# 1 An overview of building services

## 1.1 What are building services?

Building services are engineering systems. They are placed on, threaded through, and fixed to the structure and fabric of a building.

Any building services (BS) system comprises three elements:

- plant
- distribution
- terminals.

Even the most basic building requires six or seven separately identifiable systems to make it work. The building's form and function affect the complexity of building services.

Building engineering services are generally referred to by builders as M & E, mechanical and electrical services. This broad grouping can include public health, fire and security systems. Lifts and escalators are usually referred to under those names and carried out by specialist firms. Other associated but specialist building services systems which may be carried out under separate contracts are:

- sub stations
- high voltage switch gear
- data and telecommunications services
- generators
- uninterrupted power systems (UPS)
- kitchens and cold rooms
- medical gases
- process services.

These services may also be found within M & E contracts as specialist subtraders. We can understand why they are necessary by glancing at Table 1.1.

To support and operate the BS there are the essential utilities:

- gas
- water
- electricity
- drainage
- telecommunications.

**Table 1.1** The generic families of building services

| |
|---|
| Air conditioning |
| Heating and ventilation |
| Water services |
| Lighting |
| Electrical power |
| Fire fighting |
| Smoke control |
| Fuel systems |
| Waste systems |
| Data and telecoms |
| Security |
| Special processes |
| Lifts |
| Controls |
| Lightning protection |

## 1.2 Why are building services necessary?

Building services enable buildings to be used for their designated purpose. This they do within a framework of enabling and controlling legislation:

- by creating an internal environment – heating, ventilation, air conditioning, lighting and acoustics;
- by defending the building from the external environment – lightning, rain, wind, noise, heat and cold;
- by providing protection – against fire and for security;
- by enabling communication – through voice, vision and data systems;
- by providing welfare – with toilet and first aid facilities (including those for the disabled), and vending/catering;
- by disposal of waste – through plumbing, recycling and refuse collection systems and services.

Through services systems buildings are made to function safely and healthily.

During building occupation the environmental, power and public health services are dynamic, while those of fire fighting and security are generally passive. The passive systems becoming dynamic only upon activation, which may be by human intervention or automatic sensing. Outside periods of building occupancy the systems are in dormant and passive sensing modes, or in the case of environmental systems maintaining a predetermined lower level of internal climate that can be raised quickly to occupancy standard.



## 1.3 Matters of design

### 1.3.1 CLIMATE

Geographically designated as a temperate climatic zone, the weather patterns of the British Isles pose problems for the BS designer. By comparison Scandinavian countries have much lower external ambient temperatures, but the temperature tends to go down and stay down for long periods. This gives an external environmental stability to which internal climates can be matched. But in the British Isles we can be subjected to considerable unpredictable changes in temperature; rain and wind in a 12 hour daytime period. Designing for the 'average' often catches out the ability of internal climate systems to cope with such changes.

### 1.3.2 ESSENTIAL SERVICES

It is mandatory for all occupied buildings in the UK to have:

- heating
- ventilation
- plumbing
- hot and cold water
- power
- lighting.

and supporting utilities. Certainly the ventilation may be by natural means, via openable windows; it is nevertheless essential in providing the oxygen we breathe.

### 1.3.3 THE EFFECT OF FUNCTION AND FORM

Services designs are affected by building function, which dictates building form and layout. These latter have an impact on the complexity of the engineering services to be provided and the way they are integrated with the structure, and interface with the buildings fabric and finishes. Some examples of the effect of these aspects on different buildings are as follows:

- A modern hospital of 'nucleus' cruciform design has service streets meeting at intersections where operating theatres, laboratories and toilet facilities increase the density of services provision.
- Manufacturing facilities with process equipment and machinery bring demands for spaces varying from large open production lines with exposed services, to small clean/sterile atmosphere rooms and enclosed services. In either, the mix of process related services may include steam and condense, compressed air, vacuum, cooling water

and drainage lines, clean electrical supplies, high grade lighting, and volatile gases requiring state of the art leak detection.

- The acoustics of theatres and concert halls will make demands on the careful application of the heating, ventilation and air conditioning (HVAC) systems serving auditoria and rehearsal rooms, etc. The rotating machinery of fans and pumps will be of slow speed and isolated from the ducting and pipework systems. Air distribution terminals must be selected to give adequate throw of air without generating noise at the outlet.
- Leisure centres with swimming pools and ice rinks bring specialist complexity to engineering services. Flumes, diving tanks, underwater lighting effects, lighting to avoid spectral glare, water filtration and treatment are all requirements additional to the general services. For an ice rink the integration of the ice pad with the building structure and foundations is an interface requiring particular care.
- For offices the depth of floor plan (shallow or deep), relationship to an atrium, false ceiling and floor depths and the number of service cores will determine the layout of engineering services. Whether it is to be speculative, a prestigious headquarters or a local authority building will determine the standards.

### 1.3.4 LEGISLATION, CODES AND STANDARDS

The legislated requirements for buildings and their services are very extensive and are treated here in the context of scene setting. Buildings first require planning approval and must be further designed and constructed in compliance with the Building Regulations. Approval to the latter is through local authority building control departments; these may also carry the responsibility for fire approval. Alternatively, fire approval may be delegated to the local brigade. Whatever patterns of controlling organization apply, matters of public and environmental health will be generally embraced by the local authorities. If the building is being procured on behalf of the state e.g. as a prison, government laboratory or defence establishment some 'normal' building regulations may be set aside. But, be assured, they are nearly always replaced by a higher, more onerous level of requirement.

As befits a developed society there is no shortfall, locally or nationally, in the requirements for providing safe and healthy buildings. The overall architecture of relative legislation is framed in the Health and Safety at Work Act etc. 1974. Under this Act, regulations covering premises, plant and machinery, substances, procedures and people have been introduced. One of the most far reaching regulations for the site manager are the recently introduced Construction (Design and Management) Regulations 1994.



