5

Building Systems and Components

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Building systems are those primary elements which together define the shape, utility, and comfort of built space. They are classified by discipline: Architectural, Structural, Mechanical, and Electrical. These systems must be planned and designed in concert; individually, they are composed of lesser components, such as interior framing systems, air-conditioning units and plumbing fixtures. Knowledge of how these systems coordinate and interconnect, as well as familiarity with the individual component systems and disciplines is essential for the successful integration of these items. Their coordination is critical to the overall appearance and operation of the completed interiors project.

Architectural

Architectural systems define the volumes and functions of a building. Every project begins with a statement of needs, developed by the end-user and designer, from which an initial space plan is developed. This plan sets the course for the rest of the project, including the locations of mechanical rooms, electrical closets, plumbing shafts, and data/communications shafts within the space. The development of other systems follows the architectural lead. Architectural systems are primarily concerned with enclosure (walls, roof), and definition (partitions, floors, ceilings). For interiors, definition is the primary concern.

Spatial Definition is accomplished primarily by establishing a series of planes in space which organize our understanding of a place.

The primary system of organizing or defining architectural space is the **partition**. Partitions (or more commonly "walls") define and divide space. In modern construction, the stud-framed partition, either metal or wood, is most prevalent. In commercial construction metal is most frequently used (Fig. 1). A typical partition consists of studs at 400 mm (16 inches) on center with gypsum wallboard on each side. The partition may bear directly on structure, or sit on the finished floor, and may extend to the ceiling or beyond - depending upon various requirements placed on the wall to control thermal variance, acoustics, firespread, etc. Its thickness may range from 65 mm (2-1/2 inches) to more than 300 mm (12 inches) depending on what services are contained within, or what other

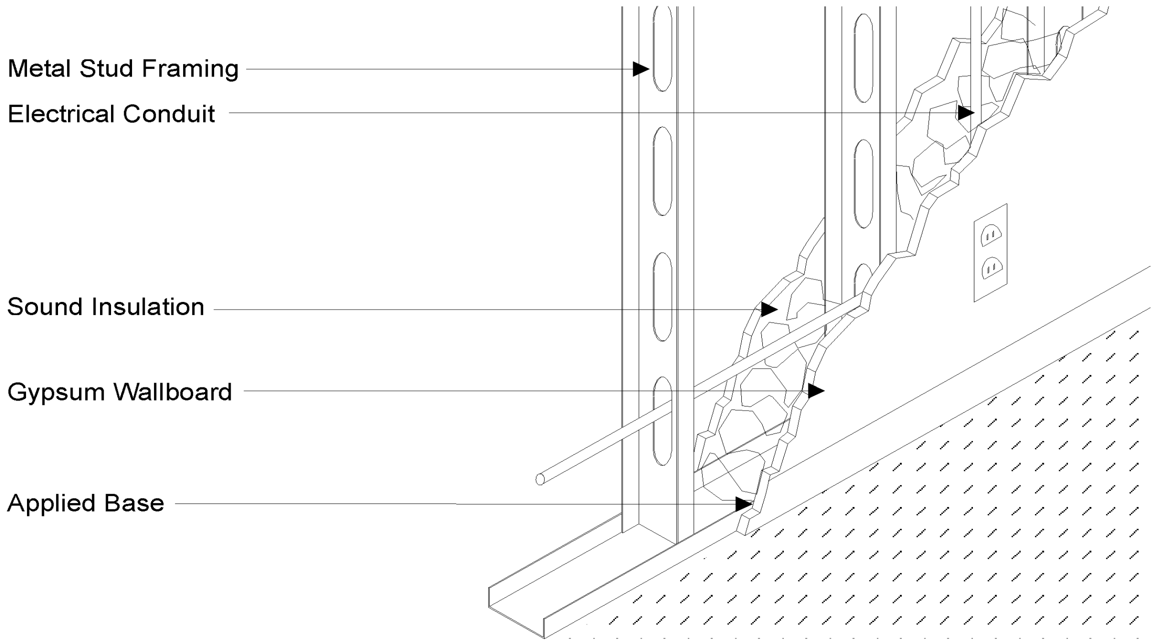

Fig. 1 Stud partition

requirements are placed upon it. Stud partitions are basically hollow, thus providing opportunity for distribution of power, communications and tempering systems. In addition, they may be filled or insulated for increased thermal and acoustical performance.

Partitions may be pre-constructed or demountable—built in factories to modular sizes and shipped to a jobsite for installation. In addition to gypsum wallboard and wood or metal studs, partitions may be glass, wood, metal, or masonry. In each case, the only requirement is that the partition satisfy the demands placed upon it, and that the existing structure be able to support it.

Floors and **ceilings** also define architectural spaces. Although partitions in the strict sense of the word, they are not typically referred to as partitions except in specific instances. (When *partitioning* off a space, the ceiling is a part of that *partition* and must therefore meet code *partition* requirements; however, it is still generally referred to as the ceiling.)

Together, floor and ceiling planes make up the largest share of an interior environment. Floors are typically flat but level changes can be added for spatial separation or aesthetic variety. Floors in commercial structures are typically constructed of concrete, or concrete on metal deck. This can be left exposed, as in industrial facilities, or totally covered with another floor covering such as carpeting, wood flooring, or vinyl tile.

Many times, ceilings are overlooked in the design of an interior environment. They are left bare and used simply as overhead protection. The ceiling is, however, an important part of the overall design of an environment. By changing the angle of the ceiling plane, piercing it with windows, or adding soffits and coves, the designer can make the ceiling an active part of the design. The

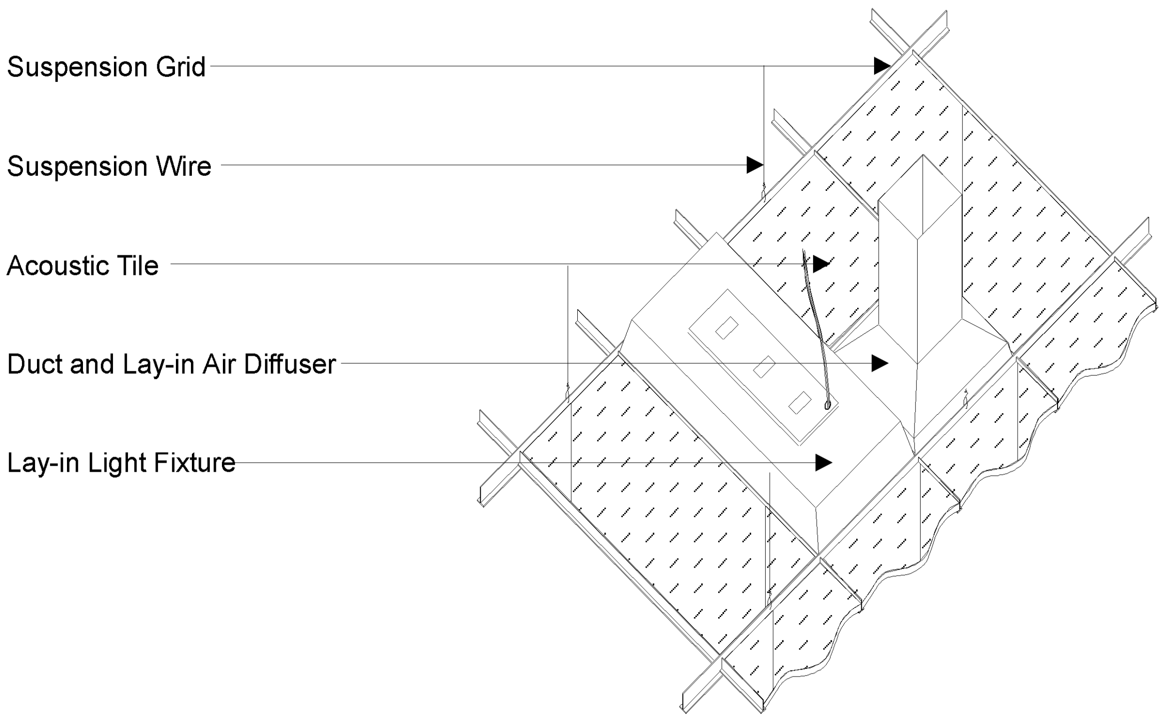

Fig. 2 Suspended ceiling

ceiling can be left smooth or fitted with light fixtures, vents and decorative elements. Ceilings can be constructed from a variety of materials: plaster and lath, gypsum board, wood, suspended ceiling systems (Fig. 2), metal, or glass.

Millwork, as a part of architectural systems and componentry, encompasses standing and running trim, paneling, doors, and windows. Broadly speaking, millwork is any ready-made product that is manufactured at a wood mill or woodworking plant. This is generally construed as piece goods. For a discussion of wood types, and casegoods construction, see chapter seven. For a discussion of wood finishes, see chapter six.

