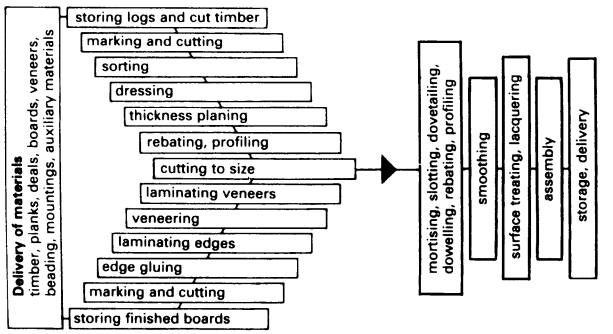
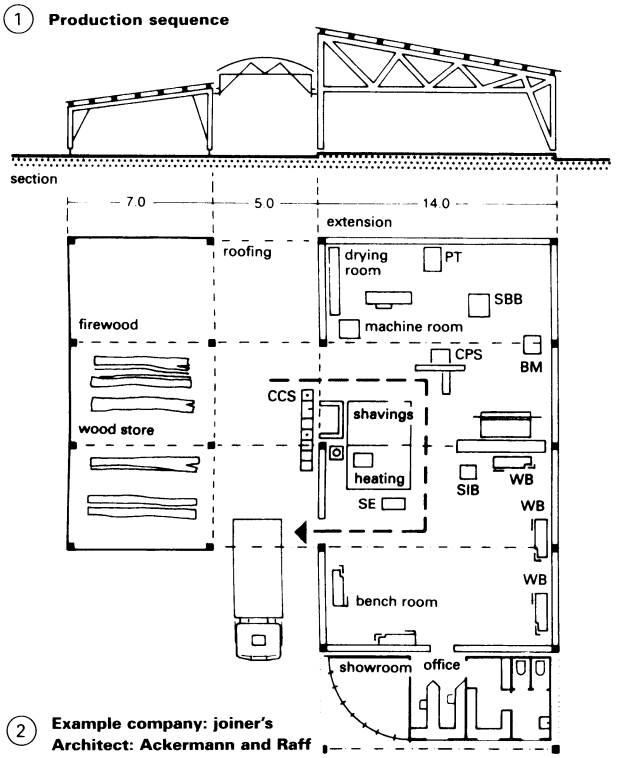
WORKSHOPS: WOODWORKING



(1) **Production sequence**



(2) **Example company: joiner's**
Architect: Ackermann and Raff

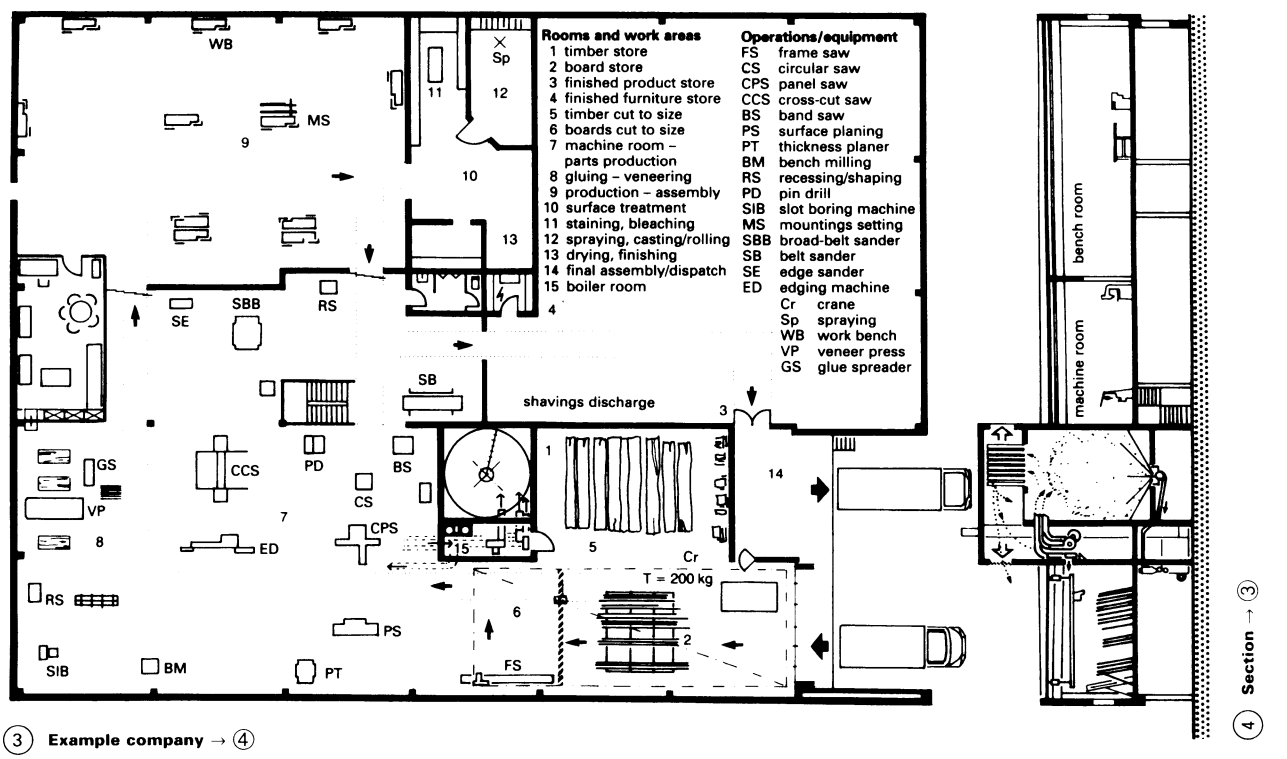
Generally the change in plan form from long sheds to more compact developments → ② – ③ improves economy: the site is more efficiently used; routes are shorter in mixed production; service ducts are shorter. Multistorey buildings are not appropriate for production areas but are recommended for offices, ancillary rooms and store rooms for small and/or valuable articles. Predominant building types have steel frames with reinforced concrete and metal or timber cladding. Walls and roofs of large manufacturing units should have good heat and sound insulation. Windows of insulating glass are mostly fixed; natural lighting from above is possible; a smaller proportion of window area as required by regulations should serve for ventilation and view.

Space requirements (for examples shown): an average of 70–80 m²per employee (without open storerooms).

An extractor system is required in virtually all cases to remove wood chippings, sawdust and wheel dust, both for the sake of regulations on health and safety at work and on economic grounds. The arrangement of machines is determined according to the sequences of operations. Rubber bonding to metal mountings can reduce high levels of machine noise.

In small companies with up to ten employees, general production flow can be in a line or L-shaped. In medium-sized companies with more than ten employees, a U-shaped or circular (or square) arrangement gives a better flow. In the latter case functions are combined: gate, load and unload, ramp, supervision, checking, goods in, dispatch.

Work sequence: timber store, cutting area, drying room, machine room, bench workshop, surface treatment, store, packing. Machine room and bench workshop is divided by a wall with doors → ③. Office and foreman's room are glazed, with view of workshop. Workshop floor: wood, wood-block or composition flooring. All workstations should face the light. Continuous strip windows, high sills (1.00–1.35 m).



(3) **Example company** → ④

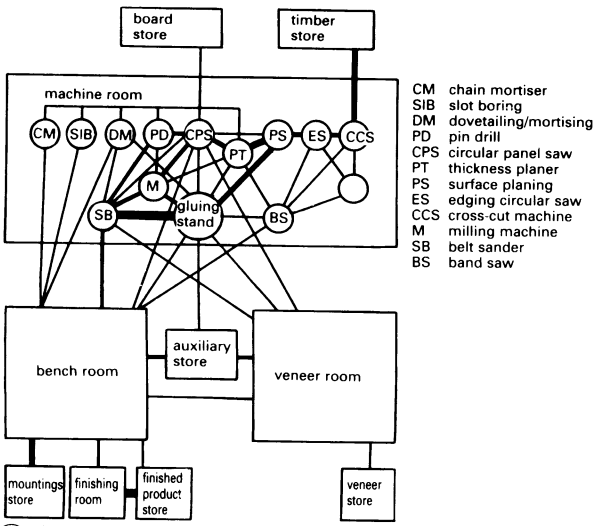
(4) **Section** → ③

WORKSHOPS: WOODWORKING

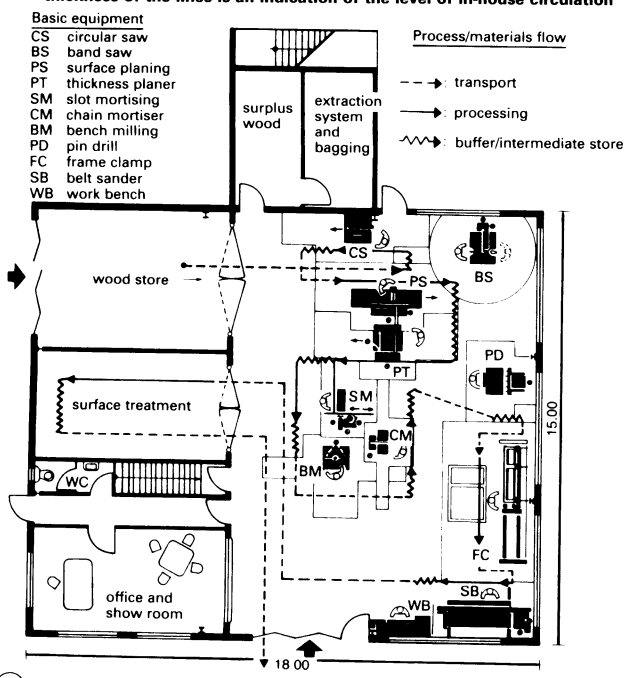
In the workshop, there should be enough space to give each worker not only sufficient bench room, but also the required space to assemble the work. A large number of joiners' shops are mechanised; larger ones have separate assembly and machine shops, but in smaller shops machines may be grouped at one end of the work area.

Rooms and areas

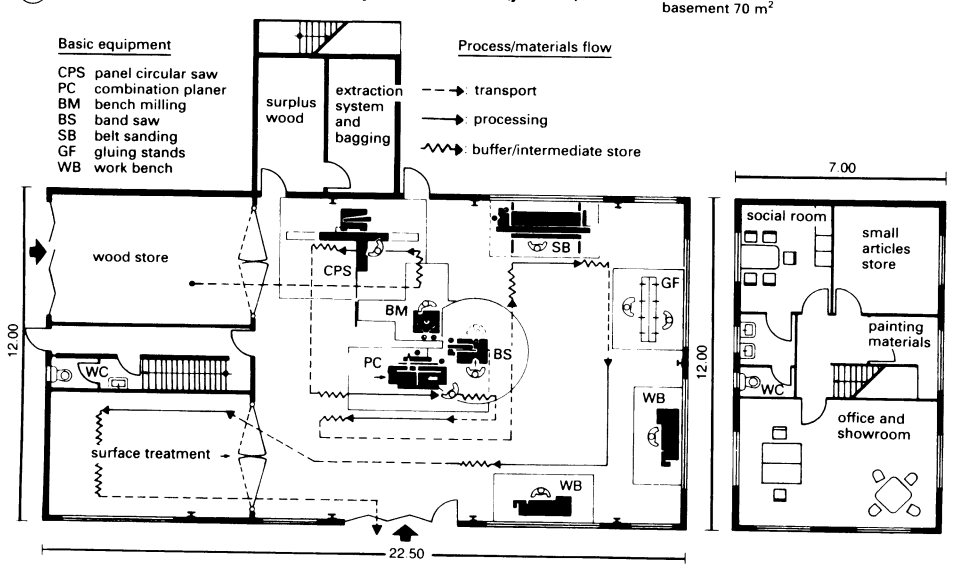
Stores: for rough timber, boards, veneers, glass, plastics, auxiliary materials and fittings; temporary stores; stores for finished and partially finished products.



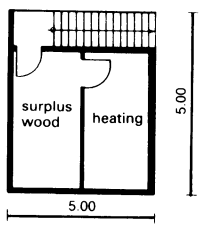
(1) **Relationship between materials, equipment and work spaces. The thickness of the lines is an indication of the level of in-house circulation**



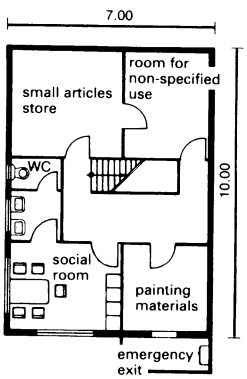
(2) **Sketch of workshop with work sequence drawn in (joiner's)**



(3) **Sketch of workshop with work sequence drawn in (interior fitters)**

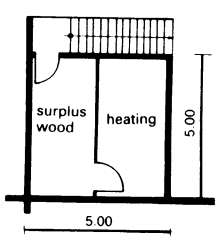


basement floor 25 m²



basement 70 m²

first floor 84 m²



basement 25 m²

Workshops:
For drying wood, and cutting timber, boards and veneers. Machine shops for parts, processing timber, boards, gluing and veneering, production and assembly, bench work, bonding, surface treatment, final assembly and dispatch. Metal working facilities are often also required.

Administration and management: works office (foreman), technical offices, commercial offices, management and secretarial offices, meeting room, sales room.

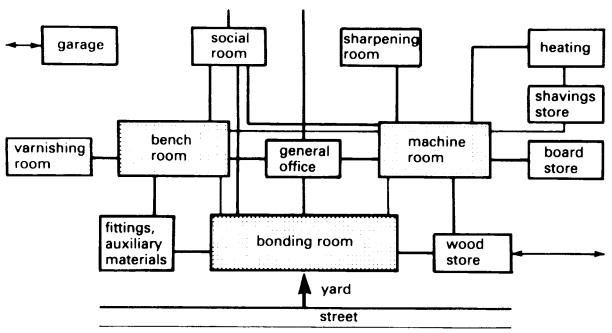
Social and ancillary rooms should have wood-block or composition flooring, (not concrete).

Storage areas should be dust free (fine dust blunts tools).

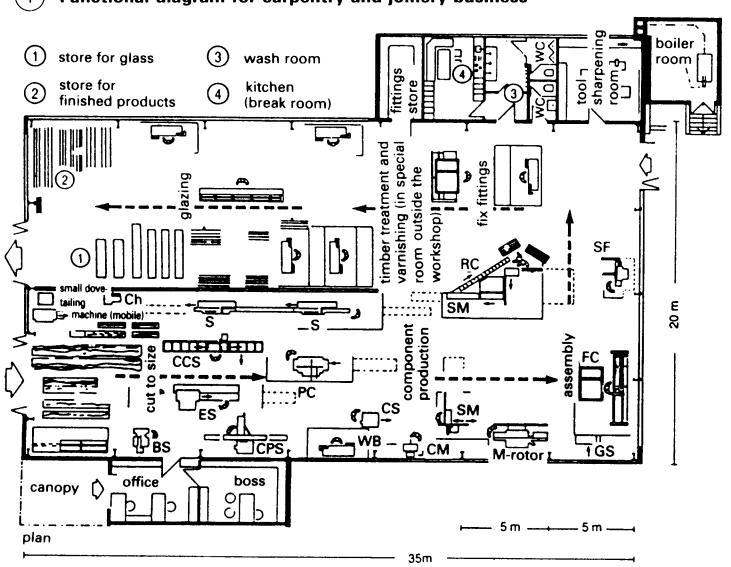
Machines should be set up to match sequence of work. All workstations should face the light. Window area should be approximately 1/8 of floor space.

WORKSHOPS: WOODWORKING

Operating design (planning): determine all factors relevant to the operational needs of the business. Machines: utilisation, costs and economic feasibility, power requirement, load-bearing capacity of floors, space requirement, costs. Production processes: production times, staffing levels, organisation of technical operations. Materials: types, quantities, weights, space requirement, storeroom dimensions. Energy supply: heat, electricity, compressed air. Waste materials: type, space requirement, waste management. Sequence of operations and tasks. Plan of operational utilisation of space (layout).



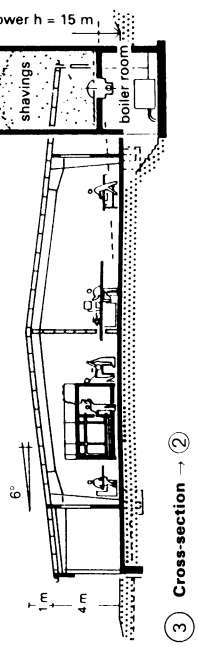
① **Functional diagram for carpentry and joinery business**



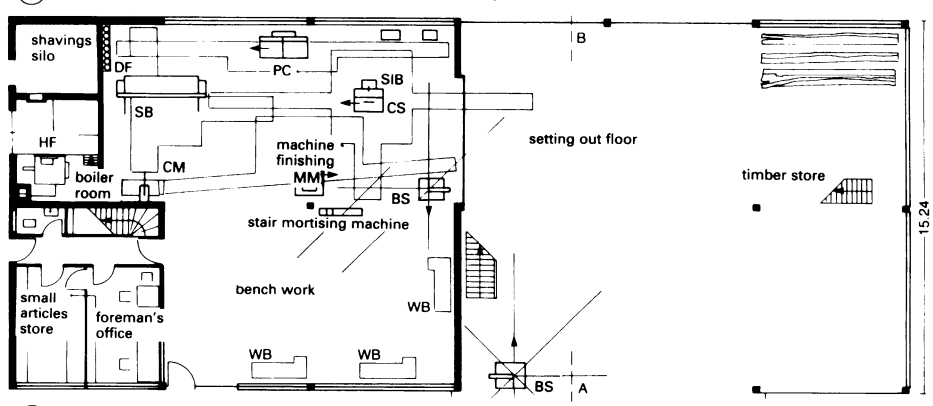
Tools and machines

CCS	cross-cut saw
CS	circular saw
ES	edging circular saw
CPS	panel circular saw
BS	band saw
PC	combination planing machine
PF	fine planing machine
S	shaping machine
M	milling machine
CM	chain mortiser
SM	slot mortising machine
SF	frame sanding machine
RC	roller conveyor
GS	glue-spreading machine
WB	work bench
FC	frame clamp
Ch	chopper

② **Example of a carpenter and glazier's business → ③**

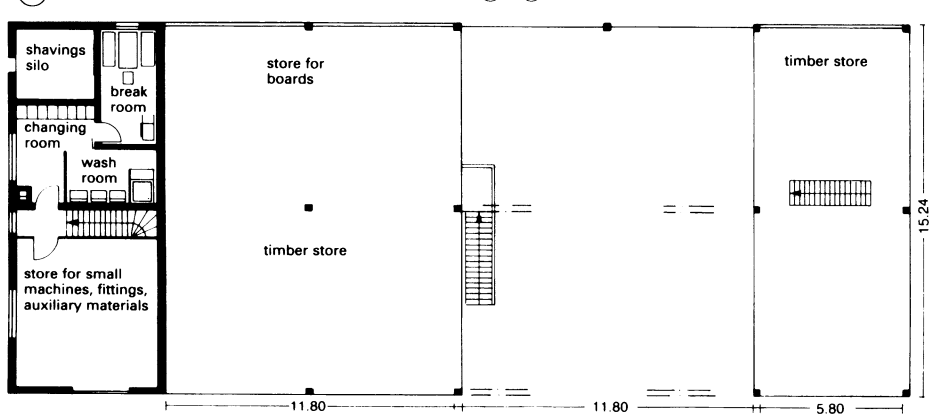


③ **Cross-section → ②**

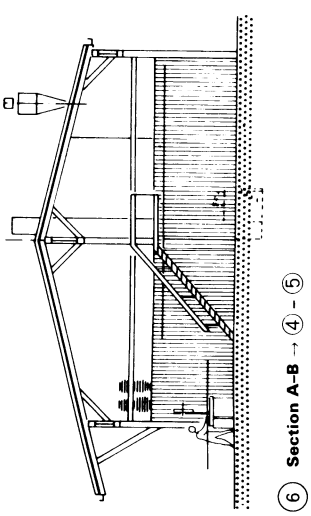


BS	band saw
CS	circular saw
SIB	slot boring machine
PC	combination surface planing machine
MM	mortising machine
CM	chain mortiser
SB	belt sanding machine
WB	work bench
HF	combined heating furnace for oil and c
DF	dust filter

④ **Example of a joiner's business - ground floor → ⑤ - ⑥**



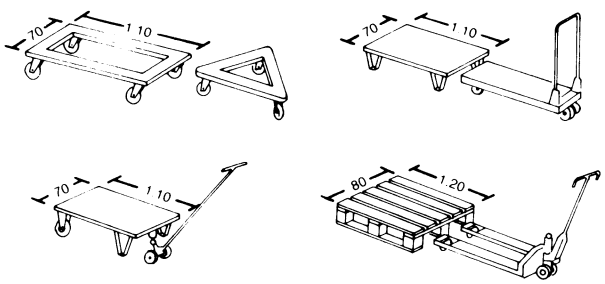
⑤ **First floor → ④ and ⑥**

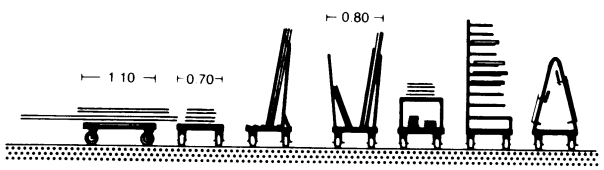


⑥ **Section A–B → ④ - ⑤**

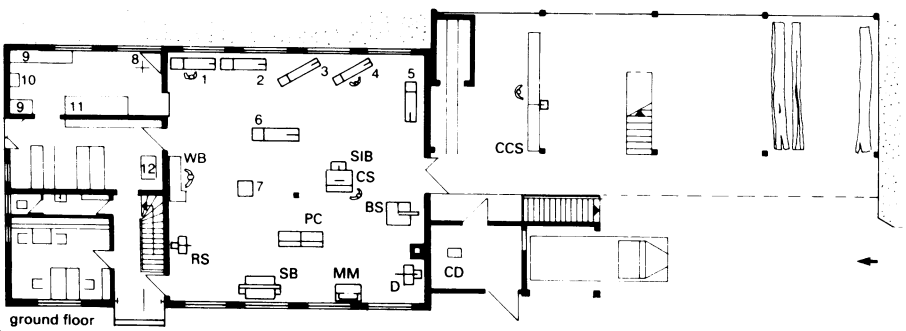
WORKSHOPS: WOODWORKING

Recent advances in automation technology in production, storage and distribution will need to be taken into account, particularly for larger businesses.