For the services designer, compliance with legislation means the acquisition of knowledge so that the system selected to meet the brief are as strong, safe and simple as they can be. Fortunately there is much guidance by way of Approved Codes of Practice (ACoP), Codes of Practice (CoPs) and of course British Standards. The last named are generally recognized as being the minimum standards for components, equipment and system designs. Some also cover system management. Further help is on hand for the designer through membership of professional institutions, with their guides, codes, manuals, standards, technical notes and memoranda. Support can be procured from a wide range of government and industry research organizations:

- the Energy Efficiency Office (EEO)
- the Building Research Establishment (BRE)
- the Fire Research Station (FRS)
- the Building Services Research and Information Association (BSRIA)
- the Construction Industry Research and Information Association (CIRIA).

BSRIA's *Reading Guide 14/95 Building Services Legislation* [1] is a good starting point for any investigation into discovering whether, or what, legislation applies to a subject. For standards, codes, guides and other information available from most of the professional institutions, consultancy associations and learned societies (see Appendix M). Much of the information is available to non-members.

All buildings have to meet minimum standards in the provision of fire detection and prevention systems. Determined by law according to the function of the building they may be enhanced, thereby attracting lower insurance premiums, or backed up because the building must operate at the highest level of availability. Security systems are not required by law but may be provided to enhanced levels for the same reasons as fire systems.

### 1.3.5 ENVIRONMENTAL IMPACT

Clients, particularly those that trade their products to the general public, are concerned with image and the environmental impact of their buildings. Environmental impact may be looked at on three levels:

- global
- neighbourhood
- internal.

These factors do not always appear in harmony. A new building on a greenfield site may require infrastructure development in the road and public utility demands that it makes. Yet it may be a very good neighbour, being sensitively landscaped and providing jobs. Its location may mean that it can possibly manage without air conditioning. In the case of an office building, the greenfield site may be no better than the town or city centre. The central location and the need to keep out noise, dirt and heat usually make the provision of mechanically refrigerated air conditioning essential; but such a development does not require new roads or services mains. Fortunately the Building Research Establishment Environmental Assessment Method (BREEAM) schemes allow comparison of buildings employing differing BS technologies. Additionally, the EEO offers much good guidance on energy targeting and usage to clients in all sectors of commerce and industry.

It is in the provision of new commercial building stock that we are seeing a greater integration of building services. The orientation of a building, application of shading overhangs and vertical screens, taller, narrower windows with deep reveals, trickle vents, and internally, mass concrete thermal sinks, are all important. They can be used in a variety of combinations to mitigate the need for comfort cooling or full air conditioning.

Building structure and fabric and building services are thus becoming more closely entwined. In such facilities it will no longer be possible to test and prove the building climate services independently of structure and fabric.

### 1.3.6 SCHEMATICS

The visualization of BS systems first takes place through the designer's production of schematics. Issued to the builder at tender enquiry stage they can be the source of much valuable information. Whether it is generic or specific, a system schematic will show the essential three elements of plant, distribution and terminals. A generic schematic, e.g. Fig. 1.1, will simply show the relationship of the parts for that type of system. Job specific schematics will diagrammatically relate the system selected by the designer to the building's basic geography; Fig. 1.2 shows a small bore heating system for a bungalow and indicates the piping routes from the boiler to the radiators, and names the rooms served.

### 1.3.7 SYSTEM SELECTION

The generic families of building services (see Table 1.1) do not define the type of lighting, security or air conditioning systems. The designer decides these for the building under consideration and takes into account:



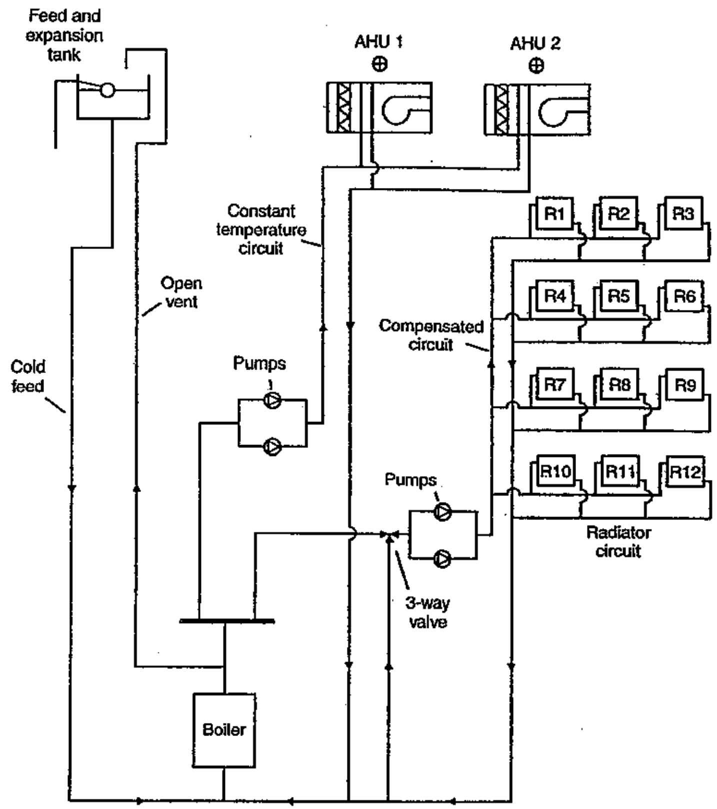


**Figure 1.1** Generic schematic of a low pressure hot water heating system. (Source: BSRIA TN 17/92, *Design Information Flow.*)

- capital cost
- running cost
- ease of maintenance
- flexibility (change of layout)
- noise
- appearance of terminals
- space requirements (plant and distribution)
- ease of control
- incursion into usable space
- user acceptability.

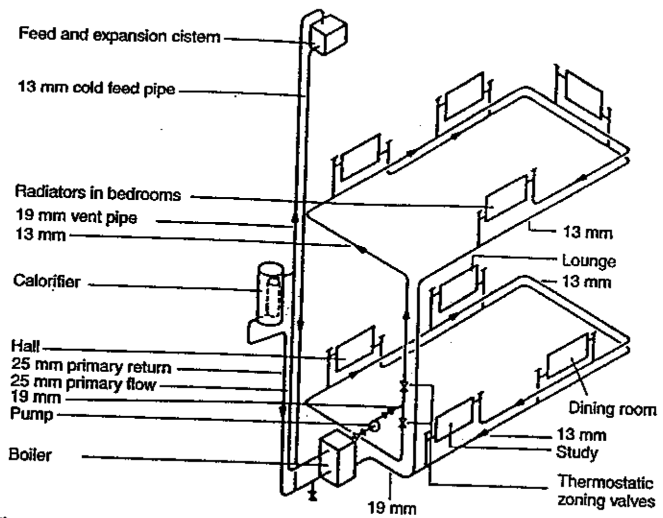


**Figure 1.2** A small bore heating system. (Reproduced from F. Hall, *Building Services and Equipment*, Vol. 1, 3rd edn, Longman Scientific and Technical.)