Millwork may be functional or decorative, largely dependent upon the designer's intent.

Architectural millwork has three primary functional origins. The first is one of necessity: doors and windows have traditionally been constructed from wood due to its wide availability and ease of workability. Millwork is also a decorative solution to concealing the construction of a space. Wood-paneled rooms were originally conceived as elegant woodgrained renditions of the expressed structure of a space. Finally, millwork serves a use which is a cross between the decorative and the functional, depending upon the intent of the user: baseboards, door trim and ceiling moldings are often the most expeditious way to close the joint that exists between two construction elements. Whether the piece becomes decorative or not is the designer's choice.

Standing and running trim refers to two distinct classes of wood trim. Standing trim refers to fixed length trim such as door and window casing, window stoops and door thresholds. Running trim is continuous trim used to form baseboards, cornice moldings, chair rails, etc. Almost any shape is available in wood trim, especially if custom trim is an option. Each millwork house or trim manufacturer offers its own standard profiles, which are then the most readily available and economical.

Paneling is the term used for wood applied to a wall surface. It may be assembled from rails and panels of solid wood, or from plywood. Simply stated, paneling is any flat assembly of wood members applied to a vertical surface.

Doors (which, like walls and ceilings, are an architectural space organizer) are typically one of two kinds. The **flush door** is available in solid or hollow core construction. Flush doors are typically constructed of two veneered faces glued to a frame which contains either a honeycomb core of kraft paper (hollowcore); or a solid core of industrial board or laminated wood staves (solid core). Solid core construction is heavier, stronger, and more resistant to the passage of sound than hollow core doors, and is generally more expensive. Flush doors of either type are available in a variety of veneer species, the least expensive of which are intended to be painted.

Stile and rail doors are traditionally constructed of a wood framework of vertical (stile) and horizontal (rail) members infilled with shaped wood panels. Today the look of stile and rail doors is available in traditional construction, stamped metal, stamped hardboard, or veneered structural plastic. The traditional wood construction stile and rail door is still the most appropriate for commercial use where the look of stile and rail is desired. Stamped metal and structural plastic tend to be limited in use to exterior applications. Stamped hardboard is simply a shaped hollow core door used primarily for economy in residential applications. Many of the problems typically associated with stile and rail doors, due to movement of the panel and loosing of joints, have been eliminated or minimized with new construction technologies and materials, and as a result, a quality stile and rail door today is nearly as stable as a solid core door.

Construction and Life Safety

In addition to giving definition to a space, the architect or interior designer needs to provide for the safety of the occupants within the space. The means of construction contribute to the total life safety package. Walls, floors, ceilings, doors, and windows are all required to provide protection from fire, environmental contaminants, and the elements. Standards for construction, as published in building codes and technical manuals dealing with specific construction materials and techniques, have been rigorously tested and confirmed to meet stringent requirements. Even minor variances in the construction of a building can change its resistance to these factors in unforeseen ways.

Acoustics

Besides providing protection, the envelope that defines interior space also affords a tempering of the environment, through acoustic and thermal control. Both sound and heat are transferable energy. Thermal requirements for an interior space are generally contained within the shell of the structure and will not be dealt with here. Acoustic control is the more pertinent topic.

Fig. 3 Elimination

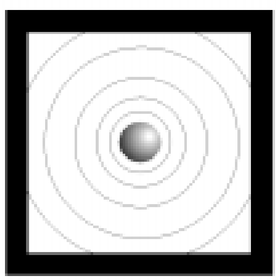

Fig. 4 Isolation

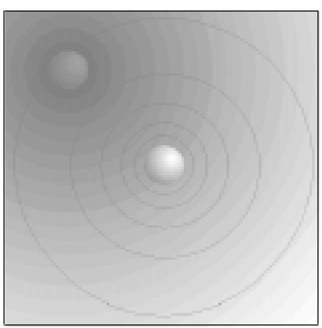

Fig. 5 Masking

Acoustics as an environmental variable significantly impacts the human impression of an interior environment. Productivity, speech intelligibility, privacy, safety, positive user attitude and response, and environmental "comfort" all depend on proper acoustic design. The interior designer is concerned with reducing unwanted noise and preserving desirable sound in a space. Enhancing the quality of communication through the use of reflective surfaces, and reducing undesirable noise through the use of absorptive surfaces is achieved by the specification of finishes, furnishings, equipment, and specially designed assemblies. Sound can be controlled in three ways.

- Eliminate the source (Fig. 3).
- Isolate the source—provide a barrier between the user and the source (Fig. 4).
- Mask the offending sound—if not possible to isolate the sound, minimize its impact on the user (Fig. 5).

In addressing acoustics and communication within an environment, it is necessary to consider levels of speech intensity. For example, intensity levels are likely to be greater among occupants over the span of a conference table than over an executive desk in a private office. Optimum planning for open areas will include consideration of background noise, and use of absorptive ceiling, flooring, and furnishing elements. With enclosed space, the noise reduction capabilities of construction between rooms significantly influences speech privacy.

Sound is measured on a relative scale, in decibels (dB or dB), with 0 dB being the threshold of audibility, and 130 dB the threshold of pain. In an office, a general noise level of 45 to 55 dB is considered satisfactory. This level will help reduce the distraction associated with squeaky chairs, opening and closing drawers, and ringing phones. It also allows for easy conversation in normal tones at close range. Other noise levels of varying activities are given in the chart shown in Figure 6.

In dealing with acoustics in an environment two major topics need to be addressed: excessive noise and sound

Pressure Level in Decibels	Example	Subjective Impression
140	Jet Plane Takeoff	(Short Exposure Can Cause Hearing Loss)
130	Artillery Fire	Deafening (Threshold of Pain)
120	Jet Plane (Passenger Ramp)	
110	Hard Rock Band	(Threshold of Discomfort)
100	Power Lawnmower	Very Loud (Intolerable for Phone Use)
90	Kitchen Blender	
80	Noisy Office	
70	Average Street Noise	Loud
60	Normal Conversation	Usual Background
50	General Office	
40	Private Office	Noticeably Quiet
30	Quiet Conversation	
20	Whisper	Very Quiet
10	Human Breathing	
0 dB		Intolerably Quiet (Threshold of Audibility)

Fig. 6 Decibel Pressure Levels of Common Environmental

transmission from one area to another.

Excessive noise within an environment includes opening/closing drawers, squeaky chairs, printers or copiers, shuffling feet, etc. Excessive noise is all noise beyond that which provides an ambient level conducive to normal conversation. All surfaces within an interior can contribute to the Noise Reduction Coefficient (NRC) of a space. The NRC indicates how well a material will absorb sound on a scale of 0.00 to 1.00, with 1.00 being total absorption. The most common use of the NRC rating appears on ceiling materials. Most acoustic ceilings have NRC ratings between 0.50 and 0.90. The minimum recommended NRC rating for acoustic material in open plan offices is 0.80. Generally, the thicker, softer and more porous a material is, the greater

Material	NRC
Bare Concrete Floor	.05
Tile or Linoleum on Concrete	.05
Carpet - 1/8" (3 mm) pile	.15
Carpet - 1/4" (6.5 mm) pile	.25
Carpet - 3/8" (9.5 mm) pile	.37
Plaster Ceiling	.45
Metal Pan Acoustic Ceiling	.60
Systems Furniture Partition Surface	.65
Carpet over Padding	.65
Suspended Mineral Board Acoustic Ceiling	.90

Fig. 7 Noise Reduction Coefficients of Common Finish Materials

its NRC. The table in Figure 7 shows NRC levels for different interior materials.

Sound transmission deals with noises coming outside the occupied space. Typically sound transmission is dealt with during construction, through use of heavy building materials or double-wall construction. However, once the structure is complete, interior materials can give some improvement. The Sound Transmission Class (STC) indicates a material's effectiveness in preventing sound transmission. The following table gives STC ratings for varying materials; the higher the number, the better noise is blocked (Fig. 8).

The selection of materials for wall finishes, floor covering and ceilings must be coordinated to assure the desired level of acoustic control. Additionally, providing window coverings over large expanses of interior/exterior window wall glazing, and/or the installation of an electronic sound masking system will contribute to a successful level of acoustic control.

Material	**STC**
5 mm (3/16") Plywood	19
Open-Plan Furniture Screen Panel (Typical)	21
16 mm (5/8") Gypsum Wallboard	27
22-Gauge Steel Plate	29
120 mm (nominal 2 x 4) Wood Stud Partition with One Layer 16 mm (5/8") Wallboard Each Side	37
170 mm Staggered Wood (nominal 2 x 4) Stud Partition with One Layer 16 mm (5/8") Wallboard Each Side	45
150 mm (6") Concrete Block Wall	46
150 mm (3-1/2:") Steel Stud Partition with Two Layers of 16 mm (5/8") Wallboard Each Side	55

Fig. 8 Sound Transmission Coefficient of Common Building Assemblies

Among interior surfaces, the ceiling is the largest surface affecting noise reflection and absorption. In a standard office environment, the ceiling system should produce minimal sound reflectance. Systems that reduce sound reflectiveness are flat, absorbent ceiling panels, baffles and vaulted ceiling components. The size, shape, number, and placement of luminaires, as well as the shape of other hard-surface ceiling components such as diffusers, will increase the specular, or mirror-like, reflectiveness of the ceiling.

