Building Components

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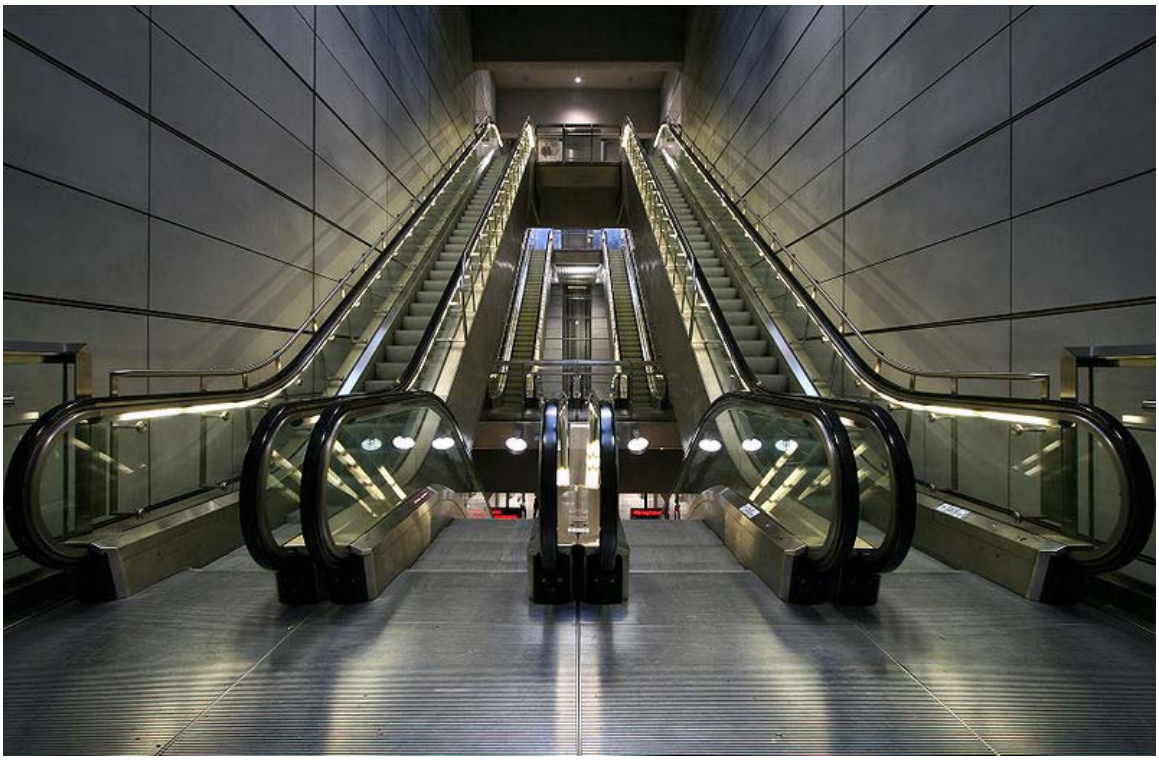
Chapter- 1

Escalator



Escalators in a Copenhagen Metro station, Denmark, 2007.

An **escalator** is a moving staircase – a conveyor transport device for carrying people between floors of a building. The device consists of a motor-driven chain of individual, linked steps that move up or down on tracks, allowing the step treads to remain horizontal.

Escalators are used around the world to move pedestrian traffic in places where elevators would be impractical. Principal areas of usage include department stores, shopping malls, airports, transit systems, convention centers, hotels, and public buildings.

The benefits of escalators are many. They have the capacity to move large numbers of people, and they can be placed in the same physical space as one might install a staircase. They have no waiting interval (except during very heavy traffic), they can be used to

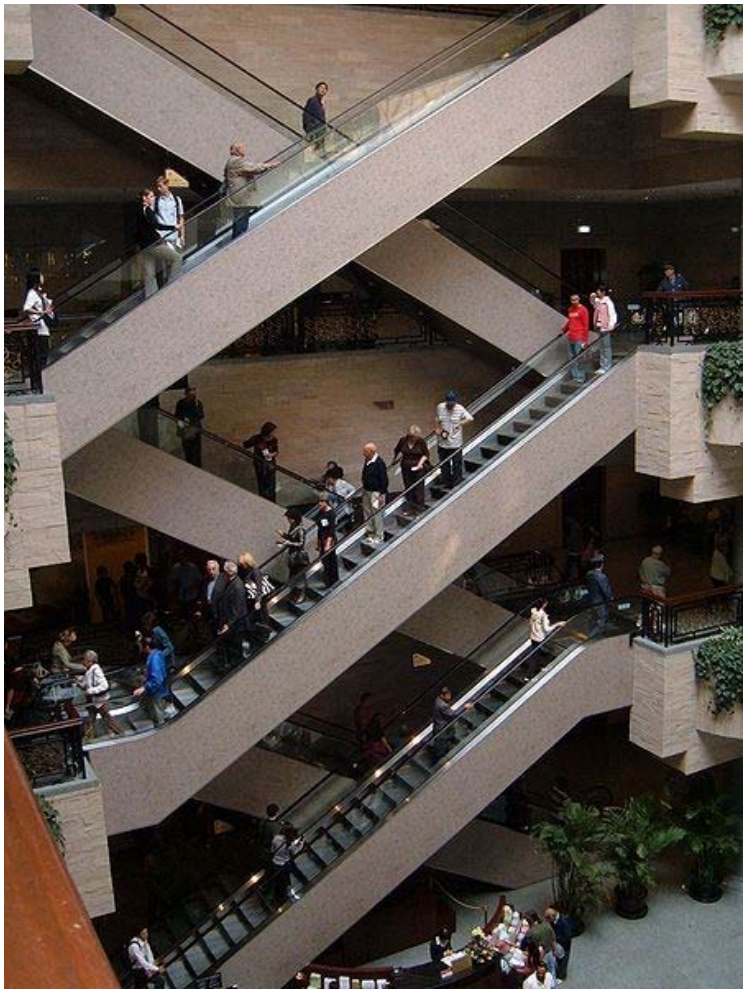
guide people toward main exits or special exhibits, and they may be weatherproofed for outdoor use.

In 2004, it was estimated that the United States had 30,000 escalators, and that people used escalators 90 billion times each year.

Design, components, and operation

Operation and layout

Escalators, like moving walkways, are powered by constant-speed alternating current motors and move at approximately 1–2 feet (0.30–0.61 m) per second. The typical angle of inclination of an escalator to the horizontal floor level is 30 degrees with a standard rise up to about 60 feet (18 m). Modern escalators have single piece aluminum or steel steps that move on a system of tracks in a continuous loop.



"**Crisscross**" layout

"**Multiple parallel**" layout

"**Parallel**" layout

Escalators have three typical configuration options: **parallel** (up and down escalators "side by side or separated by a distance", seen often in metro stations and multilevel motion picture theaters), **crisscross** (minimizes structural space requirements by "stacking" escalators that go in one direction, frequently used in department stores or shopping centers), and **multiple parallel** (two or more escalators together that travel in one direction next to one or two escalators in the same bank that travel in the other direction).

Escalators are required to have moving handrails that keep pace with the movement of the steps. The direction of movement (up or down) can be permanently the same, or be controlled by personnel according to the time of day, or automatically be controlled by whoever arrives first, whether at the bottom or at the top (the system is programmed so that the direction is not reversed while a passenger is on the escalator).