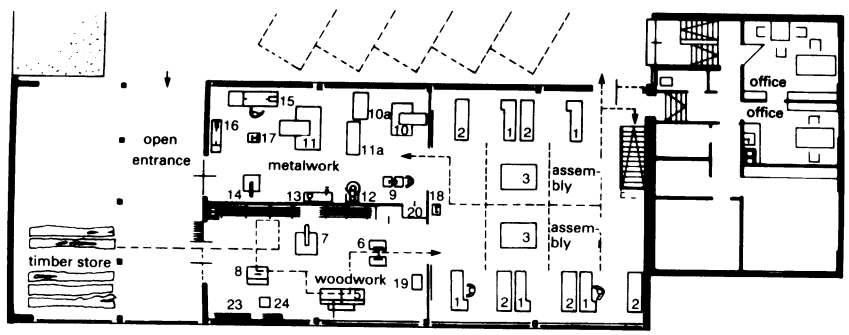


(1) **Types and dimensions of trolleys used for manual handling in a workshop environment**



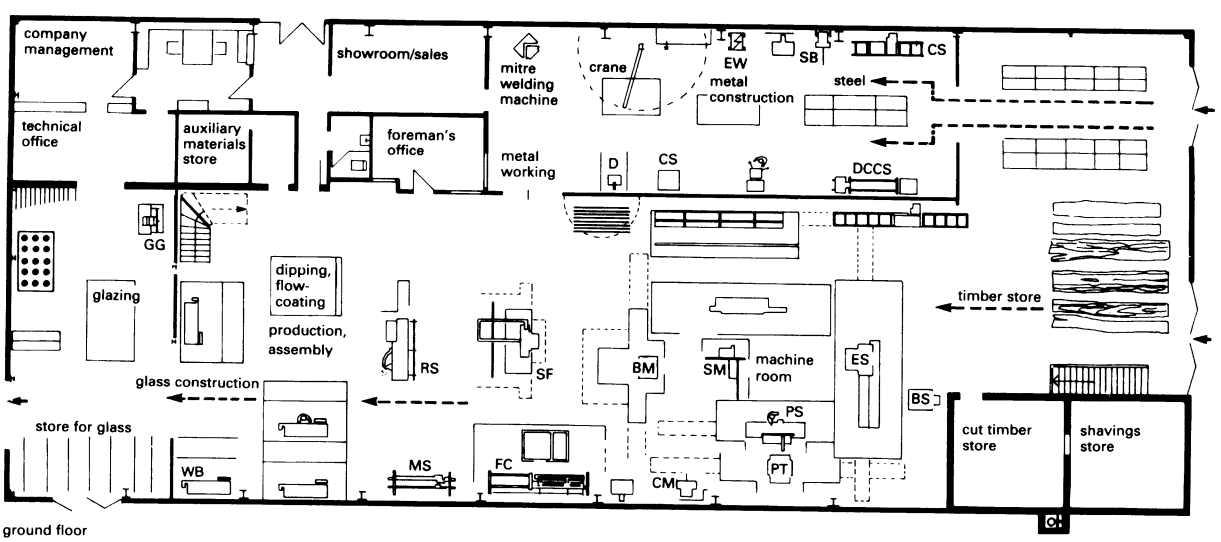
1–4 lathes
5 stave lathe
6 autolathe
7 round bar machine
8 spraying stand
9 storage bench
10 varnish dipping apparatus
11 varnish drying cupboard
12 polishing drum

(2) **Example of a wood turner's shop**



Assembly – bench room
1 carpenter's bench
2 tool bench
3 dressing plate
Woodwork
5 combined dressing and planing machine
6 disc sander
7 band saw
8 circular saw
Metalwork
9 disc grinder
10 milling machine 1 with tool bench
11 milling machine 2 with tool bench
12 post drill
13 work bench with vice and bench drill
14 band saw
15 lathe 1 (large)
16 lathe 2 (small)
17 grinding stand 1
18 grinding stand 2
19 tool sharpening machine
20/21 cupboards for auxiliary materials and tools
22 shelving for drying timber
23 board store
24 opening in the floor for ejecting wood waste

(3) **Example of a model-maker's workshop (five employees)**



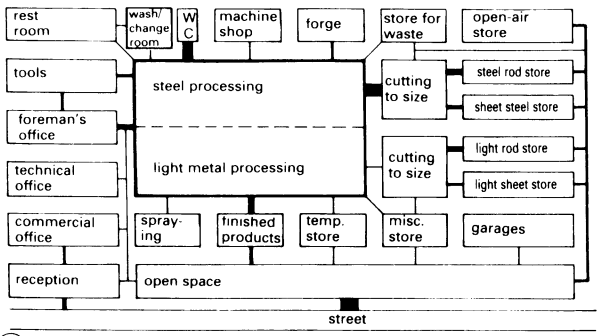
CCS cross-cut saw
SIB slot boring machine
ES edging circular saw
DCCS double cross-cut saw
BS band saw
PS surface planing machine
PT thickness planer
GG glass grinding machine

BM bench milling machine
CM chain mortiser
D drill
MS mountings setting machine
PD post drill
SM slot mortising machine
CD combination drill
CS circular saw

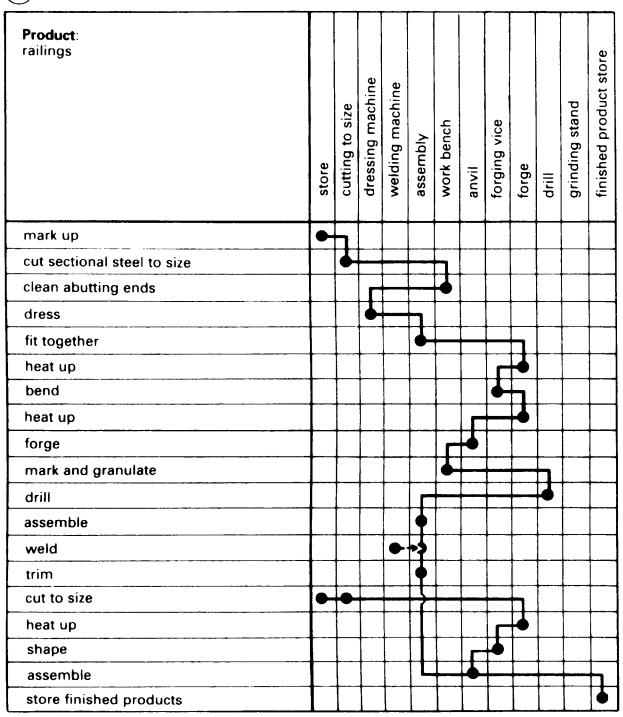
RS recessing/shaping machine
WB work bench
MM mortising machine
EW electric welder
SF frame sanding machine
FC frame clamp
SB belt sander

(4) **Example of a glazier's business**

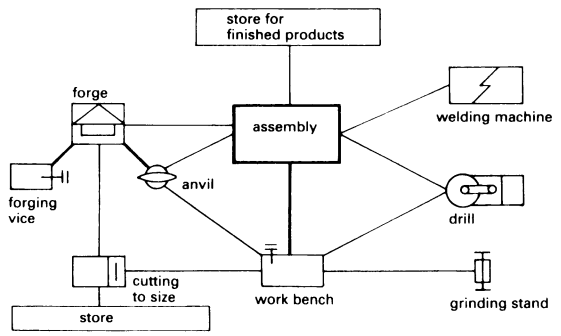
WORKSHOPS: METALWORKING



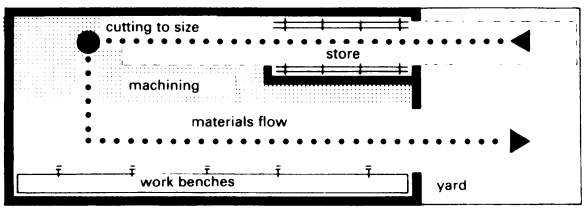
(1) **Space relationship diagram for a large metalworking company**



(2) **Production flowchart** → (3)



(3) **Example of sequence of work in an architectural ironmonger's shop** → (2)



(4) **Relationship between rod store and material flow**

Capacity of storage systems: examples

Shelving with brackets

width w = 1.0 m; height h = 2.0 m; length l = 6.0 m

Enclosed shelving space

$V = b \times h \times l = 1.0 \times 2.0 \times 6.0 = 12.0\,m^3$

If the density of material, r, is $0.8\,t/m^3$, the total weight stored would be

$R = V \times r = 12.0 \times 0.8 = 10\,t$ (rounded up)

If the number of employees working in production is 8, and each uses 7.5 t per year, the annual materials requirement is

$B = 8 \times 7.5 = 60\,t$

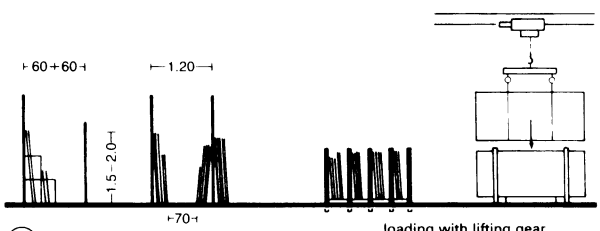
The store turnover frequency is then given by

$B \div R = 60 \div 10 = 6$ times

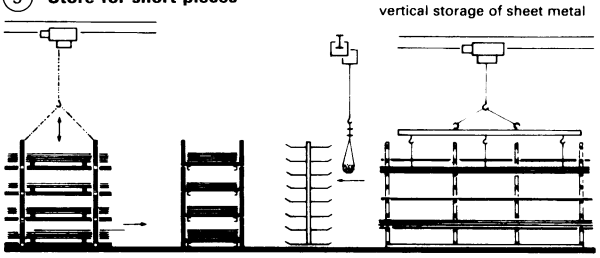
However, there is always lost space (space taken up by shelving itself, handling space, non-optimal storage) so a rack can never be fully (100%) used.

Compartments filled with objects of the same shape (homogeneous storage) – approx. 40% space usage

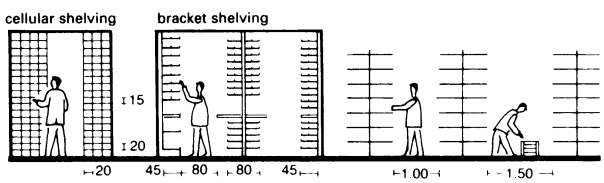
Compartments filled with a mixture of objects (heterogeneous storage) – approx. 20% space usage



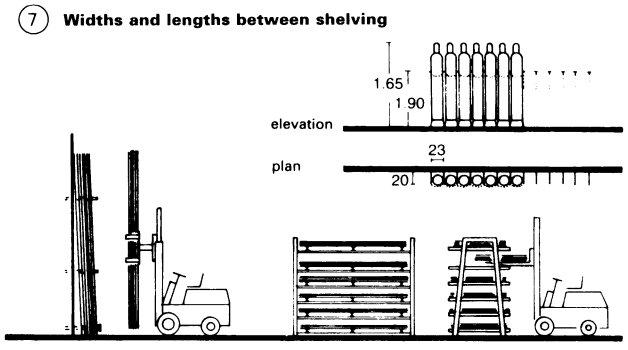
(5) **Store for short pieces**



(6) **Horizontal storage and transport of sheet metal and rods**

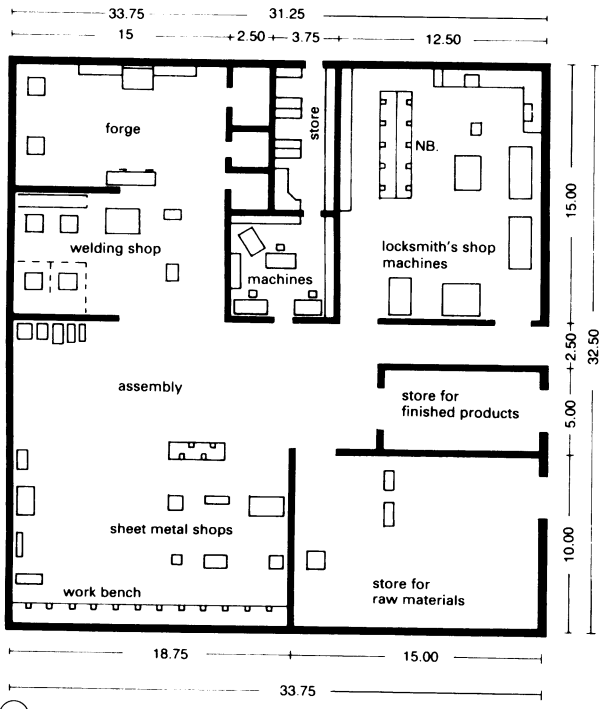


(7) **Widths and lengths between shelving**



(8) **Upright storage of rods**

WORKSHOPS: METALWORKING

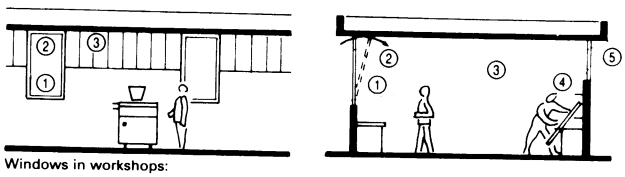


① **Position of machines and stores in a metalworking company**

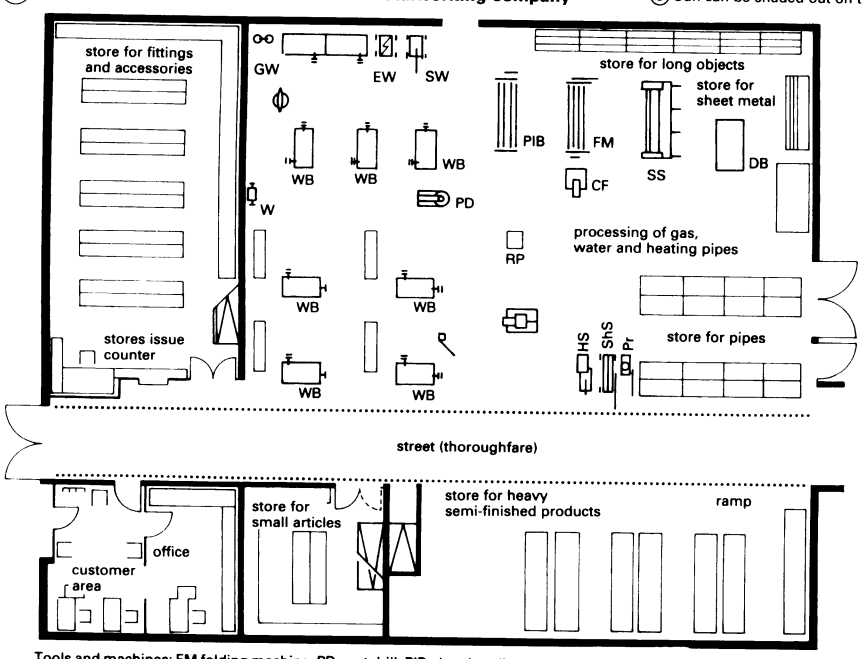
In larger metalworking businesses, the work areas are divided, as shown → ①.

Floor of concrete or, preferably, wood-block on concrete. Workshops are best lit from above and adequate lighting should be provided at each workstation. Individual control of machines is necessary (junction box in the floor).

Welding and forging shop Even in medium-sized work-shops, welding and forging areas should be sealed off by steel doors. Good ventilation should be provided. The welding bench surface should be made of firebricks. For cast iron and metal welding, charcoal pits are required for pre-warming, with small forge above that can also be used for soldering. Next to this, water and oil containers for quenching.

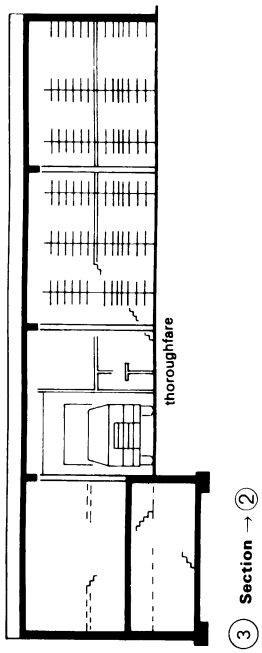


Windows in workshops:
① Workplace regulations (unrestricted view), low sill height
② Ventilation (high-level tilting windows)
③ Sufficient daylight into the middle of the shop (high windows)
④ Safety regulations (safe handling of glass sheets)
⑤ Sun can be shaded out on the southern side, e.g. using roof overhang

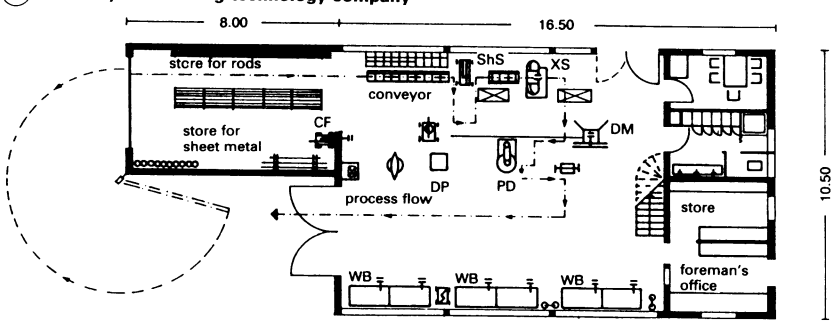


Tools and machines: FM folding machine; PD post drill; PIB plate-bending machine; DM dressing machine; DP dressing plate; HS hack-saw; XS bow-saw; SS sheet shears; ShS shaping shears; CF crimping and flanging machine; Pr press: W welding machines; GW gas welding machine; EW electrical welding machine; SW spot welding machine; DB drawing board; WB work bench

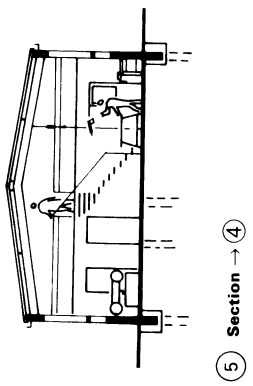
② **Sanitary and heating technology company**



Section → ② ③



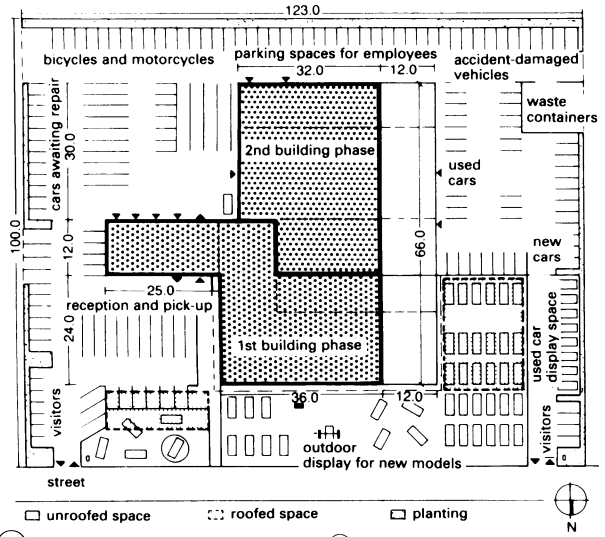
④ **Architectural ironmongery business and fine metal construction**



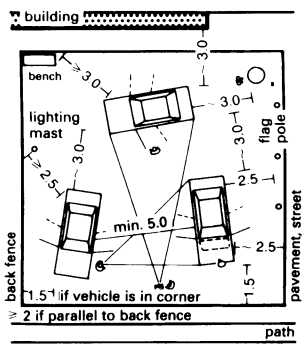
Section → ④ ⑤

WORKSHOPS: SHOWROOMS AND VEHICLE REPAIRS

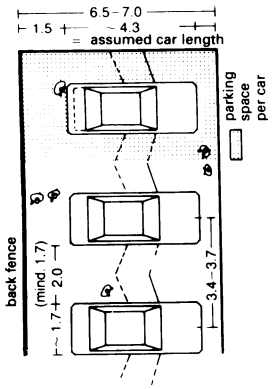
Site Ratio of built area to unbuilt area is approx. 1:3.5
Function/organisation Planning based on two versions of the 'three-point system' → ⑥
(1) works office, workshop, parts store
(2) service office, works office, parts store
Offices (depending on size of company): General manager's office 16–24 m², secretarial office 10–16 m², sales manager 16–20 m², after-sales service manager 12–15 m², stores manager 10–15 m², meeting room 12–24 m², accounts 12–20 m², sales personnel 9–12 m², computer room 9–16 m², works office 25–40 m². Storage space: 22–25 m² per workstation (in general repairs and body shop). Space per workstation: 4 × 7 m (general repairs, bodyshop, paint shop) for cars; 5 × 10 m for light commercial vehicles.



① **Standard industry repair shop** → ④



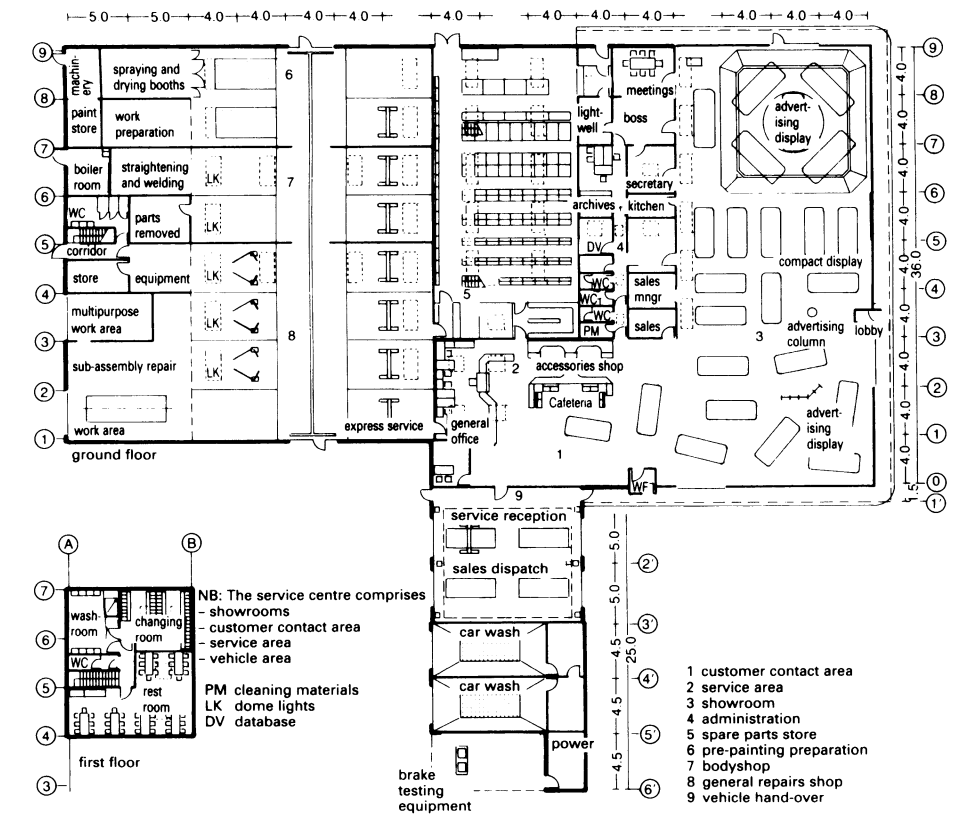
② **Average space requirement for a car showroom**



③ **Average space requirement for a compact new car display**

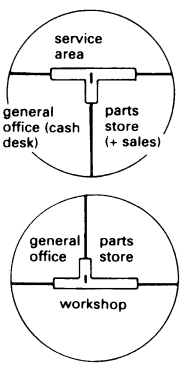
annual car sales	cars to be attended	size of site in m²	total built area in m²	space requirement per car sold	workshop area in m²	repair bays	inspection spaces	valeting bays	reception bays	car wash	polishing bays
50	150	2000	480	7.20	360	4	–	1	–	1	–
100	300	3000	835	6.25	625	7	1	1	–	1	–
200	600	4000	1420	5.70	1220	10	1	1	1	1	–
300	825	5000	2150	5.35	1610	16	3	1	1	2	–
400	1000	6000	2620	4.90	1960	19	4	2	1	2	1
500	1250	7000	2980	4.45	2230	23	5	2	2	2	2
750	1725	9000	4500	4.45	3375	32	6	3	2	X	–
1000	2000	10000	5770	4.30	4300	38	7	3	2	X	–

⑤ **Repair shop space requirements**



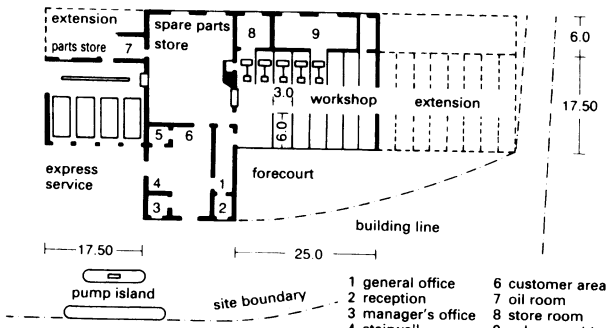
④ **Example of a motor repair shop**

Showroom: potential customers must be able to walk around the vehicle freely and to open the doors. Therefore, both the space per vehicle and the distance between them are important. To be able to see a vehicle properly the viewer ideally needs to be 5 m from it. → ② – ④
Guideline: for new cars, approximately 40–45 m² display area per car. Compact display, → ③: approximately 24 m² per car; distance between vehicles > 1.70 m.