The floor is the second largest surface area for absorption or reflectance of sound. Carpeting will absorb a significant amount of impact sounds such as chair movements and shuffling feet as well as other office sounds. Cut pile carpeting absorbs more sound than loop pile carpeting; the greater the pile height and weight in cut pile carpets the greater the absorption.

The degree of treatment of wall surfaces depends on the intensity of the sound and the distance between the sound source and the surface. Generally, fewer vertical surfaces will have to be treated in a large room than a small one. The larger room has more volume to dissipate the sound and a greatly diminished wall to floor and ceiling surface ratio. Besides providing sound insulation within partition cavities, draperies covering windows or walls, panels of acoustic material hung on the walls, and acoustic material (panels and paints) applied to interior walls all are effective treatments in minimizing noise reflectance.

Structural

The structure is the skeleton of the building. The structural plan is often the first component reviewed by the designer, especially if interior wall relocation is being considered. The structural module, a geometric increment, is the base unit of organization utilized by the structural engineer in setting the structural system for a building. In addition to providing definition and clarity to the work of the structural designer, the resultant expression of the module—whether the repetitive spacing of ceiling joists or pans, or the regular placement of columns—provides a framework for the organization of the interior spaces. The overlaid spatial organization should integrate the lighting layout, ceiling grid, mechanical systems, partition planning, and furniture layout within this larger framework. Interior columns that define bays may be concealed by integration into partitions, or left exposed within the space and used to provide reference points for the occupants, or to define specific zones of activity.

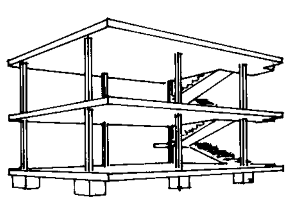

Fig. 9 Maison Domino

The paradigm of the modern building is the simple **Maison Domino** (Fig. 9), Le Corbusier's diagram of the skeletal "machine for living". It consists of a field of regularly spaced columns and floor plates. An actual structure may not be much more complicated, with greater definition given only to the structure of the floor (larger spans may require a framework of joists and beams to support the floor slabs), and to lateral bracing (to prevent the structure from rocking under wind load or other horizontal force).

The primary structural information an interior designer must be aware of is what elements of the space provide the structural support, and how do those elements interrelate (Fig. 10). A few basic guidelines will help.

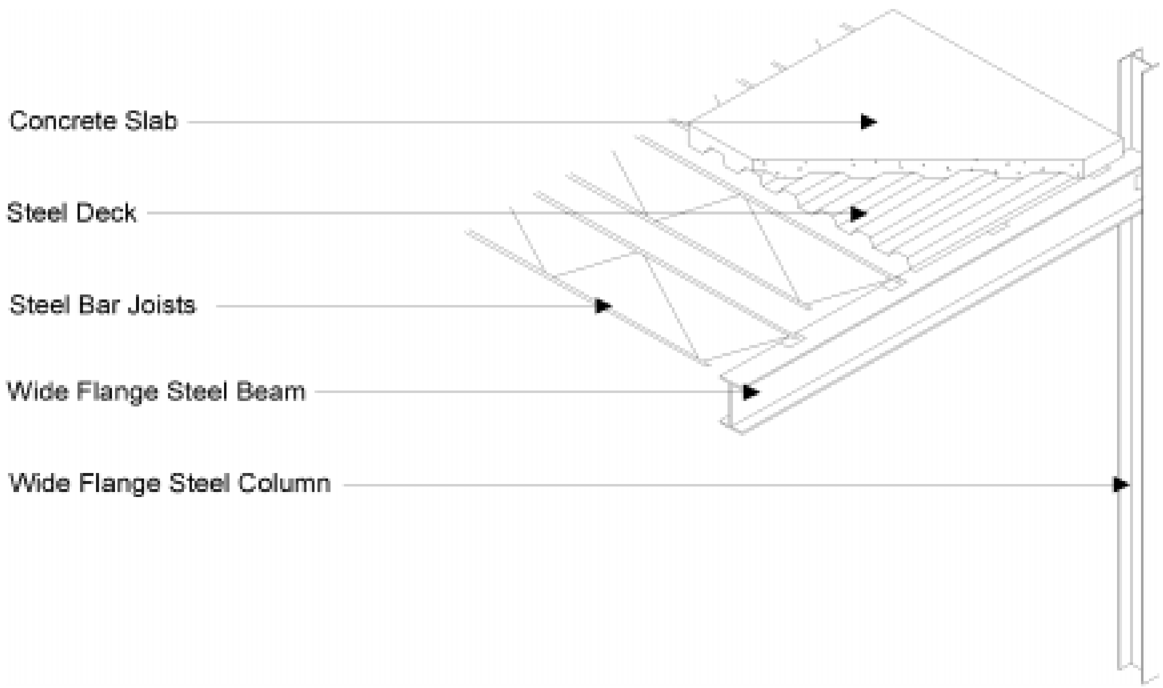

Fig. 10 Modern construction members

• Modern structures are primarily steel or concrete. The choice is based upon the availability of materials and structural constraints of the individual materials.

• Vertical support members, columns and structural walls carry loads, and are generally not modified after construction.

• Beams may be solid or trussed construction. Trussed beams have openings in them which may be used for the passage of building systems. Solid beams may be penetrated for such passage, but this is primarily done in the initial design of the building and seldom after construction. Beams join columns in perpendicular connections critical to the overall integrity of the structure. Whenever modifications are to be made to a beam, it is imperative that a structural engineer be consulted.

• Joists are smaller beam elements that carry the floor loads to other, larger, beams. The rules stated above for beams also apply to floor joists.

• Floor slabs are generally concrete, either formed over a temporary framework, or over a steel pan which remains in place and provides some portion of the structural capacity of the floor. Services may be run through floors with relative ease. Large openings may require the addition of supplementary joists to support the edges of the opening. Smaller openings require coordination to avoid interference with the supporting structure. Additional small openings for the passage of plumbing and electrical services are commonly required during the fit-out of spaces.

• Structural systems may not always be what they appear to be. A simple stud partition which terminates at the ceiling may not be a structural member, but it may in fact conceal lateral bracing for the structure. As with all systems discussed in this chapter, elements exist which may be concealed; and before proceeding with any significant reorganization of a space, it is best to ask the opinion of a structural engineer or architect.

Mechanical

The mechanical systems in a building are designed to perform a variety of functions. They are responsible for heating, ventilating and cooling the environment as well as supplying fresh water and disposing of waste water. The designer must have a basic knowledge of these systems and equipment functions to understand their impact on interior design.

Heating, Ventilating and Air Conditioning (HVAC)

HVAC system concerns for the interior designer relate not only to the visible elements such as radiators, convectors, registers, outlet grilles, or ducts—which are the end nodes of the systems—but also to the infrastructure that supplies those elements. Two primary types of systems exist: central and local. Central systems provide either tempered air or water throughout the facility from a single location. Local systems are generally stand-alone and receive their energy via gas or power lines. While central systems provide an economy of scale in operation, local systems may allow for greater comfort and economy if demand is not uniform throughout a facility.

Central air distribution systems (Fig. 11) circulate tempered air from a central plant through ducts which are typically located above the ceiling. Return air may also be carried through ducts or may travel through an open ceiling plenum.

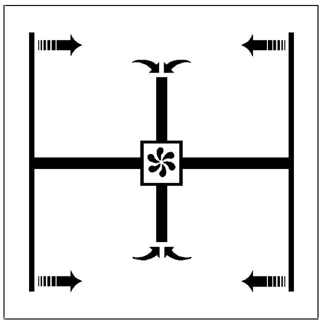

Fig. 11 Central air distribution system

Air systems may be configured as one or two duct systems: hot *or* cold, or hot *and* cold. Ductwork design plays a critical role in the planning of a space, particularly as it affects ceiling clearances. The main duct line that feeds directly from the central plant may be quite large, but as it branches out, the end-ducts require less space.

Friction within the ductwork affects the efficiency of the system. It is determined by length and difficulty of travel for the air stream. Straight travel, with no turns vertically or horizontally, through square or circular ducts is preferred. Rectangular ductwork is more common due to size limitations.

Economy of scale and ease of introducing fresh air are the primary reasons for choosing a central air distribution system. Conversely, these systems may create undesirable linkages—acoustically as well as environmentally—between spaces which, ideally, should be separated.