Design and layout considerations

A number of factors affect escalator design, including physical requirements, location, traffic patterns, safety considerations, and aesthetic preferences. Foremost, physical factors like the vertical and horizontal distance to be spanned must be considered. These factors will determine the pitch of the escalator and its actual length. The ability of the building infrastructure to support the heavy components is also a critical physical concern. Location is important because escalators should be situated where they can be easily seen by the general public. In department stores, customers should be able to view the merchandise easily. Furthermore, up and down escalator traffic should be physically separated and should not lead into confined spaces.

Traffic patterns must also be anticipated in escalator design. In some buildings, the objective is simply to move people from one floor to another, but in others there may be a more specific requirement, such as funneling visitors towards a main exit or exhibit. The number of passengers is important because escalators are designed to carry a certain maximum number of people. For example, a single-width escalator traveling at about 1.5 feet (0.46 m) per second can move an estimated 170 persons per five minute period. The carrying capacity of an escalator system must match the expected peak traffic demand, presuming that passengers ride single file. This is crucial for applications in which there are sudden increases in the number of riders. For example, escalators at stations must be designed to cater for the peak traffic flow discharged from a train, without causing excessive bunching at the escalator entrance.

In this regard, escalators help in controlling traffic flow of people. For example, an escalator to an exit effectively discourages most people from using it as an entrance, and may reduce security concerns. Similarly, escalators often are used as the exit of airport security checkpoints. Such an egress point would generally be staffed to prevent its use as an entrance, as well.

It is preferred that staircases be located adjacent to the escalator if the escalator is the primary means of transport between floors. It may also be necessary to provide an

elevator lift adjacent to an escalator for wheelchairs and disabled persons. Finally, consideration should be given to the aesthetics of the escalator. The architects and designers can choose from a wide range of styles and colors for the handrails and balustrades.

Model sizes and other specifications

Escalator step widths and energy usage

Size	Width (between balustrade panels)	Single-step capacity	Applications	Energy consumption
Very small	400 mm (16 in)	One passenger, with feet together	A rare historic design found mostly in older department stores	3.7 kW (5.0 hp)
Small	600 mm (24 in)	One passenger	Low-volume sites, uppermost levels of department stores, when space is limited	3.7 kW (5.0 hp)
Medium	800 mm (31 in)	One passenger + one package or one piece of luggage	Shopping malls, department stores, smaller airports	7.5 kW (10.1 hp)
Large	1,000 mm (39 in)	Two passengers – one may walk past another	Mainstay of metro systems, larger airports, train stations, some retail usage	7.5 kW (10.1 hp)

Components

An escalator being repaired at Town Hall Station in Sydney, Australia

Landing platforms

These two platforms house the curved sections of the tracks, as well as the gears and motors that drive the stairs. The top platform contains the motor assembly and the main drive gear, while the bottom holds the step return idler sprockets. These sections also anchor the ends of the escalator truss. In addition, the platforms contain a floor plate and a combplate. The floor plate provides a place for the passengers to stand before they step onto the moving stairs. This plate is flush with the finished floor and is either hinged or removable to allow easy access to the machinery below. The combplate is the piece between the stationary floor

plate and the moving step. It is so named because its edge has a series of cleats that resemble the teeth of a comb. These teeth mesh with matching cleats on the edges of the steps. This design is necessary to minimize the gap between the stair and the landing, which helps prevent objects from getting caught in the gap.

Truss

The truss is a hollow metal structure that bridges the lower and upper landings. It is composed of two side sections joined together with cross braces across the bottom and just below the top. The ends of the truss are attached to the top and bottom landing platforms via steel or concrete supports. The truss carries all the straight track sections connecting the upper and lower sections.

Tracks

The track system is built into the truss to guide the step chain, which continuously pulls the steps from the bottom platform and back to the top in an endless loop. There are actually two tracks: one for the front wheels of the steps (called the step-wheel track) and one for the back wheels of the steps (called the trailer-wheel track). The relative positions of these tracks cause the steps to form a staircase as they move out from under the combplate. Along the straight section of the truss the tracks are at their maximum distance apart. This configuration forces the back of one step to be at a 90-degree angle relative to the step behind it. This right angle bends the steps into a shape resembling a staircase. At the top and bottom of the escalator, the two tracks converge so that the front and back wheels of the steps are almost in a straight line. This causes the stairs to lay in a flat sheetlike arrangement, one after another, so they can easily travel around the bend in the curved section of track. The tracks carry the steps down along the underside of the truss until they reach the bottom landing, where they pass through another curved section of track before exiting the bottom landing. At this point the tracks separate and the steps once again assume a staircase configuration. This cycle is repeated continually as the steps are pulled from bottom to top and back to the bottom again.

Steps

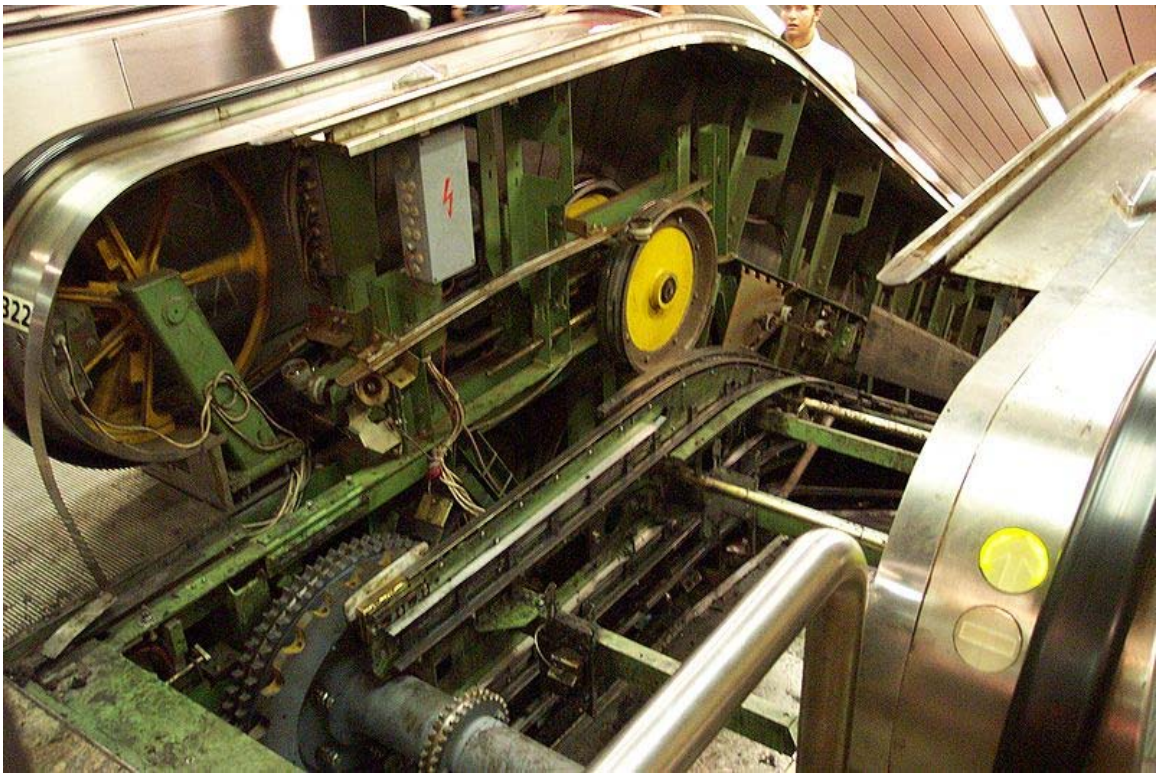
The steps themselves are solid, one piece, die-cast aluminum or steel. Yellow demarcation lines may be added to clearly indicate their edges. In most escalator models manufactured after 1950, both the riser and the tread of each step is cleated (given a ribbed appearance) with comblike protrusions that mesh with the combplates on the top and bottom platforms and the succeeding steps in the chain. Seeberger- or "step-type" escalators featured flat treads and smooth risers; other escalator models have cleated treads and smooth risers. The steps are linked by a continuous metal chain that forms a closed loop. The front and back edges of the steps are each connected to two wheels. The rear wheels are set further apart to fit into the back track and the front wheels have shorter axles to fit into the narrower front track. As described above, the position of the tracks controls the orientation of the steps.