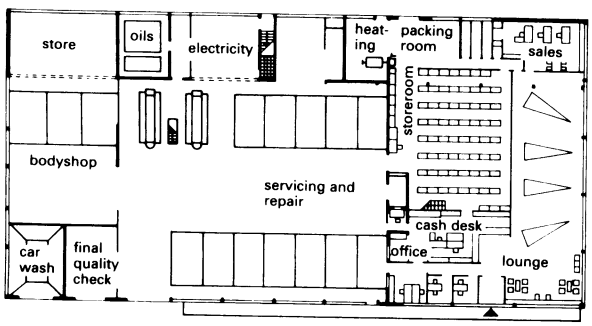


⑥ **Interdepartmental relationships (three-point system)**

VEHICLE REPAIR SHOPS



(1) **Example of a medium-sized car repair shop**



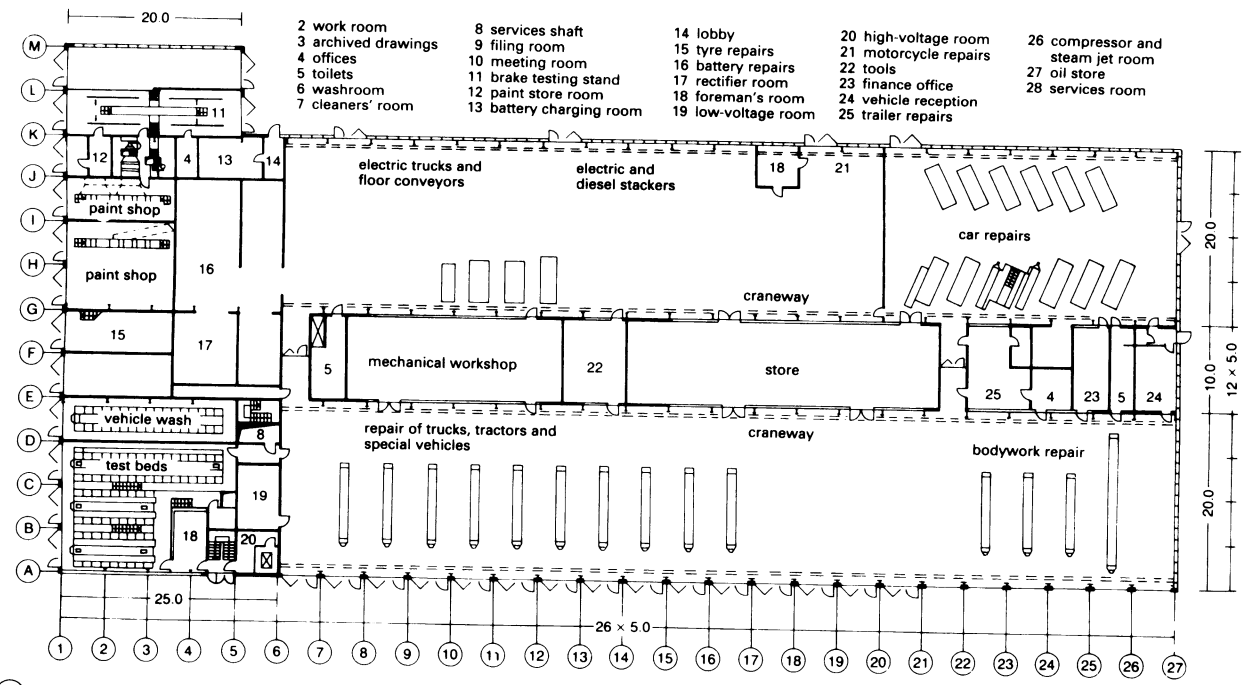
(2) **Car repair shop with administration and sales**

Usually single storey of light steel construction or prefabricated elements. Single-span shed without columns is preferable. Choose an appropriate module to allow extension.

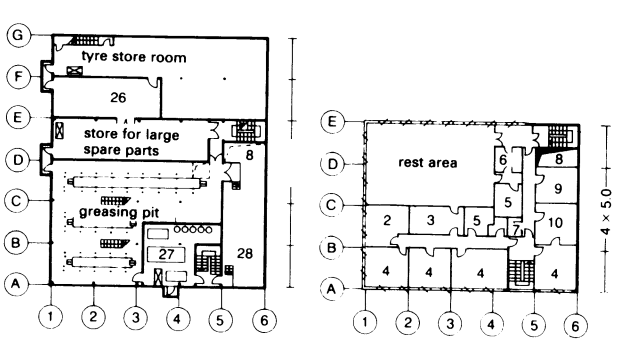
Workshop floors should be sealed against grease and oil. Petrol and oil traps are essential. Provide extractor duct for exhaust fumes. Provide automatic doors with hot-air curtain → p. 185–6. Installation of ducts for electricity, compressed air, used oil and water is recommended. For companies with a service department choose a location with good transport links if possible, even if development and building costs are higher. If the site is on the edge of town provide appropriate advertising and transport for customers.

Basic rules: site built area 1/3 to 2/3 unbuilt area. Allow for possible extension. For larger companies the average area is 200 m² per workshop employee. Added to this are rooms for sales, works office, customers' waiting room, social rooms etc. Check mains services. For car washes high water consumption should be taken into account.

Large company workshop → ③ – ⑦ for lorries, towing vehicles, special vehicles, containers and trailers, cars, fork-lifts and electric vehicles.

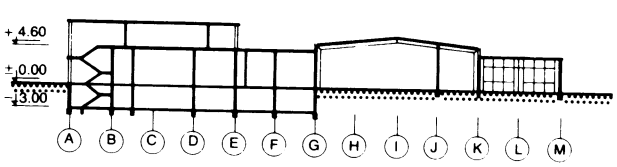


(3) **Workshop for transport vehicles, ground floor**

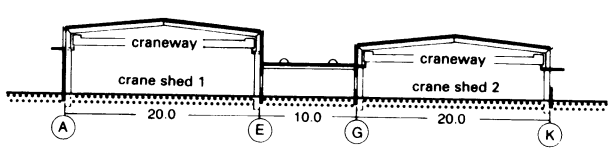


(4) **Basement**

(5) **First floor**

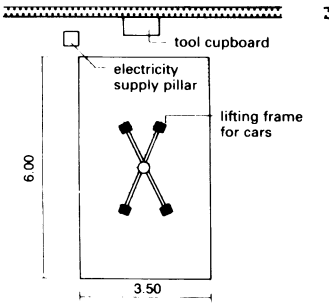


(6) **Cross-section, axis 5**

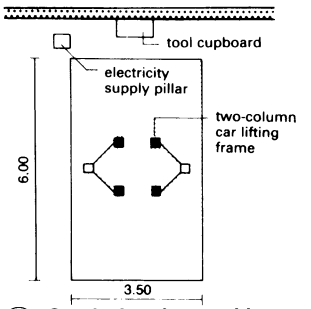


(7) **Cross-section, axis 16**

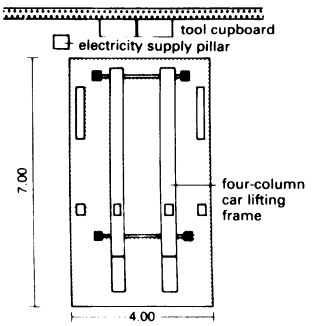
VEHICLE REPAIR SHOPS



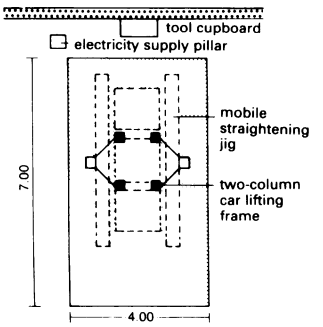
① **Standard work area with lifting frame for cars 3.5m × 6.0m: hoist height 1.0m**



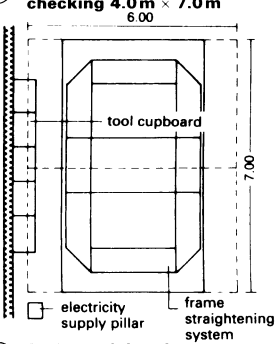
② **Standard work area with two-column car lift 3.5m × 6.0m: hoist height 0.70–1.10m**



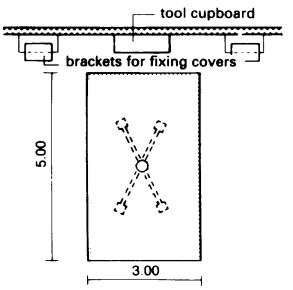
③ **Optical alignment checking 4.0m × 7.0m**



④ **Body straightening jig 4.0m × 7.0m**



⑤ **Body straightening jig 7.0m × 6.0m**



⑥ **Pre-painting preparation area – with or without lifting frame 3.0m × 5.0m**

It is not possible to use a fixed scheme when planning and building car-body repair shops, as local conditions usually vary considerably. Instead, it is necessary to use a planning method which is based on service and working procedures and which takes company-specific features and needs into account.

On completion of the first building phase the operation should be fully functional. Thereafter, it should be possible to enlarge the company at any time.

In a car-body repair shop the workstations are virtually all fixed and equipped with different tools. They should be designed in such a way that tasks can be carried out economically and in the shortest possible time, with minimum movement.

For companies involved in vehicle repair it is useful to structure the workshop on a 'performance production principle'. Vehicles are driven into the workshop and remain at the designated repair bay until the work is finished.

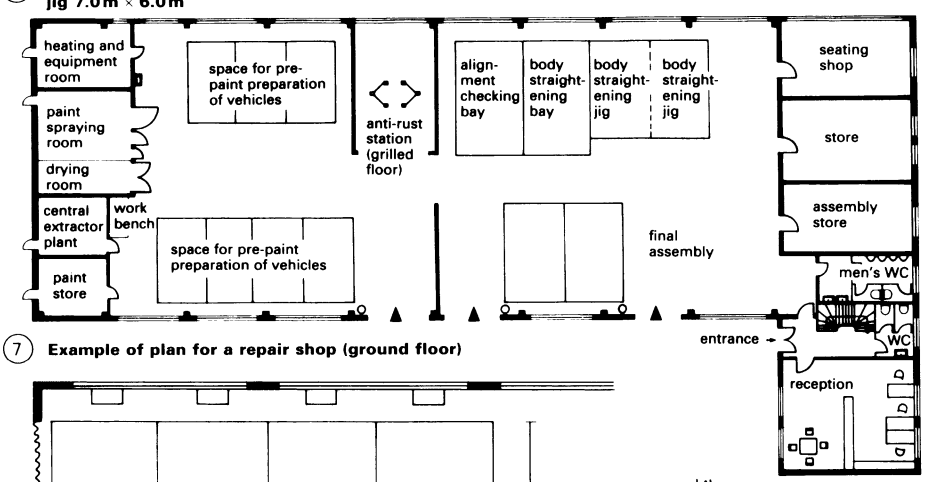
Example → ⑦ shows a plan of a bodyshop for repairing and servicing cars and small trucks, employing about 14 people in the workshop and two in the offices. All functional areas where repair work is done are on one level and kept apart from the customer area by separate entrances.

To avoid noise and dust pollution the paint- and bodyshops should be separate. Due to the different sizes of vehicles to be repaired and the different kinds of repair work there is only a limited possibility of making fixed plans for workstations and machine positions.

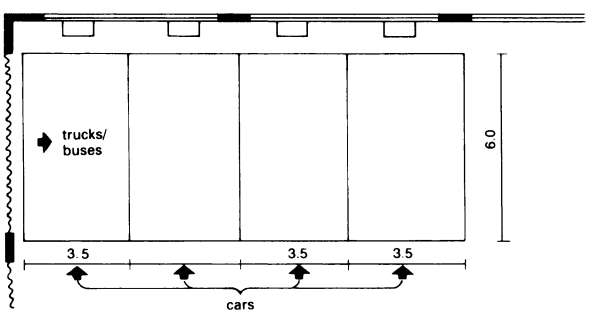
The dimensions of the workstations should therefore be such that even when the repair shop is fully occupied, mobile work benches or the required tools can be moved to the vehicle. Lay service ducts overhead.

In paintshops use the following standard dimensions for spray booths (clear dimensions): length 7.00m, width 4.00m, height 2.85m. Design: construction in insulated sheet metal or brickwork or self-contained system for use outdoors.

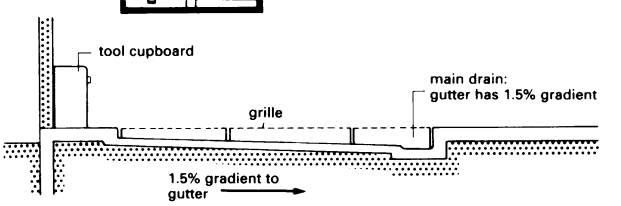
Customer reception area should be on the ground floor; accounts, manager's office, social rooms etc. can be on upper floors.



⑦ **Example of plan for a repair shop (ground floor)**

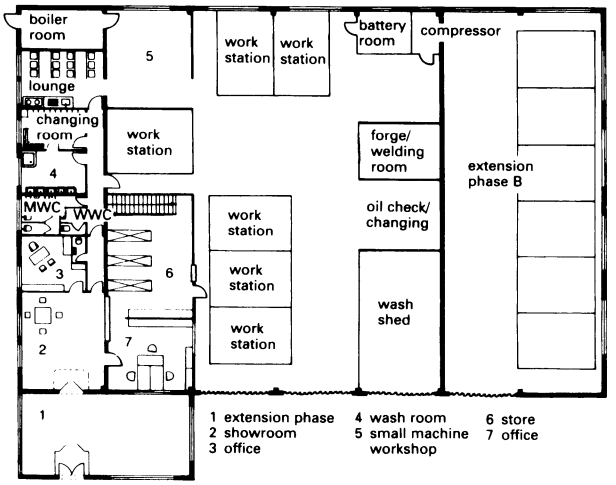


⑧ **Area for work on trucks 6.0m × 14.0m, consisting of four standard work bays, 3.5m × 6.0m each**

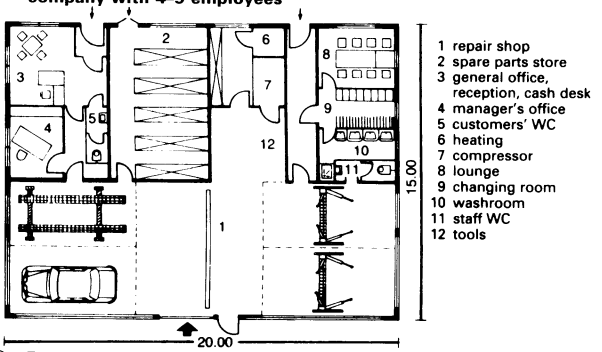


⑨ **Schematic diagram of a painting preparation shop with a grilled floor → ⑥**

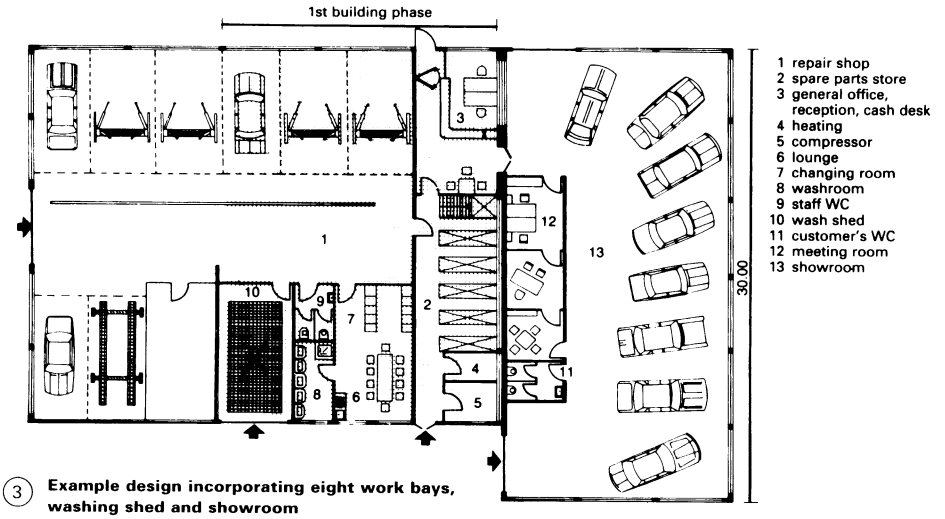
VEHICLE COMPANY WORKSHOPS



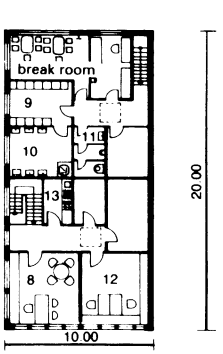
(1) **Example design for an agricultural machinery company with 4–9 employees**



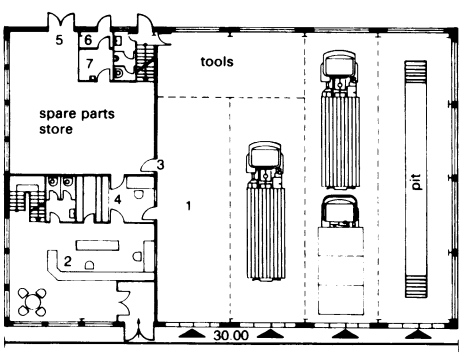
(2) **Example design incorporating four work bays on a site with broad street frontage**



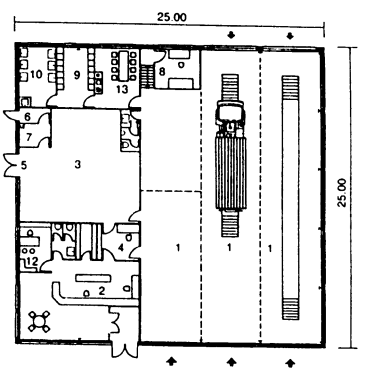
(3) **Example design incorporating eight work bays, washing shed and showroom**



(4) **First floor → (5)**



(5) **Example plan for a truck company without thoroughfare**



(6) **With thoroughfare**

Design of premises: after space requirement has been established and a site chosen, planning the building can begin. The characteristics of the site, such as size, shape, vehicle access, road design etc., must be taken into consideration.

Planning example → (2) Planning permits an efficient functioning design of all required spaces and facilities. The repair shop is designed to accommodate four 6.50 m × 3.50 m workstations, and equipped with a four-column car lifting frame and wheel balancing equipment; nearby spare parts store.

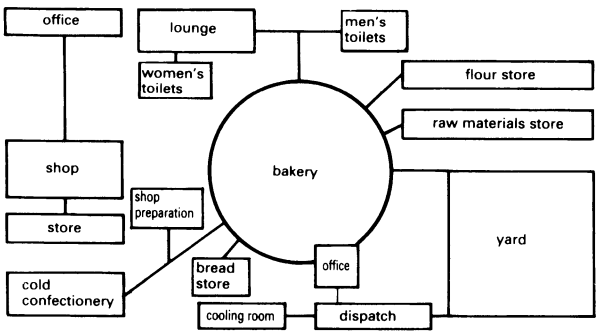
Planning example → (3) First construction phase includes three work bays in the repair shop and a car wash. The finished scheme has an extra five workstations in the repair shop and a showroom.

In a company working with commercial vehicles the choice of position for the gates depends primarily on the shape of the site. From both the fitters' and customers' points of view, the best design is one where entry to and exit from the repair bays are through separate gates, particularly for work on articulated vehicles.

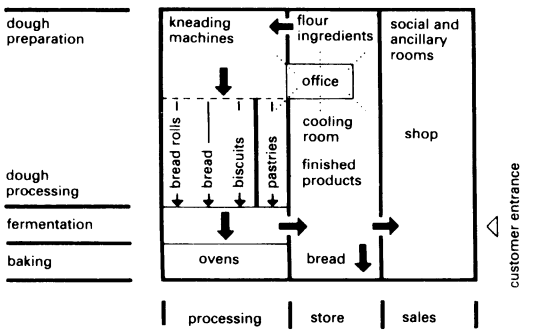
Ideally, the site depth or width should be ≥ 80 m but repair shops for light commercial vehicles are possible on sites with little depth (minimum 40 m). → (4) - (5) for a company working with light commercial vehicles and buses.

Plan examples → (4) - (6) show the smallest unit of an independent commercial vehicle repair service. Offices and social rooms on the first floor → (4).

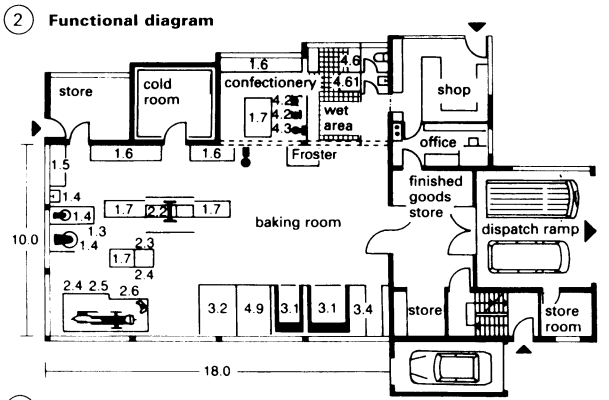
WORKSHOPS: BAKERY



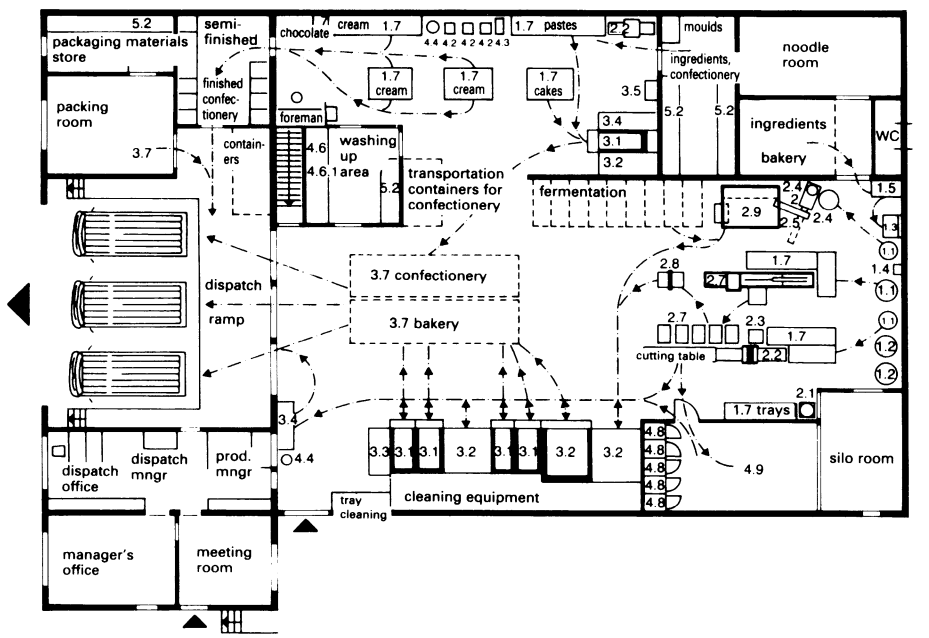
① **Space relationship plan**



② **Functional diagram**



③ **Example plan layout**



④ **Example plan layout**

③ – ④ key

1 dough preparation
1.1 kneading machine
1.2 kneading bowl
1.3 suspended or floor scales (flour)
1.4 basin – for mixing and measuring water
1.5 ingredients table
1.6 work table with flour trolley
1.7 work table
1.8 mixer
2 dough processing
2.1 dough portioning and kneading machine
2.2 rolling machine
2.3 croissant machine
2.4 dough portioner (by weight)
2.5 rotary kneading machine
2.6 rolling machine
2.7 bread roll machine
2.8 dipping machine
2.9 hydraulic portion cutter
3 baking area
3.1 oven
3.2 fermentation room
3.3 soaking machine
3.4 metal covered finishing table (icing etc.)
3.5 hand basin
3.6 baking tray washing machine
3.7 finished goods store
4 confectionery
4.1 confectionery cooling table
4.2 mixing and whipping machine
4.3 orbital paddle mixer
4.4 gas cooker
4.5 deep fat cooking
4.6 sink with floor drain
4.6.1 dishwasher
4.7 cream cooler
4.8 froster
4.9 fermentation interrupter
5 miscellaneous
5.1 floor drainage
5.2 shelving

Systematic planning must anticipate possible future developments in technology and operating procedures to which building elements will have to adapt. The planning procedure must also always include a review of the location.

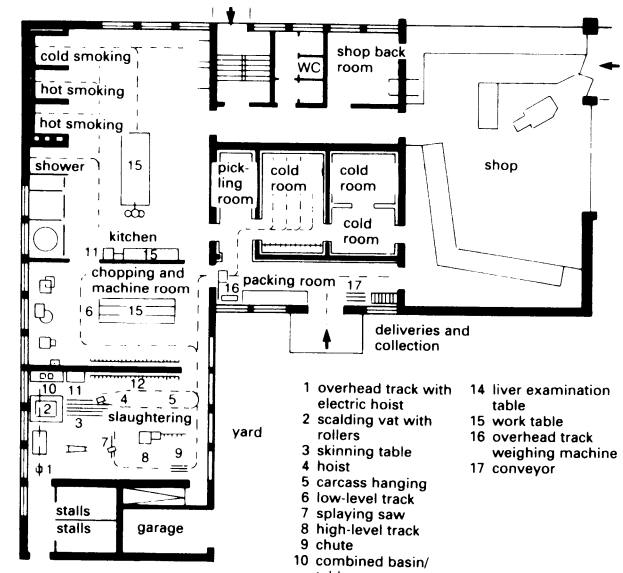
Schedule of accommodation and space requirements
There is a basic division into store areas, production areas, sales areas, building services areas, offices for administration and management, social rooms and ancillary rooms. → ①

Work processes in or between the individual areas → ②

Distinction should be made between store rooms for raw materials (coarse meal, sugar, salt, baking powder, dry goods in sacks, flour in silos or sacks), ingredients (fruit, garnishings, dried fruit, fats, eggs) and packaging. Daily supplies are stored at the workstations. Establish space requirement for containers (shelving, racks, cupboards), stacks, counters and circulation (corridors). Minimum area for stores is 15 m²; roughly 8–10 m² per employee for all store rooms. Routes between stores and work areas should be short.