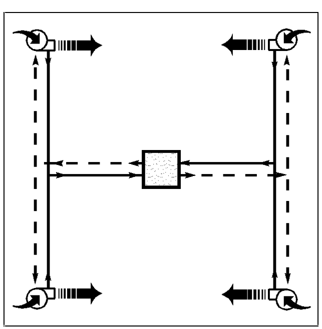

Fig. 12 Central water distribution system

Central water distribution systems (Fig. 12) circulate tempered water or steam through a series of branching pipes. Relative to air ducts, these conduits are fairly small —only 200 mm (8 inches) or less in diameter. Travel distance and configuration are not as critical as in air systems. Water systems may be configured as two (hot or cold, and return), three (hot, cold, and return), or four (hot, hot return, cold, and cold return) pipe systems. Two pipe systems require central switching from heating to cooling, and are less flexible than three or four pipe systems, which can deliver both heating and cooling at the same time.

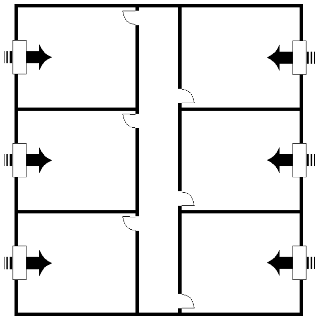

Fig. 13 Local distribution system

Local distribution systems (Fig. 13) are typically electric or gas powered fan or radiant units. If fresh air is required, it must also be brought in locally. This system is best used in facilities which have a relatively high perimeter to floor area ratio. Local systems are commonly found in motels, where each room has an individual heating/cooling system. Computer rooms also commonly utilize local, stand-alone units to maintain a temperature and humidity level which is different from the surrounding spaces.

Hybrid distribution systems combine either central air or water distribution with localized reheat, cooling, and/or ventilation to take advantage of the benefits of each components' specific application.

Delivery systems—the final means of transfer from distribution system to room—also vary, but fall generally into three categories: forced air, convection, and radiation. **Forced air** systems (Fig. 14) literally replace the air in a space with tempered air, and then

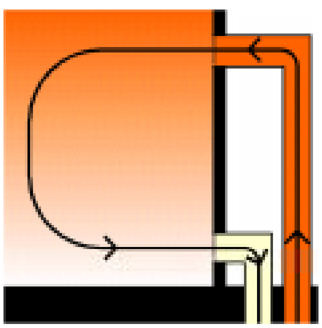

Fig. 14 Forced air heat transfer

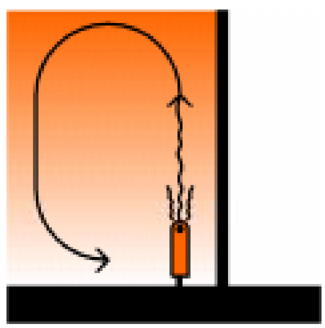

Fig. 15 Convection heat transfer

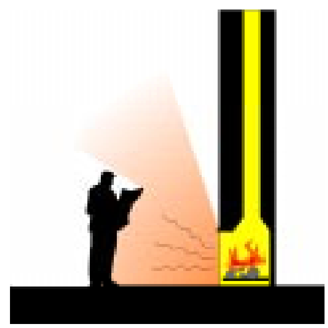

Fig. 16 Radiant heat transfer

Once a system is in place and running, controls must be provided to deal with pollutants and humidity.

retemper or exhaust displaced air. **Convection** systems (Fig. 15) rely on the natural movement of warm air to heat a space, and are typically located at the perimeter where convection units (or radiators) are placed below windows, to counter conductive transfer. **Radiant** systems (Fig. 16) rely on heat energy radiated by a warm source to condition not the air, but the occupants or objects within a space. Radiant heat, while efficient as a means of delivery, is hampered by the line-of-sight operation of the delivery system. If an object cannot see the source, it cannot feel the heat. Radiant transfer is also ineffective at cooling a space for human occupancy.

Ventilation provides fresh air to replace air contaminated by smoke, grease, pollen, dust, heat, odors, or carbon monoxide.

Humidity control prolongs the life of wood, metal and painted surfaces. Too much moisture may cause condensation on cool surfaces, wood warpage, mildew propagation, rust, musty odors, and peeling wallcoverings. Lack of moisture dries wood, leather and adhesives, causing splitting and separation, and increases **static electricity** transfer from carpets. Too little moisture also causes human discomfort by parching delicate respiratory membranes and aggravating allergies.

Humidity also affects the loss of body heat. High moisture levels in the air slow evaporation of skin moisture, keeping the body warm, while low humidity levels increase skin moisture vaporization, cooling the body. **Relative humidity** is a measure of the percentage of humidity in the air relative to the maximum possible at a given temperature. Relative humidity determines the rate at which evaporation can take place in an environment as well as its net effect on the occupant. A relative humidity range of 20 to 60 percent is within the range of comfort for most people.

In buildings with central HVAC systems, humidity is controlled by two separate mechanisms. Humidifiers add moisture to the air. Cooling coils provide a surface for transfer of heat from the air but also provide a surface for condensation of moisture—dehumidification. Self-contained dehumidifiers are used in spaces where additional dehumidification may be required. In bathrooms, laundries and kitchens exhaust fans are most often used to remove excess humidity generated by use. Natural flow ventilators which simply provide a means for moisture to escape are used in basements, crawl spaces, tunnels, and attics.

Sick Building Syndrome

In recent years, buildings have been designed to retain tempered and conditioned air. As a result, problems with ventilation and the accumulation of air pollutants have increased. These problems lead to lower levels of indoor air quality and cause decreases in perceived levels of comfort for the users of the space. Physical symptoms

*When a building's occupants complain about acute discomfort for an extended period of time and most of their discomfort ends when they leave the building**, Sick Building Syndrome** is suspected.*

may include headaches, fatigue, eye irritation, memory loss, and respiratory irritation. The predominant cause of indoor air contamination is inadequate ventilation. Contaminants from activities taking place in or around the building or inappropriate environmental controls and maintenance may be causes. Off-gassing of building materials, microbial sources within the building, and soil contaminants around a building are a lesser concern due to their infrequent occurrence.

The interior designer must understand the potential problems that arise from the use of specific materials, processes and installations. Some guidelines for dealing with Sick Building Syndrome include the following.

- Increase fresh air supply.
- Ensure that fresh air is free from pollutants from the interior (kitchens) and exterior (exhaust fumes).
- Improve maintenance operations on air distribution equipment—particularly fans, ducts, filters.
- Install plants to condition interior air

Plumbing

A basic knowledge of the workings of a plumbing system is critical to making decisions about the efficient arrangement of such utilities within a facility.

The vertical movement of water through a building is accomplished by **risers:** vertical lines of pipe running through a building, typically located adjacent to groupings of water-using spaces such as restrooms, kitchens, laundry rooms, etc. (Fig. 17). Risers are connected to the branch pipes, which run horizontally to the fixtures. Pipes may be concealed in walls, under floors, above ceilings, or in specially built enclosures or chases.

In most buildings, hot and cold water are supplied by a pressurized system. Branch supply pipes are typically quite small - 19 mm (3/4-inch) or so - making it easy to supply water to new locations.

Drain pipes are dependent upon gravity—not pressure—to move water. As drain pipes must slope downward, they figure more greatly in determining where wet facilities can be located than pressure systems. Drains from lavatories, disposers and sinks need only slope down at a gentle angle; larger soil pipes must slope sharply to discourage sedimentation and clogging. When adding wet facilities during remodeling where new risers are not feasible, these new facilities must be placed close enough to existing risers to achieve the required slope without interfering with spaces below.