This random listing will vary in hierarchy of importance for each building type and the services within it.

To give an indication of the wide range of building services systems and their subsystems the Co-ordinating Committee for Project Information (CCPI), Common Arrangement Work Section (CAWS) listings R–X are included in Appendix A. The listing takes the form of an alphanumeric reference for each work section. The CAWS are the basis for the Standard Method of Measurement 7 (SMM 7). An indication of the wide choice of systems from which the designer can make selection can be seen under U, ventilation/air conditioning systems, and V, electrical supply/power/lighting systems.

Laid out in a three-level hierarchy from generic to specific type even these are not exhaustive listings. For V 21 general lighting could be provided by tungsten, fluorescent and halogen lamps combined in a similar seemingly bewildering choice of luminaires.

### 1.3.8 SYSTEM LAYOUT

The design engineer lays out the terminal positions on general arrangement drawings perhaps using computer aided design (CAD). For those terminals on a common system, interconnecting distribution lines will be drawn from the source plant room along distribution routes. The designer will seek, in discussion with the other design team (DT) members, to locate the thermal and electrical power plant in positions which will keep distribution routes as short as possible, while remaining convenient for the connection of utilities.



## 1.4 Where do they go?

### 1.4.1 GENERAL

Having given the site manager a basic insight into some aspects of design for M & E we can enhance his (or her) understanding of where they can be expected to be found on the project. A building's function, form and required levels of fire, safety, security, internal climate and reliability, determine the complexity and density of services to be provided. This in turn affects the spaces services occupy and ultimately the size of the building and its overall cost. It is these aspects rather than the sheer size of building served that determine the space given over to BS.

### 1.4.2 PLANT ROOMS

The size of plant rooms examples the last point. The greater the boiler, chiller, diesel generator required, the more cost efficient they become on a weight and volume occupied basis compared pro rata with units of smaller capacity. In addition the space required around plant items for construction, repair and maintenance seemingly differ very little between the smallest and largest units in a catalogue.

Table 1.2 takes the generic listing of BS and expands it to indicate where the location of major items of plant and equipment are most commonly found.

Figure 1.3 shows (a) the basement plant areas and (b) a section through a prestigious building in which the financial services functions require a high degree of reliability from their services support. The section shows best the take up of space for air conditioning in the general offices and a closer controlled climate for the computer suite. Generator, UPS and Private Automatic Branch Exchange (PABX) make their claim for space. At roof level there is equipment to reject heat from the air conditioning systems, water storage and air handling unit plant rooms, lift motor room, aerial and satellite arrays. The plan depicts the loss of floor area due to vertical transport systems and interconnection between chillers and condensers; with these we are starting to move away into the general distribution routes.

Table 1.2 Location of plant and equipment

| *Services* | *Major plant items* | *Possible locations Low/inter/high level/ External/other* |
|---|---|---|
| Air conditioning | Refrigeration | Low/high/external |
| | Cooling towers | High/external |
| | Air cooled condensers | High/external |
| | Pumps | Low/high/external |
| Heating and ventilation | Fuel store | Low/external |
| | Boilers | Low/high/external |
| | Flues | As boiler location |
| | Pumps | As boiler location |
| | Air handling units | Low/inter/high |
| | Hot water storage | Low/inter/high |
| | Pumps and panels | Related/to storage location |
| Lighting and electrical power | Substation (transformers) | Low/external |
| | High voltage (HV)/low voltage (LV) switchrooms | Low |
| | Generators | Low/external |
| | UPS | Low |
| Fire fighting | Hosereel water storage and pumps | Low/external |
| | Sprinkler control room/ Water storage | Low/external |
| | Wet riser storage and pumps | Low/external |
| | $CO_2$ and foam | Near space served |
| Smoke control | Fans | In or near space served |
| Fuel systems | Solid/oil/gas | Low/external |
| Waste systems | Sewage holding tanks | Low |
| | Sewage and sump pumps | low |
| Data and telecoms | Exchanges | low |
| | Frame rooms | low |
| | Equipment rooms and closets | Low and all intermediate |
| | Satellites and aerials | High (roof) |
| Security | Monitoring station (control) | Low |
| Special processes | Plant and Equipment for compressors, vacuum pumps and generators | Low/external/near served area |
| Lifts | Electric traction M/C rooms | Above/below shaft served |
| | Hydraulic ram | Borehole below car, pump room adjacent |
| | Hydraulic side acting pumps | Low near shaft |



Table 1.2 *Continued*

| *Services* | *Major plant items* | *Possible locations Low/inter/high level/ External/other* |
|---|---|---|
| Control room | Energy, fire and security building management monitoring station | Low |

1.4.3 UTILITIES

Before considering internal distribution let us go back to Table 1.2 and unravel the space and location requirements for the utilities. Following the privatization of water, gas and electricity, supply companies are now happier to contract for providing a service into a building. Whereas previously, even for sites with no more than a few metres from boundary to building, the utility service would be terminated and metered at the boundary, now privatized companies are not only happy to come into the building but may seek to contract for carrying out internal services. Nevertheless, gas, water and electricity metering and intake rooms are best provided near to ground level, preferably with controlled access from the external face of the building. This is particularly so with respect to electrical supplies where, in the case of sharing

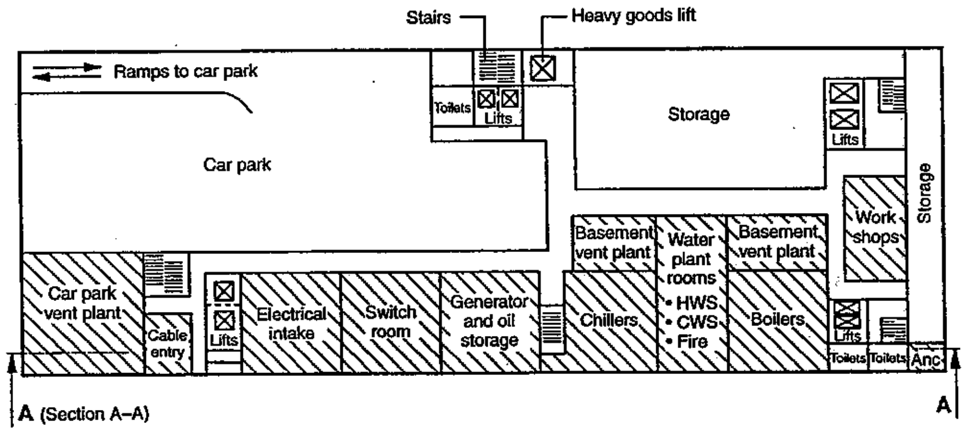


Figure 1.3(a) Prestigious commercial offices, basement plant areas.

