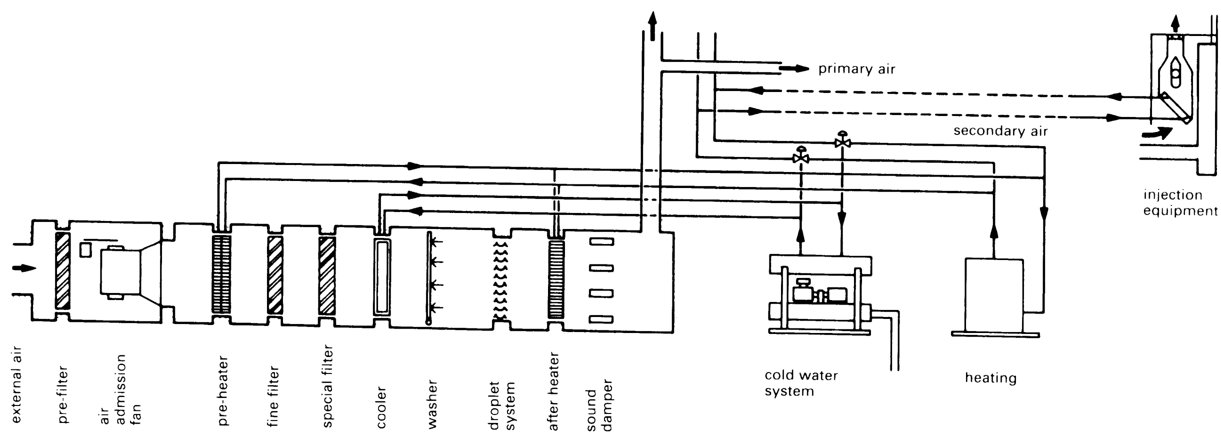
To meet the demand for heat in winter and cooling in summer, large cross-sections of low-pressure air conditioning systems are needed – it is not for ventilation. High-pressure air conditioning systems require only approx. 1/3 of the usual air quantities; they use external air for ventilation while transporting heat and cold through water pipes ($1\,m^3$ of water can transport approx. 3450 times more heat than $1\,m^3$ of air). An air conditioning convector unit (with special air outlet jets and a heat exchanger) installed under every window is supplied with conditioned air and cooled or heated water. Regulation takes place only at the heat exchanger. Smaller quantities of air enable smaller control rooms to be used and with acceptable air conditioning. The external air is cleaned using a pre-filter and a fine filter. The whole building is at a slight positive pressure with respect to the outside, so that any air gaps in the building fabric have virtually no effect.

Air conditioning convectors

General requirements: noise intensity ≤ 30–33 phon; air filter for cleaning the secondary air; heat exchanger must be able to ensure full heating to room temperature in any weather, even without the ventilation air system; cold water temperature in summer must be 15–16°C, or the cooling operation will be uneconomical and condensation will form on window systems (soiling of cooling surfaces). For ideal flow conditions without vibration, high-pressure air ductwork should be of round section where possible. With a vertical arrangement of supply lines and window spacings of 1.5–2 m, alternate the structural columns with vertical service ducts containing the air ductwork and water pipes. Rising air ductwork for buildings with 7 storeys are 175–255 mm diameter. For taller buildings, separate supplies lines are needed for each 7–10 storeys and a storey devoted to the installation of heating and ventilation plant. A more expensive arrangement involves a main air shaft, with horizontal distribution along the corridors and branching ductwork directed outwards into the ceiling voids above rooms, to terminate directly behind the facade above the windows, or, at floor level, in the rooms above through holes in the floor structure. Max. office depth for high-pressure installations: 6 m, beyond which air cooling requires an additional central conditioning system. Max. building depth without a central system: (2 × 6 =) 12 m plus the corridor. Air can be removed through ducts over corridor wall storage cupboards or in ducting above the corridors and through WCs. In high-pressure systems, air is not recirculated (the air mass has already been reduced to that required for acceptable ventilation). For limited operation, the primary air flow can be reduced in the plant room.

Ventilation systems for kitchens

For large kitchens (height 3–5 m), render the upper sections (walls and ceilings) in porous plaster (no oil painting); provide 15–30 air changes, pressure below atmospheric, creating air flow from adjacent rooms into the kitchen; use larger radiators as appropriate; group boilers, cookers and fryers together; provide air extraction with a fat filter; clean ducting annually; filter and heat the air inlet flow in winter. No air circulation system is needed; local heating and insulating glazing are needed.