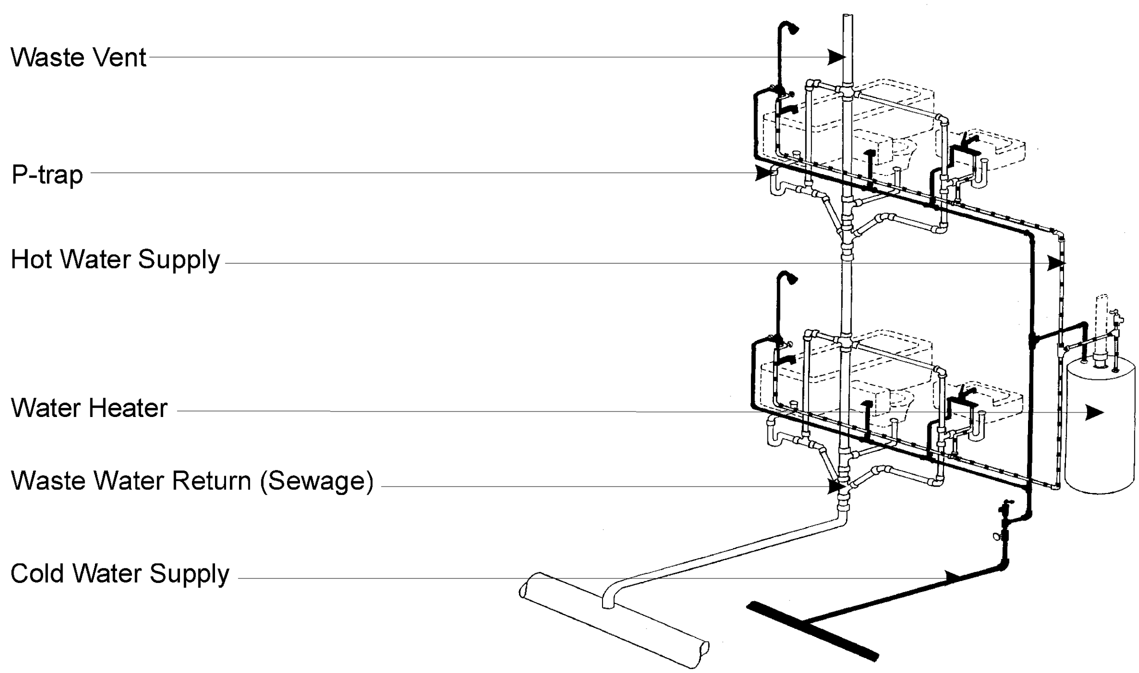

Fig. 17 Plumbing system showing risers, branch pipes, drain pipes, traps, vents

Traps and **vents,** which prevent gases in drainage pipes from entering living spaces, and allow for free flow of effluence without obstruction by trapped gases, are additional details which add to the complexity of a plumbing system.

When locating new plumbing services, consideration must be given to the feasibility of routing both the supply and return systems and the impact of the installation and repair on adjacent space. Basic design guidelines include locating pipes away from places where a leak might cause danger or damage, and locating access panels or pipes in closets or other semi-hidden spaces that can be easily identified.

Fire Protection

The most common method of fire protection within buildings is the sprinkler system. **Automatic sprinkler systems** generally consist of two types: wet and dry. **Wet pipe** sprinkler systems contain water in both main and distribution pipes. **Dry pipe** sprinklers are charged with a gas which is released upon activation, after which water flows through the system. Wet pipe systems are the simplest and most common, but pose a threat of damage due to leakage. Dry pipe systems are generally used where the threat of damage due to leakage is considered too great, such as in electrical control and computer rooms. Halon systems, which were once common in computer rooms, are largely being replaced by dry pipe systems. Halon, a chloro-fluorocarbon is harmful to the environment as well as directly hazardous to persons exposed to it upon release. Dry pipe systems reduce the risk of leakage, and additional preactivation controls increase the safety of the system relative to damage from accidental discharge. Preactivation systems require multiple releases, both automatic and manual, prior to release.

Automatic sprinkler systems consist of horizontal distributions of pipes generally located above the ceiling. Sprinkler heads are fused so that open automatically to spray water when temperatures reach 60 to 70° C. Spacing of sprinkler heads depends upon the number of occupants, use of the space, construction of the building, and partition placement.

A sprinkler system is typically fed by a water source that is supplemental to the domestic (drinking water) source within a building to ensure sufficient pressure and supply during a fire. This may be a separate reserve such as tanks or an artificial lake.

Fire hose stations, a frequent supplement to a sprinkler system, are located at or near stairwells to allow fire fighters to approach a fire. **Standpipes** provide a back-up water supply system—an independent water delivery system for access to a supplementary source of water during a fire. Often this water is provided by connection to a pumper truck or direct connection to an external hydrant.

Electrical

The primary electrical systems seen in facilities today are electrical power supply and data/communications or signal systems. Electrical power supply in the United States is available in a number of configurations, the most common of which are 120/240 volt single-phase three wire, 120/208 volt 3-phase 4-wire, and 277/480 volt 3-phase 4-wire. The first is used primarily for small scale and residential projects, the second for the majority of commercial projects and the last for very large-scale projects which have intensive fluorescent lighting and 480v machinery use. In all cases the service voltage supplied to a typical wall receptacle is 120 volts. The source voltage is used to power permanently-wired equipment and lighting. The criteria used for determining the system selected are the size of the project and the ratio of 120 volt usage to the total. While the higher voltage systems dictate equipment costs which are higher than those of lower voltage systems, this is compensated for through reduced installation and operating costs.

Data and Communications

Many specific electrical and communication systems other than power are used in a building. Although these systems require electricity for operation, they are often of a specialized electrical nature, independent of the primary electrical system. Some, such as emergency lighting and intercoms, are permanently installed, but others, such as telephones and computer data systems, can be easily relocated.

Communications systems may enter a building as an independent, low voltage electrical current, or—in the case of fiber-optic systems—as pulsed light. Specialized telephone wiring or fiber optic cables are routed throughout the structure from primary entrance to regional distribution points, and terminate at telephone receptacles located per specific telephone requirements. Wireless transmission stations may also be employed for use with portable or cellular phones. These systems are changing rapidly and range from phones which may work on a global basis to those which operate only within a few hundred feet of a single base sending unit. Communications systems handle the transport of voice and data; e.g. telephone conversation, facsimile transmission, video teleconferencing and data transfer.

Alarm systems commonly detect entry, monitor activity, and sense heat or smoke; and sound an alarm or initiate some other action when required. These systems generally operate off a low voltage supply , and require back-up power in the event of a system power failure. Signal transmission is most often handled locally by an independent network, and then relayed to a central watch station over a shared or dedicated telephone line.

Data and Communication Systems

Data and communication systems are constantly changing. The expanding fields of electronics, fiber optics, light-wave technology, low voltage circuitry, and satellite links continually create new modes of communication and data transfer. Increasingly, these are being handled as a networked communication system.

The interior designer faces the responsibility of specifying and designing around these communication systems as they shape interior spaces.

Distribution Systems

Distribution of electrical and electronic systems through a building is generally accomplished through branched distribution. A central chase or trunk will run the length or height of the facility, then horizontal distribution systems run from a central connection closet to the end-user. This distribution may be overhead or underfoot, and in many instances is a combination of the two.

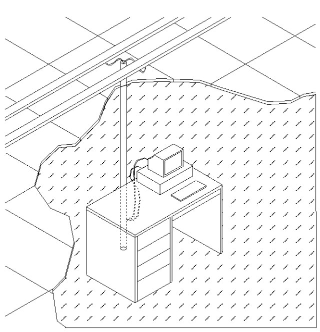

Fig. 18 Overhead distribution

Overhead cables (Fig. 18) installed in the ceiling plenum are the most common means of distribution of electrical systems. Depending upon the specific application, cables may be laid directly over the ceiling membrane (for some telephone systems), or they may need to be run in conduit (as is often the case regarding electrical wiring). They may also be laid in raceways or cable trays specifically designed to ease the maintenance of electronic systems. From the ceiling space, distribution is made through wall or partition cavities to equipment. The **power pole** is a direct method of distribution from the ceiling plenum by means of vertical poles or flexible conduit located at workstations. While providing unlimited flexibility, pole locations must be coordinated with furniture and partition systems in order to avoid undesirable visual results.

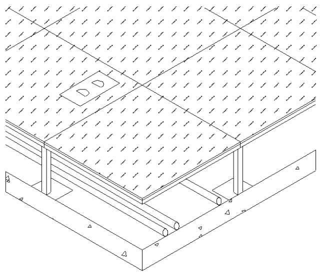

Fig. 19 Raised access flooring

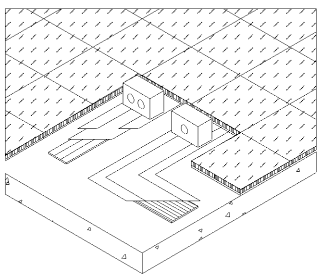

Fig. 20 Flat wire distribution

Raised access flooring, (Fig. 19) a system of interconnecting floor panels raised sufficiently above the structural floor, allows for installation of electrical, mechanical, and/or air distribution systems beneath it. Virtually unlimited access flexibility allows for a total integration of distribution systems with furniture. Due to the expense of this system, application is generally limited to areas where ease of access is essential, such as spaces with intensive computer and communication needs. Common uses are computer rooms and training facilities.

Flat wire (Fig. 20) is an electrical distribution system in which continuous flat wire cabling is located directly beneath modular carpeting. Relocation can be completed by maintenance personnel if new power connections are not required. However, significant disadvantages are associated with flat wire cable as well.

- Due to requirements for accessibility, broadloom carpet cannot be used over flat wire. Only polyvinyl chloride (PVC) backed carpet tiles are permitted by building codes.
- Flat wire cable cannot withstand long-term heavy traffic or local concentrated loads such as casters.
- Telephone cable lengths are limited to 35 feet.
- Ripples in carpet tiles may be visible at cable locations.

For these reasons, flat wire electrical distribution systems are typically not used.