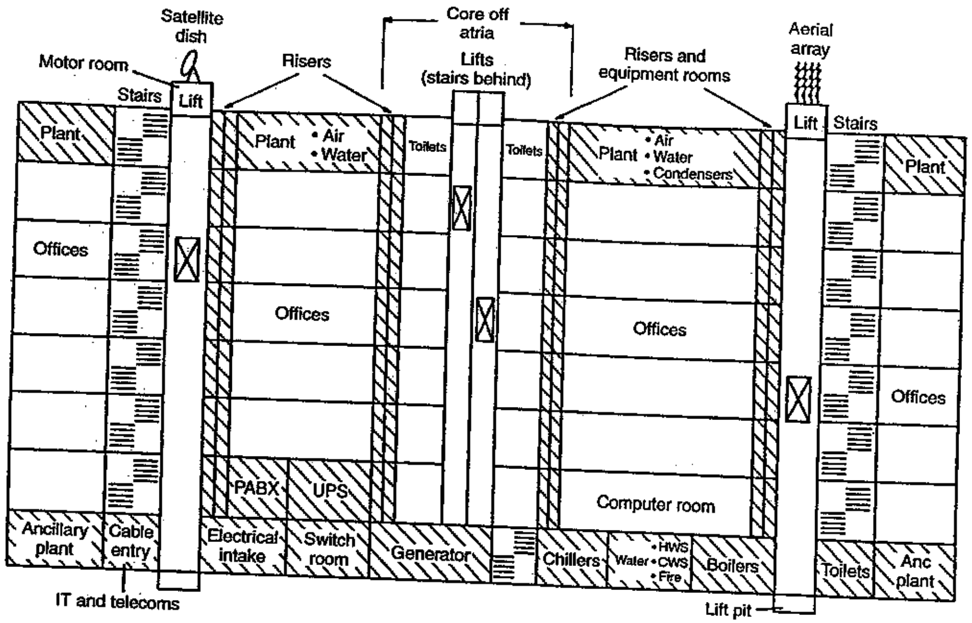


**Figure 1.3(b)** Prestigious commercial offices, section A–A and plant and risers.

an area substation or a dedicated low voltage supply, permanent access to the intake room must be granted with wayleaves to the supply company. If the size of building warrants it, and a more preferential tariff is available, electrical supply may be at high voltage. Here the substation and its maintenance becomes the responsibility of the building owner. The requirements for access to the high voltage meter and switch remain with the supply company, as with low voltage.

Water supplies for fire, e.g. hydrant main, sprinklers and hosereels, may be unmetered. The supply for all other services usually designated 'domestic' will be metered. Many supply companies now require the hosereel service to be metered as it has been known to be subject to abuse in cleaning vehicles and watering landscapes.

Most gas companies are only interested in a single metered supply. The building services designer may be briefed to provide submetering for individual tenancies and kitchens.

The deregulation of communications has also increased demand on building space for engineering services. Previously one only had to consider British Telecom; now we have Mercury and others.

It is usually possible to design the rainwater and foul drainage installations to gravitate from the building. Where this is not possible, soil and surface water drainage can be collected in chambers and discharged through pumped mains into the local authority systems. Normally, sewage pumps are duplicate sets arranged for cascade back up operation.

### 1.4.4 DISTRIBUTION ROUTES

We return to consider the distribution of services between and through buildings. There is a hierarchy of level to be considered. Primary distribution takes place from plant areas both horizontally and vertically. Common route types are, horizontal – crawlways, ducts and trenches and the corridor ceiling void – and vertical – risers (multistorey).

As Fig. 1.4 shows, within a heirarchy of primary and secondary distribution routes there can be considerable geometrical variation. The example could apply to ventilation distribution from an air handling unit, heating pipework from a roof level boiler plant, or water distribution to laboratory benches.

Figure 1.5 is an example of vertical primary distribution within a city centre air conditioned office building. Homing in on the toilet block core in Fig. 1.6, it is seen to be encased by the vertical distribution of nearly every conceivable service system for a building of that type.

Secondary distribution in most types of buildings is arranged horizontally. In some buildings such as hotels and vertically stacked toilet blocks, the connections between risers and terminals are short. Here the concept of secondary and tertiary distribution becomes blurred, but in many buildings, particularly offices, secondary distribution takes place in either floor and ceiling or in both. Figures 1.7 and 1.8 show secondary distribution taking place mainly in the ceiling and floor respectively. In these examples of secondary distribution through floor and ceiling voids it is seen that the terminals are located on the surface of the false floor and ceiling, i.e. the tertiary distribution takes place in the same space. This occurs most commonly with lighting, ventilation or air conditioning systems and to a lesser degree with sprinklers and fire detection heads.

Tertiary distribution is defined as a situation where services are taken from either the secondary distribution or boundary of the serviced space to some point within it. The method of distribution such as dado or skirting trunking, service poles and rails usually takes up some room space. In highly serviced buildings or for aesthetic reasons this final services distribution can be integrated by designers into the furniture

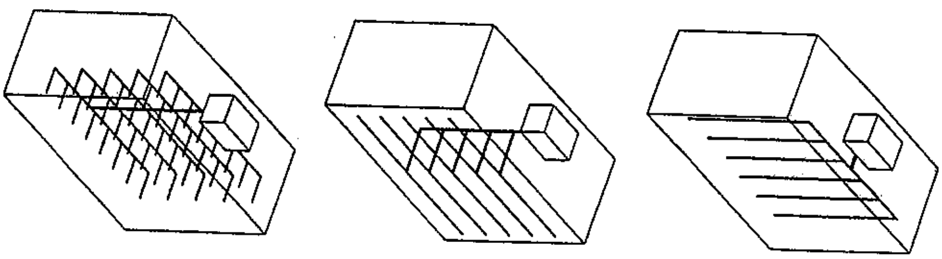

Figure 1.4 Primary and secondary distribution routes – geometrical variation.