(1) **High-pressure air conditioning system (System LTG)**

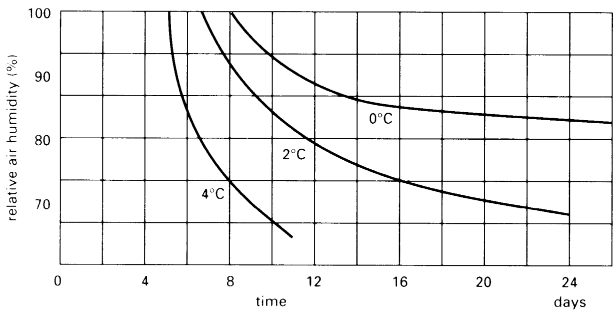
COLD STORAGE ROOMS

component	maximum heat exchange coefficient W/(m²K)[1]	required minimum thickness of insulating material without certificate[2]
external walls	0.60	50 mm
windows	double windows or double glazing	
ceilings under uninsulated roof space, and ceilings (including sloping roofs) and floors that form a boundary between rooms and the outside air above or below	0.45	80 mm
cellar floors and other floors which separate the building from the surrounding ground; walls/floors which form boundaries to an unheated room	0.70	40 mm

[1] heat transfer coefficients can be determined taking account of existing structural components

[2] thickness data relates to a thermal conductivity (-0.04 W/(mK); where the insulating material has to be built in, or in the case of materials with other thermal conductivity values, the insulation material thicknesses must be balanced accordingly; existing mineral fibre or foam plastic materials can be assumed to have a thermal conductivity of 0.04 W/(mK).

(1) **Limitation of heat transfer on initial construction, replacement and on renewal of structural components**



(2) **Maximum storage duration at various temperatures and degrees of humidity (0 K = -273.15°C)**

type of meat	storage temperature	storage duration (months)
beef	- 18 - 12 - 9.5	15 4 3
pork	- 18 - 12 - 9.5	12 2 up to 4 1
loin of pork	- 18 - 10	5 1/2 4
chicken	- 22 - 18 - 12 - 9.5	up to 18 up to 10 4 2
turkey	- 35 - 23 - 18 - 12	over 12 12 6 3

(3) **Storage temperature and duration of storage**

To determine the cooling requirements for cold rooms, attention must be paid to the requirements of the commodities stored; humidity content, air changes, cooling or freezing duration, type of storage, etc. Also, consider the specific heat of the goods, internal environment, method of manufacture, position, heat from lighting and movements within the cold store. Calculation of the cooling requirement takes the following form (→ pp. 111–16):

(1) Cooling/refrigeration of the goods (cooling to the freezing point – freezing – supercooling) ($Q = m \times cp \times \Delta t$); if goods are to be frozen solid, the necessary heat must be removed at the freezing point, and, subsequently, the specific heat of the frozen goods is lower; the humidity extraction is approximately 5%
(2) Cooling and drying of the extracted air
(3) Heating effects through walls, ceiling, floor
(4) Losses: movements in and out of storage (door opening), natural and electric lighting, pump and ventilator operation
(5) Condensation of water vapour on walls

The cold storage of freshly slaughtered meat is cooled from 303.15 K to a temperature of 288.15 K. This is achieved by placing it in a temperature of 280.15–281.15 K at a relative humidity of 85–90% in the pre-cooling room for 8–10 hours, and then storing it at 275.15 K–281.15 K at a relative humidity of 75% for up to 28–30 hours in the cool room. Cooling and storage takes place separately. Weight loss over 7 days is 4–5%. Today, rapid cooling is used increasingly, no pre-cooling stage, meat is cooled from a slaughter temp. of 303.15 K to a storage temp. of 274.15 K, with 60–80 circulations of the air per hour and at a relative humidity of 90–95%.

Meat cooling and refrigeration

The freezing process changes the condition and distribution of the water in meat, while the meat composition remains unchanged.

Beef is frozen to 261.15 K and pork to 258.15 K, at a relative humidity of 90%. Duration of freezing: mutton, veal, pork, 2–4 days; beef, hindquarters 4 days, forequarters, 3 days. Correct thawing period: 3–5 days to 278.15–281.15 K, restores the meat to a fresh condition.