Handrail

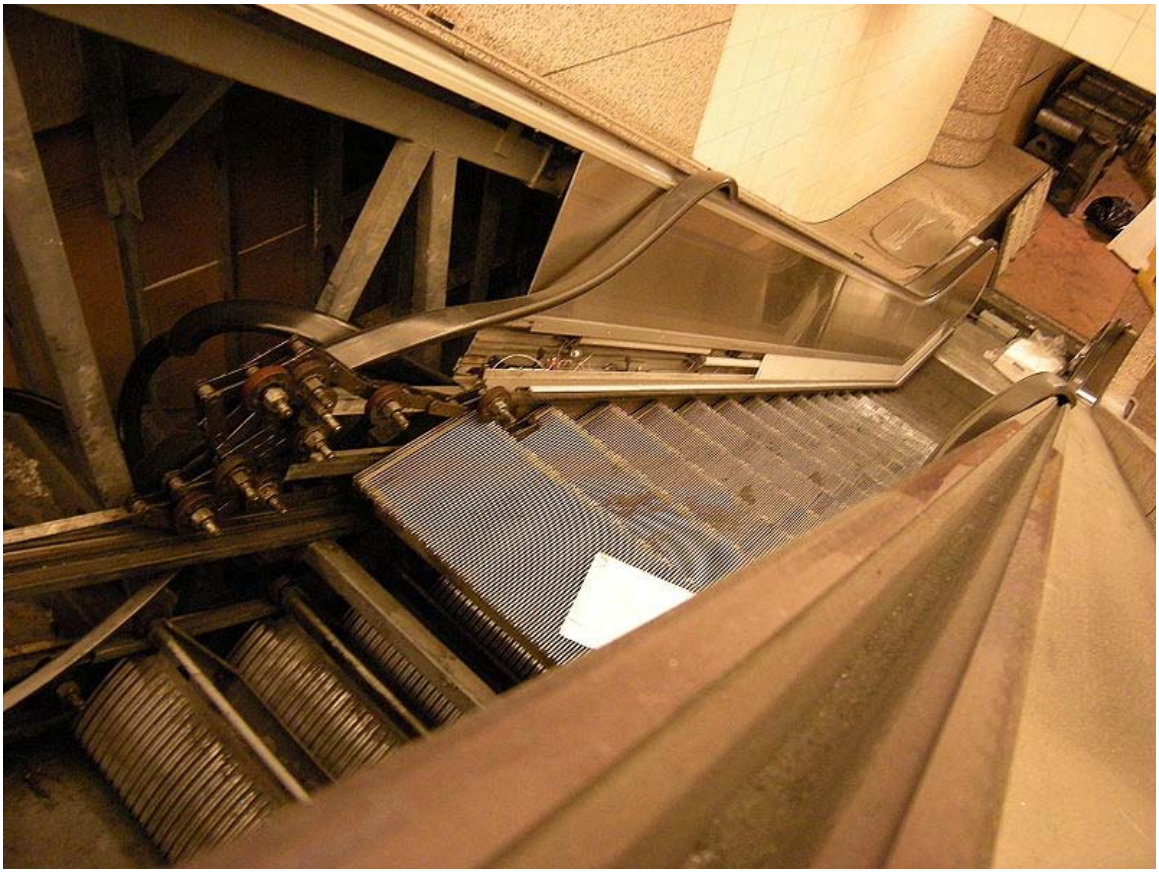
The handrail provides a convenient handhold for passengers while they are riding the escalator. In an escalator, the handrail is pulled along its track by a chain that is connected to the main drive gear by a series of pulleys. It is constructed of four

distinct sections. At the center of the handrail is a "slider", also known as a "glider ply", which is a layer of a cotton or synthetic textile. The purpose of the slider layer is to allow the handrail to move smoothly along its track. The next layer, known as the "tension member", consists of either steel cable or flat steel tape, and provides the handrail with tensile strength and flexibility. On top of tension member are the inner construction components, which are made of chemically treated rubber designed to prevent the layers from separating. Finally, the outer layer—the only part that passengers actually see—is the cover, which is a blend of synthetic polymers and rubber. This cover is designed to resist degradation from environmental conditions, mechanical wear and tear, and human vandalism.
In the factory, handrails are constructed by feeding rubber through a computer-controlled extrusion machine to produce layers of the required size and type in order to match specific orders. The component layers of fabric, rubber, and steel are shaped by skilled workers before being fed into the presses, where they are fused together.
In the mid-twentieth century, some handrail designs consisted of a rubber bellows, with rings of smooth metal cladding called "bracelets" placed between each coil. This gave the handrail a rigid yet flexible feel. Additionally, each bellows section was no more than a few feet long, so if part of the handrail was damaged, only the bad segment needed to be replaced. These forms of handrail have largely been replaced with conventional fabric-and-rubber railings.

A "freestanding" escalator reveals its inner components through the transparent truss.



Escalator truss connects to the landing platform (lower left). Also visible: exposed drive gears (center) for steps and handrail drive (left).



View of escalator steps on continuous chain

An escalator equipped with a "bellows" handrail. The bracelets are colored grey, with occasional strings of black ones to appear as moving spacers.

Safety

Safety is also major concern in escalator design. In India where women wear saris, there are heavy chances of getting the *pallu* entangled in the escalator special *sari guard* is inbuilt in most escalators.

There is a risk of feet injuries for children wearing footwear such as Crocs and flip-flops that might get caught in escalator mechanisms. This was due to the softness of the shoe's material combined with the smaller size of children's feet.

Fire protection of an escalator floor opening may be provided by adding automatic sprinklers or fireproof shutters to the opening, or by installing the escalator in an enclosed fire-protected hall. To limit the danger of overheating, ventilation for the spaces that contain the motors and gears must be provided.