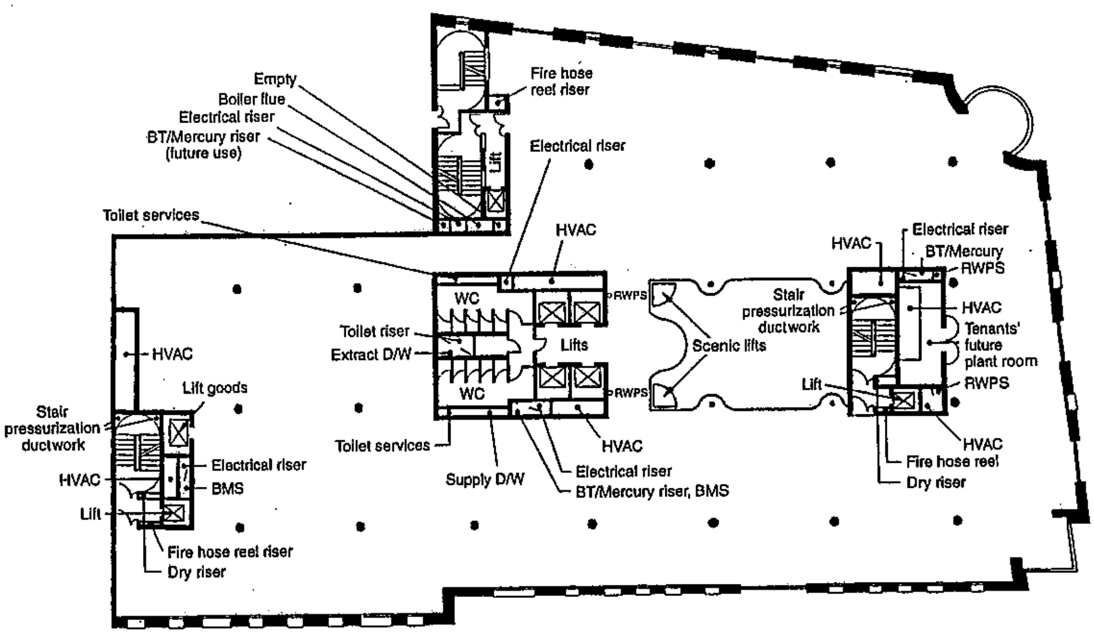


Figure 1.5 Vertical primary distribution spaces within a city centre air conditioned office building.

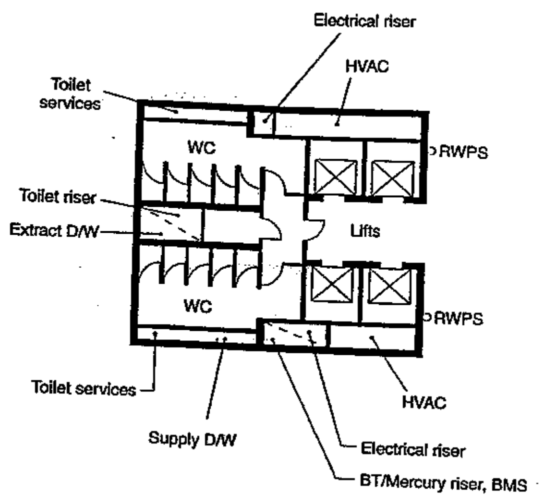


**Figure 1.6** Toilet block core – vertical services distribution spaces.

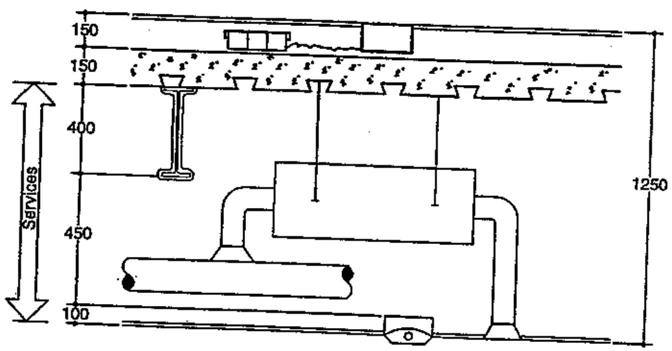


**Figure 1.7** Secondary distribution in ceiling: steel frame metal deck, small raised floor, full access false ceiling, recessed light fittings. (Source: J. Berry, Ove Arup and Partners.)



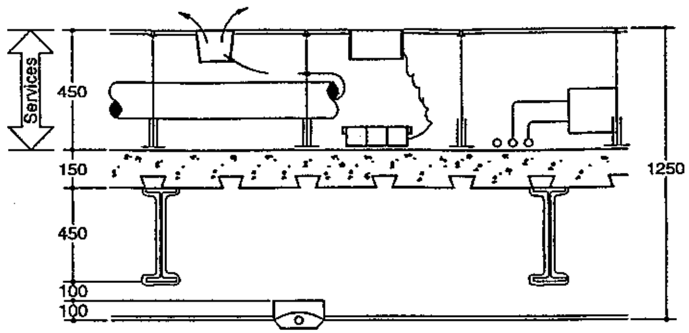


**Figure 1.8** Secondary distribution in floor: false floor depth increased, services removed from ceiling, zone-transferred to floor zone. (Source: J. Berry, Ove Arup and Partners.)

and partitioning. Figure 1.9 shows servicing at the perimeter and screen wall, and Fig. 1.10 workstation servicing in lay-in ducts and hollow section risers.