In **integral distribution systems**, steel raceways are incorporated into the structural floor. Commonly found in steel framed buildings, ducts are made part of the steel pan that forms the bottom of the structural floor. Junction boxes at key points along the ducts have removable covers to allow full access. Covers are level with the finished floor and can be finished to match. Also called **underfloor duct systems**, common types include trench duct and cellular floor.

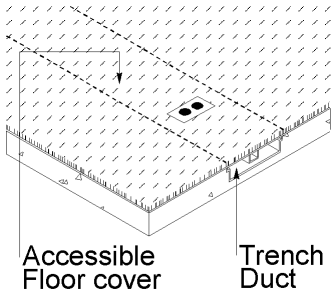

Fig. 21 Trench duct distribution

Trench duct systems (Fig. 21) utilize ducts which are flush with the surface of a floor slab as raceways. These often serve as feeders for the cells of a cellular steel floor system as well as self-contained raceway systems for computer areas, laboratories and hospital X-ray rooms. The trench duct may have either single or multiple compartments, providing for different services and access along the full length of the system. The pre-established grid system will influence the subsequent furniture layout.

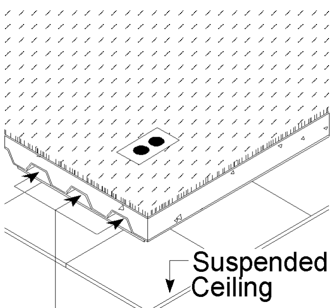

Fig. 22 Cellular floor distribution

Cellular floor systems (Fig. 22) take advantage of the cavities within corrugated steel decking, using these as the branches of a distribution system. Headers, typically fastened to the surface of the decking but still buried beneath the finish slab, provide the main trunk distribution. The cells are accessed by a grid of regularly spaced access ports.

The purpose of any integral system is to establish a supply grid which allows easy access to power and communication distribution. The grid system provides a matrix of regularly spaced access points at appropriate locations around the floor.

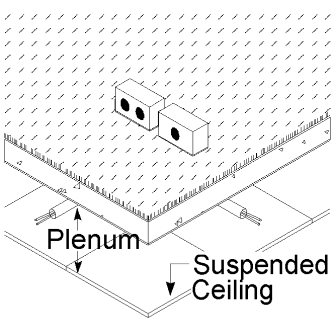

Fig. 23 Poke-through distribution

Poke-through systems (Fig. 23) are not considered integral systems and are essentially the same as above ceiling distribution systems. The primary horizontal distribution is made through a ceiling plenum; however, instead of feeding down from the ceiling above, the distribution travels up from the plenum below through penetrations in the floor. Although aesthetically preferable to power poles for connection to free-standing equipment, the system becomes costly because the poke-through connections require alterations to the floor slab and fire separation.

Combined distribution systems often employ poke-through feeds for free-standing elements where visual clarity is valued, in conjunction with overhead distribution for ease of maintenance where feeds may be carried through existing architectural elements such as partitions.

The choice of an electrical distribution system requires consideration of both the initial cost of installing the system as well as the cost of maintaining it. Dynamic systems may warrant the increased initial expense of a flexible installation, whereas stable systems may be satisfied by more permanent configurations.

Lighting

The final quality and quantity of light present in an interior is directly related to the process which has guided the interior designer. In order to successfully plan for the lighting of a space, the designer must possess an understanding of the principles and processes of visual perception, comfort and the nature of human need for visual information (see Chapter 3).

When designing with light, emphasis is placed on focal elements and drawn away from those of lesser interest. The nature of the patterns of light sources and their relationships to other elements in the visual field largely determines the overall quality of the luminous environment. The distribution and characteristics of the illumination, the information conveyed by the pattern of the light sources and the degree to which they reinforce or contradict the relationships to the architecture, and the planned activities also affect the overall quality of light in an environment. At the same time, one-quarter to one-third of the energy consumption of a building is in lighting. Lighting design, therefore, must be a study of both art and technology.

Lamp Types

Through continued research and technological advancements, thousands of lamp types are available to serve a great spectrum of users. General application lamps are currently classified into three basic categories: incandescent, fluorescent and high intensity discharge. Each category has its own unique operating characteristics, special considerations, and applications. Figure 28 provides a summary of the lamp types as discussed below.

Incandescent

Incandescent sources come in a variety of forms and shapes (Fig. 24). Their versatility is enhanced by their availability in a wide range of wattages. Incandescent light emanates from a relatively small source; because some lamps themselves are quite small, their light distribution can be controlled easily. Incandescents are easy to install, are not adversely affected by frequent switching, and can be easily dimmed.

General service lamps—A, S, P, PS, and T—are most suitable for lighting public spaces and are used in table

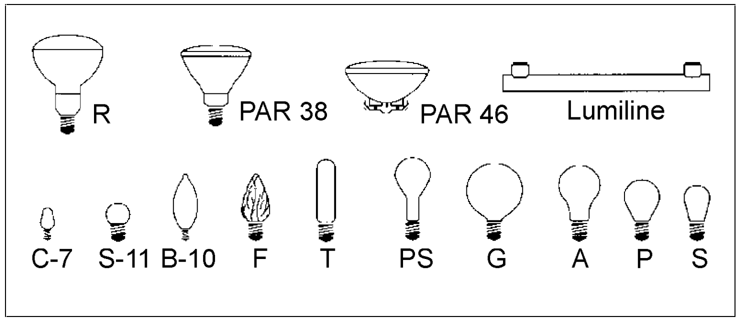

Fig. 24 Standard incandescent lamp types

lamps and many fixtures with reflectors. The S and P lamp types have a shorter neck than the standard A lamp, which makes them better for use in smaller sources. The PS lamps, having a slightly longer neck, are sometimes used in downlighting fixtures. T lamps are used for reflective lighting, often in display case lighting.

Decorative lamps —F, G, C, and B—radiate light in all directions. They are used in decorative applications such as chandeliers, sconces, lamp posts, and vanities.

Reflector lamps—R, ER, and PAR—are designed with built-in reflectors. They are constructed to cause light to be emitted in a particular direction and specific beam spread. R lamps are designed for indoor application only. Their reflectors are not very precise and can only be made in flood or spot beams. R lamps are best used in recessed downlights or track applications that do not require precise beam control. The ER lamp, a modification of the R lamp, has an ellipsoidal reflector. Its unique shape concentrates the light beam into a small area in front of the lamp and spreads the light into a wider beam, improving efficiency. PAR lamps have a parabolic shaped design which yields better control of the beam. They offer the opportunity to develop a number of lens patterns, thus increasing the variety of beam spreads. They are most effective in indoor track and accent lighting.

Tungsten-halogen lamps (Fig. 25) are more energy efficient than standard incandescent lamps. For the same amount of electricity, they generate up to 30 percent more lumens per light, up to 22 lumens per watt. Also, because tungsten-halogen bulbs blacken much less than standard incandescents, they stay almost continuously bright as they age. The brilliant light and small size

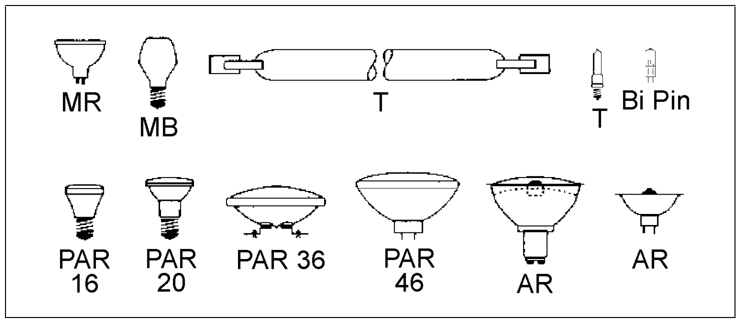

Fig. 25 Standard tungsten halogen lamp types

makes halogens ideal for activity and accent lighting. The typical life ranges from 2,000 to 4,000 hours with wattage ranges of 5 to 300 watts. Other benefits include brilliant, intensely focused light and ease of use with dimmers for energy savings.

PAR 36's, MR 16's and MR 11's are all **low voltage lamps**. The low voltage lamp, running on only 12 volts of electricity instead of the household standard of 120 volts, requires a transformer for operation. A smaller lamp than most, with a very small filament, these low voltage lamps allow the light to be precisely focused by a reflector or other optical system. The precise beams of light are ideal for lighting small objects or where a long throw of light is necessary. Low voltage lamps are available in both tungsten-halogen and general incandescent. Some contain their own integral reflectors while others are designed to be placed in a luminaire to properly focus the light output.

Much of the energy consumed by incandescent lighting produces heat as a by-product of light. This lost energy makes incandescent lighting one of the least efficient light sources. In addition, the heat produced increases the air-conditioning load of the building, requiring additional energy to be spent on cooling. Incandescent lighting, therefore, is most often used for residential lighting or the aesthetic display of merchandise.