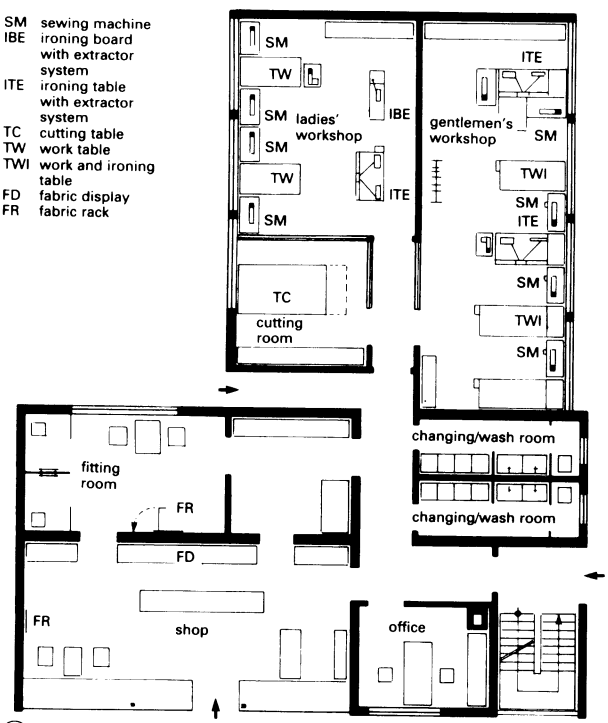
Work areas for bakery and pastry should be separate. The bakery needs a warm and humid environment; pastry making needs a rather cooler environment. The bakery includes the following areas: dough preparation, working of dough, baking, storage of finished products. Pastry making is split: cold area (butter cream, cream, chocolate, fruit) and warm area (pastes, cake, pastries and biscuits).

The space requirement can be determined using a layout plan. In a work area space is needed for equipment, for handling and working, for intermediate storage (trolleys) and counters, and for circulation (lost space).

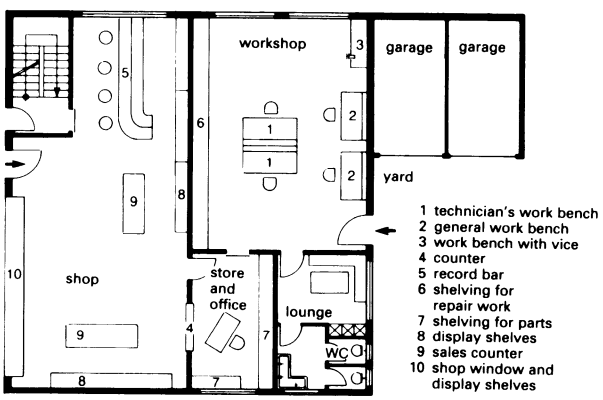


(1) **Example of a butcher's**

SM sewing machine
IBE ironing board with extractor system
ITE ironing table with extractor system
TC cutting table
TW work table
TWI work and ironing table
FD fabric display
FR fabric rack



(2) **Example of a tailor's (ground floor)**



(3) **Example of an electrical repair (ground floor)**

Butcher's shop → (1)
Model plan; 6–7 employees
Functional sequence within a sausage making company. Meat arrives in machine room for cutting and mincing, is taken into the smoking chamber and then into the boiler (kitchen). From there it is sent to the cooling area or shop.

Height of working areas (depending on size of company) ≥ 4.0 m. Width of circulation routes ≥ 2.0 m. Work space around cutter and mincer: 3 m² each.

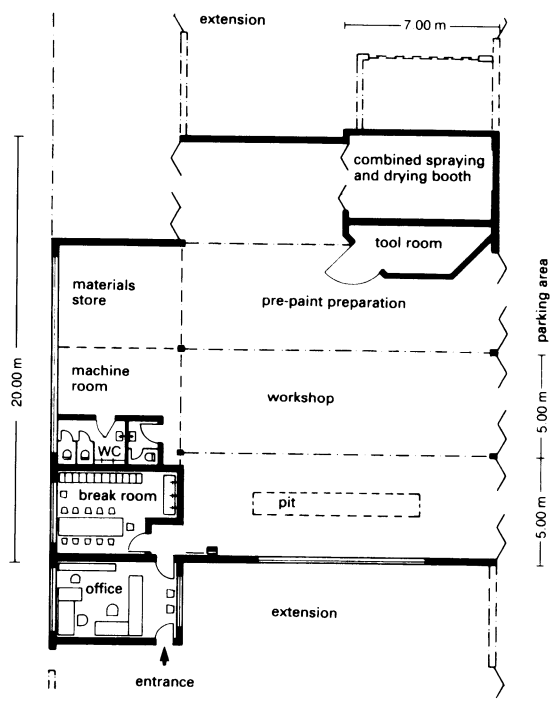
Distance of machines from walls (for repairs) 40–50 cm. Cooling machines which work day and night must have good sound insulation. Water supply with hose connection should be provided in the kitchen, machine room and salting room. Floors should be non-slip and waterproof, preferably with corrugated tiles and drains. Walls should be tiled high. Good general lighting is needed, with 300 lx at workstations. Provide staff room, lockers, WC and shower for employees. Comply with relevant regulations on health and safety in the workplace, building regulations and accident insurance.

Ladies' and gentlemen's tailor → (2)
Model layout for 10 employees

Electrical repair shop → (3)
Work spaces should have a clear height of ≥ 3 m with 15 m³ air volume per employee. To minimise the risk of electrocution in the workshop, faultless insulating floor coverings should ideally be provided; at the very least the work benches for the technicians should be insulated. Recommended lighting level is 500 lx; 1500 lx for very fine assembly work.

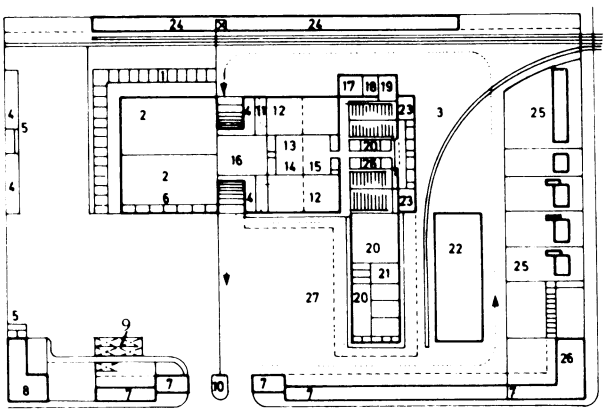
Work benches must have a spacious worktop (1.0 m × 2.0 m if possible). Provide two under-desk units with shallow drawers for circuit diagrams, documentation and tools.

Example paint shop → (4)
Includes extension possibilities.



(4) **Example of a spray painting shop (ground floor)**

WHOLESALE BUTCHERS



1 unloading bays
2 market hall
3 railway track
4 stall
5 hot fermentation
6 staff and equipment rooms
7 administration
8 sanitary facilities
9 disinfection
10 porter
11 blood draining
12 slaughter hall
13 examination for diseases
14 vets
15 offal
16 yard
17 heating plant
18 workshop
19 plant room
20 cold room
21 freezer and storage room
22 cold store
23 staff
24 bone silos
25 works flats
26 garden restaurant
27 collection area

(1) **Layout of large abattoir and cattle yard**

Animals in abattoirs need to be provided with modern pens where they can be fed, watered and kept calm because this influences the quality of the meat, as does humane, painless anaesthetisation and slaughtering. This also allows a more complete draining of the blood and in turn ensures that the meat looks attractive and can be preserved for longer.

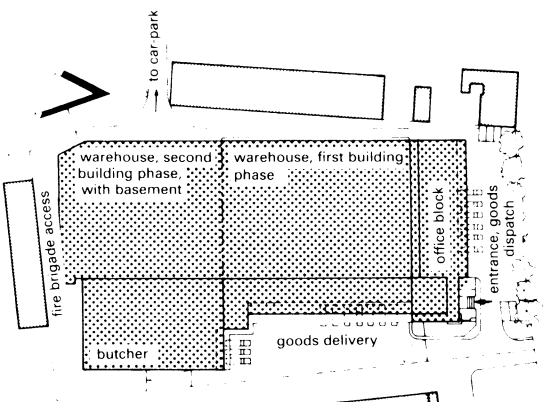
Following the BSE crisis many new practices have become compulsory so it is essential to consult the relevant guidelines at the start of the planning process.

The examples shown in ② - ⑤ are constructed on a grid of 15.50 × 15.50m. This evolved from the positioning of shelving in the central food store and allows for the width needed for fork-lift trucks (→ p. 392). Pallets are stacked in fives in racks, the two lower shelves containing pallets ready for dispatch, the top three shelves containing stocks.

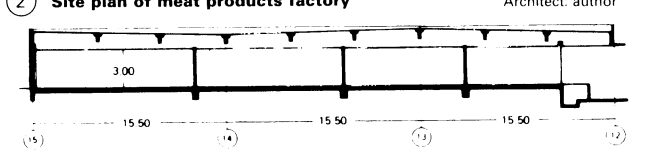
This uniform grid is also used for other parts of the building such as the butchers' workshop (2 × 3 grid panels) and the offices. Extensions can be made using the same grid.

The butcher receives half-carcasses of pigs and cattle from the abattoir and processes them into ready-to-sell portions or cooked meat products and sausages. A deep freeze room is needed for imported poultry and a separate cold room for butter and margarine. A waste incinerator can be used alongside the oil heating system to heat the building, and in summer to air-condition the offices and run small cooling plants.

The required minimum height for processing is 3m → ③. The slaughter area for large animals, which includes a winch, should be 1.50m higher. The windows should be high enough to prevent children from looking in and walls should be tiled to a height of ≥2m.

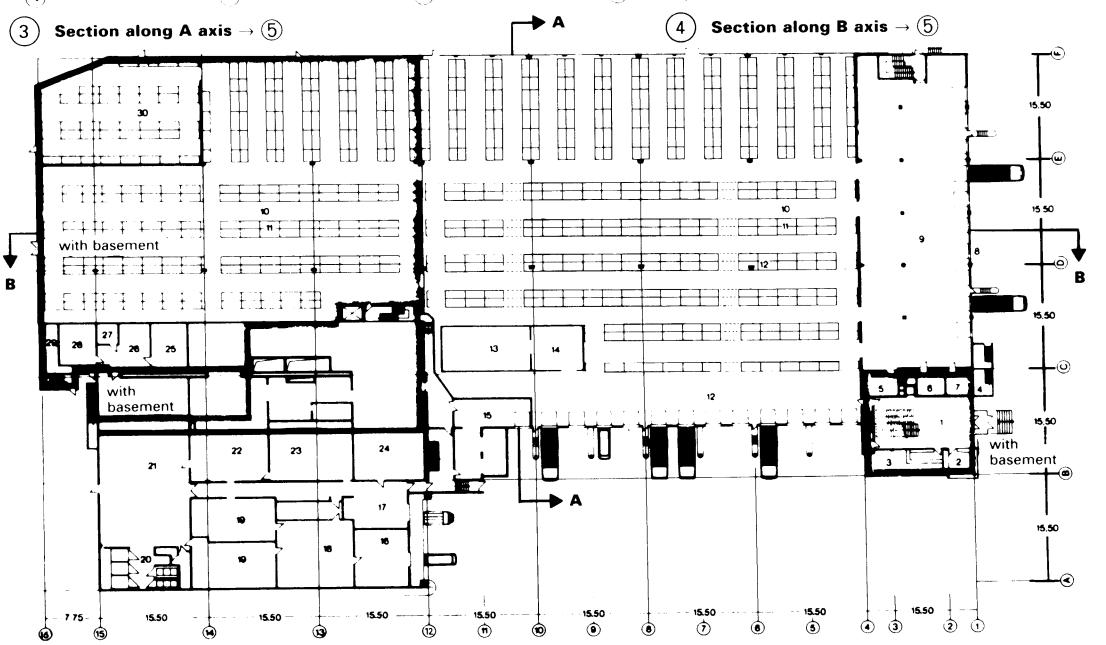


(2) **Site plan of meat products factory** Architect: author



(3) **Section along A axis** → ⑤

(4) **Section along B axis** → ⑤



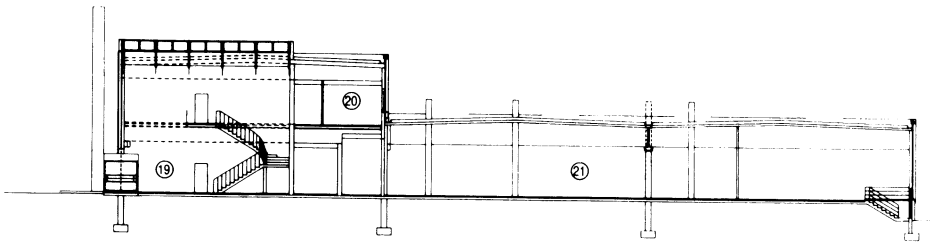
1 entrance hall
2 reception
3 wages deptartment
4 waste elevator
5 foreman's office
6 returns
7 refuse bunker
8 rolling shutter doors
9 goods out
10 store area
11 storage racks
12 goods in
13 cold room
14 cold room
15 washing machine for containers
16 order preparation
17 goods in
18 dispatch
19 cold room
20 smoke room
21 cold meat processing
22 defrosting room
23 cold room for meat
24 cold room for fats
25 pickling room
26 cold room for processed products
27 offal
28 freezer room
29 spices
30 spray store

(5) **Ground floor of meat products factory**

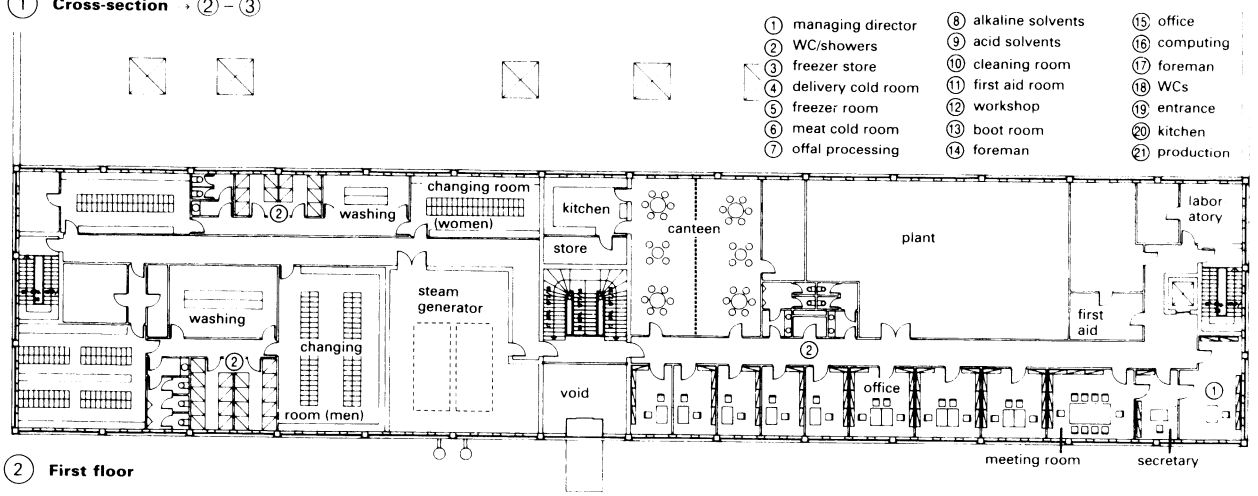
MEAT PROCESSING CENTRE

On a ground floor area of 4500 m² → ③, cold meats, ham, sausages and delicatessen products are manufactured (approximately 25 tonnes per day). Offices, laboratories, canteen, kitchen, wash and changing rooms are on the first floor → ②. Different types of rooms require different temperatures: social rooms, offices, WC, 20°C; processing rooms, 18°C; air-conditioned rooms, 14–18°C; cool rooms 10–12°C; cold rooms, 0–8°C; deep-freeze rooms, –20°C.

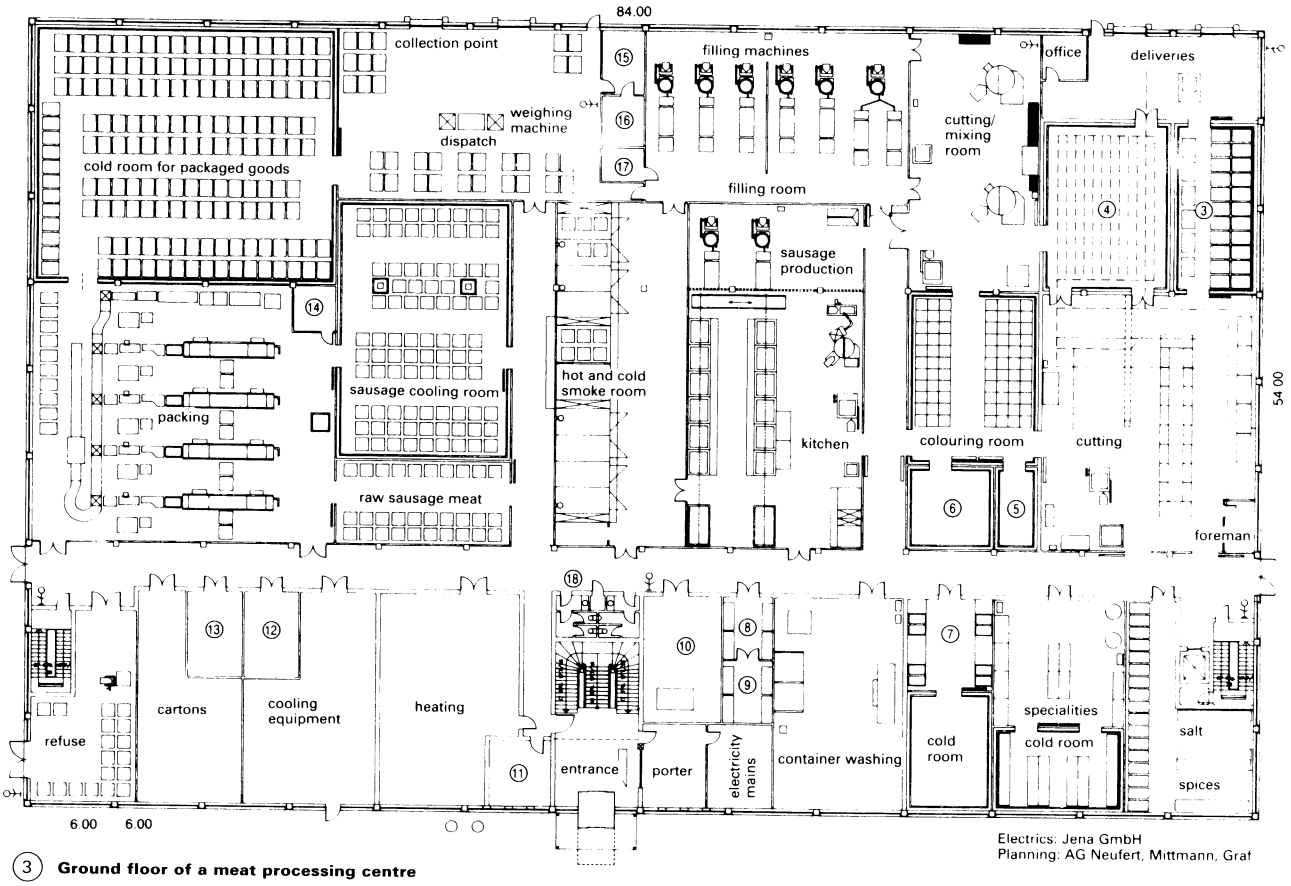
A high standard of structure and materials is essential and all health regulations should be satisfied.



① **Cross-section** → ② – ③



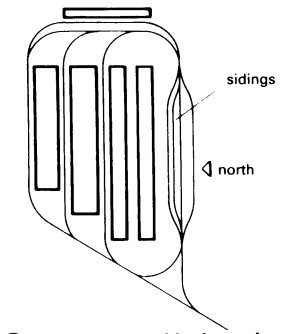
② **First floor**



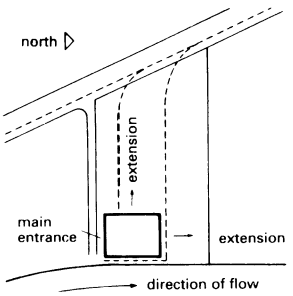
Electrics: Jena GmbH
Planning: AG Neufert, Mittmann, Graf

③ **Ground floor of a meat processing centre**

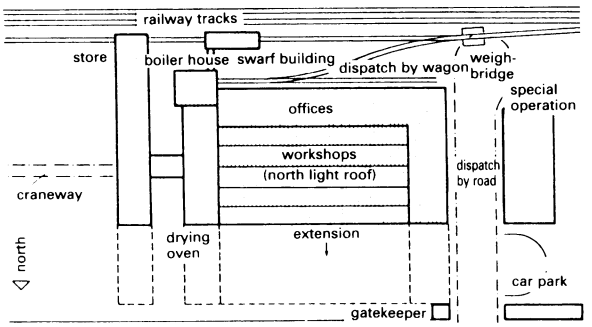
INDUSTRIAL BUILDINGS: PLANNING



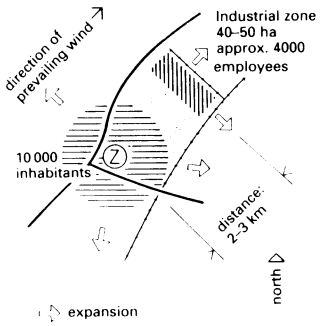
① **Factory served by looped branch railway lines**



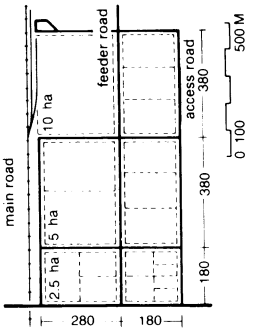
② **Factory on a waterway, with extension possibilities on two sides**



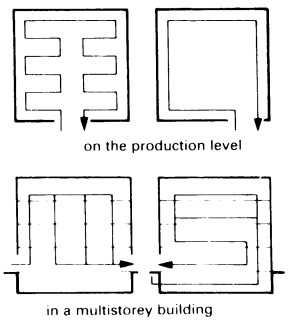
③ **Factory beside a railway line; possibility of extension towards the road** Architect: Walter Gropius



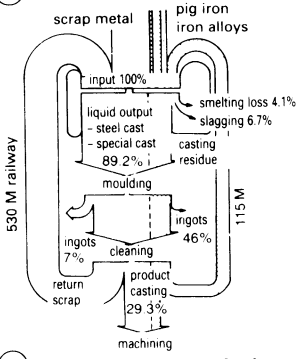
④ **Siting of an industrial zone**



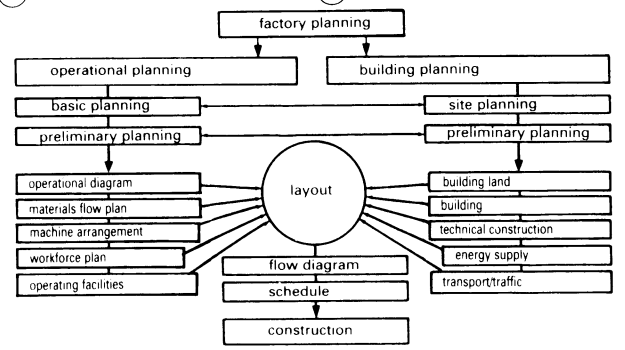
⑤ **Diagram of an industrial zone**



⑥ **Materials flow**



⑦ **Materials flow – quantitative**



⑧ **Planning diagram for a factory**

(1) Siting

Location factors:

- raw materials
- markets
- workforce

The order of priority of these factors when selecting a location depends on the individual company's strategy in relation to the cost of raw materials, transport costs and labour costs.

(2) Site

Needs relating to site area are determined by the space required by the building, roads and rail track.

A rail track plan should be drawn up, since railway lines take up a lot of space due to wide turning circles. → ①

Suitable sites are those with railway lines running into the site diagonally. Otherwise the building can if necessary be positioned at an oblique angle.

In case of frequent rail traffic branch lines through site should be provided, which would allow a continuous flow. → ①

Sidings ending at the front of the shed are often sufficient for goods loaded by crane.

(3) Schedule of accommodation

The schedule of accommodation includes details about:

- type of use
- room sizes in square metres
- room sizes in clear dimensions
- number of employees, segregated according to gender (sanitary facilities)
- machine layout plan
- live (rolling, working) loads, single or point loads

Special requirements and other specifications include:

- noise and vibration countermeasures
- protection from fire, toxic and explosive substances
- energy mains supplies
- air conditioning
- escape routes
- intended or possible extension

(4) Operational planning

Careful operational planning is essential before work on planning the building begins. Process flows are depicted according to the type of production and estimated on the basis of annual production figures or number of employees.

If no empirical data are available, the works engineer will have to determine the usable space requirement on the basis of the machine layout plan and other company operating facilities.