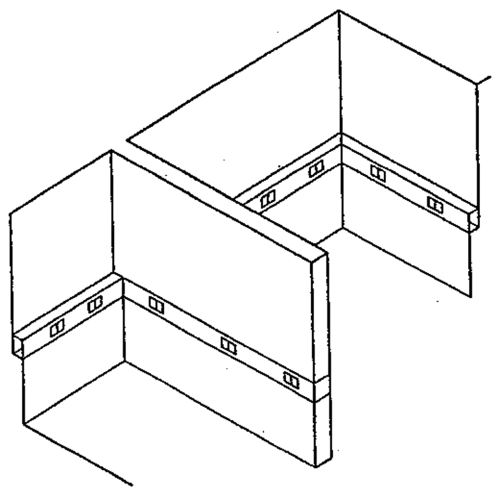

**Figure 1.9** Tertiary distribution – servicing at perimeter and screen wall. (Source: DEGW.)

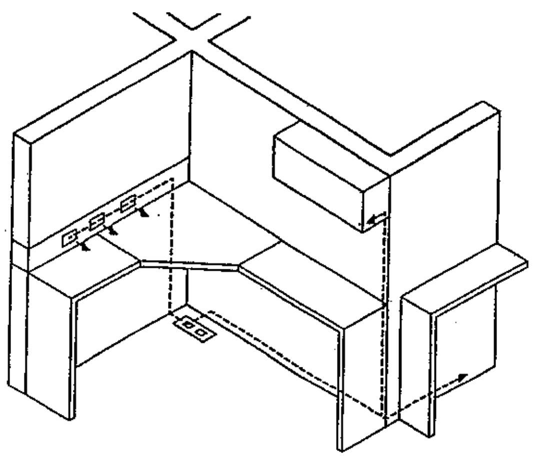

Figure 1.10 Tertiary distribution – workstation servicing in lay-in ducts and hollow section risers. (Source: DECW.)

### Terminals

The terminals of M & E systems are therefore to be found in walls, floors and ceilings, and the fit out furniture of e.g. offices, laboratories and hotels. They may be surface mounted, semi- or fully recessed.

### Industrial buildings

In the large open space of factories, warehouses and DIY superstores the distribution of building services is generally exposed. The main distribution takes place parallel to eaves and valleys from which there are a variety of routes to the terminals. Where required by legislation or insurance, sprinklers may run parallel to the pitch of the roof. At intervals electrical power will follow this slope to smoke vents and openable roof lights. Both of these may alternatively be activated by compressed air. Depending on the form of structural frame, truss or portal, secondary support grids may be required from which will be suspended ducting, piping and power and lighting distribution to fittings suspended to create a notional horizontal plane at eaves and valley level.

Piped services to process machinery featuring steam and condense, compressed air, vacuum, gas, treated and chilled water, can be run in various ways. Commonly, they will drop adjacent to structural columns



and run in floor ducts to the production lines. For steam or water 'used once', or even where process heating or cooling water is closed circuit, sumps, possibly with pumps, will be provided with an underslab gravity drainage system. The piped services may also be provided via overhead tracks with drops to the machines. These may be encased in service poles.

### 1.4.5 FIRE SERVICES TO BUILDING CORES

As with the plumbing and water services obviously associated with toilet areas, there are other services to be found in building core areas. For economy of building layout enabling common use of circulation space, toilets in multistorey buildings are found arranged with lift lobbies, disabled refuge areas and staircases. Contained in an appropriately fire rated compartment, it is here that we will find break glass unit fire alarms and hosereels, wet and dry fire risers. The staircases and lift lobbies are increasingly being required to be pressurized against smoke ingress.

### Fire and acoustic transmission paths

Wherever building services pass through an element of structure or building fabric there is a risk of creating a fire and noise transmission path. Should any of those penetrations occur in a fire rated element it must be sealed to maintain the integrity of the fire compartmentation.

Both the requirements for fire compartmentation and the methods for compliant 'fire stopping', where services pass from one fire compartment to another, are given in the Building Regulations. Many of the methods available to satisfy these regulations will also be effective in preventing or minimizing noise transmission.

## 1.5 Who designs them?

### 1.5.1 GENERAL

From the trunk of generic families of BS listed in Table 1.1 there are many branches. There are literally hundreds of different types of BS systems. There are forty to fifty derivations under air conditioning. The constant churn of technological advancement in lighting, voice, vision and data services seems exponential in its progression curve. Everywhere the application of microprocessor technology aids these advancements. What does all this mean for the BS designer? The need to acquire, disseminate and apply this knowledge means there are few BS consultancies or designer contractors with capabilities to design every building service in house.

### 1.5.2 CONSULTANTS

Consultants do not design lifts, escalators, transformers or generators, equipment or terminals. However, from their knowledge of the function of these components they are able to select and integrate them into services systems for incorporation into buildings. The situation is similar with respect to sprinkler installations: few consultants have the capability or, more importantly, are certified to carry out the complex hydraulic calculations in compliance with the 29th edition Loss Prevention Council (LPC) *Rules for Automatic Sprinkler Installations* (now concomitant with, BS 5306) [2].

For all services, the consultant engineer must be capable of defining the performance criteria and giving weight, and spatial requirements to the structural and architectural members of the design team. To do this it may be necessary for the consultant to obtain information and take advice from the plant and equipment manufacturers.

Prior to 1995 most engineering services design appointments were made under, or derived from the Association of Consulting Engineers three Schedules of Duties. Known as Appendices 1, 2 and 3, they rose in levels of responsibility from 'Performance', through 'Abridged' to 'Full duties' respectively. Building services technology, limits of harmonization with the RIBA Plan of Work, the use of a wider choice of contractual routes and politics outpaced the usefulness of these schedules. The hard market conditions of the early 1990s and political calls for fee competition increasingly exposed their limitations. They have now been replaced by the Association of Consulting Engineers (ACE) Conditions of Engagement 1995, Agreements A(2), B(2) and C(2) [4]. These allow the knowledgeable client to list those duties he wishes the designer to carry out. In other cases, and these may include fee bids, the designer will list duties and a fee for their discharge. In both cases you get what you pay for and there is an onus on the design procurer knowing what is needed; see section 2.2.3, 'Terms of engagement'.

There is an aid to the assignment of duties. The BSRIA has published Technical Note TN8/94, *The Allocation of Design Responsibilities for Building Engineering Services – a code of conduct to avoid conflict* [5]. This provides pro formas for more closely defining those areas of design responsibility that, through differing interpretation, regularly lead to dispute between the designer and the installer (see section 2.2.4, 'Division of responsibilities').