Recently, mainly in the USA, rapid freezing methods have been employed, at temperatures of 248.15–243.15 K, involving 120–150 air circulations per hour. The advantages are: lower weight loss, increase in tenderness, replacement of the curing process, lower liquid loss, good consistency and preservability after thawing.

Storage duration is dependent on the storage temperature; for example, for beef the storage duration is 15 months at 255.15 K, 4 months at 261.15 K and 3 months at 263.65 K.

Cold room volume: 1 m³ is suitable for the storage of 400–500 kg of mutton, 350–500 kg of pork, 400–500 kg of beef, with a standard stacking height of 2.5 m.

Refrigeration of fish

Fresh fish can be maintained in this condition on ice at 272.15 K and at a relative humidity of 90–100% for a period of 7 days. Longer storage times can be achieved through the use of bactericidal ice (calcium hypochlorite or caporite). For even longer storage, rapid freezing to 248.15 -233.15 K is required, if necessary use glazing with fresh water to keep air out and prevent drying up. Fish crates are 90 × 50 × 34, giving a weight of approx. 150 kg.

Refrigeration of butter

Butter refrigerated to 265.15 K has a storage duration of 3-4 months and a duration of 6–8 months at a temperature of 258.15–252.15 K. Lower temperatures can provide a period of up to 12 months. The relative humidity should be 85–90%. Butter drums are 600 mm high with a diameter of 350–450 mm, resulting in a weight of 50-60 kg.

Refrigeration of fruit and vegetables

Immediate cooling is required, since a reduction of temperature to 281.15 K delays ripening by 50%. Storage duration depends on air quality (temperature, relative humidity, movement), variety, maturity, soil quality, fertilising, climate, transportation, pre-cooling, etc.

Cooling of eggs
Cold storage eggs are those stored in rooms whose temperature has been artificially controlled to a value lower than 8°C. Such eggs must be identified as 'cold storage eggs'. To avoid sweating, if the temperature outside the cold storage room is more than 5°C greater than inside, the eggs must be warmed in a defrosting room with controlled air conditioning on removal from cold storage. The area of the defrosting room is approx.12% of that of the cold storage room. The warming-up time for quarter crates is approx. 10 hours; 18–24 hours for complete and half crates. Stacking of the quarter crates in the defrosting room: around 5000–6000 eggs (approx. 400kg gross) per m^2. Crates of 500 eggs are 920mm long, 480mm wide and 180mm high; for 122 dozen (= 1440) eggs, 1750 × 530 × 250mm. A basis for calculation is 10–13 crates for 30 dozen, occupying 1 m^3 in the storage room; since one egg weighs 50–60 grams, there is a weight of between 180–220kg of eggs in the 1 m^3. A net volume of 2.8 m^3 cold room capacity is required for 10,000 eggs. Two million eggs fill 15 freight wagons. For export, the eggs are packed in crates of 1440 items; wood shavings are used as packing between the eggs, giving a gross weight of 80–105kg. For Egyptian eggs, this weight is 70–87kg, tare, i.e. the empty crate and shavings weigh 16–18kg. One wagon contains 100 half export crates holding 144,000 eggs or 400 'lost' crates with 360 items each. Standard crates for 360 eggs are 660mm long, 316mm wide and 361mm high (the so-called 'lost' crates). They can be divided into two by a central partition. Cardboard inserts are used. The crates are made from dry spruce; pine is unsuitable. Stacked 7 crates high, 10,000–11,000 eggs can be stored on a net area of 1 m^2. Dry air, at 75% humidity and air-tight packaging is used, with cube-shaped crates with 360 eggs in each, in protective cardboard pockets. If the eggs are exposed to the ingress of air, the air humidity can be 83–85%. The air humidity in the store is controlled by first supercooling then heating it within the ventilation system. The weight loss during the first months in cold storage is severer than later months; a weight loss of 3–4.5% occurs after 7 months. Eggs can also be conserved in a gaseous atmosphere of 88% CO_2 and 12% N, after Lescardé-Everaert, in gas-filled autoclaves at around 0°C. This preserves the eggs in their natural state. Uniformity of temperature and air humidity are important factors. Ozone is frequently introduced into egg cold storage rooms. The cooling requirement during storage is 3300–5000kJ/day per m^2 of floor surface – higher during the period when eggs are introduced. The storage periods run from Apr/May to Oct/Nov.