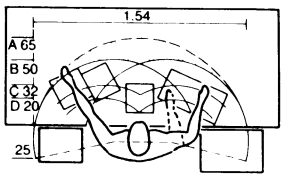
The basis for the operational planning is taken from analysis of the following:

- operational diagram (of the production systems)
- materials flow diagram (essential criteria for evaluating economic efficiency and important basis for layout plan)
- machine location plan
- workforce plan
- schedule of accommodation
- list of buildings

Layout planning (i.e. allocation of employees, materials and machines designed to bring about the lowest production costs per unit) is the starting point for all industrial planning. From this, the basis for the factory design is derived – adaptability, extension possibilities, economic efficiency.

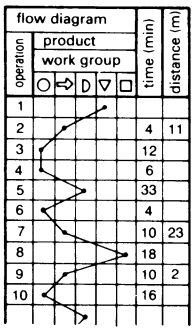
Note: the techniques of network planning and other methods are appropriate → ⑧

INDUSTRIAL BUILDINGS: PLANNING

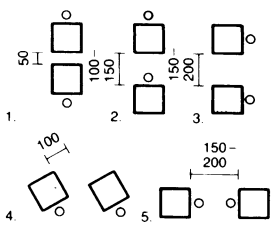


A maximum possible reach (≈ 65 cm)
B physiological limits of reach (≈ 50 cm)
C normal reach (≈ 32 cm)
D physiological inner limits of reach (16–20 cm)

① **Stier's guideline dimensions for optimum accessibility**

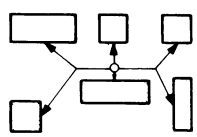


② **Production process flow**

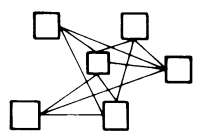


- work bench with small machinery (10–15 m²)
- regular machines (15–40 m²)
- add on space for: circulation; storage (30%)

③ **Guidelines for space requirements in engineering factories**

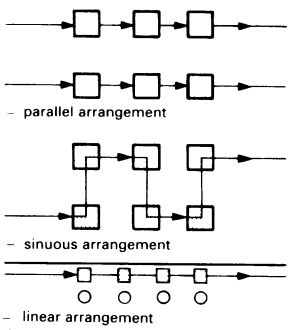


- work place system



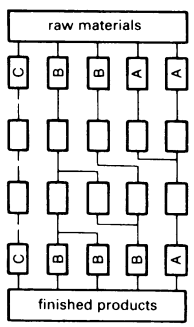
- workshop system

④ **Production systems**

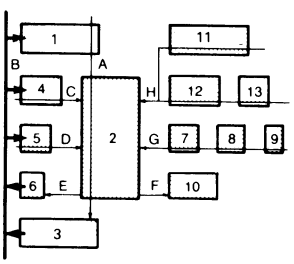


- parallel arrangement
- sinuous arrangement
- linear arrangement

⑤ **Line/flow systems**

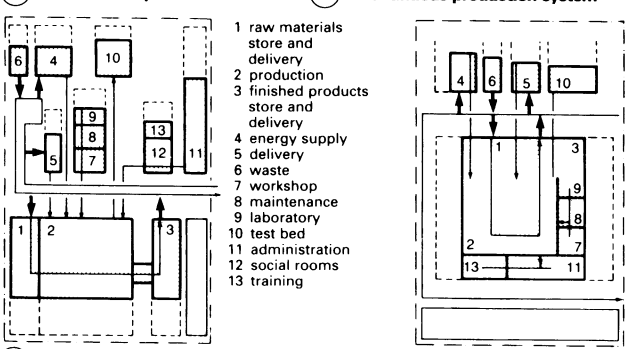


⑥ **Continuous production system**



A production
B transport
C energy
D deliveries
E waste
F checking
G maintenance
H staff

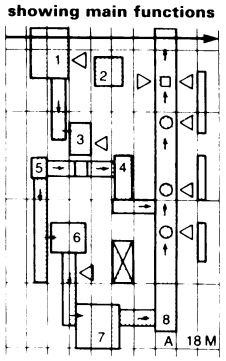
⑦ **Operational diagram showing main functions**



1 raw materials store and delivery
2 production
3 finished products store and delivery
4 energy supply
5 delivery
6 waste
7 workshop
8 maintenance
9 laboratory
10 test bed
11 administration
12 social rooms
13 training

⑧ **Open system**

⑨ **Closed system**



⑩ **Arrangement of machines**

planning symbols		AMSE	VDI
No.	process		
1	processing	○	+
2	storage	▽	△
3	delay	D	D
4	checking	□	□
5	transport	⇨	>
6	handling		○
7	finishing/testing	◎	□

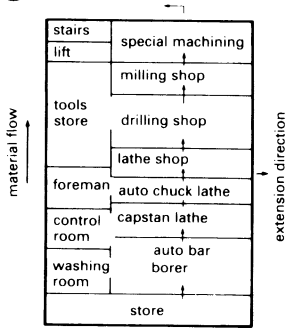
VDI symbols apply to Germany; those of the ASME are recommended for international use

⑪ **Planning symbols**

No.	mains connections	
1	operating station	▼
2	electrics	E
3	water (hydraulics)	W
4	air (pneumatics)	P
5	coolants	C
6	waste	W

common symbols denoting technical connection of mains services

⑫ **Mains connections**



⑬ **Extension at right angles to materials flow**

Space requirements for workshops and offices in precision engineering factories in multistorey buildings:

Useful floor space (m²/employee):	
dense occupation	4.5–5.0
add on for:	
ancillary spaces	2.0–2.5
	6.0–7.5
Ancillary areas:	
stairs	0.3–0.6
toilets	0.2–0.4
changing rooms	0.5–1.0
Corridors	0.5–1.5
lifts	0.0–0.2
walls/partitions	0.5–0.8
	2.0–4.5
Total floor space (m²/employee):	8.0–12.0
on average:	10.0

Generally valid guidelines for floor space requirements of industrial businesses cannot be provided because the continual advances in conditions and equipment change the basis of statistical data.

⑭ **Example space requirement guidelines**

⑮ **Example space requirement guidelines**

(5) Production

Production planning: work flow diagrams illustrate the steps within a production process and form a basis for the machine layout and material flow diagram.

Production systems vary according to the disposition of operating materials and the production process: workplace system; workshop system; line system; row system; flow system. The process can involve several production stages. The basic form is: delivery–raw materials store –production (preparation) –processing–intermediate storage–assembly–checking /testing –finished product store– delivery. → ④ – ⑥

(6) Building design

Examples of design methods include: layout method, design using functional axes, design using grid axes.

Guidelines for workstation space requirements in factories with work benches and machines are as follows:

- small machines 10–15 m²
- standard machines 15–40 m²

Add on 30% for circulation space. → ③

(7) Routes for two-way circulation

The calculation of the number of people moving to and from specific areas depends on the type of production system. Peak movement times (e.g. at shift changes) should be taken into account.

The width of corridors can in exceptional cases be as low as 0.60 m.

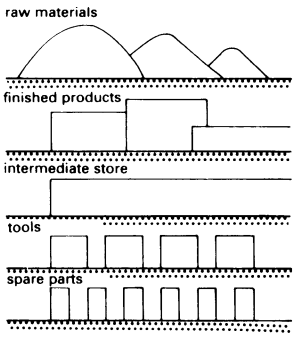
People (no.)	Width* (normal)
up to 5	0.875 m
up to 20	1.000 m
up to 100	1.250 m
up to 250	1.750 m
up to 400	2.250 m

* guideline dimension

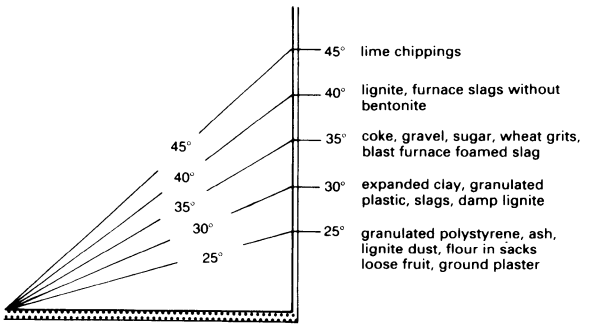
Minimum clear height above the circulation routes should be 2.00 m.

A protective guard should be provided under overhead transport systems in circulation areas if there is any risk of falling objects. The clear height to the protective guard must be not less than 2.00 m.

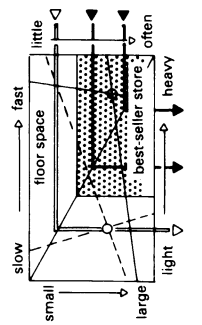
WAREHOUSE DESIGN



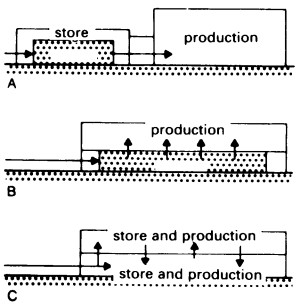
① **Types of store**



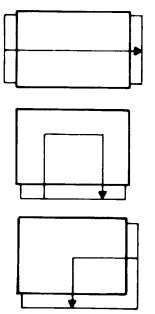
② **Angles of response** → ③



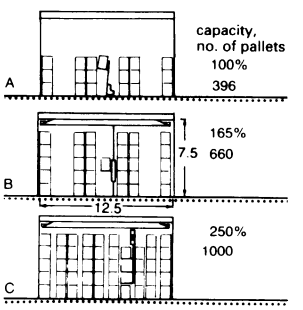
③ **Materials stored** → ②



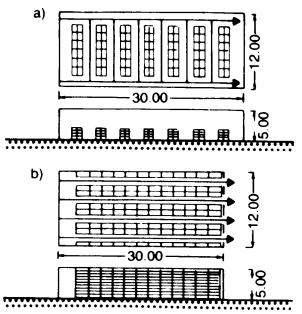
④ **Arrangement of stores**



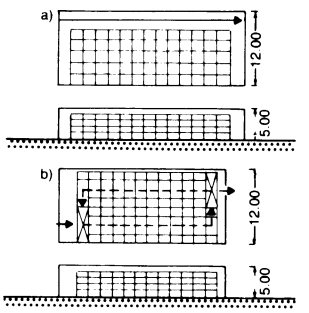
⑤ **Material flow to fixed points**



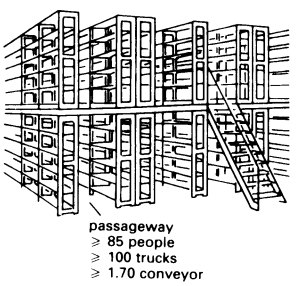
⑥ **Material flow in relation to material stored**



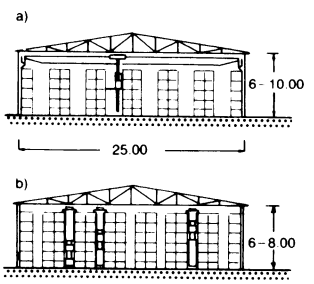
⑦ **a) Inefficient and b) optimal use of floor space and store height**



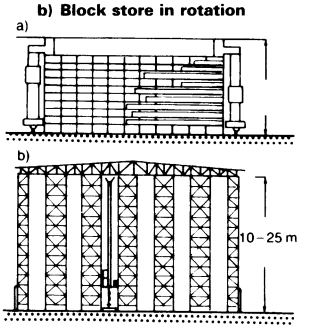
⑧ **a) Block store with optimal space/height usage**
b) Block store in rotation



⑨ **Different warehouse usage**

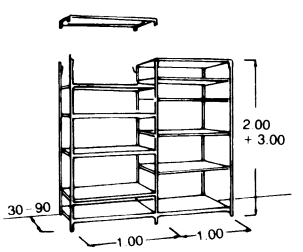


⑩ **a) Universal store with overhead gantry crane**
b) Warehouse with built in pallet racks

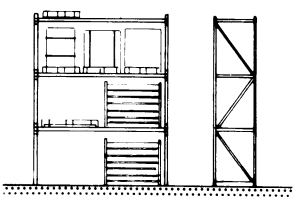


⑪ **a) Flow in block store with shelf stackers**
b) High shelving system

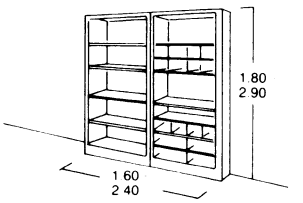
⑫ **Shelving, one or two levels, made from units of wood or steel**



⑬ **Self-assembly steel shelving**



⑭ **Pallet racks of prefabricated components (longitudinal transverse shelving)**



⑮ **Shelf/cupboard system manufacturer's dimensions**

Warehouses are part of the production process and material flow. Store unit–transport unit–production unit–dispatch unit. Reduce 'non-production' elements as much as possible; integrate them (mobile stores) or avoid them entirely.

Articles stored: bulk goods stored according to quantities involved. → ⑤

Large quantities: silos, sheds, bunkers, stockpiles.

Small quantities: boxes, canisters, bins, dishes.

Options → ④

(A) Store and production on one level

(B) Store underneath production level

(C) Store and production, depending on use, on two or more levels

Determination of co-ordinates for the 'best-seller warehouse' with optimum 'playtime' for handling equipment (roughly 1/3 of the total space of the store). → ⑥

Handling equipment in an existing store: a two-tonne fork-lift requires an aisle width of 3.45 m; stacker can stack three containers on top of each other. → ⑨ A Stacking crane permits stack height up to crane bridge. Five containers can be stacked. → ⑨ B Stacking crane with mechanised load lifting device, which grips the containers, requires only narrow aisles (storage volume 250%). → ⑨ C

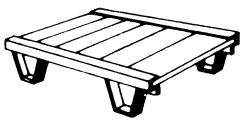
Structure of high-bay stores

- Steel structure (roof and walls of the store, as well as guide rails of the handling equipment)
- Reinforced concrete structure (shelving is flexibly mounted on concrete walls as longitudinal and transverse cross-beams)

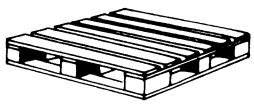
Advantages: greater stability; possibility of space segregation (fire compartments).

Control system: punch cards; off-line control; on-line system. → ⑩ – ⑪

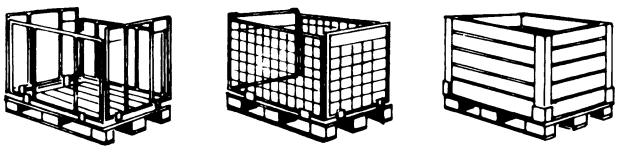
HIGH-BAY WAREHOUSES



① **Pallet platform**



② **Flat pallet 80/120 100/120**

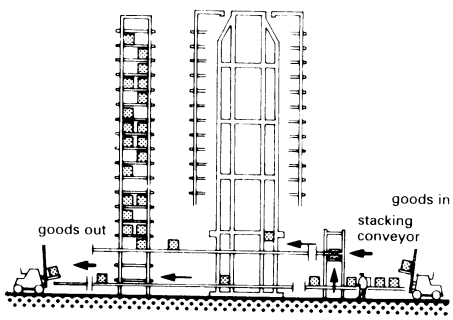


③ - ⑤ **Stacking containers**

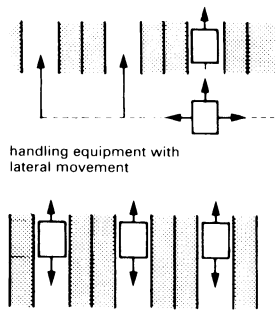
High-bay warehouses are changing modern warehousing techniques through the use of efficient stacking equipment or automatic computer-controlled systems. Handling equipment includes fork-lifts → ⑫, rack trucks, rack stacking equipment → ⑭ and stacker cranes → ⑬ which usually run in the storage area without an operator or supervision.

Many manufacturers of stackers or fork-lifts supply tailor-made systems to improve storage capacity and speed of dispatch.

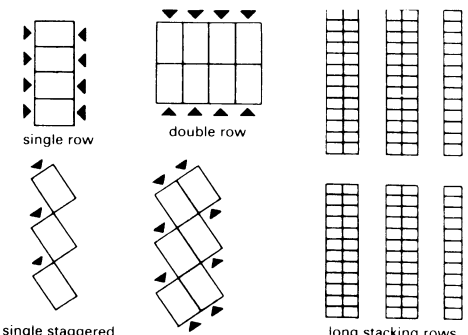
Distributing warehouses throughout the field shortens transportation distances and allows rapid response to customer demand. Items can be picked and dispatched even on a daily basis.



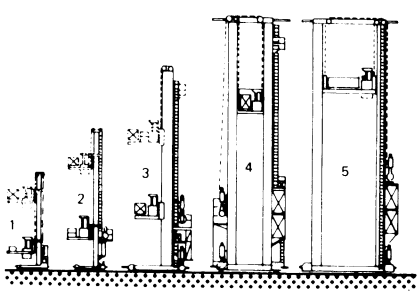
⑥ **Computerised storage system**



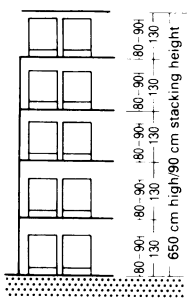
⑦ separate handling machines for each aisle



⑧ **Ways of stacking pallets**



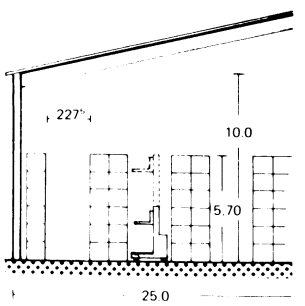
⑨ **Handling machines**



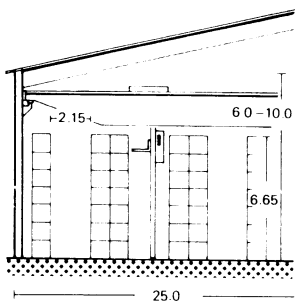
⑩ **Total stacking height**

Type	1				2		3								4	5
standard height (m) 1000 / 500					15	15	10	10	15	15	20	20	30	30	40	40
useful load (daN) 300	8		15													
(daN = kp) 200		8		15												
max useful load (daN)	300	200	300	200	500	500	1500								1500	3000
width of aisle min-max (mm)	950 - 1200				1050 / 1400		1250 - 1800								1400 / 1800	1500 / 2000
driving speed max (m/min)	80				125		160								160	160
lifting speed max (m/min)	12				25		32								40	40
stacking speed max (m/min)		25		25		32	32								32	32
goods pallet	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
order assembly						•	•	•	•	•	•	•	•	•	•	•
automatic control						•	•	•	•	•	•	•	•	•	•	•
lateral stacker	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

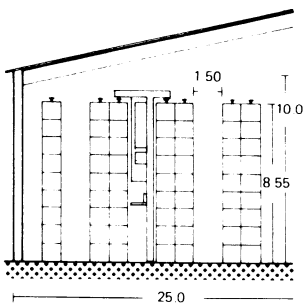
⑪ **Characteristics of handling machines** → ⑨



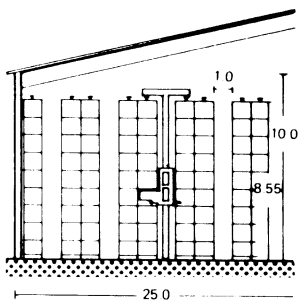
⑫ **Use of storage space with fork-lift**



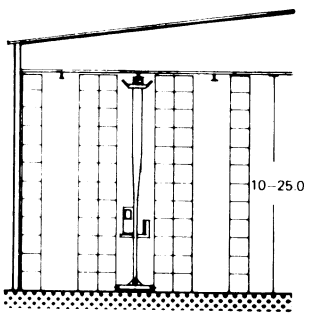
⑬ **With stacker crane**



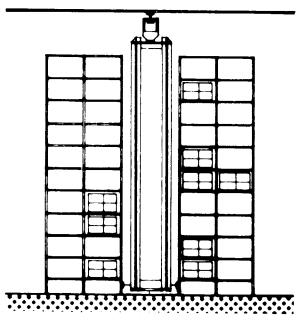
⑭ **With stacker and extendable mast**



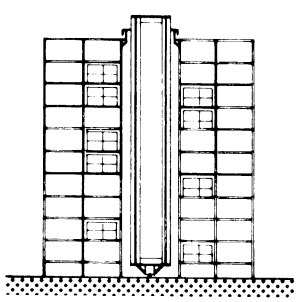
⑮ **With stacker and reach fork-lift**



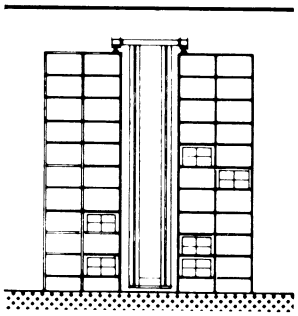
⑯ **High-bay store (pallet silo)**



⑰ **Possibilities for fixing guide rails: guide rails above**



⑱ **Guide rails below**



⑲ **Dual guide rails on racks**

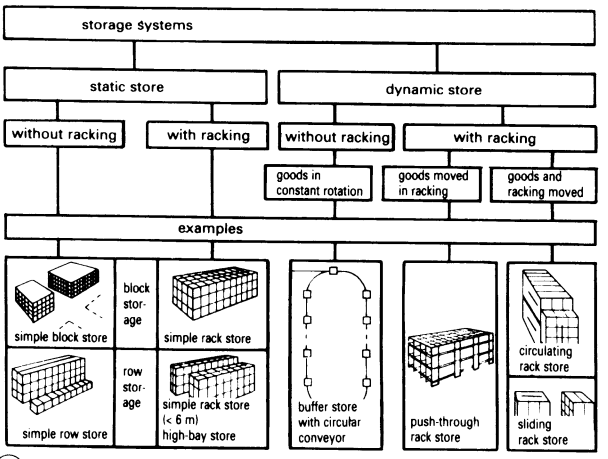
WAREHOUSING TECHNOLOGY

Planning/Logistics

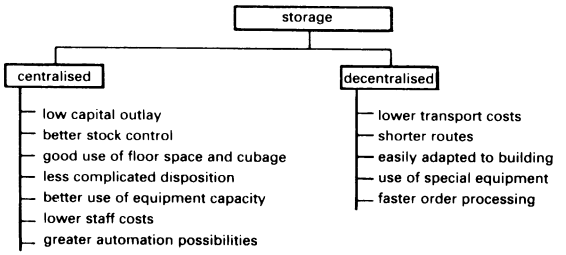
Before planning a particular system of storage, various aspects concerning the logistics of materials and product flow must be considered. Co-operation between the commercial and design team is essential. Selection should be based on the following factors:

- Centralised or decentralised storage
- Throughput capacity of each system
- Internal storage organisation and operating method (which must be established with the long-term in view)
- Suitability of type of storage to handling method

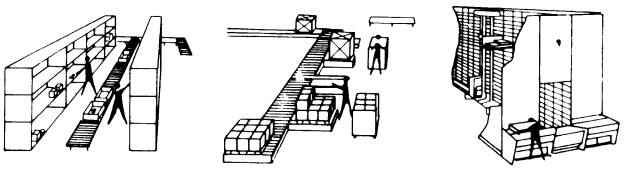
In general, material storage considerations include the size, weight, condition, and stackability of the material; the required throughput; and the building constraints such as the floor loading, floor condition, column spacing, and clear height.