### 1.5.3 THE DESIGNER – CONTRACTOR

The reader will have noticed the use of both terms 'consultant' and 'designer'. Not all design is carried out by consultants or specialists



under their control. A considerable number of BS contractors undertake design in a variety of ways:

- as designer installers working for design-and-build main contractors;
- appointed by developers and other end user clients to work with the separately appointed professional design team;
- appointed by the lead professional designer, usually the architect;
- appointed by project managers to work with the professional team.

There are a number of variations, but all have some direct line design warranty to the end client.

### 1.5.4 NOVATED DESIGN

A further design procurement variant quite frequently used is that of novation, often found in the main contract design-and-build route. Here a consultant may produce a performance or abridged duties design which is passed via the design and build (D & B) contractor to the services designer–installer. These may be novated with a requirement to accept full responsibility for the design and its further development. Sometimes the employer's requirements ask for the D & B main contractor to take the consultant under contract. In turn this leads to the main contractor seeking to mitigate his design responsibility by bringing the consultant and designer–installer together with a form of 'back to back' design warranty.

### 1.5.5 THE INSTALLER

Historically, the greatest percentage of BS design work has been undertaken by consultants working to the ACE 'Abridged duties'. Reduced to its simplest terms this comprised a specification and set of drawings. These last named took the form of general arrangement drawings at 1:100 scale. Some plant room layouts were to larger scale – 1:50; for toilet block layouts, 1:20 and perhaps a few sections depicting the preferred arrangement of services in risers, crawlways, ducts, trenches, ceiling and floor voids. Some consultants enlightened as to where 'pinch points' would occur at congested intersections along the distribution routes would produce better details to show the viability of installation. At best these schemes on 'Abridged duties' were only numerical solutions. Through the development of working drawings and at the workface of construction the installer proved whether they would work.

That now defunct major client, the Property Services Agency (PSA), under the spotlight of scrutiny in spending public money, could not be seen even via its agents, the design consultants, to bestow favour upon one manufacturer or supplier in preference to another. The PSA's consultants were not allowed to obtain competitive quotations, or to preselect plant, equipment or terminals. This led to a certain imprecision in designs for the PSA. There are still many clients appointing consultants who will not let them preselect on 'Abridged duties'. The installer – and remember he is not seeking to trade on his design knowledge – bids the material content for the contract by preparing estimates for plant, equipment and terminals, scheduled by capacity/performance only. Having won the contract the installer sets about producing working drawings. Working with better detail than the consultant on structure, cladding, brickwork, floors and ceilings, etc., the installer will naturally seek economical routing and fixings. Notwithstanding that reasonable objective he will find the need for more bends and sets in his distribution systems than the consultant envisaged, when working with less detail. The consultant, being aware of this, would have called upon the installer to calculate the final air and water circuit resistances to flow, for sizing fans and pumps. The picture is emerging of the extent of 'design' knowledge that the installer must have. More than in any other construction trade the installer's working drawings, offsite construction and work face practices can affect the consultant's 'Abridged duties' design intentions, via:

- fixings;
- anchor points;
- take up of expansion;
- gradient of pipework (venting and draining);
- change sections on ductwork;
- the routeing of electrical conduit;
- the interpretation of earthing and bonding;
- quality of system preparation (cleaning ducts, flushing and chemical cleaning of pipework);
- offsite validation of software.

### 1.5.6 THE DESIGN ENGINEER

The designer has been referred to as one person. Obviously, this not the case. Whether or not it is theoretically possible for one individual to be capable of designing every building service system, that person has yet to exist. From an early point in an engineer's academic and industrial training, personal preferences come to the fore, and trainees set out to become a sprinkler, lift, electrical, controls, plumbing or HVAC engineer. Some engineers encompass a wider range of building services design than others and go on to be called mechanical or electrical engineers. Most start from some specialist base. All are BS engineers and



according to their function and status you may find a mechanical, electrical or public health engineer with overall responsibility for coordinating the design of a project's services.

## 1.6 What do building services cost?

### 1.6.1 AS A PERCENTAGE OF OVERALL PROJECT VALUE

There are lies, damn lies and statistics and then averages. What follows is in the last category. The figures in Table 1.3 are averages. Those who wish to denigrate them by quoting their latest, or most recent project experience with services values outside these ranges will certainly be able to do so. It is considered that the percentages may be of use to the site manager who, by calculating both upper and lower percentages, will arrive at a capital cost range. If the site manager's project falls significantly outside that range he would be advised to seek some understanding as to why. The percentage figures are to be applied in calculating the value of services inside the building and must be related to the overall cost of buildings. A great number of quantity surveying practices are very skilful at cost planning external works with their infinite variables for city, out of town, hard and soft landscaping permutations. But even the most skilful of QSs can fall foul of the unpatterned costs for utilities connections, mains network reinforcement costs, and that great catch all, contribution charges. For all these reasons it is inappropriate to give any worthwhile assessment of what external costs may amount to. In defence of the bet hedging width of

**Table 1.3** Building services costs as percentage of overall job value (internal services only)

| | | % |
|---|---|---|
| Offices | Natural ventilation | 20–30 |
| | Air conditioned | 25–35 |
| Warehouses | | 15–20 |
| Shopping centres | | 15 +/–5 |
| Factories | 7.5 shell: | 20–30 working |
| Leisure centres | | 20–40 |
| Hospitals | | 30–50 |
| Motels | | 20+/–5 |
| 3/4 star | | 30–45 |
| Computer centres | | 50–60+ |
| Social housing | | 15–25 |
| Student accommodation | | 15–20 |

the percentage ranges quoted in Table 1.3 note the following commentary.