Fluorescent

Fluorescent lamps are low-pressure discharge light sources. The typical fluorescent lamp is comprised of a cylindrical glass tube, sealed at both ends, which contains a mixture of an inert gas and low-pressure mercury vapor. Cathodes at the tube's ends emit a stream of electrons, activating the phosphor coating on the

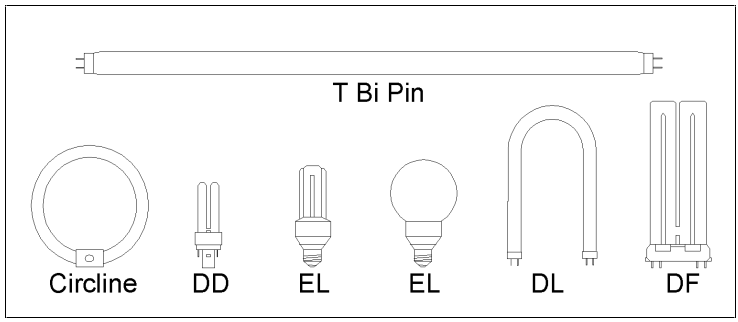

Fig. 26 Fluorescent lamp types

inside of the tube, thus producing light. Fluorescent lamps have a long life, typically lasting 10 to 15 times longer than incandescent lamps, while producing about four times as much light per watt (60 to 80 lumens per watt). They come in a wide variety of size, wattage and color choices (Fig. 26).

Straight-linear fluorescent "T" lamps are the most common, available in over one hundred configurations ranging in length from 75-2440 mm (3 to 96 inches) and wattage from 4 to 75. Other shapes include the **U-shaped** and **circle-shaped** lamps, developed in response to a desire to minimize fixture size.

Compact fluorescent lamps have been developed to fit into the space of the conventional 25 to 100 watt incandescent lamp. These fluorescents provide longer life and high energy savings, as much as 82 percent over incandescents, while approaching the preferred color of incandescent light. Now they include sizes and colors to replace conventional fluorescent lamps in reduced size luminaires as well. Compact fluorescent lamps are available in a number of formats for dedicated fluorescent fixtures (DD, DL, DF); as well as for retrofitting standard incandescent fixtures (globe, EL), with screw-in bulbs and globes. Although the lamps cannot be dimmed, their life—9 to 13 times longer than comparable incandescent lamps—will be maximized if used in locations where the light remains on for long periods of time.

While fluorescent lamps have a longer life, produce more light and save more energy than incandescent lamps do, some disadvantages to their use exist. They can produce a flat, diffuse light which may appear monotonous and tiring. Also, large tube sizes limit optical control. A disadvantage with compact fluorescent appears in the mounting positions: some compact lamps require specific mounting positions (e.g. vertical-base up).

High Intensity Discharge (HID)

Whereas fluorescent lamps rely on the interaction between an energized gas and the reactant coating on the inside of the lamp, HID lamps produce light through the direct excitement of a pressurized gas (Fig. 27). HID sources tend to be extremely efficient and long-lived, but typically have long start-up times and operate with poor color rendition and consistency.

Mercury vapor lamps were the first HID source developed but are used less frequently than other HID sources. They produce light by passing an electron stream through a gas vapor. Advantages of **mercury vapor lamps** include excellent maintained light output, high light output in relation to energy use, low cost, and

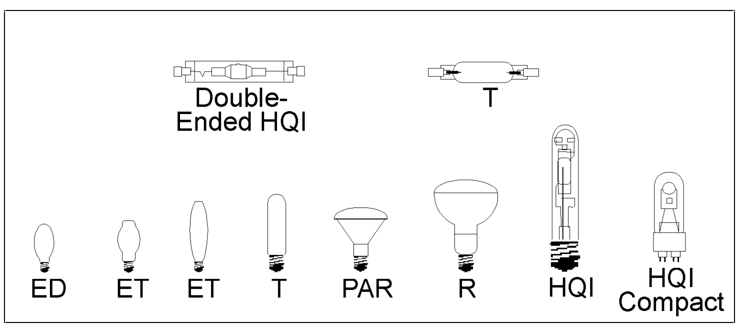

Fig. 27 Standard HID lamp types

exceptionally long life. Warm-up time before full brightness, time to cool down before restarting if power is interrupted and high heat output are a few disadvantages. Exterior landscape lighting makes the best use of mercury vapor lamps as the color rendition emphasizes the greens of landscape. Due to limited color rendering and mercury content, mercury vapor lamps are seldom used any longer.

LAMP TYPE	Incandescent		Fluorescent	HID
ATTRIBUTE	120 volt Tungsten	12 volt Halogen		
Initial Cost	Low	High	Moderate	Very High
Efficiency	5 - 20 Lumens per Watt	10-20 Lumens per Watt	60-90 Lumens per Watt	40-80 Lumens per Watt
Operating Cost	High	Moderate	Low	Very Low
Life Cycle Cost	High	Moderate	Low	Moderate
Life	1000 - 2000 Hrs	2000 - 4000 Hrs	8000 - 10,000 Hrs	6000 - 30,000 Hrs
Lumen Maintenance	Low	High	High	High
Flexibility of Application	Very High	High	Limited	Limited
Color	Good	Superior	Varied	Poor
Color Rendering Index	100	100	70-85	30-75
Auxiliary Circuiting Requirements	None	Minimal	Moderate	Moderate
Dimming Abilities	Yes	Yes	Limited	No
Start up & Restrike	None	None	0 - 15 Seconds	0 - 10 Minutes
Heat Output	High	Very High	Limited	Moderate
Glare Potential	Yes	High	Limited	Yes
Circuiting	120v	12/120v	120/277v	120/277/480v
Recommended Application	Accent Task	Accent Task	Accent Task Ambient	Ambient

Fig. 28 Lamp Type Attributes

Metal halide lamps work in much the same way as mercury vapor lamps. The primary difference is the addition of metal halides to the mercury or argon in the metal halide arc tube. Metal halides have superior efficacies, high light, better color rendering, and precise beam control (due to their small size). Disadvantages to these lamps include shorter life, lower lumen maintenance (light output decreases faster), and certain restrictions on the positions in which the lamps may be burned. If operated improperly metal halide lamps may explode, thus they require fixtures with protective lenses. These lamps work well in offices, retail spaces and public interiors.

High Pressure Sodium (HPS) lamps are the newest addition to the HID field. The lamps have efficacies of 60 to 140 lumens per watt and rated lives of 10,000 to 24,000 hours. Unlike metal halide lamps, they are not as sensitive to burning position. While normally the light source has a yellow-orange glow, recent improvements have resulted in a white color-rendering property. Unfortunately, improvement of color rendering results in lower lamp life and efficacy. Due to its thin, linear shape, the HPS provides excellent optical control. The two distinct disadvantages are shorter life compared to other HID sources and severely distorted salmon-appearing color output among non-color-corrected lamps. HPS lamps have generally been used for street lamps, but even then have limited application.

Lamps and their Effect on Color

In selecting a lamp for a particular space, two primary criteria must be considered. The **Correlated Color Temperature** (**CCT**) describes the color of the light given off by the lamp, while the **Color Rendering Index (CRI)** describes the effect that the light source has on the apparent color of an object.

Color temperature is measured in degrees Kelvin (K), ranging from 9,000K to 1,500K (Fig. 29). The greater the number, the cooler the lamp color; the smaller the number, the warmer the lamp color. Most light sources fall in the middle range, leaning either toward cool or warm. Generally, a lamp source should be selected to suit the color scheme of the space: warm range lights for warm color schemes and cool range lights for cool color schemes. Predominantly neutral or gray color schemes can be lit with either to accentuate or draw the scheme one way or another, or may employ a more neutral, mid-range light.

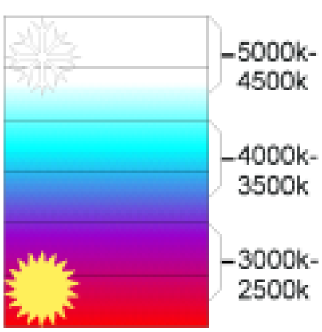

Fig. 29 Common correlated color temperature ranges

The second consideration when selecting a light source is the CRI. Color rendering is measured on a scale of 0 to 100 (Fig. 30). A CRI of 100 indicates no color shift in the object when compared to a reference source. The lower the CRI the more pronounced the color shift will be. CRI values are only taken into consideration once a color temperature range has been determined; however, the temperature effect cannot be discounted when assessing CRI.

