WORKSHOPS: WOODWORKING

Generally the change in plan form from long sheds to more compact developments 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 70-80m² per 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. 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 (1.00–1.35m).
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.

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


1. Functional diagram for carpentry and joinery business

2. Example of a carpenter and glazier's business

3. Example of a joiner's business - ground floor

4. Example of a joiner's business - ground floor

5. First floor - 4 and 5
WORKSHOPS: WOODWORKING

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

Capacity of storage systems: examples

Shelving with brackets

width \( w = 1.0 \text{ m} \)

height \( h = 2.0 \text{ m} \)

length \( l = 6.0 \text{ m} \)

Enclosed shelving space

\[ V = b \times h \times l = 1.0 \times 2.0 \times 6.0 = 12.0 \text{ m}^3 \]

If the density of material, \( r \), is \( 0.8 \text{ t/m}^3 \), the total weight stored would be

\[ R = V \times r = 12.0 \times 0.8 = 10 \text{ t} \]

(rounded up)

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

\[ B = 8 \times 7.5 = 60 \text{ t} \]

The store turnover frequency is then given by

\[ B = R \times 60 = 60 = 6 \text{ times} \]

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
WORKSHOPS: METALWORKING

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.

Tools and machines: FM folding machine; PD post driller; FBM plate-bending machine; DM dressing machine; DP dressing plate; HS hack saw; KS bow saw; SS sheet shears; SNS 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

Sanitary and heating technology company

Architectural ironmongery business and fine metal construction
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’ →
(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.

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. Guideline: for new cars, approximately 40-45 m² display area per car. Compact display, approximately 24 m² per car; distance between vehicles > 1.70 m.
VEHICLE REPAIR SHOPS

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 1½ to 2½ 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 [1] - 7 for lorries, towing vehicles, special vehicles, containers and trailers, cars, forklifts and electric vehicles.
VEHICLE REPAIR SHOPS

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 7.00 m, width 4.00 m, height 2.85 m. 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.
VEHICLE COMPANY WORKSHOPS

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 6.50m x 3.50m 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 ≥ 80m but repair shops for light commercial vehicles are possible on sites with little depth (minimum 40m). → ④ - ⑤ for a company working with light commercial vehicles and buses.

Plan examples → ⑥ - ⑧ show the smallest unit of an independent commercial vehicle repair service. Offices and social rooms on the first floor → ⑨.
WORKSHOPS: BAKERY

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.

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, rakes, 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).
**WORKSHOPS**

*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) ≥ 4.0m. Width of circulation routes ≥ 2.0m. Work space around cutter and mincer: 3m² each.

Distance of machines from walls (for repairs) 40–50cm. 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.
WHOLESALE BUTCHERS

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 slaughter. 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 to 5 are constructed on a grid of 15.50 x 15.50 m. 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 five 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 x 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 3 m. The slaughter area for large animals, which includes a winch, should be 1.50 m higher. The windows should be high enough to prevent children from looking in and walls should be tiled to a height of 2 m.

1. Unloading bays
2. Market hall
3. Railway track
4. Staff
5. Hot fermentation
6. Staff and equipment rooms
7. Administration
8. Sanitary facilities
9. Dissection
10. Porter
11. Blood drawing
12. Slaughter hall
13. Examination for diseases
14. Vets
15. Stables
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
2. Site plan of meat products factory
3. Section along A axis
4. Section along B axis
5. Ground floor of meat products factory
On a ground floor area of 4500 m², 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. 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.
INDUSTRIAL BUILDINGS: PLANNING

(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 → ①
INDUSTRIAL BUILDINGS: PLANNING

(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; work shop 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 work-station 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 Width* (no.) (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 of the protective guard must be not less than 2.00 m.
WAREHOUSE DESIGN

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 coordinates 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 3.45m; 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

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, rack trucks, rack stacking equipment, and stacker cranes 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.