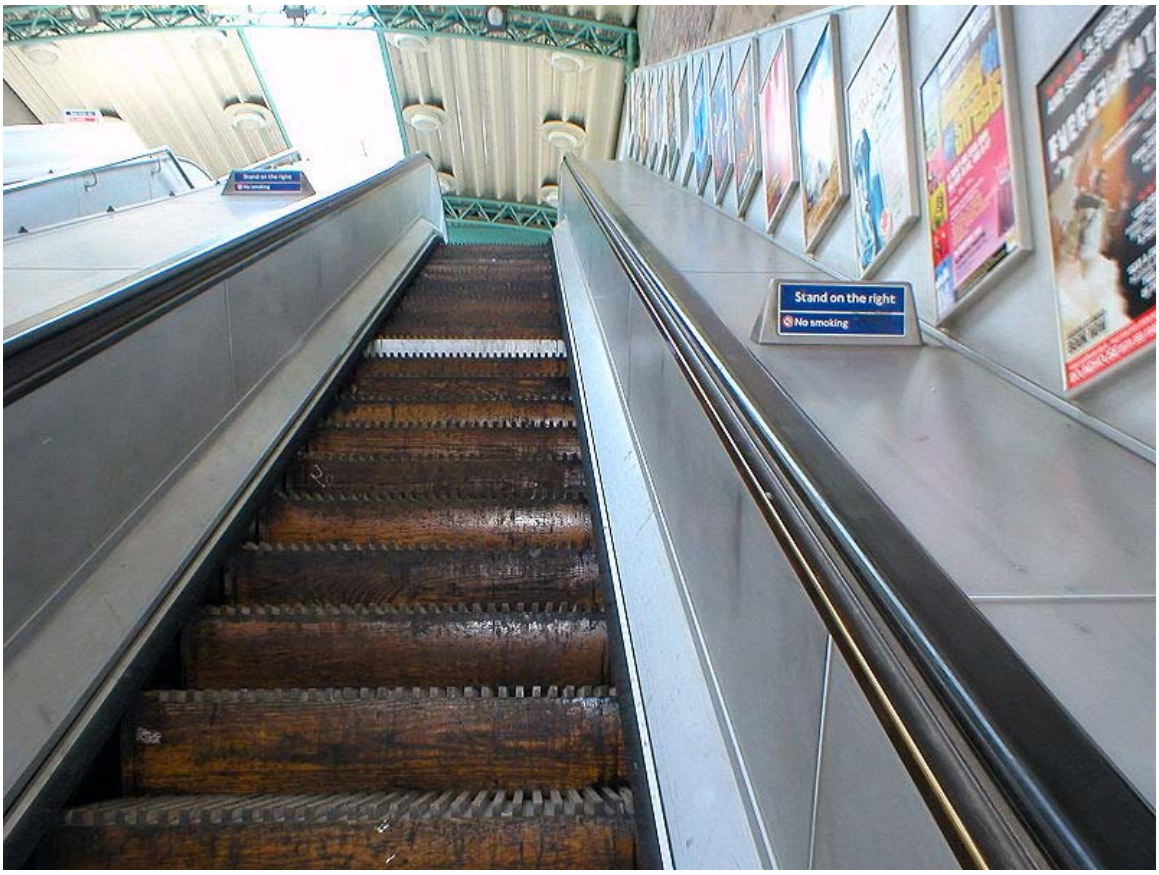
Accidents and litigation

Accidents

There have been reports of people falling off a moving escalator or getting their shoe stuck in part of the escalator; shoe laces are a hazard when loose. Some accidents are caused by improper or unsafe use such as riding the hand rails or by escalator spinning. A few fatal accidents are:

- Eight people died and 30 more were injured on Wednesday, February 17, 1982, when an escalator collapsed on the Moscow Metro. Wrongly set up service brakes were later blamed for the accident.
- 31 people died after a fire, begun in the undercarriage of an MH-type Otis escalator, exploded into the ticketing hall at King's Cross St. Pancras station in 1987.
- On Monday, December 13, 1999, 8-year-old Jyotsna Jethani was killed at New Delhi's international airport. Jethani fell into a gaping hole that resulted from improper maintenance.
- On Saturday, June 15, 2002, Andrea Albright, a 24-year-old J.C. Penney employee in Columbia, Maryland, was critically injured while riding the store's escalator from the first to the second level. She somehow got her head caught between the escalator rail and a low ceiling. In 2005, her parents sued the property manager, two design firms, and the escalator company for $5 million.
- On New Years Eve, 2004, escalators at the Taipei City Hall Station kept moving commuters onto the overcrowded island platform. A woman whose hair got caught in the escalator received 20 stitches to the scalp.
- Francisco Portillo, a Salvadoran sushi chef, died after being strangled when his sweatshirt got caught in an escalator at the Porter Square MBTA station in Cambridge, Massachusetts on February 21, 2005. He was allegedly drunk at the time.
- On Saturday, September 13, 2008, an 11-year old boy died after falling off an escalator in Lyngdal, Norway. On Monday, April 20, 2009, a teenage boy died after getting very serious skull injuries after falling off an escalator in Falun, Sweden. On Friday, June 26, 2009, a man died after falling off an escalator in Helsingborg, Sweden. All three were riding the handrail.

Lessons of the King's Cross fire



Greenford station escalators (2006)

The King's Cross fire illustrated the demanding nature of escalator upkeep and the devices' propensity to collect "fluff" when not properly maintained.

Since the station was part of a public institution (the London Underground) and there was a substantial casualty rate, the incident yielded vociferous public outcry as riders and victims' families demanded the removal of all wooden escalators systemwide. In the official inquiry that followed, the Fennell Report, it was determined that the fire started slowly, smoldered virtually undetected for a time, then exploded into the ticketing hall above in a phenomenon known as the "trench effect." This slow-burning fire, Fennell found, was allegedly kindled by a discarded unextinguished cigarette, which was shown in laboratory tests to be a more powerful ignition source than a lit match. In the escalators' undercarriage, approximately 8,800 kilograms (19,000 lb) of accumulated detritus acted as a wick to a neglected buildup of interior lubricants; wood veneers, paper and plastic advertisements, solvent-based paint, plywood in the ticket hall, and melamine combustion added to the impact of the calamity. Taking this particular situation as an example, one could easily speculate that any accretion of flammable fuels, cloth, or scraps (the "fluff" denoted by Fennell) could likewise lead to a devastating fire.

Consequentially, older wooden escalators were removed from service in the London Underground, though at least one set remains in operation, at Greenford Station. Additionally, sections of the London Underground that were actually below ground were made nonsmoking; eventually the whole system became a smoke-free zone.

Litigation

In the 1930s, at least one suit was filed against a department store, alleging that its escalators posed an attractive nuisance, responsible for a child's injury. These cases were almost always dismissed. Moreover, continual updating of escalator safety codes facilitated increased levels of consumer safety as well as a reduction in court cases.

Legislation and escalators

United States

Despite their considerable scope, two Congressional Acts, the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 (ADA), did not directly affect escalators or their public installations. Since Section 504 of the Rehabilitation Act included public transportation systems, for a few years, the United States Department of Transportation considered designs to retrofit existing escalators for wheelchair access. Nonetheless, Foster-Miller Associates' 1980 plan, *Escalator Modification for the Handicapped* was ultimately ignored in favor of increased elevator installations in subway systems. Likewise, the ADA provided more accessibility options, but expressly excluded escalators as "accessible means of egress," advocating neither their removal nor retention in public structures.

Codes and regulation

In the United States and Canada, new escalators must abide by ASME A17.1 standards, and old/historic escalators must conform to the safety guidelines of ASME A17.3. In Europe, the escalator safety code is EN115.

Key safety features developed over time

Notice on escalators in Spain.

To enhance passenger safety, newer models of escalators are equipped with one or more of the following safety implementations, as per ASME A17.1 code:

- Antislide devices: Raised circular objects that often stud the escalator balustrade. Sometimes informally called "hockey pucks" due to their appearance, their purpose is to prevent objects (and people) from precipitously sliding down the otherwise smooth metallic surface.
- Combplate impact switches: Stop the escalator if a foreign object gets caught between the steps and the combplate on either end.
- Deflector brush: A long continuous brush made of stiff bristles running up the sides of the escalator just above the step level. This helps deflect garments, shoes, and other items away from the gap between the moving steps and the skirt board.
- Emergency stop button: At each end of the escalator (in some models, also on the balustrade), a large red button can be pressed to stop the device in the event of an emergency. Typically, an alarmed transparent plastic guardplate covers the button; restarting requires turning a key.
- Extended balustrades: Allows riders to grasp the handrail before setting foot on an escalator, to ease customer comfort and stability/equilibrium. (The effect is similar to the flat steps described below.)