Cooling and refrigeration of poultry and game
Large game (red deer, roe deer, wild boar) must be drawn before freezing, but this is not necessary for small game (hare, rabbit, game birds). Freezing takes place before plucking, with the game free-hanging; storage being in stacks on gridded floor panels. There should be plenty of air movement during freezing, but little during storage. These numbers of game can be stored per square metre of floor area (3[t]m high): approx. 100 hares, or 20 roe deer, or 7–10 red deer. The air humidity should be approx. 85% at −12°C.

Domestic poultry should not be frozen and stored with game, as the fat content of the former requires a lower temp. and is sensitive to the smell of game. The cooling of poultry takes place at 0°C and at 80–85% relative humidity, with the birds suspended on frames, or alternatively, in iced water; storage at 0°C and 85% relative humidity, with a storage duration of approx. 7 days. Freezing at approx. −30– −35°C, storage at around −25°C and 85–90% relative humidity. The freezing time for a chicken is approx. 4 hours at an air velocity of 2–3m/sec. Deep freezing, using the cryovac method, takes place in vacuum latex bags. Young chickens will freeze through in 2–3 hours. Storage duration is approx. 8 months at −18°C. To prevent rancidity, the poultry is protected by wrapping in water vapour tight polyethylene film.

Brewery products
Malt floors: 8–0°C
Cooling requirement per m^2 of floor area: 5000–6300kJ/day
Fermentation cellars: duration is 8–10 days at 3.5–6°C
Cooling requirement: 4200–5000kJ/day per m^2 of floor area
Cooling requirement for the fermentation vat cooling: 500–630kJ per hl fermented wort per day
Storage cellar: −1.0°C to +1.5°C; cooling requirement approx. 20–25 Wm^3, related to the empty room, or 2.5–3kcal/h per hl of storage capacity
Installed cooling power: approx. 2.1–2.3Whl yearly output

Room cooling, general
From the viewpoint of reserves and safety, the cooling system is designed to have a higher performance than the calculated cooling requirement. It is assumed that the cooling system will operate for 16–20 hours per day in cooling and freezing rooms; in individual cases, e.g. for efficient utilisation of electrical tariffs, the period may be even shorter. In meat cold storage rooms, the cooling power should not be too high, so that during periods of reduced cooling requirements, adequate operating durations and the required throughput of air in the room will still be guaranteed.

In small commercial cold storage rooms with a temperature of approx. 2–4°C and a product throughput of 50 kg/m^2 per day, the following table serves as a reference to determine the cooling requirement and the requisite power of the cooling system.

cold storage room floor area requirement m^2	cooling power (kJ/day)	cooling system (W)
5	50000	870
10	82000	1400
15	111300	1900
20	138600	2400
25	163800	2850
30	187000	3250

The following figures can be used for further calculations:
Cold storage rooms with multi-storey construction: 5000–8400 $kJ/day/m^2$
Cold stores of single-storey construction: 1050–1700 $kJ/day/m^2$
Storage capacity per m^2 of floor area – hanging storage – after reduction of approx. 15–20% for gangways: mutton 150–200kg (5–6 items), pork 250–300kg (3–3.5 whole, 6–7 sides), beef 350kg (4–5 quarters of beef)
Per running metre – low hanging rail: 5 halves of pork or 3 quarters of beef or 2–3 calves
Distance from centre to centre of rails (low rail): approx. 0.65m, height to centre of rail: 2.3–2.5m
Distance from rail to rail (high rail): 1.20–1.50m with free passage way; height with tubular track: 3.3–3.5m
Per running metre of high rail: 1–1 5m (2–3 sides of beef), depending on size

Estimate of cooling requirements for meat: rapid cold storage room, 21000–31500 $kJ/m^2/day$; most rapid cold storage room, 4200 $kJ/m^2/hour$

Storage room for frozen meat – storage capacity per m^3 of room volume: frozen mutton, 400–500kg; frozen pork, 350–500kg; frozen beef, 400–500kg

Standard stacking height: 2.5m

Fats become rancid with the passage of time under the effects of light and oxygen, so that the storage duration is limited.

Meat curing room: temperature 6–8°C

Cooling requirement per m^2 of floor area: 4200–5000kJ/day

Brine in curing vats absorbs moisture from the air.

One railway goods wagon of 15000kg loaded weight can accept approx. 170 hanging sides of pork over a floor area of 21.8 m^2.