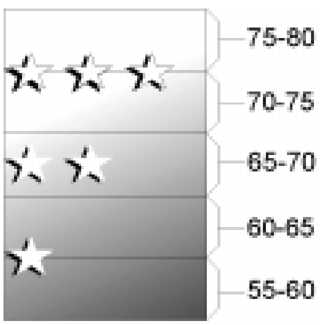

Fig. 30 Color rendering index

Incandescent sources radiate energy throughout the visible spectrum but with a greater proportion in the yellow-red range. A standard incandescent lamp has a color temperature of 2,700 K and appears yellow-white. When the incandescent lamp is dimmed, the color of the light shifts to the red end of the spectrum, making reds appear more saturated while greens and blues become grayed. A **tungsten-halogen lamp** may have a color temperature in the range of 3,000 to 3,200K and appear brilliant white. These lamps render all colors very close to their actual hue.

Fluorescent lamps are available in many different “whites", each with a different color temperature. Their color relates directly to the type of phosphor used to coat the inside wall of the tube. Red, green and blue phosphors are blended to achieve the desired shade of white. Thus, color rendering capabilities vary among fluorescent sources.

High intensity discharge sources produce light in a rather narrow range of the spectrum. Mercury lamps produce a bluish-white light. Because of the strong blue, green, and yellow rendition of the mercury, objects of these colors are enhanced under this source, while red and orange objects appear brown. The addition of phosphors activates energy in the red portion of the visible spectrum and enhances the overall color of light by improving the color rendition of red and orange objects. Metal halide lamps already produce a better color rendition than mercury lamps, emphasizing the colors that tend to create a cool visual atmosphere: hues of blue-purple through blue-green to yellow-green. High pressure sodium lamps produce a yellow-orange light that, while intensifying yellow-orange objects, distorts other colored objects.

Designing with Light

Designers define, articulate, or manipulate a space using various forms of light. Common terminology employed

• *Types of lighting*

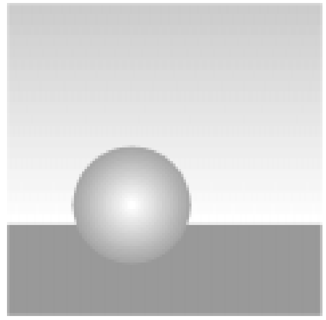

Fig. 31 Ambient light

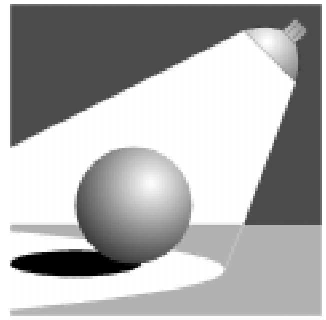

Fig. 32 Task light

in the discussion of lighting follows.

Ambient (Fig. 31) lighting involves a uniform light with no apparent single source. It provides a low level of overall diffuse lighting adequate for circulation needs and for preventing areas of darkness.

Task (Fig. 32) lighting is a focused light utilized for a specific task. This approach to lighting is based upon illuminating a task in an appropriate manner while balancing the illumination of surrounding areas (ambient light).

The major advantages of task lighting include:

- highly controllable and user-friendly sources,
- energy savings possible through lower overall ambient light level,
- wide range of sources and models,
- highly portable and adjustable, and
- can be used to create high local light levels where necessary.

The major disadvantages of task lighting include:

- expense in terms of capital investment,
- requirement for multiple power outlets,
- wide assortment of models can lead to problems with aesthetics, coherence, and maintenance,
- desk versions can be space consuming,
- poor adjustment can lead to glare for colleagues, and

• undershelf models may produce glare for user.

Direct (Fig. 33) light refers to light which has traveled in a straight line from its source. This type of light creates highlights and shadows which emphasize texture, identity and aesthetics of mass and form. Spaces can be made to look smaller or more intimate by the use of direct shielded luminaires recessed in ceilings or surface mounted on walls or ceilings. Other visual effects achieved with direct light include high contrast, vibrant color, and glitter.

Indirect (Fig. 34) light, sometimes referred to as a

Methods of distributing light from an artificial source

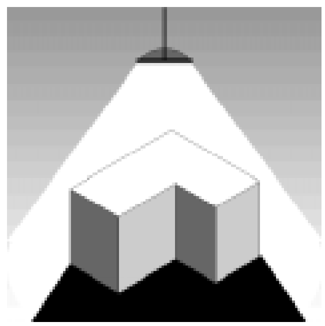

Fig. 33 Direct Light

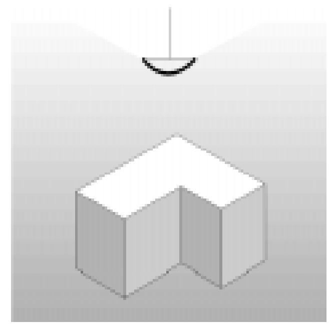

Fig. 34 Indirect Light

diffuse or "soft" light, tends to minimize shadows and contributes to a more relaxing and less visually dynamic environment. Indirect light is reflected off a single surface or multiple surfaces to diffuse the light and make it appear more uniform in nature. When used alone, the result can be very monotonous and uninteresting.

Brightness, duration, size, and contrast are important factors when determining the appropriate amount of light for an environment. Specific recommended illuminance categories have been prepared by the Illuminating Engineering Society of North America (IESNA) and may be found in their *Lighting Handbook*, *Reference Application*, an excerpt from which is shown in Figure 35.

Lighting "Rules of Thumb"

In the design of lighting for various spaces, some general guidelines should be considered.

• To see the detail of an object, contrast between the object and its background is necessary.

• Luminance of surfaces in the area surrounding an object can adversely affect a person's ability to see surface detail of the object.

Type of Activity	Illuminance Category	Range of Illumination in Lux	Reference Work-Plane
Public Spaces with Dark Surroundings	A	20-50	General Lighting Throughout Spaces
Simple Orientation for Short Temporary Visits	B	50-100	General Lighting Throughout Spaces
Working Spaces Where Visual Tasks are Only Occasionally Performed	C	100-200	General Lighting Throughout Spaces
Performance of Visual Tasks of High Contrast or Large Size	D	200-500	Illuminance on Task
Performance of Visual Tasks of Medium Contrast or Small Size	E	500-1000	Illuminance on Task
Performance of Visual Tasks of Low Contrast or Very Small Size	F	1000-2000	Illuminance on Task
Performance of Visual Tasks of Low Contrast or Very Small Size over a Prolonged Period of Time	G	2000-5000	Illuminance on Task Obtained by Combination of General and Supplementary Lighting
Performance of Very Prolonged and Exacting Visual Tasks	H	5000-10,000	Illuminance on Task Obtained by Combination of General and Supplementary Lighting
Performance of Very Special Visual Tasks of Extremely Low Contrast and Small Size	I	10,000-20,000	Illuminance on Task Obtained by Combination of General and Supplementary Lighting

Fig. 35 Illuminance categories and values for generic interior activities

• When a space is to be illuminated directly, the lighting should emphasize the prominent characteristics—module, shape and material—in a consistent and complimentary fashion.

• To conform with expectations, use light sources of relatively low color temperature at low levels of illumination, and sources of higher color temperature at higher levels of illumination.

• In general, illuminate continuous elements such as walls evenly or with even gradients so they appear continuous.

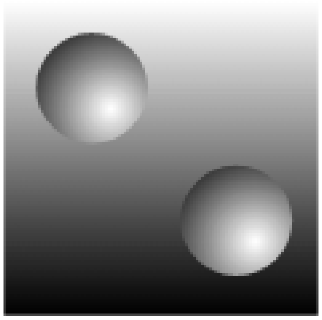
Fig. 36 Simultaneous contrast

- Because of adaptation and time orientation, the same amount of artificial lighting in interior spaces will appear much brighter at night than during the day.
- Because of simultaneous contrast and adaptation, objects with identical levels of illumination appear brighter when seen against a darker background (Fig. 36).
- When illumination levels must be low, emphasize potentially dangerous edges in circulation paths by changes in material, the use of color, or definitive shadows.
- Grazing lighting (lighting at a shallow angle of incidence) always highlights irregularities in the surface upon which it falls.

Design	Checklist
Architectural Systems and Components *How do they affect the way the space is defined?*	Construction Walls Interior Perimeter Ceilings Floors Acoustical Concerns Privacy Communication Isolation
Structural Systems and Components *How do they affect architectural definition, utility, and mechanical and electrical systems distribution?*	Location of Bearing Walls, Structural Members Depth of Ceiling Structure Type of Floor Construction How does it affect allowable loads/acceptable uses How does it affect location of penetrations for systems distribution
Mechanical Systems and Components *How do they affect architectural definition, and utility?*	HVAC System Type of System Spatial Requirements for Distribution Vertical Horizontal Ventilation Requirements Humidity Control Requirements Plumbing Spatial Requirements for Distribution Chase Dimensions Location of Chases to Ensure Adequate Slope
Electrical Systems and Components *How do they affect architectural definition? How are they limited by architecture and structure?*	Primary Distribution System Power Requirements Data and Communications Requirements Auxiliary Systems Lighting Lamp Type Lighting Method Spatial Requirements