- Flat steps: Like a moving walkway, the first two or three steps at either end of the escalator are flat. This gives the passenger extra time to orient him/herself when boarding, and more time to maintain balance when exiting. Longer escalators often have four or more flat steps.
- Handrail inlet switches: . Sensors located at the bottom and top of the unit that guard the handrail termini. If something gets caught in these locations, a hard fault is generated in the controller, and the escalator shuts down automatically.
- Handrail speed sensors: These sensors are usually optical, and monitor how fast the handrail moves. If the sensor notices a speed difference between the handrail and the steps, it sounds an alarm, pauses, and then automatically stops the escalator. In these situations, the escalator must be serviced by authorized personnel before returning to an operable state.
- Missing step detectors: Depending on the manufacturer and model, this sensor is either optical or physical. When a missing step is detected, the escalator automatically shuts down.
- Raised step edges: In some models, a difference in tread height is utilized to keep passengers' feet from the skirt board.
- Safety instructions: A sign, typically posted on both escalator newels at the entrance landing platform. In some situations, safety precautions are posted on walls near the escalator, included on freestanding signs, or—as in some models—printed on the riser surface itself.
- Sensor switch: In automatic-start/stop escalators, this sensor automatically engages the escalator motion when a rider is detected on the first step of the entrance landing platform, and stops the escalator when there are no riders on the unit.
- Step demarcation lights: Either fluorescent or LED lights (traditionally green in color) located inside the truss. The illumination between the steps improves the passengers' awareness of the step divisions.
- Step demarcation lines: In order to clearly delineate the edges of each individual step, manufacturers offer steps trimmed in yellow, either painted or with plastic inserts.

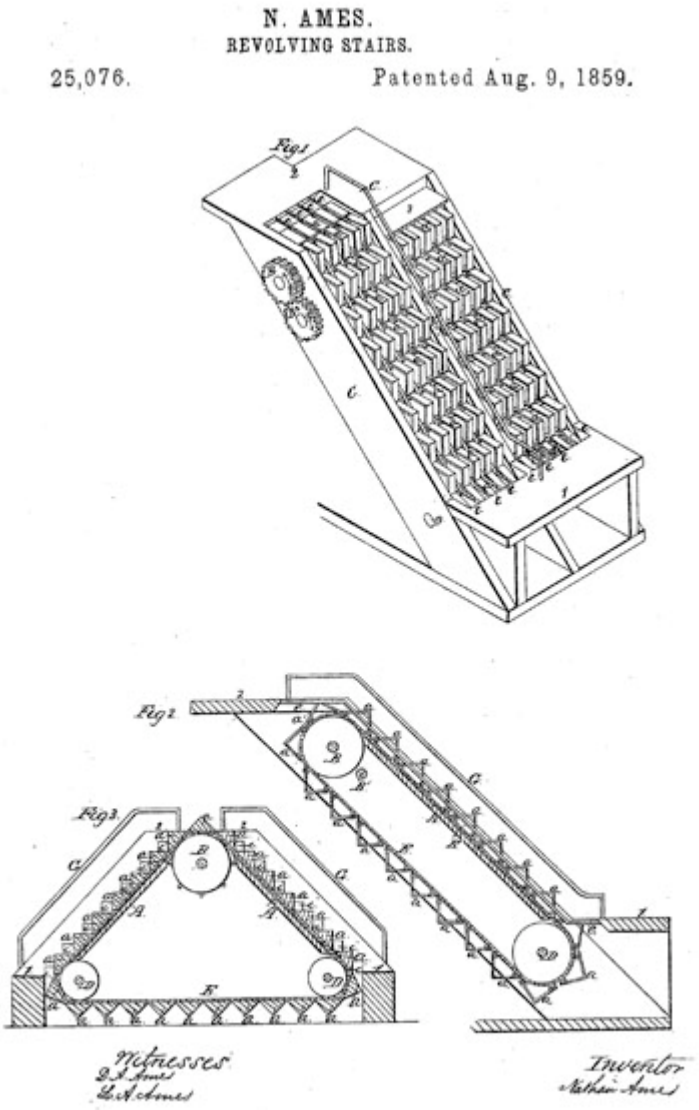
Safe riding: official safety foundation guidelines

While some escalator accidents are caused by a mechanical failure, most can be avoided by following some simple safety precautions. The Elevator Escalator Safety Foundation is a major advocate for safe riding in the United States and Canada, sponsors National Elevator Escalator Safety Week each year, and publishes its own suggestions for safe riding.

History

Inventors and manufacturers

Nathan Ames



Nathan Ames, a patent solicitor from Saugus, Massachusetts, is credited with patenting the first "escalator" in 1859, despite the fact that no working model of his design was ever built. His invention, the "revolving stairs", is largely speculative and the patent specifications indicate that he had no preference for materials or potential use (he noted that steps could be upholstered or made of wood, and suggested that the units might benefit the infirm within a household use), though the mechanization was suggested to run either by manual or hydraulic power.

Leamon Souder

In 1889, Leamon Souder successfully patented the "stairway", an escalator-type device that featured a "series of steps and links jointed to each other". No model was ever built. This was the first of at least four escalator-style patents issued to Souder, including two for spiral designs (U. S. Patent Nos. 723,325 and 792,623).

Jesse Wilford Reno, George A. Wheeler, and Charles Seeberger

In 1892, Jesse W. Reno patented the "Endless Conveyor or Elevator." A few months after Reno's patent was approved, George A. Wheeler patented his ideas for a more recognizable moving staircase, though it was never built. Wheeler's patents were bought by Charles Seeberger; some features of Wheeler's designs were incorporated in Seeberger's prototype built by the Otis Elevator Company in 1899.

Reno produced the first working escalator (he actually called it the "inclined elevator") and installed it alongside the Old Iron Pier at Coney Island, New York in 1896. This particular device was little more than an inclined belt with cast-iron slats or cleats on the surface for traction, and traveled along a 25° incline. A few months later, the same prototype was used for a monthlong trial period on the Manhattan side of the Brooklyn Bridge. Reno eventually joined forces with Otis Elevator Company, and retired once his patents were purchased outright. Some Reno-type escalators were still being used in the Boston subway until construction for the Big Dig precipitated their removal. The Smithsonian Institution considered re-assembling one of these historic units from 1914 in their collection of Americana, but "logistics and reassembly costs won out over nostalgia", and the project was discarded.

Around May 1895, Charles Seeberger began drawings on a form of escalator similar to those patented by Wheeler in 1892. This device actually consisted of flat, moving stairs, not unlike the escalators of today, except for one important detail: the step surface was smooth, with no comb effect to safely guide the rider's feet off at the ends. Instead, the passenger had to step off sideways. To facilitate this, at the top or bottom of the escalator the steps continued moving horizontally beyond the end of the handrail (like a miniature moving sidewalk) until they disappeared under a triangular "divider" which guided the passenger to either side. Seeberger teamed with Otis Elevator Company in 1899, and together they produced the first commercial escalator which won the first prize at the Paris 1900 *Exposition Universelle* in France. Also on display at the *Exposition* were Reno's inclined elevator, a similar model by James M. Dodge and the Link Belt Machinery Co., and two different devices by French manufacturers Hallé and Piat.