<table>
<thead>
<tr>
<th>WAYS OF STACKING PALLET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1500</td>
</tr>
<tr>
<td>2000</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
<td>15000</td>
</tr>
<tr>
<td>20000</td>
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<tr>
<td>30000</td>
</tr>
</tbody>
</table>

Characteristics of handling machines:
- Max. stacking height
- Max. load
- Max. speed
- Max. turning radius
- Max. travel speed

Use of storage space with fork-lift

With stacker crane

With stacker and extendable mast

With stacker and reach fork-lift

Possibilities for fixing guide rails:
- Rails below gear
- Guide rails above gear

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

3. Different order assembly systems

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 m²
- 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
WAREHOUSING TECHNOLOGY

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 4.5m and for loads of up to 250kg/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 2.80m have become standard (large enough to take three Euro pallets next to each other). They can be stacked to a height of 12.00m. Intermediate platforms can be constructed for multistorey, self-supporting platforms with load bearing capacities of up to 500kg/m².

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

**Table: Width of Racking (depth 600-1100 mm)**

<table>
<thead>
<tr>
<th>Height of racking</th>
<th>Depth of frame b/B</th>
<th>Number of barrels</th>
<th>Height of racking/d</th>
<th>Depth of roof (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
<td>400 x 900</td>
<td>9</td>
<td>3600</td>
<td>1450</td>
</tr>
<tr>
<td>3300</td>
<td>400 x 950</td>
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<td>4000</td>
<td>1450</td>
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<tr>
<td>3600</td>
<td>400 x 1000</td>
<td></td>
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<td>1450</td>
</tr>
<tr>
<td>3900</td>
<td>400 x 1050</td>
<td></td>
<td>4000</td>
<td>1450</td>
</tr>
</tbody>
</table>

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

**6 Cable mast standard racking**

**7 Barrel racking for outdoor storage**

**8 Continuous bracket racking**
HANDLING

Basic dimensions of pallets according to European standards: 0.80 m x 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.

Wheel 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 reloading 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.
INDUSTRIAL BUILDINGS: SHEDS

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. →

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). →

Dimensions: for lightweight buildings bay widths of 5–7.5 m; economically efficient for spans of 10–30 m. In cases where columns are air-hurdance, spans of up to 50 m are possible. →

If possible, strutting which takes up space should be avoided and solid frames used instead. →

The shed height may have to be adapted to the 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.

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MULTISTOREY INDUSTRIAL BUILDINGS

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. – 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). – 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. – Circulation routes in the middle of the building are not included in the calculation – see 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. – 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. – 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. – Workstation to window distance should not be more than twice the height of the window head above the table surface.
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 kiosks. 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 cm² is required, or possibly 1000 cm² 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.

<table>
<thead>
<tr>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of WCs</strong></td>
<td><strong>Number of WCs</strong></td>
</tr>
<tr>
<td><strong>Public WCs</strong></td>
<td><strong>Public WCs</strong></td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>75</td>
<td>4</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>130</td>
<td>6</td>
</tr>
<tr>
<td>160</td>
<td>7</td>
</tr>
<tr>
<td>190</td>
<td>8</td>
</tr>
<tr>
<td>220</td>
<td>9</td>
</tr>
<tr>
<td>250</td>
<td>10</td>
</tr>
</tbody>
</table>

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

Large WC facilities

Dual row WCs, doors opening outwards

As 9 but with doors opening inwards

Single row urinal bowls and trough

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.