- *Offices*. With the increasing use of building design to minimize the worst effects of our climate, the cost of services in these buildings may fall to around or below 20% of the project value. But beware, we are moving into an area where BS and building works can become blurred. Similar thinking can be applied to air conditioning, where building structure such as reinforced concrete high mass thermal sinks, dense building envelope fabric and/or some screening, reduces the size and cost of air conditioning systems. Some of the newer variable refrigerant volume (VRV) systems, usually of Japanese origin, may be applied as comfort cooling systems. Then the percentage cost for an air conditioned building may fall even further, from 25% to 20%.
- *Warehouses*. If they are simple with few workers and the stored product does not require in-rack sprinkler systems then 15% is about right. This may also apply to basic services in DIY stores. For warehouses requiring a more sophisticated environment, high bay lighting of good colour rendition, fire protection and detection, with security systems wiring and battery charging for automatic guided vehicles, 20% is nearer the mark as you approach the bottom level figure of a working factory.
- *Shopping centres*. Here 15% will cover the provision of landlord's services to the public areas, i.e. malls, toilets, stair and lift lobbies, and car parks. It will also cover services along trucking routes and into each unit, for extension and fit out by the tenant. The 15% plus or minus 5% can also be applied to multistorey car parks.
- *Factories*. Services to factory shells and small industrial units are around 7.5%. When you get into working factories the range is quite wide with the upper figure probably being capable of providing some services connections to the machinery.
- *Leisure centres*. At the lower end of the range we have the 'dry' leisure centre, i.e. sports hall with a number of smaller multifunction rooms, gymnasium and snooker rooms. At around the 40% value mark we are extending from the 'dry' into leisure pools with their flumes, diving tanks, water filtration and treatment requirements and on into the truly multifunctional leisure centre which also incorporates an ice rink.
- *Hospitals*. At around 30% we are covering the provision of major hospital extensions, while new district general facilities can absorb towards 50% of the project's cost.
- *Hotels*. Motels can be serviced for around 20% of the overall value. Three- to four-star hotels if out of town will cost about 30%, possibly up to 40% with conference and leisure facilities. For the same level of accommodation in town and city centres with conference and leisure facilities plus a greater variety of speciality restaurants, etc., costs can rise to 45% and above.
- *Computer centres*. For those dedicated facilities located out of town on secure greenfield sites operating possibly as 'back up' to the 'back up' centre of financial institutions, services costs can easily account for 60% plus. This high figure is caused by the need for 100% reliability involving standby generation, UPS, high security, high fire safety, duplicate pumps, fans and standby everything.
- *Social housing*. The wide range is affected by the mix of accommodation units and whether they are provided with low capital electric heating or the higher cost wet systems (radiators/fan convectors).
- *Student accommodation*. This follows the pattern of social housing for similar reasons.



To all of these cost indicators must be added lifts and escalators, where the cost varies according to whether the building is low or high rise.

### 1.6.2 COST RATIOS

In the same way that averages exist for overall building services costs, so also there is a crude pattern of cost relationship between the building services. This applies for a wide variety of buildings, the main affecting variable being that of air conditioning. These ratios which are most accurate for office buildings are shown in Table 1.4.

**Table 1.4** Approximate cost ratios for offices (internal services, excluding underslab drainage)

| Natural ventilation | Air conditioned |
|---|---|
| Electrical = 50% of mechanical | Electrical = 40% of mechanical |
| Public health = 50% of electrical | Public health = 40% of electrical |
| Example (5000 $m^2$ offices) | |
| @£150/$m^2$ = £750 000 | @£300/$m^2$ = £1.5 million |
| Mechanical = £430 000 | Mechanical = £970 000 |
| Electrical = £215 000 | Electrical = £380 000 |
| Public health = £105 000 | Public health = £150 000 |

**Table 1.5** Building services costs material/labour ratios

| | |
|---|---|
| Mechanical | 2.5 to 5:1 |
| Electrical | 1 to 2.5:1 |
| Public health | 1 to 2:1 |
| Sprinklers | 1:1 |
| Lifts/escalators | 10:1 |

### 1.6.3 MATERIAL AND LABOUR RATIOS

The relationship that holds up well is the ratio of material, and here we are including sublet trades, i.e. ducting, insulation and controls, to the cost of labour. These ratios are shown in Table 1.5.

- *Mechanical services*. Where these are predominantly piped services then the ratio of material and labour can be found around 2.5 to 1. Where there is a greater use of offsite manufacture such as in air conditioning with its appetite for sheet metal ductwork and large pieces of plant like chillers, air handling units, etc., then the material to labour ratio widens steeply.
- *Electrical services*. The ratios are closer here, increasing at the upper end due to large pieces of equipment or major sublet items, e.g. diesel generators and HV substations.
- *Public health*. An even closer range than for electrical services due to the high predominance of pipework services. Where the cost of sanitary fittings is included the materials/labour ratio edges upwards.
- *Sprinklers*. The extensive use of labour intensive pipework holds the ratio at around 1 to 1. The use of prefabricated piping can increase this ratio.
- *Lifts and escalators*. The assembly on site of major components manufactured offsite gives these items the highest ratio of all.

### 1.6.4 LABOUR RATES

For 10- or 11-man gangs, obviously quite large projects, all inclusive but unprofited labour rates can be found in the order of:

- mechanical services: £8–9 per hour;
- electrician: £9–10 per hour;
- ductworkers: £8–9 per hour.

In a period of relatively low inflation (1996) it is impossible to predict for how long these figures will remain valid. In addition to these there are of course many specialist trades for which other rates will prevail, e.g. high voltage electrical workers, controls technicians, commissioning engineers and data and telecom installers.



### 1.6.5 M & E SERVICES PRICE BOOKS

A great deal of this information on costs has been gathered over time and through analysis and application of Spon's *Mechanical and Electrical Services Price Book* [6]. Published annually it is of the greatest value in acquiring familiarity through regular use. This and similar works are commended to the site manager so that he can check the value of services, their cost and material-to-labour ratios on every job. The site manager who does this will acquire a useful 'feel' for the correct level of project services costs.

## References

[1] BSRIA (1995) *Reading Guide 14/95, Building Services Legislation*, Bracknell.
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[3] The Association of Consulting Engineers (1981) *Conditions of Engagement*, Agreement, 4a for Engineering Services in Relation to Sub-contract Works, amended 1990–1993, London.
[4] The Association of Consulting Engineers (1995) *Conditions of Engagement 1995*, Agreements A[2], B[2], and C[2], London.
[5] BSRIA (1994) *The Allocation of Design Responsibilities for Building Services – a code of conduct to avoid conflict*, Technical Note N 8/94, Bracknell.
[6] E & FN Spon (annual) *Spon's Mechanical and Electrical Price Book*, London.