Early European manufacturers: Hallé, Hocquardt, and Piat

Piat installed its "stepless" escalator in Harrods Knightsbridge store on Wednesday, November 16, 1898, though the company relinquished its patent rights to the department store. Noted by Bill Lancaster in *The Department Store: a Social History*, "customers unnerved by the experience were revived by shopmen dispensing free smelling salts and

cognac." The Harrods unit was a continuous leather belt made of "224 pieces . . . strongly linked together traveling in an upward direction," and was the first "moving staircase" in England.

Hocquardt received European patent rights for the *Fahrtreppe* in 1906. After the *Exposition*, Hallé continued to sell its escalator device in Europe, but was eventually eclipsed in sales by other major manufacturers.

Major competitors and product nomenclature

In the first half of the twentieth century, several manufacturers developed their own escalator products, though they had to market their devices under different names, due to Otis' hold on the trademark rights to the word "escalator." New York-based Peelle Company called their models the ***Motorstair***, and Westinghouse called their model an ***Electric Stairway***. The Toledo-based Haughton Elevator company referred to their product as simply ***Moving Stairs***.

Manufacturing mergers and buyouts: the playing field narrows

Kone and Schindler introduced their first escalator models several decades after the Otis Elevator Co., but grew to dominance in the field over time. Today, they, Mitsubishi, and ThyssenKrupp are Otis' primary rivals.

Schindler now stands as the largest maker of escalators and second largest maker of elevators in the world, though their first escalator installation did not occur until 1936. In 1979, the company entered the United States market by purchasing Haughton Elevator; nine years later, Schindler assumed control of the North American escalator/elevator operations of Westinghouse.

Kone expanded internationally by acquisition in the 1970s, buying out Swedish elevator manufacturer Asea-Graham, and purchasing other minor French, German, and Austrian elevator makers before assuming control of Westinghouse's European elevator business. As the last "big four" manufacturers held on to the escalator market, KONE first acquired Montgomery Elevator Company, then took control of Germany's Orenstein & Koppel *Rolltreppen*.

Model development and design types

"Cleat-type" escalators

Jesse Reno's escalators did not resemble modern escalators too closely. Passengers' feet tilted upward at an angle, and the treads consisted of cleated metal (initially) or wood (later models). Reno worked on his own for several years, gaining success with installations from Toronto to Cape Town, South Africa. Similar units of the day by other manufacturers resembled conveyor belts more than moving staircases. For a time, Otis Elevator sold Reno's escalators as their own "cleat-type" escalators.

"Step-type" escalators

Seeberger's model, bought by Otis, clearly became the first "step-type" escalator, so called after its visual likeness to steps on a regular staircase. The company later combined the best aspects of both inventions (guiding slats and flat steps) and in 1921 produced an escalator similar to the type used today: they called it the "L-type" escalator. It was succeeded by the "M-type", the "O-type", and current models by Otis such as the "NCE-type" escalator.

Spiral escalators: from Reno to Mitsubishi

A spiral escalator in Hong Kong

Reno, in addition to his notoriety for the first “practical” escalator in public use, also bears the unique distinction of designing the very first escalators installed in any underground subway system – a single spiral escalator at Holloway Road tube station in London in 1906. The experimental device never saw public use, and was forgotten for several decades. The remains of this are now in the London Transport Museum's depot in Acton. Also the first fully operational spiral escalator, Reno’s design was nonetheless only one in a series of several similar proposed contraptions. Souder patented two spiral designs, Wheeler drafted spiral stairway plans in 1905, Seeberger devised at least two different spiral units between 1906 and 1911 (including an unrealized arrangement for the

London Underground), and Gilbert Luna obtained West German, Japanese, and United States patents for his version of a spiral escalator by 1973. When interviewed for the *Los Angeles Times* that year, Luna was in the process of soliciting “major firms” for acquisition of his patents and company, but statistics are unclear on the outcome of his endeavors in that regard.

The Mitsubishi Electric Corporation was most successful in its development of "spiral" (more "curve" than true spiral) escalators, and has sold them exclusively since the mid-1980s. The world's first "practical" spiral escalator—a Mitsubishi model—was installed in Osaka, Japan, in 1985.

In use, a major planning advantage presented by spiral escalators is that they take up much less horizontal floor space than traditional units, which frequently house large machine rooms underneath the truss.

Etymology

Several authors and historians have contributed their own differing interpretations of the source of the word “escalator”, and some degree of misinformation has heretofore proliferated on the Internet. For reference, contradictory citations by seven separate individuals, including the Otis Elevator Company itself, are provided below.

Name development and original intentions

Charles Seeberger trademarked the word "escalator" in 1900, to coincide with his device’s debut at the *Exposition Universelle*. According to his own account, in 1895, his legal counsel advised him to name his new invention, and he then set out to devise a title for it on his own. As evidenced in Seeberger's own handwritten documents, archived at the Otis Elevator Company headquarters in Farmington, Connecticut, the inventor consulted "a Latin lexicon" and "adopted as the root of the new word, 'Scala'; as a prefix, 'E' and as a suffix, 'Tor.'" His own rough translation of the word thus created was "means of traversing from", and he intended for the word to be pronounced, "es·ˈkæl ·ə·tər" (es-**CAL**-a-tor).

"Escalator" was not a combination of other French or Greek words, and was never a derivative of "elevator" in the original sense, which means "one who raises up, a deliverer" in Latin. Similarly, the root word "*scala*" does not mean "a flight of steps", but is defined by Lewis and Short’s *A Latin Dictionary* as the singular form of the plural noun "*scalae*", which denotes any of the following: "a flight of steps or stairs, a staircase; a ladder, [or] a scaling-ladder."

The alleged intended capitalization of "escalator" is likewise a topic of debate. Seeberger’s trademark application lists the word not only with the "E" but also with all of the letters capitalized (in two different instances), and he specifies that, "any other form and character of type may be employed . . . without altering in any essential manner the character of [the] trade-mark." That his initial specifications are ostensibly inconsistent,

and since Otis Elevator Co. advertisements so frequently capitalized all of the letters in the word, suppositions about the "capital ‘e’" are difficult to formulate.

Derivatives of 'escalator'

The verb "escalate" originated in 1922, and has two uses, the primary: "to climb or reach by means of an escalator" or "to travel on an escalator", and the secondary: "to increase or develop by successive stages; *spec.* to develop from 'conventional' warfare into nuclear warfare." The latter definition was first printed in the *Manchester Guardian* in 1959, but grew to prominent use during the late 1960s and early 1970s.

Loss of trademark rights

In 1950, the landmark case *Haughton Elevator Co. v. Seeberger* precipitated the end of Otis' reign over exclusive use of the word "escalator", and simultaneously created a cautionary study for companies and individuals interested in trademark retention. Confirming the contention of the Examiner of Trademark Interferences, Assistant Commissioner of Patents Murphy’s decision rejected the Otis Elevator Company’s appeal to keep their trademark intact, and noted that "the term 'escalator' is recognized by the general public as the name for a moving stairway and not the source thereof", observing that the Otis Elevator Co. had "used the term as a generic descriptive term…in a number of patents which [had] been issued to them and…in their advertising matter." All trademark protections were removed from the word "escalator", the term was officially genericized, and it fell into the public domain.

Primary uses and application

Department stores/shopping

As noted above, a few escalator types were installed in major department stores (including Harrods) before the *Expo*. Escalators proved instrumental in the layout and design of shopping venues in the twentieth century.

By 1898, the first of Reno’s "inclined elevators" were incorporated into the Bloomingdale Bros. store at Third Avenue and 59th Street. This was the first retail application of the devices in the US, and no small coincidence, considering that Reno's primary financier was Lyman Bloomingdale, co-owner of the department store with brother Joseph Bloomingdale.