(1) **Classification of storage systems**



(2) **Advantages of centralised and decentralised storage**

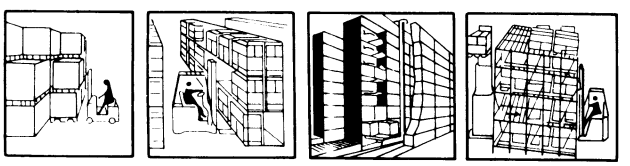


consignment system
static assembly
one-dimensional movement
manual picking
decentralised check-out

consignment system
dynamic assembly
one-dimensional movement
manual picking
centralised check-out

consignment system
dynamic assembly
two-dimensional movement
manual picking
decentralised check-out

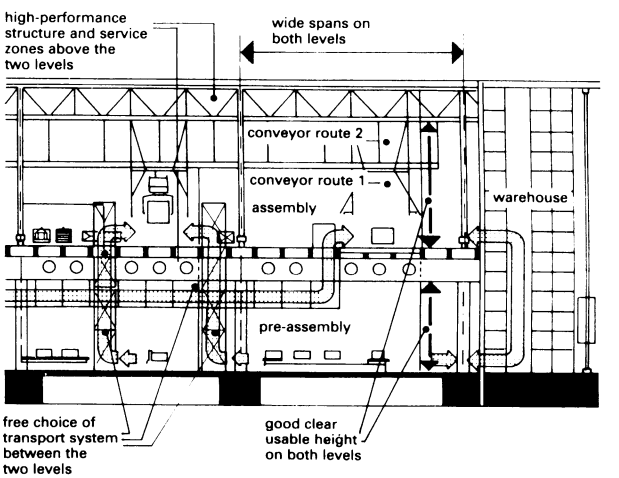
(3) **Different order assembly systems**



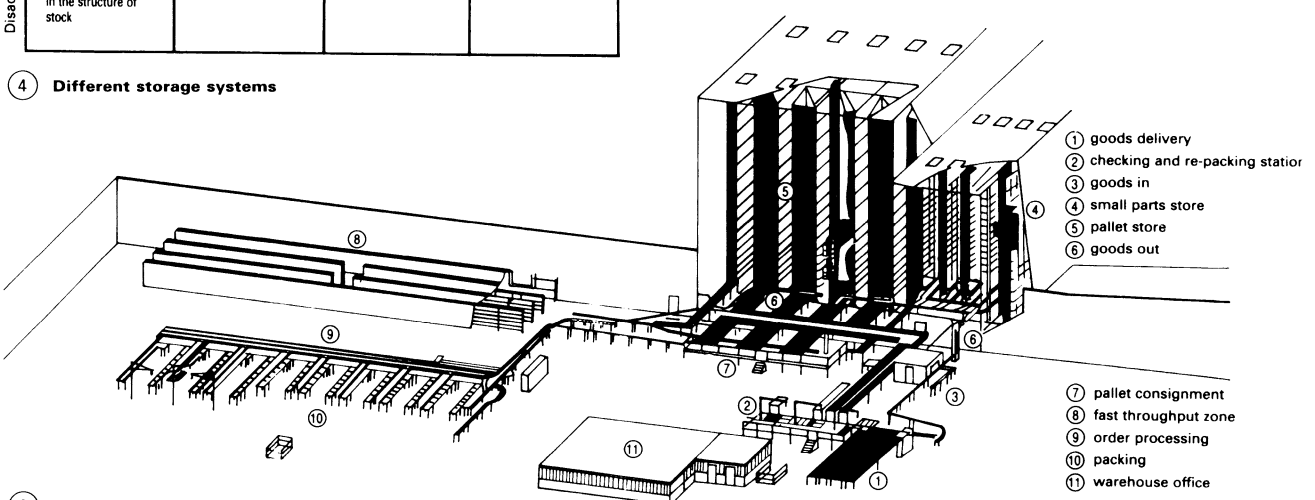
block store | high-bay store | high rack store | push-through rack store

Suitability	Large stocks of stackable goods Interim store	High frequency of movement	Good sorting of large range of small stock items Automatic operation	Small range of medium-size stock articles Large stocks of each article High throughput
Advantages	No fitting costs High utilisation of floor space and cubage (80%)	Low medium-term capital outlay Good access Universal application	Good access to each article Good use of floor space and cubage (60%) FIFO by organisation	FIFO ensured Constant, good access to each article High use of floor space and cubage (65%)
Disadvantages	No FIFO No direct access to each pallet Difficult to automate Susceptible to changes in the structure of stock	Only limited FIFO Low (45%) use of floor space and cubage High staffing levels	Single purpose building High capital outlay	High capital outlay Complicated technology Susceptible to changes in the nature of stock

(4) **Different storage systems**



(5) **Example of a production store integrated into the assembly**



(6) **Functional connections of a spare parts centre**

WAREHOUSING TECHNOLOGY

Safety regulations

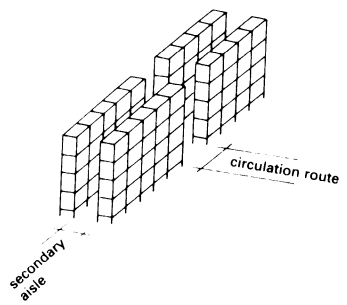
The choice of a high-bay store requires considerations about structure, assembly and internal work procedures. Material handling equipment and methods must concord with existing safety codes and regulations. Racks over 12 m high are subject to special approval procedures.

Fire precautions The building inspectorate imposes the following conditions for warehouses and other storage areas:

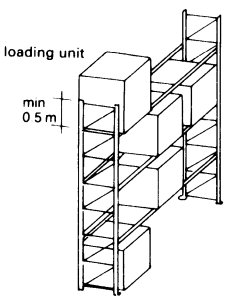
- Escape routes and exits must lead outside or to a protected stairwell, with a maximum length of 35 m
- Fire walls or compartments should be in place every 2000–3000 m^2
- Extinguisher systems as well as smoke and heat vents must be provided
- Automatic sprinklers are required for combustible materials stored in high bays
- The structure itself must be fire resistant for an adequate length of time

Security Security of storage areas will be a problem if the layout is not specifically designed to secure the contents. Consider:

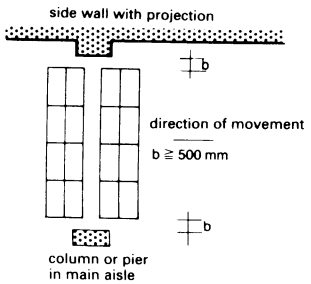
- Doors barred with heavy duty locks
- Constant casual observation, including security patrolling at night
- Good fencing around the site, with permanent lighting of the area between fence and building



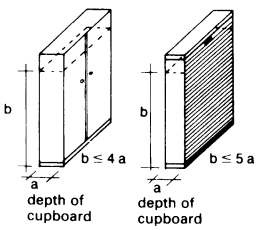
(1) **Minimum width of aisles between racks which are manually served only**



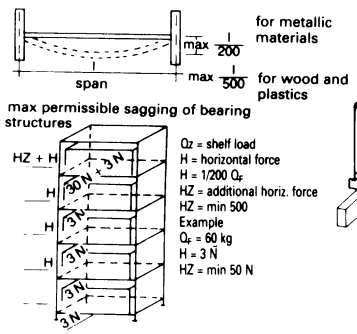
(2) **Example of device to stop goods from falling off the end of shelves**



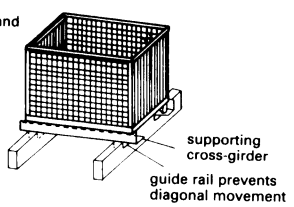
(3) **Distance between walls of movable rack units and cupboards**



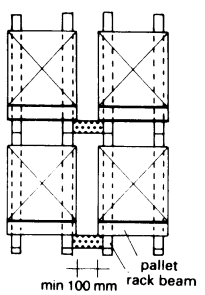
(4) **Relationship between depth and height of cupboards**



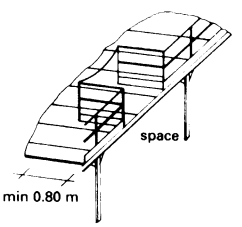
(5) **Assumed loads for storage equipment**



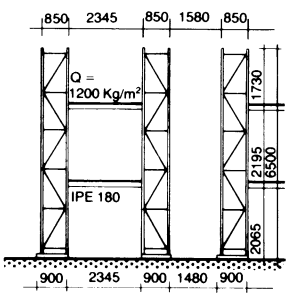
(6) **Ground supports for wire-mesh pallets**



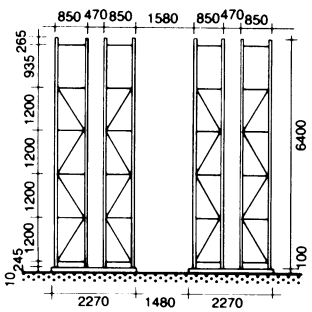
(7) **Device to stop pallet racks from sliding**



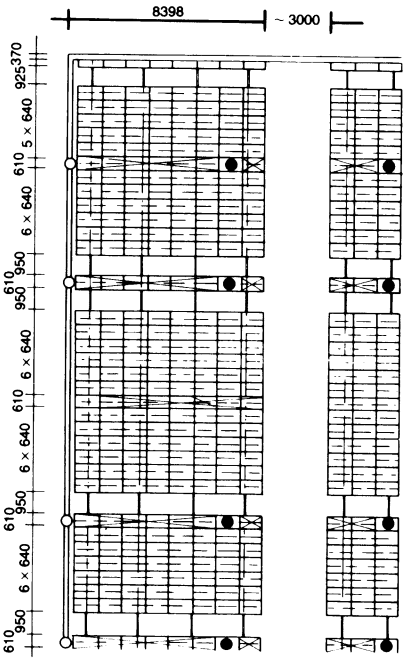
(8) **Example of an integrated storage space**



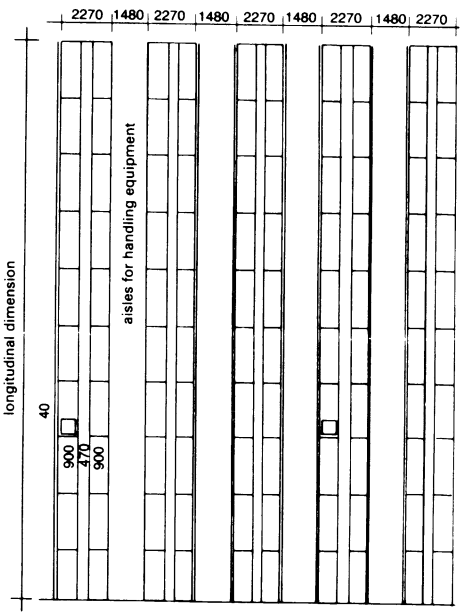
(9) **Section through pallet rack for combined manual operation and operation by stacker (small articles)**



(10) **Section through pallet rack for stacker loading. U-section steel guide rails for stackers**



(11) **Detail of a sliding rack system for storing files**



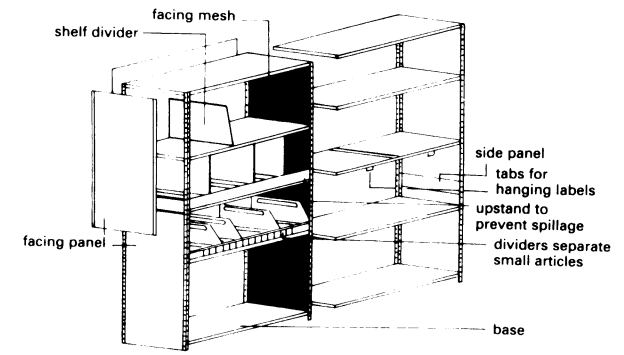
(12) **Detail of a plan for a pallet rack store for ball bearings (structural elements of shed concealed in shelving)**

Rack systems

The traditional storage system used in industrial buildings is shelving, either the screws and brackets type or the plug-in shelf system with prefabricated frames into which the steel shelves are slotted (the advantage of which is that it offers shorter assembly times). The latter type of shelving comes in different versions, in sheet metal, with or without perforations or wire netting.

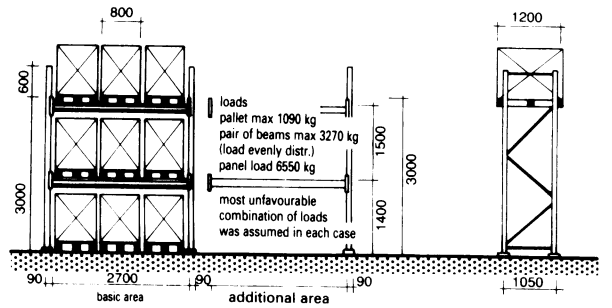
Prefabricated systems are appropriate up to heights of about 4.5 m and for loads of up to 250 kg/shelf. For greater loads or heights, pallet racking is more suitable. Beams of IPE profiles with welded-in clips are hung in the prefabricated frames made of U-profiles into which grooves have been punched. Diagonal steel strips give vertical bracing. Racking systems at centres of 2.80 m have become standard (large enough to take three Euro pallets next to each other). They can be stacked to a height of 12.00 m. Intermediate platforms can be constructed for multistorey, self-supporting platforms with load bearing capacities of up to 500 kg/m^2.

Special types of racking such as barrel racks (2000 kg load per shelf), coil racks (coil weight per axis approx 1000 kg), comb racks, peg racks, tyre racks, wide-span racks and sliding racks are also available.

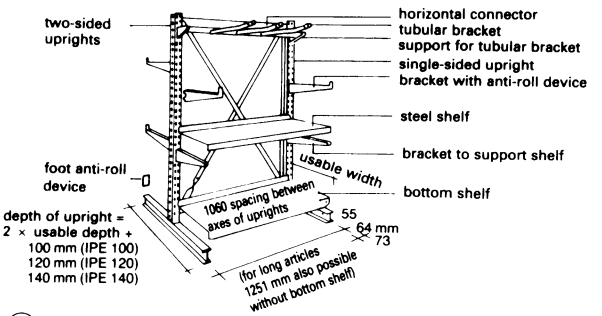


system: Hofe

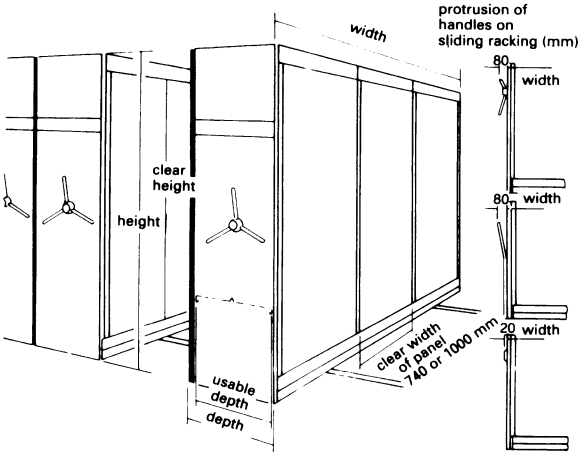
① **Angle-section bolted system for all-round use**



② **Pallet racking system for Euro pallets** system: Händi/Opitz



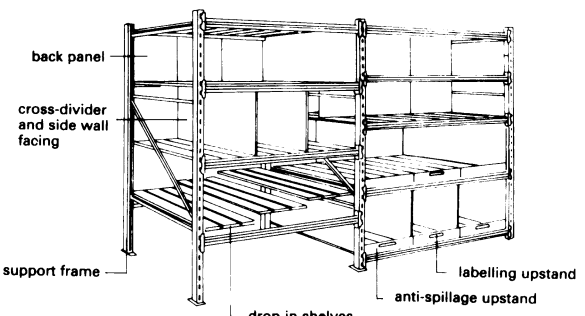
③ **Bracket rack system** system: Hofe



depths									heights	
depth	sliding				640	760	840	940	1040	h.	clear h.
(mm)	stationary	370	410	510	610	730	810	910	1010	(mm)	(mm)
useable depth		360	400	500	600	720	800	900	1000	2105	1850
										2405	2150
										2705	2450

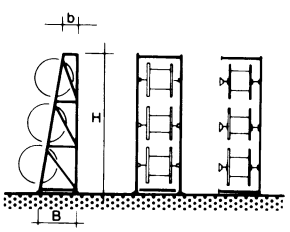
system: Mauer

⑤ **Sliding racking (operated by hand or electric motor)**



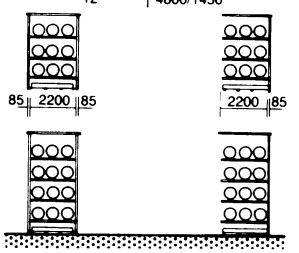
④ **Wide-span racking (depth 600–1100 mm)** system: Hofe

height of racking H	depth of frame b/B
3000	400 × 900
3300	400 × 950
3600	400 × 1000
3900	400 × 1050

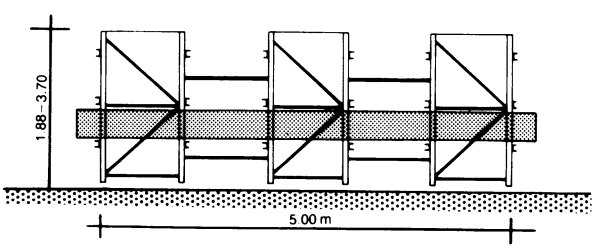


⑥ **Cable mast standard racking**

number of barrels 2006	height of racking/ depth of roof (mm)
9	3600/1450
12	4800/1450

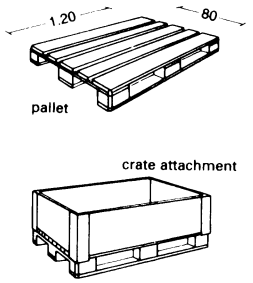


⑦ **Barrel racking for outdoor storage**

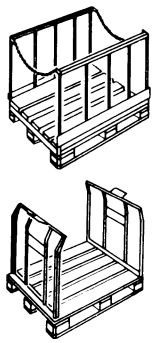


⑧ **Continuous bracket racking**

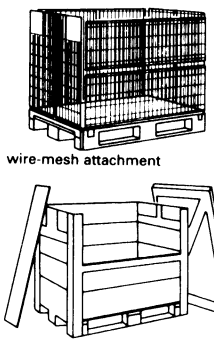
HANDLING



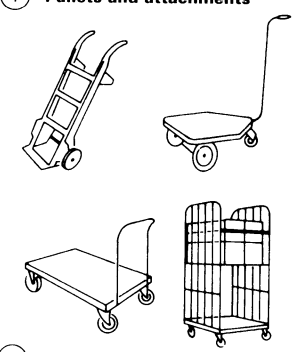
① **Pallets and attachments**



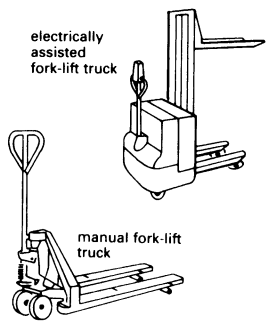
② **Attachments** → ①



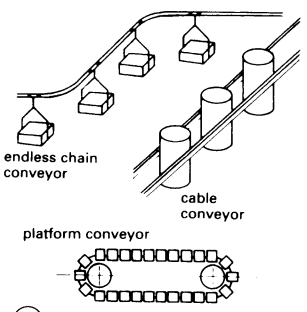
③ **Pallet boxes**



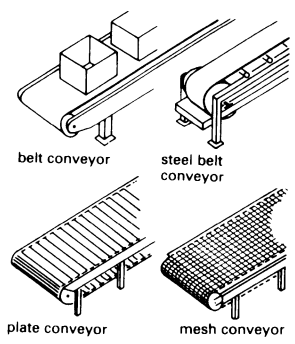
④ **Hand trolleys**



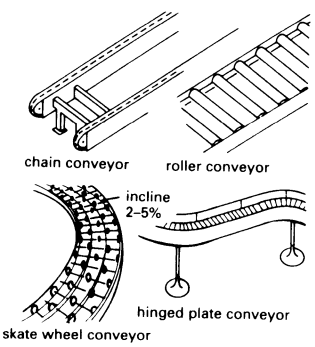
⑤ **Hand trucks**



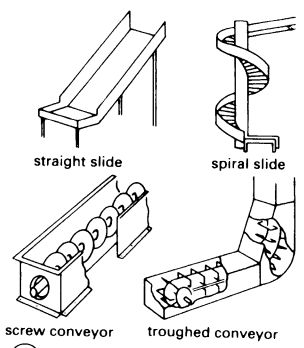
⑥ **Continuous conveyors**



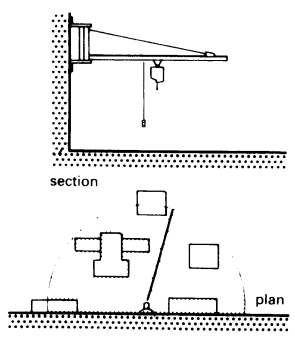
⑦ → ⑥



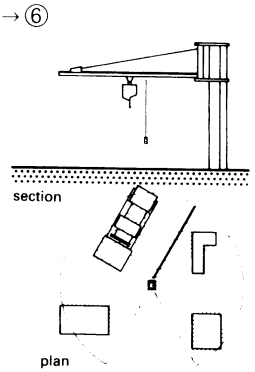
⑧ → ⑥



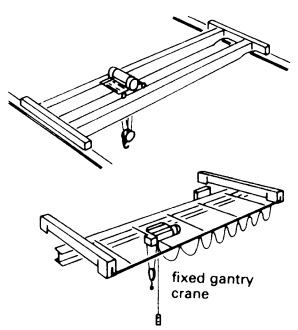
⑨ **Loose materials conveyors**



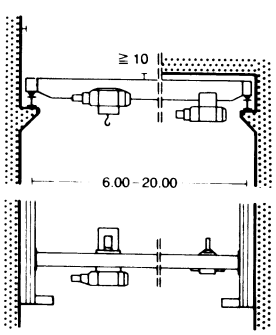
⑩ **Wall mounted swivel crane**



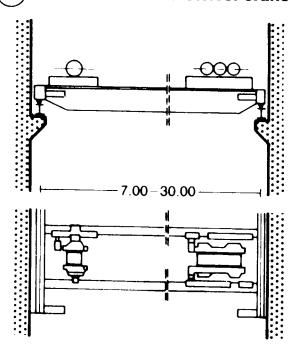
⑪ **Column mounted swivel crane**



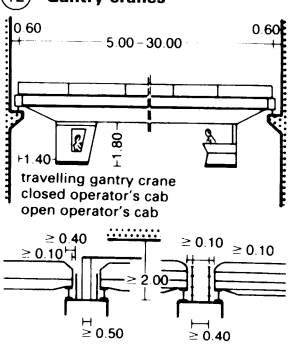
⑫ **Gantry cranes**



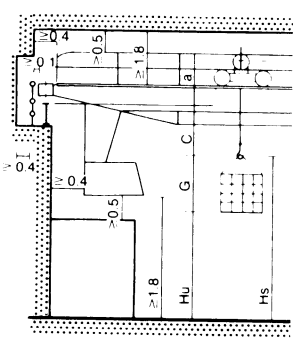
⑬ **Simple-girder gantry crane (capacity: 0.5–6.0 t)**



⑭ **Double-girder gantry crane (capacity: 2–20 t)**



⑮ **Runway catwalks (safety dimensions)**



⑯ **Gantry crane (safety dimensions)**

Basic dimensions of pallets according to European standards: 0.80 m × 1.20 m. Flat pallets (four-way pallets of wood), weight approx. 28–32 kg. → ① Lattice box pallets with fixed sides of structural steel mesh; max. stacking height five boxes.

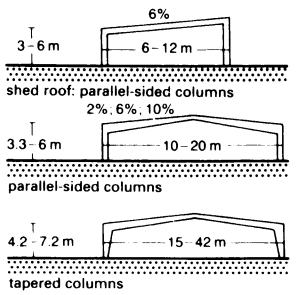
Transport is part of the materials flow. Cost-savings are possible through simplification of handling method: choose uniform handling materials (e.g. pool pallets); adapt handling method to the tasks required and technical needs of the building.

Wheeled handling equipment has variable uses. → ④ – ⑤ Stacking heights up to 6 m are possible; in special cases up to 10 m using hub stacker trucks. Economically efficient owing to low capital cost and no re-loading if standard loading units are used (pallets). Flat routes with hard-wearing surface required.

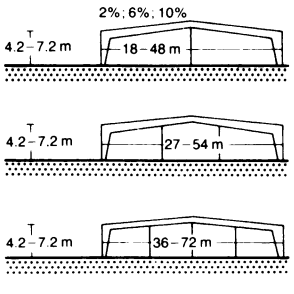
Continuous conveying equipment allows easy handling of a range of goods (unit loads, boxes, bulk goods and liquids) → ⑦ – ⑨

Swivel cranes → ⑩ – ⑪ make it possible to move loads throughout a particular area.