The temperature in changing and washing facilities should be 20–22°C. Water consumption per person per day is roughly 50 litres.
<table>
<thead>
<tr>
<th>Type of space</th>
<th>Hygiene facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC(s) for women</td>
<td>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</td>
</tr>
<tr>
<td>WC(s) for men</td>
<td>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</td>
</tr>
<tr>
<td>Offices</td>
<td>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</td>
</tr>
<tr>
<td>Cleaner's room</td>
<td>1 cleaner's sink</td>
</tr>
<tr>
<td>Tea rooms</td>
<td>1 boiling water dispenser 1 washing up sink with draining board</td>
</tr>
</tbody>
</table>

1) Maximum of 16 toilets per facility.
2) Average boiling water consumption per person per day is 0.15 litres (1 litre of water equals 5 to 6 cups)

1. Facilities for office buildings

<table>
<thead>
<tr>
<th>Women</th>
<th>WC(s)</th>
<th>Bidets</th>
<th>Wash-basins</th>
<th>Cleaner’s sinks</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-10</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17-20</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>25-30</td>
<td>3</td>
<td>1-2</td>
<td>2-3</td>
<td>1</td>
</tr>
<tr>
<td>35-40</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>45-50</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Men</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10-13</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20-25</td>
<td>2</td>
<td>1-2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>30-39</td>
<td>2-3</td>
<td>2-3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>40-49</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>50-59</td>
<td>3-4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

1) When planning small offices it is advisable to double the (1) number of wash basins, WCs and urinals

2. Number of items per person

<table>
<thead>
<tr>
<th>Normal working conditions</th>
<th>Number of washing facilities per 100 people</th>
<th>Wash-basins</th>
<th>Foot baths</th>
<th>Showers for the disabled</th>
<th>Baths</th>
<th>Baths for the disabled</th>
<th>Drinking fountains</th>
</tr>
</thead>
<tbody>
<tr>
<td>little dirt</td>
<td>15</td>
<td>10</td>
<td>(10)</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>clothing, wood, light engineering</td>
<td>20</td>
<td>10</td>
<td>(10)</td>
<td>8</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>moderately dirty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>builder’s yards, engineering works</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exceptional working conditions</th>
<th>Number of washing facilities per 100 people</th>
<th>Wash-basins</th>
<th>Foot baths</th>
<th>Showers for the disabled</th>
<th>Baths</th>
<th>Baths for the disabled</th>
<th>Drinking fountains</th>
</tr>
</thead>
<tbody>
<tr>
<td>very dirty coal industry, limestone and cement ind., tar works</td>
<td>25</td>
<td>12</td>
<td>-</td>
<td>10</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>hot steel works, glass factories, work places using heat treatments</td>
<td>25</td>
<td>12</td>
<td>-</td>
<td>10</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>dusty aggregate crushers, quarries, parts of the ceramics industry</td>
<td>25</td>
<td>12</td>
<td>-</td>
<td>10</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>humid laundries, dye works</td>
<td>25</td>
<td>16</td>
<td>-</td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>humid and very dirty coal and ore mines, coal washing, ore processing plants</td>
<td>25</td>
<td>12</td>
<td>-</td>
<td>10</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>smelly sewage plants, animal waste processing works</td>
<td>25</td>
<td>16</td>
<td>-</td>
<td>7</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dangerous working conditions: processing toxic, infectious or radio-active</td>
<td>25</td>
<td>12</td>
<td>-</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

3. Facilities for industrial companies

4. Types of work and appropriate washing, shower and bath facilities
CHANGING ROOMS, LOCKERS

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 shelves 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:

<table>
<thead>
<tr>
<th>Description</th>
<th>Space (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal working figure</td>
<td>0.50</td>
</tr>
<tr>
<td>with locker and wash basin</td>
<td>0.50–0.60</td>
</tr>
<tr>
<td>with locker but without wash basin</td>
<td>0.30–0.40</td>
</tr>
</tbody>
</table>

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
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 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 circulating systems. Due to the increasing emphasis on protection of the environment, the trend is towards circulating 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 are:

- Steam generation is a very significant part of the installation, consisting of the boiler house, with a number of boilers, the coal bunkers and 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 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 directly 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 and the plan of a power station give the dimensions of the salient parts. The dimensions apply to a medium industrial power station consisting of three boilers, each generating 200t/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

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.

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

The pumps in pumped 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 main 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.