The longest escalators in the Western Hemisphere, at the Wheaton station, Washington DC Metro

Public transportation

The first "standard" escalator installed on the London Underground was a Seeberger model at Earls Court. Noted above, London's Underground installed a rare spiral escalator designed by Reno, William Henry Aston and Scott Kietzman for the Holloway Road Underground station in 1906; it was run for a short time but was taken out of service the same day it debuted. The older lines of the London Underground had many escalators with wooden treads (ca. 1930s) until they were rapidly replaced following the King's Cross fire, noted above.

Other applications

Factories and other industrial production environments

In 1905, the American Woolen Company’s Wood Mill in Lawrence, Massachusetts (then "the largest single worsted mill in the world") utilized Otis' Seeberger-type "reversible" escalators to carry its workers between floors four times a day. The machines did not run all day: rather, escalators ran solely to transport employees to/from midday meals and in/out of the mill. In its advertising, Otis Elevator Company hailed this unconventional

use for its unique benefits to both workers and owners: "The profitable and practicable feature of the Escalator, from the viewpoint of the owner, is the increased efficiency of each operator due to the elimination of stair climbing."

Military use

In San Francisco, an escalator at Hunters Point Naval Shipyard was used to convey personnel between the first and third floors. At the time of its construction in 1948, it was touted thus: "[it has the] highest lift of any industrial building in the world. It rises 42 feet."

Escalators were also utilized on aircraft carriers such as the USS *Hornet* (CV-12), to transport pilots from "ready rooms" to the flight deck.

Extant historic escalator models

Macy's Herald Square store in New York City holds some of the more famous historic escalators. The models shown here, retrofitted with metal steps in the 1990s, are among the oldest of the store's 40 escalators. Otis "L-type" escalators with distinctive wood treads (not shown) have operated in the store since 1927.

Wooden treads on a 1930s Otis escalator at Wynyard railway station, Sydney, Australia

A few notable examples of historic escalators still in operation are:

Australia

- Town Hall Railway Station, Sydney, Australia
- Wynyard Railway Station, Sydney, Australia

Europe

- St. Anna Pedestrian Tunnel underneath the Schelde in Antwerp, Belgium. This tunnel was opened in 1933.
- Tyne Cyclist and Pedestrian Tunnel, Tyne and Wear, England

  -These escalators, manufactured by Waygood Otis in 1951, were "believed to be the longest single lift escalators in the world", at the time of installation. Presumably the first escalators in Britain designed specifically for cyclists, they are also "thought to be still" the longest escalators in the United Kingdom. At most, they may be the longest extant wooden escalators in operation in the world.

- Greenford Station, Greenford, England

North America

- Macy's Herald Square department store, Otis L-type units with wood treads and replacement metal treads, New York, New York
- Kaufmann's department store (now Macy's), two 16-inch (400 mm) Otis L-type units with original floorplates, several 40-inch (1000 mm) Otis escalators ca. 1950s, Pittsburgh, Pennsylvania
- Westfield San Francisco Centre (formerly The Emporium), chrome-and-glass escalator by Eleanor LeMaire for Otis, San Francisco, California

Escalators: superlatives

Longest systems

- Central-Mid-Levels escalator: in Hong Kong, tens of thousands of commuters travel each work day between Central, the central business district, and the Mid-levels, a residential district hundreds of feet uphill, using this long distance system of escalators and moving walkways. It is the world's longest outdoor escalator *system* (not a single escalator span), at a total length of 2,600 feet (790 m). It goes only one way at a time; the direction reverses depending on rush hour traffic direction.
- Ocean Park, Hong Kong: a long escalator system connecting two parts of the Park, with an overall length of 730 feet (220 m).

Longest examples

Asia and Europe

Several "metro" or "subway" systems in Central and Eastern Europe feature very long escalators.

- In the Park Pobedy station of the Moscow Metro, opened in 2003, the escalators are 126.8 m (63.4 m high), or 740 steps, long, and take nearly three minutes to transit. Deep underground stations in St. Petersburg have escalators up to approximately 142 m long (71 m high).
- The Kiev Metro Kreschatik station's lower-level second exit escalator (a type ЛТ-2, circa 1965), lifts riders 216 feet (66 m), or 743 steps, up a 432-foot (132 m)-long incline.
- The longest escalator in Prague is at the Náměstí Míru station at 290 feet (88 m).
- The longest escalator of a European shopping mall is at MyZeil, Frankfurt, Germany, with a length of 150 feet (46 m).
- The tallest escalator on the London Underground system is at Angel station with a length of 197 feet (60 m), and a vertical rise of 90 feet (27 m).
- The longest wooden escalators in the United Kingdom are at the Tyne Tunnel, with a length of 200 feet (61 m).

- The longest escalator on the Stockholm Metro, and in Western Europe, is at Västra skogen with a length of 220 feet (67 m) and in Helsinki Metro at Kamppi station with a length of 210 feet (64 m).
- The largest "single truss escalator" is in the Bentall Centre in Kingston upon Thames in Greater London, UK. It connects the ground floor with the second floor with only top and bottom supports.

North and South America

View from bottom of Porter Square escalator, 2010

- The longest set of single-span uninterrupted escalators in the Western Hemisphere is at the Wheaton station of the Washington Metro system. They are 230 feet (70 m) long with a vertical rise of 115 feet (35 m), and take what is variously described as 2 minutes and 45 seconds or nearly three-and-a-half minutes, to ascend or descend without walking.
- The longest *freestanding* (supported only at the ends) escalator in the world is inside CNN Center's atrium in Atlanta, Georgia. It rises 8 stories and is 205 feet (62 m) long. Originally built as the entrance to the amusement park The World of Sid and Marty Krofft, the escalator is now used for CNN studio tours.
- The longest set of single-span uninterrupted escalators in the United States is located in the Wheaton WMATA subway station in Wheaton Maryland.

Shortest examples

Asia

According to Guinness, the shortest escalator in the world is in the Okadaya Mores shopping mall in Kawasaki, Japan. Its vertical rise is only 32.8 inches (83 cm).

North America

The shortest escalator in the United States is a Schindler unit at the entrance to the JCPenney Department Store in Westfield Garden State Plaza in Paramus, New Jersey.

Notable spiral escalator installations

Escalators in the Yokohama Minato Mirai 21, Japan.

Asia

- Wheelock Place, Singapore
- Jeddah Hilton, Saudi Arabia
- Landmark Tower, Japan
- Times Square shopping mall, Causeway Bay, Hong Kong
- Langham Place, Mongkok, Hong Kong
- Lotte World, South Korea
- The Venetian hotel and casino, Cotai, Macau
- WTC Mangga Dua, Jakarta, Indonesia (the only one in Indonesia)
- Taipei, Taiwan

North America

- Wynn Las Vegas, Las Vegas, Nevada, United States
- The Forum Shops at Caesars, Las Vegas, Nevada, United States
- (Former) San Francisco Centre, San Francisco, California, United States—the first such installation in the Western Hemisphere.
- River Rock Casino Resort, Richmond, British Columbia, Canada-the first in Canada.

Chapter- 2

Electrical Wiring

Electrical wiring in general refers to insulated conductors used to carry electricity, and associated devices. Here we describes general aspects of electrical wiring as used to provide power in buildings and structures, commonly referred to as **building wiring**. Here we, intend to describe common features of electrical wiring that should apply worldwide.

Wiring safety codes

Wiring safety codes are intended to protect people and buildings from electrical shock and fire hazards. Regulations may be established by city, county, provincial/state or national legislation, sometimes by adopting in amended form a model code produced by a technical standards-setting organization, or by a national standard electrical code.