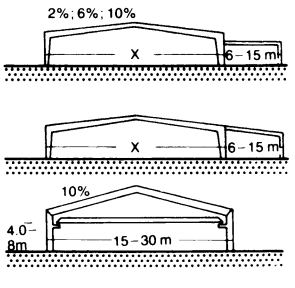
Track-borne cranes are the simplest lifting device for vertical lifting. Simple travelling winches through to gantry cranes offer good horizontal mobility and can handle loads from 0.5–20 t → ⑫ – ⑭



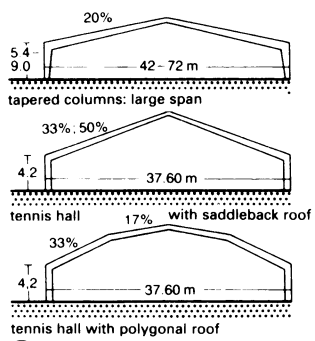
① **Single-span types of shed**



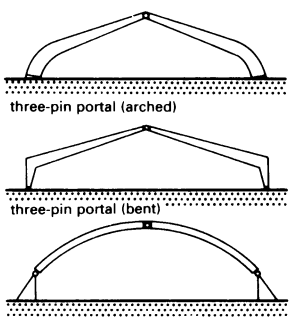
② **Modular sheds with primary and secondary columns**



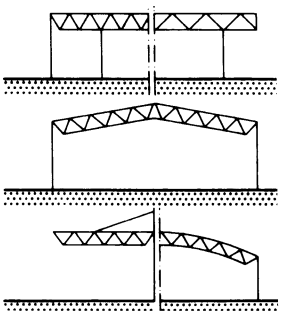
③ **Part frames as shed extension modules**



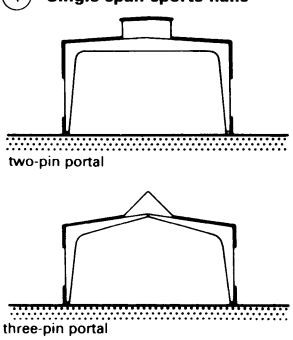
④ **Single-span sports halls**



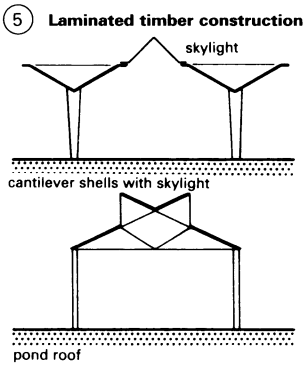
⑤ **Laminated timber construction**



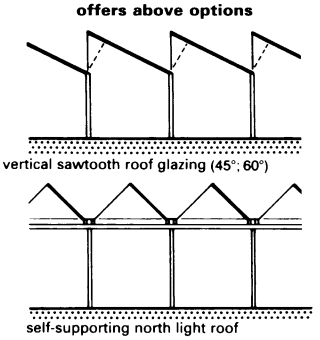
⑥ **Lightweight construction: space frame geometry offers above options**



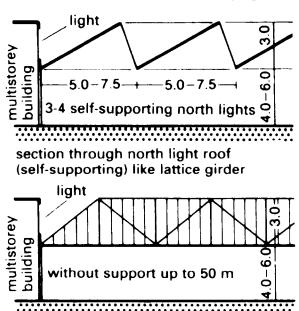
⑦ **Laminated timber construction with skylight**



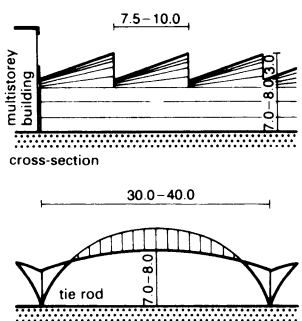
⑧ **Roofs on rigid columns**



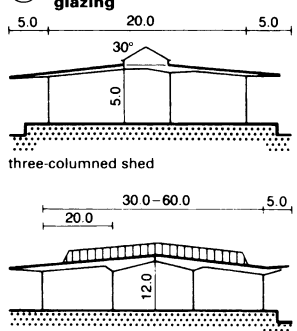
⑨ **Sheds with sawtooth roof glazing**



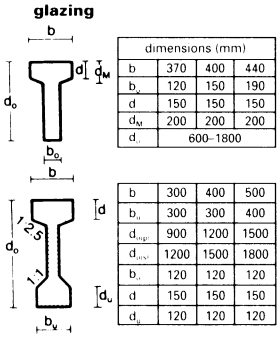
⑩ **Section through sawtooth roof with cross-bracing in glazing**



⑪ **Vaulted shed roof**



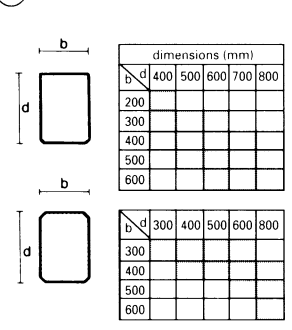
⑫ **Shed with transverse roof lights; frame with cantilevered beams**



	dimensions (mm)		
b	370	400	440
b_{o_1}	120	150	190
d	150	150	150
d_M	200	200	200
d_u	600–1800		

b	300	400	500
b_{o_1}	300	300	400
d_{M1}	900	1200	1500
d_{M2}	1200	1500	1800
b_u	120	120	120
d	150	150	150
d_u	120	120	120

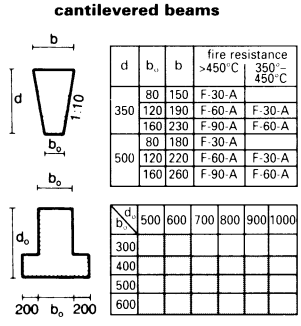
⑬ **Pre-cast concrete elements**
– roof beam: T section
I section



b \ d	400	500	600	700	800
200					
300					
400					
500					
600					

b \ d	300	400	500	600	800
300					
400					
500					
600					

⑭ **Pre-cast concrete elements**
– joists/cross-members lower corners chamfered
– pillars: all chamfered



d	b_{o_1}	b	fire resistance >450°C	fire resistance 350°–450°C
350	80	150	F-30-A	
	120	190	F-60-A	F-30-A
	160	230	F-90-A	F-60-A
500	80	180	F-30-A	
	120	220	F-60-A	F-30-A
	160	260	F-90-A	F-60-A

d_o \ b	500	600	700	800	900	1000
300						
400						
500						
600						

⑮ **Pre-cast concrete elements**
– purlins
– joists (inverted T section)

Shed designs satisfy the requirement for economy, standardisation, and the need for flexible non-specific or dumb space.

Advantages of single-storey: low building costs; even daylight; high floor loads possible; can be built on difficult sites; lower accident risk. Disadvantages: high heat loss (sky lights); high maintenance costs; large land requirement.

Wooden structures are suitable for lightweight buildings, and particularly for roofing in large buildings using modern truss systems with timber connectors. Construction using laminated timber beams is also a possibility. → ⑤

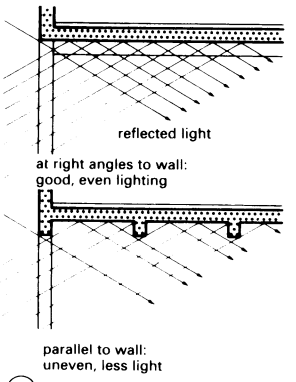
Steel structures are appropriate for industrial buildings because modifications or additions are easy to carry out in steel. Maintenance costs (painting) are higher than for masonry or concrete.

Reinforced concrete structures: constructed by casting in situ or using pre-cast elements; more resistant to chemical attack than steel and therefore necessary for certain industrial buildings. Normal (unstressed) reinforcement for small spans (heavy sections); for larger spans usually pre-stressed (often pre-cast elements). → ⑬ – ⑮ Dimensions: for lightweight buildings bay widths of 5–7.5 m; economically efficient for spans of 10–30 m. In cases where columns are a hindrance, spans of up to 50 m are possible. → ⑨ – ⑫

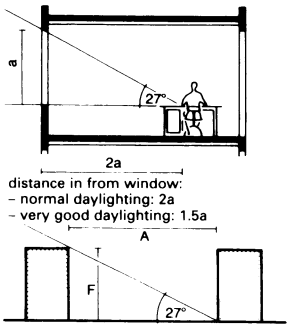
If possible, strutting which takes up space should be avoided and solid frames used instead → ① – ⑤ with tension members in the floor. When calculating the distance between columns take into account the arrangement of machines and access routes and turning circles of vehicles.

The shed height may have to be adapted to size of cranes. Usually no advantage in terms of ventilation with higher sheds; more important is an appropriate number of air changes, facilitated by ventilation elements (windows, ventilation hoods, air heaters) which are of the correct size and properly placed.

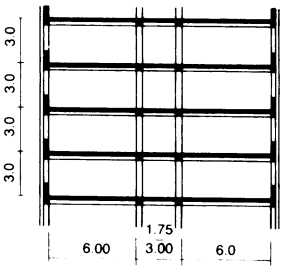
MULTISTOREY INDUSTRIAL BUILDINGS



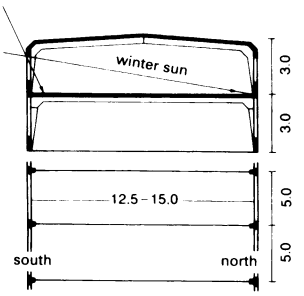
① **Joist orientation**



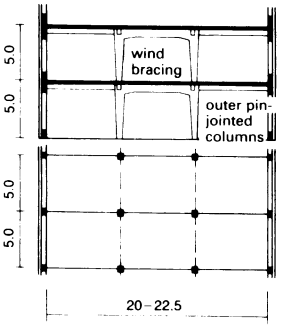
② **Inter-building distance for optimal daylighting**



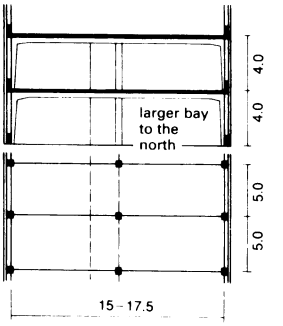
③ **Depths at specified storey heights**



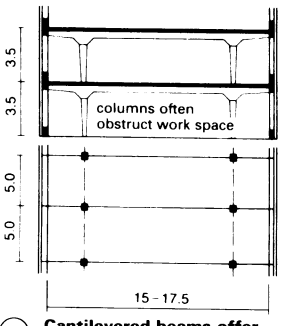
④ **Free-spanning main frame: unrestricted space**



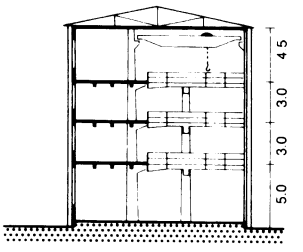
⑤ **Deepest spaces with two central columns for bracing**



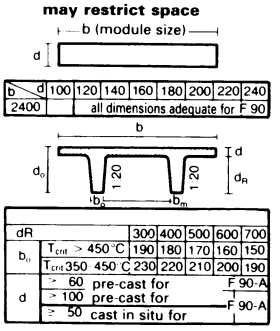
⑥ **Central columns; central aisle to either side**



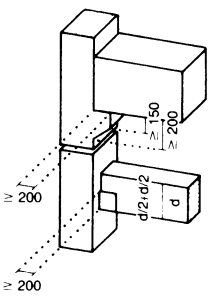
⑦ **Cantilevered beams offer structural advantages but may restrict space**



⑧ **Multistorey crane shed; work items moved between balconies via crane shaft**



⑨ **Double-T profile, pre-cast concrete floor slabs**



⑩ **Joist/cross member support, rectangular cross-section**

Advantages over single-storey buildings

Smaller footprint, shorter routes between departments if the vertical connections are effective, shorter pipe runs, cheaper maintenance and heating, simpler ventilation. Suitable for breweries, paper mills, warehouses and other buildings where the materials are conveyed once to the upper floors and then move by gravity down onto the lower floors. Good side-lighting. Useful for optical, precision engineering and electronics firms, food processors and packagers, and textiles industries.

Siting

Depends on urban planning and operational considerations. If fenestration on one side only, building should face north-east; if, as is the norm, windows are on two sides, the building runs east–west with windows facing north and south. The summer sun then only shines a short distance into the rooms and can be easily controlled by awnings whilst in winter the sunlight penetrates even to the north side of the spaces. →④ On the northern side: stairwell, WC (cool). Minimise distracting shadows in working areas.

On the free southern side it is possible to use motor-operated awnings. The best daylighting is achieved in free-standing high-rise buildings, which are twice their height apart (light incidence angle for the ground floor is 27 degrees). →② Low buildings with roof lights can be positioned between them.

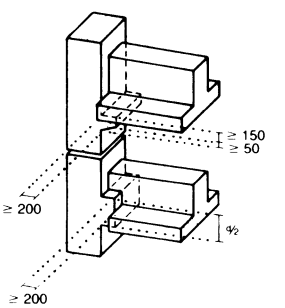
Dimensions: room height in accordance with building regulations for commercial buildings, ≥ 3.0 m and ≥ 2.5 m in basement and attic. Permitted depth of building depends on room height. Single room depth of free-standing multistorey factories is generally twice the height, with windows up to the ceiling. →① Circulation routes in the middle of the building are not included in the calculation – see ③ for example with 3 m room height, giving total depth of 13.75 m–15.00 m. This is the most economic depth when roofing has no central supports. →④ Rooms 4 m high are 15–17.5 m deep, usually with one or two central supports. Rooms 5 m high and 20–22.5 m deep with two columns are economically efficient. →⑤ + ⑥

In special cases (courtyards etc.) the possible building depth can be calculated easily, taking into account the desired brightness, which differs according to the type of activity.

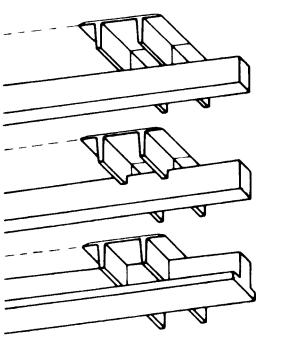
Approximate values for window areas:

ancillary and store rooms	10% of floor area
workshops for heavy work	12% of floor area
workshops for precision work	20% of floor area

At greater room depths, diffusion of the incoming light is desirable (pay attention to awnings, blinds, light refracting glass etc.). The direction of the joist span is also important. →① Workstation to window distance should not be more than twice the height of the window head above the table surface. →②



⑪ **Joist supports, inverted T**



⑫ **Floor slab supports, double-T**

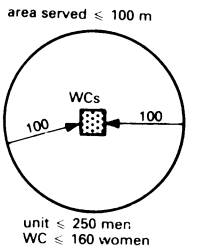
TOILET FACILITIES

To ensure a good working atmosphere it is essential to design sanitary facilities which are both functional and attractive.

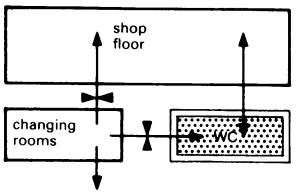
Toilets should be approximately 100 m from each workstation; 75 m in the case of work at conveyor belts. In large companies it is useful to divide them into smaller units (e.g. on each floor next to the stairs on the landing). In companies with more than five employees separate toilets must be provided for men and women, as well as toilets for the exclusive use of employees where necessary. A lobby is not required if there is only one WC per toilet facility and no direct access to a work place or area used for breaks, for changing, washing or first aid. Toilet cubicles must be lockable. If ventilation is through windows on one side only, an area of 1700 cm^2 is required, or possibly 1000 cm^2 if space is restricted.

In toilet facilities for ≤250 men or ≤160 women a drainage point with smell seal and tap connection with stop cock and hose union must be provided, and a sink for cleaning purposes. Flooring should be non-slip, water-resistant and easy to clean. Walls should be washable to ≥2 m high. Room temperature 21°C. Well-ventilated lobbies are required in front of toilet facilities and should have one wash basin per five WCs minimum and the means for drying hands. If soap dispensers are fitted, one is sufficient for two wash basins. A minimum of one mirror for every two to three wash basins should be fitted. The minimum room height for toilets with four or fewer WCs can be 2.20 m.

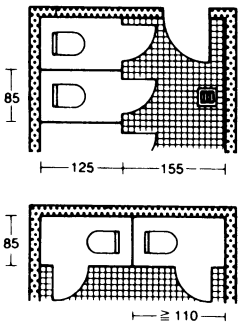
Install washing facility for disabled people, according to regulations, recommendations and types of activities.



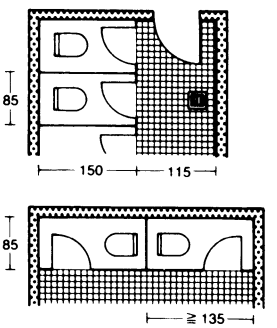
① **Area served**



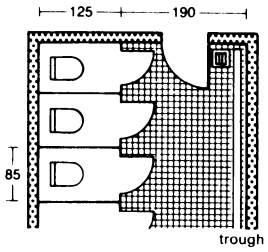
② **Arrangement of WCs**



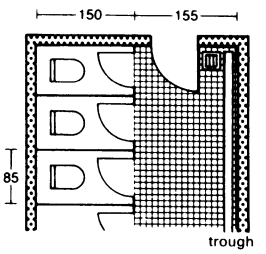
③ **Single row WCs, doors opening outwards**



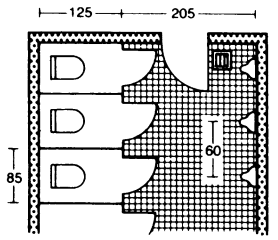
④ **Single row WCs, doors opening inwards**



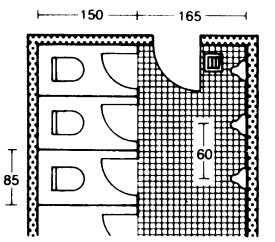
⑤ **Doors opening outwards; with urinal trough**



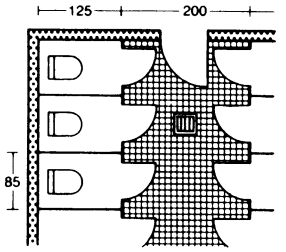
⑥ **Doors opening inwards; with urinal trough**



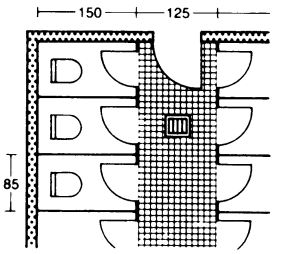
⑦ **With urinal bowls; doors opening outwards**



⑧ **As ⑦ but with doors opening inwards**



⑨ **Dual row WCs, doors opening outwards**

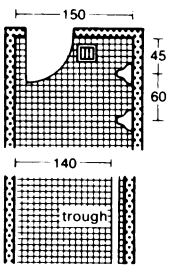


⑩ **As ⑨ but with doors opening inwards**

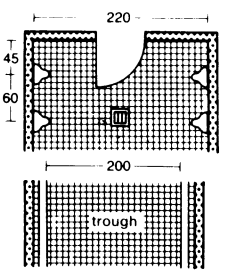
Men							Women					
number of employees	flush toilets	urinals	troughs (m)[1]	hand basins[2]	additional flush toilets	additional urinals	number of employees	flush toilets	hand basins[2]	additional flush toilets	waste bins	sink
10[3]	1	1	0.6	1	1	1	10[3]	1	1	1	1	1
25	2	2	1.2	1	1	1	20	2	1	1	1	1
50	3	3	1.8	1	1	1	35	3	1	1	1	1
75	4	4	2.4	1	1	2	50	4	2	2	1	1
100	5	5	3.0	2	1	2	65	5	2	2	1	1
130	6	6	3.6	2	2	2	80	6	2	2	1	1
160	7	7	4.2	2	2	2	100	7	2	3	1	1
190	8	8	4.8	2	2	3	120	8	3	3	1	1
220	9	9	5.4	3	3	3	140	9	3	4	1	1
250[4]	10	10	6.0	3	3	4	160[4]	10	3	4	1	1

[1] an increase of up to 1.5 times is possible
[2] legislation stipulates that hot water taps must be situated above hand basins in the vestibules of toilet facilities in workplaces
[3] A shared facility is permissible for up to five employees
[4] WC facility should be no larger than for use by 250 men or 160 women

⑪ **Large WC facilities**



⑫ **Single row urinal bowls and trough**



⑬ **Dual row urinal bowls and troughs**

WASHING FACILITIES

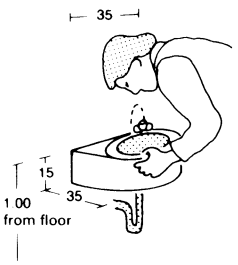
'Washing facilities' include all amenities and rooms which are used by staff for maintaining personal hygiene. They are divided into washrooms, shower rooms and bathrooms.

They should have a hot and cold water or mixed water supply. Each facility should have at least one drainage point with stop cock and hose union. During use the facilities should have adequate artificial ventilation.

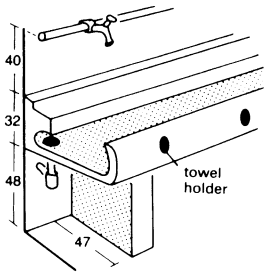
The number of washing facilities depends on type of company. For 100 users: doing clean work, 15; doing moderately dirty work, 20; doing very dirty work, 25; doing hot, wet, dusty, smelly work, or handling toxic or germ-carrying substances, in sterile and pharmaceutical processes or the food industry, 25.

Depending on the type of company, the facilities should be divided into washing and showering facilities. Also depending on the type of company, drinking fountains should be provided close to work places. → ①

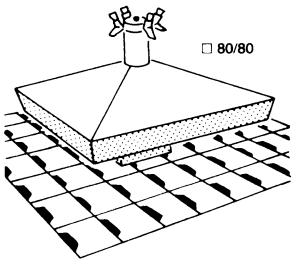
The temperature in changing and washing facilities should be 20–22°C. Water consumption per person per day is roughly 50 litres.



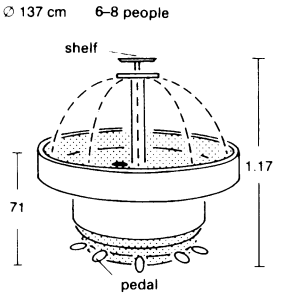
① **Drinking fountain, operated by lever < 100 m from workstations**



② **Row washing trough (Rotter system)**



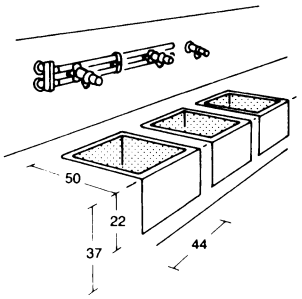
③ **Foot-washing system**



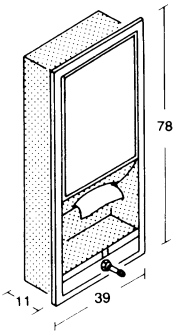
④ **Washing fountain (gives 25% space saving over rows of wash-basins → ② + ⑪)**

Washing spaces required

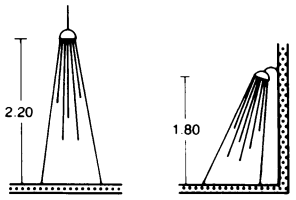
type of work	use per person	no. of users per space given a wash time of	
	min	15 min a	20 min b
slightly dirty	2	7	10
moderately dirty	3	5	6
very dirty	4	4	5



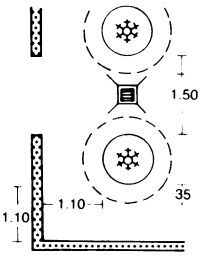
⑤ **Foot baths**



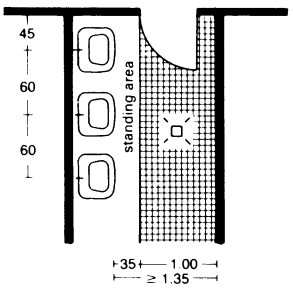
⑥ **Paper towel dispenser, shelf and soap dispenser**



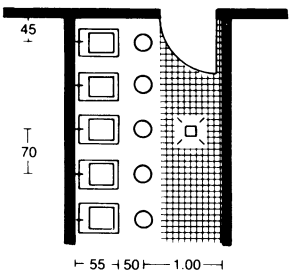
⑦ **Clear height of shower heads**



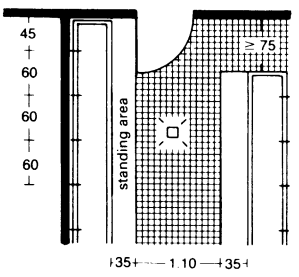
⑧ **Space requirement for circular wash-basins**



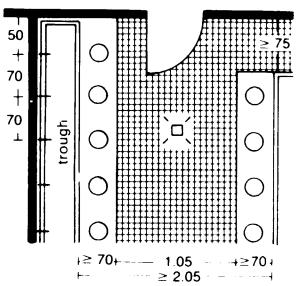
⑨ **Washroom and hand basins**



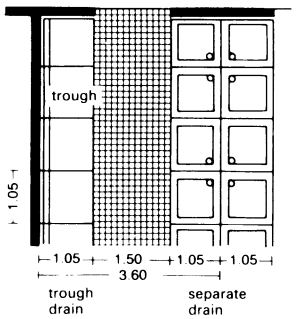
⑩ **Washrooms with foot baths**



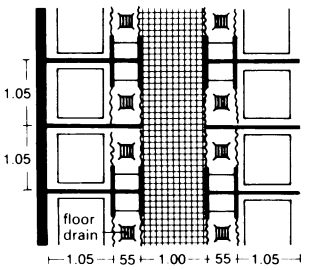
⑪ **Washroom with washing trough**



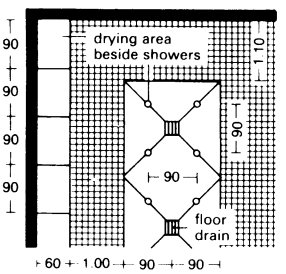
⑫ **Washroom with foot washing trough**



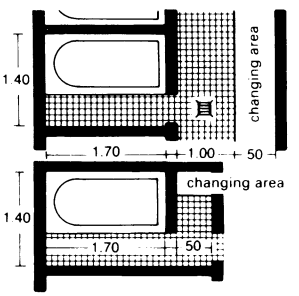
⑬ **Semi-open showers**



⑭ **Individual showers with changing cubicle**



⑮ **Open showers with drying area**



⑯ **Bath cubicles**

Type of space	Hygiene facilities
WCs[1] for women	1 cleaner's sink 1 toilet for every 3 to 10 women or 50 to 100 m² 1 wash-basin for maximum of 5 WCs
WCs[1] for men	1 cleaner's sink 1 toilet for every 10 to 15 men or 50 to 100 m² 1 to 3 urinal bowls for every 10 to 15 men or 50 to 100 m² 1 wash-basin for maximum of 5 WCs
Offices	1 wash-basin for every 8 to 10 people or 100 m² or at least 1 per office or 1 wash-basin for 3 to 7 people
Cleaner's room	1 cleaner's sink
Tea rooms	1 boiling water dispenser[2] 1 washing-up sink with draining board

[1] Maximum of 10 toilets per facility
[2] Average boiling water consumption per person per day is 0.75 litres (1 litre of water equals 5 to 6 cups)

(1) Facilities for office buildings

Women	WCs	Bidets	Wash- basins	Cleaner's sinks
8–10[1]	1	1	1	1
17–20	2	1	2	1
25–30	3	1–2	2–3	1
35–40	4	2	3	1
45–50	5	2	4	1
Men		Urinals		
10–13[1]	1	1	1	1
20–25	2	1–2	1	1
30–39	2–3	2–3	2	1
40–49	3	3	3	1
50–59	3–4	4	3	1

[1] When planning small offices it is advisable to double the [z1]number of wash-basins, WCs and urinals

(2) Number of items per person

Room	Type of work	Fittings	
Women's washroom/ toilets[1]	not very dirty	3 wash-basins 3 WCs 1 bidet 1 cleaner's sink	per 10–15 women
	moderately dirty	3 wash-basins 1 shower 1 foot bath 3 WCs 1 bidet 1 cleaner's sink	per 10–15 women
Men's washroom/ toilets[1]	not very dirty	3 wash-basins 2 WCs 2 urinals 1 cleaner's sink	per 10–15 men
	moderately dirty	3 wash-basins 1 shower 1 foot bath 2 WCs 2 urinals 1 cleaner's sink	per 10–15 men
	very dirty	as above, but add 1 shower per 10–15 people 1 bath per 2–3 people	
	with dirty or hot floor	as above, but add 1 foot bath per 10–15 people	
		1 disinfecting foot bath per 6–8 showers 1–2 drinking fountains per washroom	
Cleaner's room		1 cleaner's sink	
Tea room[2]		1 cleaner's sink 1 boiling water urn 1 double sink with draining board	
Work rooms[3]		1 drinking fountain per 100 people	

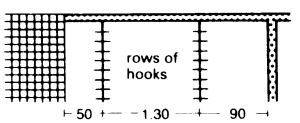
[1] Max 10 toilets per facility; 1 hand basin per 5 toilets
[2] Consumption of boiling water per person 0.75 l/day (1 litre of water equals 5 or 6 cups)
[3] 100 m max between work spaces and drinking fountain

(3) Facilities for industrial companies

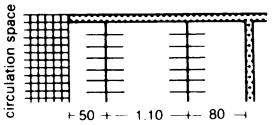
			Number of washing facilities per 100 employees	Wash-basins	Foot baths	Showers	Showers for the disabled (e.g. poliban bath)	Baths	Baths for the disabled	Drinking fountains
Normal working conditions	little dirt	office and administration								
		clothing, wood, light engineering	15	10	(10)	4	1	–	–	1
	moderately dirty	builder's yards, engineering works	20	10	(10)	8	2	–	–	1
Exceptional working conditions	very dirty	coal industry, limestone and cement industry, tar works	25	12	–	10	3	–	–	1
	hot	steel works, glass factories, work places using heat treatments	25	12	–	10	3	–	–	2
	dusty	aggregate crushers, quarries, parts of the ceramics industry	25	12	–	10	3	–	–	2
	humid	laundries, dyeworks	25	16	–	7	3	–	–	1
	humid and very dirty	coal and ore mines, coal washing, ore processing plants	25	12	–	10	3	–	–	1
	smelly	sewage plants, animal waste processing works	25	16	–	7	2	–	–	2
Dangerous working conditions	processing toxic, infectious or radio- active materials	plants processing lead, arsenic, mercury, phosphorous; animal waste processing (intestines and bones); biological research and isotope laboratories	25	12	–	5	2	5	–	1

(4) Types of work and appropriate washing, shower and bath facilities

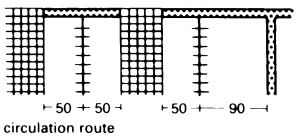
CHANGING ROOMS, LOCKERS



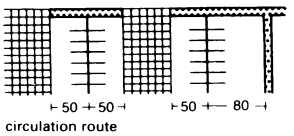
① **Changing facilities with simple rows of hooks**



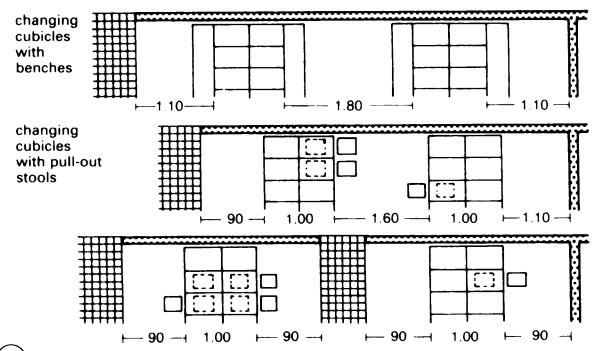
② **Racks of coat-hangers**



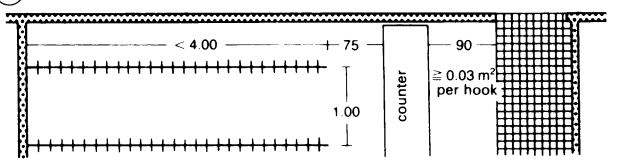
③ **Self-service facilities with simple rows of hooks**



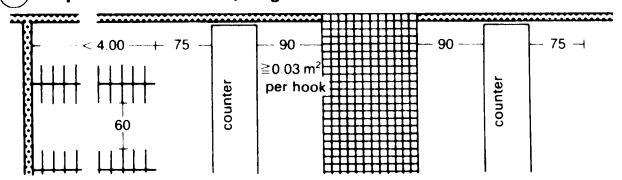
④ **Self-service facilities with racks of coat-hangers**



⑤ **Minimum dimensions for changing facilities**



⑥ **Supervised cloakroom, single rows of hooks**



⑦ **Supervised cloakroom, with racks of coat-hangers**

Changing rooms are amenities used by staff to change from outdoor clothing into work clothes and store their belongings. They should be between the entrance to the factory and the working areas and be easily accessible. Changing rooms with a floor area of up to 30 m² must have a clear height of at least 2.30 m² and at least 2.50 m if the floor area exceeds 30 m². The basic floor area of a changing room should be at least 6 m². When changing rooms are not required provision should be made for hanging clothes and a locker provided for each employee. → ⑬ – ⑭

It is best to place rows of cupboards and shelving at right angles to the windows. Window sills should if possible be at the height of the cupboards.

Changing rooms for men and women must be separate, sheltered from view and draughtproof. Washing and changing facilities must be in separate rooms that are directly linked.

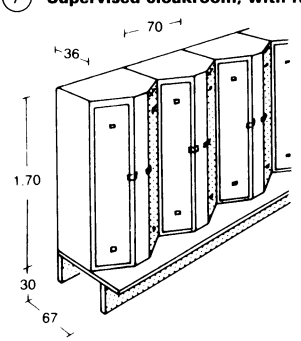
Guidelines for widths of circulation routes: for companies with 20 people or less, routes should be between 0.875 and 1.00 m wide; for up to 100 people, min. 1.10 m and usually 1.20 m; for up to 250 people, min. 1.65 m and usually 1.80 m; for up to 400 people, min. 2.20 m and usually 2.40 m. → ① – ⑦

For open cloakrooms the following minimum distances between hooks or coat hangers must be adhered to: for street clothing, hooks 20 cm apart, coat hangers 10 cm; for dry work clothing, hooks 10 cm apart, coat hangers 6 cm; for wet work clothing, hooks 30 cm apart, coat hangers 20 cm. → ① – ④

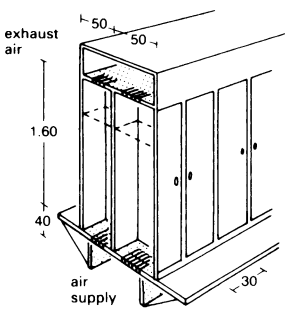
Changing facilities: for normal work, one clothes locker per worker; for dirty work, one double locker (divided into compartments for work clothing and street clothing) per worker.

Changing space requirements per employee:

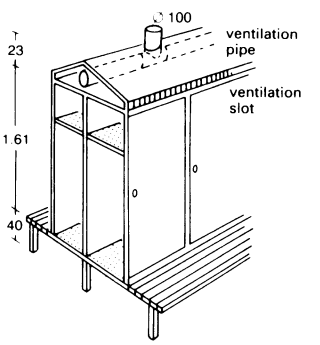
ideal working figure	0.50 m²
with locker and wash basin	0.50–0.60 m²
with locker but without wash basin	0.30–0.40 m²



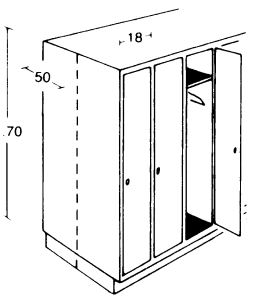
⑧ **Trapezoid changing cubicles (Rotter system)**



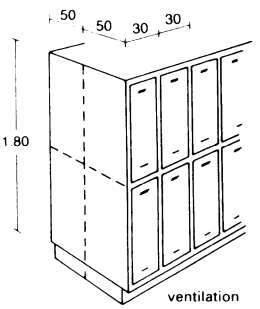
⑨ **Double rows of ventilated lockers and benches**



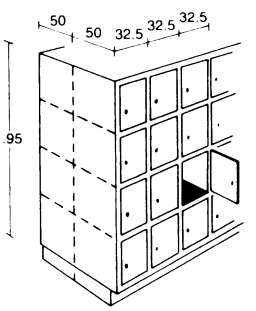
⑩ **Lockers with sloping roofs and ventilation pipe**



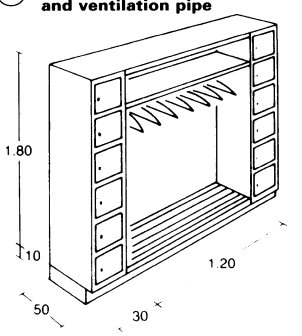
⑪ **Narrow locker**



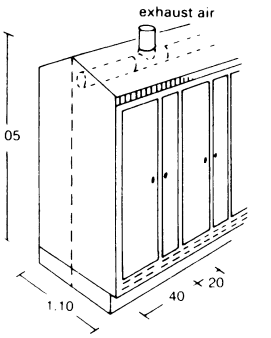
⑫ **Two-level row of lockers**



⑬ **Small lockers**

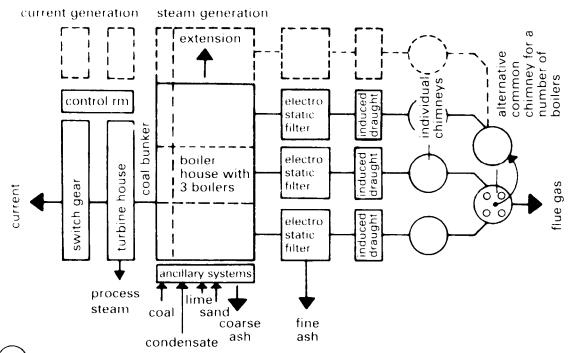


⑭ **Lockers with open coat-hanging arrangement**

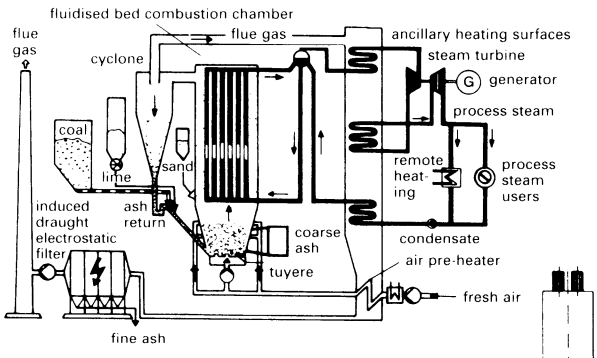


⑮ **Two-compartment lockers (20 and 40 cm wide) for street and work clothes**

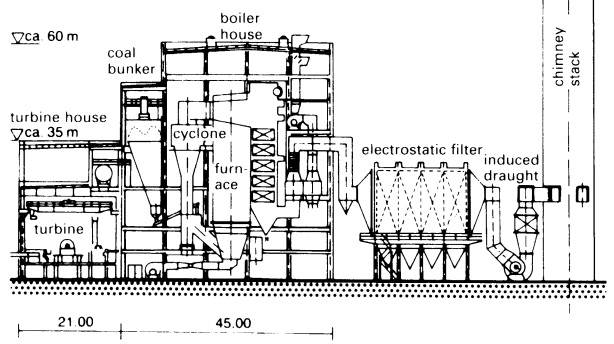
POWER STATIONS



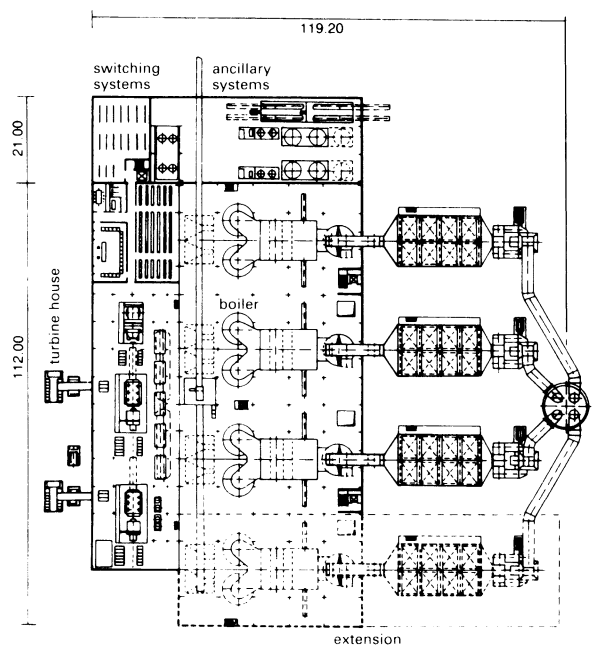
① **Power station schematic diagram**



② **Scheme for a power station with heat/power coupling**



③ **Cross-section of the power station shown in the plan view ④**



④ **Plan of power station with fluidised bed firing**

Power station with fluidised bed firing

The function of a power station is to generate electrical current, steam or hot water in a safe and environmentally acceptable manner. In coal-fired power stations, fluidised bed firing became popular in the 1980s as an alternative to other means of firing, such as coal dust firing or grate firing. Various concepts and practical designs were developed: from stationary through to circulatory systems. Due to the increasing emphasis on protection of the environment, the trend is towards circulatory fluidised bed firing. Further developments are anticipated in the direction of pressurised fluidised bed firing.

The *essential system components* and the most important *process flows*. → ①

- Steam generation is a very significant part of the installation, consisting of the boiler house, with a number of boilers, the coal bunkers and small storage containers, auxiliary systems, electrostatic filters, induced draught plant and chimney stacks.
- There is a second complex for current generation, which contains the turbine house with turbines and steam distribution, switch gear with transformers, current distribution, electrical measuring, control and instrumentation equipment.
- The monitoring and control of all systems is carried out from a centralised control room.

The essential *material flows* are:

- inputs of coal, oil or gas, lime, sand and condensate
- output flows of electrical current, process steam, ash and flue gases
- internal flows such as cooling water.

The processing and storage of the solid and fluid substances take place centrally in the ancillary systems; the individual user equipment within the power station is supplied from this source.

The kind of application shown in the functional diagram of a power station with fluidised bed firing and heat/power coupling → ④ occurs in industry and heat generating stations.

The coal fuel is supplied by a mechanical conveyor to the hot ashes in the return ash circuit; it passes from there to the lower section of the furnace. In the case of dried types of coal, pneumatic conveyance direct into the furnace is preferred. Complete combustion takes place at 800–900°C. The air required for combustion is extracted from the boiler house or from the fresh air outside, warmed by an air pre-heater and fed via a pressurising blower through the base of the tuyere as primary air, and also on a number of levels, as secondary air. Hot flue gases arise during the combustion. The ash in the furnace, absorbing a portion of the heat of combustion due to intensive turbulence, is entrained by the flue gases and imparts heat to the heating surfaces in the furnace up to the point of entry into the cyclone.

The solid matter is mostly separated from the mixture of flue gas/solids in the cyclone and returns to the furnace via the ash return circuit – hence, a circulation of solid matter is achieved. The hot flue gases are cooled on the ancillary heating surfaces; depending on the temperature level, high pressure steam and medium pressure steam becomes superheated, then becomes a condensate, and combustion air is heated. The flue gases are cleaned at approximately 140°C in the electrofilter – or alternatively, in the gauze filter –and drawn off by the induced draught plant via either a single chimney stack or a collector chimney stack.

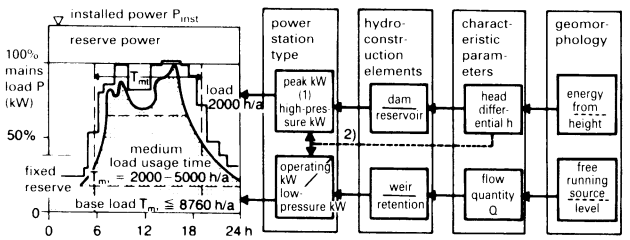
To maintain the sulphur emissions at an acceptable level, lime is fed into the furnace in metered quantities; sand and other materials are used on the first filling and, subsequently, provide a build-up of the circulating solid matter.

The generated high pressure steam is used to drive a steam turbine, and, then, following intermediate superheating as medium pressure steam, expanded to a condition suitable for process steam. The energy in the flow is converted to power in the turbine and thence to electrical current in the generator. The process steam is used, among other things, for the generation of hot water for remote heating systems, for drying processes and for chemical reactions. This steam gives up heat essentially through condensation and the condensate is collected, cleaned if necessary and returned to the boiler as feed water.

A cross-section → ③ and the plan of a power station → ④ give the dimensions of the salient parts. The dimensions apply to a medium industrial power station consisting of three boilers, each generating 200 t/h of steam. An extension is shown with an additional boiler.

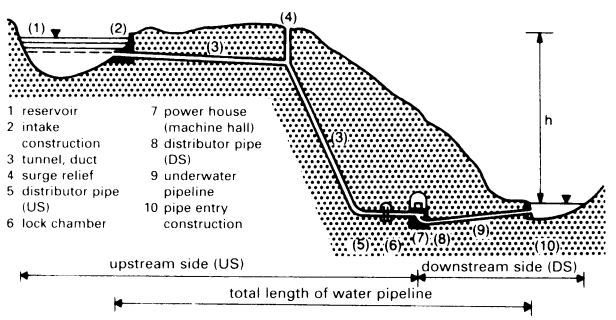
Stage-by-stage extension is possible by integrating new systems in existing power station complexes; new designs must also incorporate the facility for extension while existing systems are operated continuously and must reserve space for such developments.

HYDRO-ELECTRIC POWER STATIONS

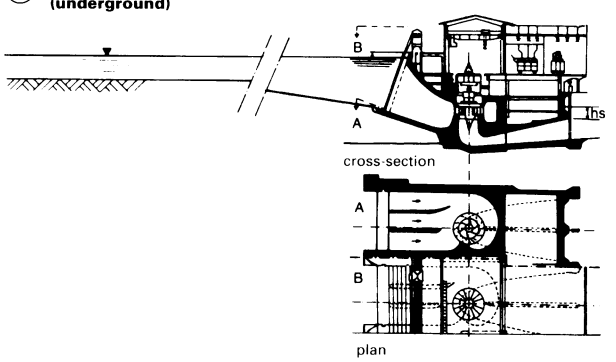


(1) also pump-fed power stations
(2) high-pressure power station (without reservoir)

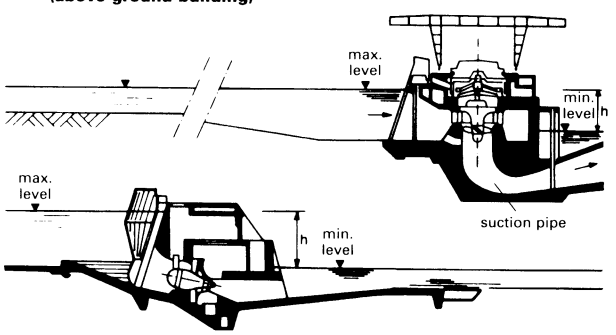
① **Grid supply loading sequence and hydro-electric power station types**



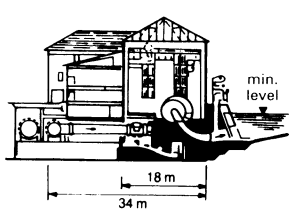
② **Power station with high-level reservoir and long supply pipe line (underground)**



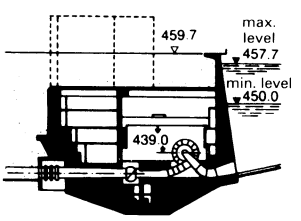
③ **Low-pressure power station with a vertical axis spiral turbine (above ground building)**



④ **Power house with inclined ducted turbine and spur**



⑤ **Power station with vertical Kaplan turbine (open air construction)**



⑥ **Power house with free-standing machinery hall**

⑦ **Power house in trench infill installation**

The construction, shape and size of power stations in hydro-electric installations depend on the natural conditions and the type, housing shape, axial position and number of fluid power machines: the smaller the machine, the smaller the built elements.

Types of turbine are distinguished by their rotational speed. The different categories overlap with one another.

Turbine types	Applications
free jet (Pelton)-turbine	large heads (up to 1820 m), low mass flows; multi-nozzled at high mass flows
Francis turbine	medium heads (670–50 m) at high mass flows
Kaplan turbine	strongly fluctuating mass flows and low heads (max. 70 m)
through flow (Ossberger) T	for power up to a max. 800 kW with strongly fluctuating heads and mass flows

The pumps in pump-fed reservoir power stations, which store excess current as hydraulic energy, are centrifugal pumps of the Francis type. They may, however, be multi-staged when used to overcome greater supply heads. Pump turbines are reversible machines for pump and turbine operation.

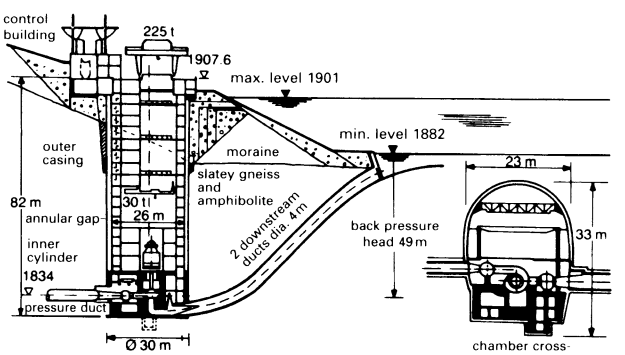
In Francis and Kaplan turbines, as a rule, the water is fed to the turbine through a spiral housing, but at low powers and low-pressure heads the turbine assembly can be supplied from a duct. For Kaplan turbines of low to medium power, the ducted turbine has emerged, in which the ship's propeller type turbine wheel is installed in a tube. On free flow turbines, the housing acts as a spray protection for the water that has passed through the turbine. The axial direction of the machines can be vertical, horizontal, or even inclined, in the case of ducted turbines.

The output power is distributed by optimising the number of machines, each of which is of the same rating. Each set of machines is installed as a block, the 3D dimensions of which are directly dependent on the type and diameter of the turbine wheel. Correct vertical positioning of the turbines is crucial to construction costs and trouble-free operation; it is dependent on the type of turbine and on the height of the location relative to sea level.

The complete power station comprises the machine assemblies, the foundation blocks, which in plan view occupy about the same area, and the ancillary system housings, which are grouped around the main assemblies with the minimum demands on construction costs and space.

Methods of construction

With the exception of underground installations, the size and shape of the space occupied by the machines follows two trends: halls with gantry cranes, designed for the movement of the largest machine components (standard power station construction) or, alternatively, open air, low-lying construction, in which the largest machine components are lifted by means of an external mobile portal crane (or conventional mobile crane). Low-lying machine installations, which occur in high-pressure and pump storage power stations, are constructed in trench excavations with infill (horizontal machines), or using shaft construction (vertical machines). In underground installations, the turbine machinery is sited in mining industry type cavities, wherever possible in solid rock which requires little use of constructional concrete.



⑧ **Power station in shaft installation**

⑨ **Underground power station**

chamber cross-section, F = 670 m²