Electrical codes arose in the 1880s with the commercial introduction of electrical power. Many conflicting standards existed for the selection of wire sizes and other design rules for electrical installations.

The first electrical codes in the United States originated in New York in 1881 to regulate installations of electric lighting. Since 1897 the U.S. National Fire Protection Association, a private nonprofit association formed by insurance companies, has published the National Electrical Code (NEC). States, counties or cities often include the NEC in their local building codes by reference along with local differences. The NEC is modified every three years. It is a consensus code considering suggestions from interested parties. The proposals are studied by committees of engineers, tradesmen, manufacturer representatives, fire fighters, and other invitees.

Since 1927, the Canadian Standards Association (CSA) has produced the Canadian *Safety Standard for Electrical Installations*, which is the basis for provincial electrical codes. The CSA also produces the Canadian Electrical Code, the 2006 edition of which references IEC 60364 (*Electrical Installations for Buildings*) and states that the code addresses the fundamental principles of electrical protection in Section 131. The Canadian code reprints Chapter 13 of IEC 60364, and it is interesting to note that there are no numerical criteria listed in that chapter whereby the adequacy of any electrical installation can be assessed.

Although the U.S. and Canadian national standards deal with the same physical phenomena and broadly similar objectives, they differ occasionally in technical detail. As part of the North American Free Trade Agreement (NAFTA) program, U.S. and Canadian standards are slowly converging toward each other, in a process known as harmonization.

In European countries, an attempt has been made to harmonize national wiring standards in an IEC standard, IEC 60364 *Electrical Installations for Buildings*. Hence national standards follow an identical system of sections and chapters. However, this standard is not written in such language that it can readily be adapted as a national wiring code. Neither is it designed for field use by electrical tradesmen and inspectors for testing compliance with national wiring standards. National codes, such as the NEC or CSA C22.1, exemplify the common objectives of IEC 60364, and provide rules in a form that allows for guidance of those installing and inspecting electrical systems.

DKE - the German Commission for Electrical, Electronic and Information Technologies of DIN and VDE - is the German organisation responsible for the promulgation of electrical standards and safety specifications. DIN VDE 0100 is the German wiring regulations document harmonised with IEC 60364.

In the United Kingdom wiring installations are regulated by the Institution of Engineering and Technology *Requirements for Electrical Installations: IEE Wiring Regulations, BS 7671: 2008,* which are harmonised with IEC 60364. The previous edition (16th) was replaced by the current 17th Edition in January 2008. The 17th edition includes new sections for microgeneration and solar photovoltaic systems. The first edition was published in 1882.

AS/NZS 3000 is an Australian/New Zealand standard, commonly known as the "wiring rules," that specifies the requirements for the selection and installation of electrical equipment and the design and testing of such installations. The standard is a mandatory standard in both New Zealand and Australia; therefore, all electrical work covered by the standard must comply.

The international standard wire sizes are given in the IEC 60228 standard of the International Electrotechnical Commission. In North America, the American Wire Gauge is used.

Colour code

To enable wires to be easily and safely identified all common wiring safety codes mandate a colour scheme for the insulation on power conductors. Many local rules and exceptions exist. Older installations vary in colour codes, and colours may shift with heat and age of insulation.

Standard wire colours for flexible cable
Such as Extension cords, power (line) cords and lamp cords

World Region, country or other entity(ies)	Hot (Live)	Neutral	Protective earth/ground
EU, Australia & South Africa (IEC 60446)	brown	blue	green & yellow
Australia & New Zealand (AS/NZS 3000:2007 3.8.1)	brown	light blue	green/yellow
United States and Canada	black (*brass*)	white (*silver*)	green (*green*)

Standard wire colours for fixed cable
(In or behind the wall wiring cables)

Region	Phases	Neutral	Protective earth/ground
EU (IEC 60446) including UK from 31 March 2004	brown, black, grey	blue	green & yellow
Australia and South Africa	red	black	green & yellow (core is usually bare and should be sleeved at terminations. In Australia the earth core has been separately insulated with green or green/yellow plastic since about 1980.
United States and Canada	120/208/240V: black, red, blue (*brass*) 277/480V: brown, orange, yellow	120/208/240V: white (*silver*) 277/480V: grey	green (*green*) or bare copper wire Isolated ground: Green with yellow stripe

Note: the colours in this table represent the most common and preferred standard colours for single phase wiring however others may be in use, especially in older installations.

Wiring methods

Installing electrical wiring by cutting into the bricks of the building

Materials for wiring interior electrical systems in buildings vary depending on:

- Intended use and amount of power demand on the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

Wiring systems in a single family home or duplex, for example, are simple, with relatively low power requirements, infrequent changes to the building structure and layout, usually with dry, moderate temperature, and noncorrosive environmental conditions. In a light commercial environment, more frequent wiring changes can be expected, large apparatus may be installed, and special conditions of heat or moisture may apply. Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages, frequent changes of equipment layout, corrosive, or wet or explosive atmospheres. In facilities that handle flammable gases or liquids, special rules may govern the installation and wiring of electrical equipment in hazardous areas.

Wires and cables are rated by the circuit voltage, temperature rating, and environmental conditions (moisture, sunlight, oil, chemicals) in which they can be used. A wire or cable has a voltage (to neutral) rating, and a maximum conductor surface temperature rating. The amount of current a cable or wire can safely carry depends on the installation conditions.

Early wiring methods

The very first interior power wiring systems used conductors that were bare or covered with cloth, which were secured by staples to the framing of the building or on running boards. Where conductors went through walls, they were protected with cloth tape. Splices were done similarly to telegraph connections, and soldered for security. Underground conductors were insulated with wrappings of cloth tape soaked in pitch, and laid in wooden troughs which were then buried. Such wiring systems were unsatisfactory because of the danger of electrocution and fire and the high labor cost for such installations.

Knob and tube

Knob-and-Tube wiring

The earliest standardized method of wiring in buildings, in common use in North America from about 1880 to the 1930s, was *knob and tube* (K&T) wiring: single conductors were run through cavities between the structural members in walls and ceilings, with ceramic tubes forming protective channels through joists and ceramic knobs attached to the structural members to provide air between the wire and the lumber and to support the wires. Since air was free to circulate over the wires, smaller conductors could be used than required in cables. By arranging wires on opposite sides of building structural members, some protection was afforded against short-circuits that can be caused by driving a nail into both conductors simultaneously. By the 1940s, the labour cost of installing two conductors rather than one cable resulted in a decline in new knob-and-tube installations.

Metal-sheathed wires

In the United Kingdom, an early form of insulated cable, introduced in 1896, consisted of two impregnated-paper-insulated conductors in an overall lead sheath. Joints were soldered, and special fittings were used for lamp holders and switches. These cables were similar to underground telegraph and telephone cables of the time. Paper-insulated cables

proved unsuitable for interior wiring installations because very careful workmanship was required on the lead sheaths to ensure moisture did not affect the insulation.

A system later invented in the UK in 1908 employed vulcanized-rubber insulated wire enclosed in a strip metal sheath. The metal sheath was bonded to each metal wiring device to ensure continuity.

A system developed in Germany called *Kuhlo wire* used one, two, or three rubber-insulated wires in a brass or lead-coated iron sheet tube, with a crimped seam. The enclosure could also be used as a return conductor. Kuhlo wire could be run exposed on surfaces and painted, or embedded in plaster. Special outlet and junction boxes were made for lamps and switches, made either of porcelain or sheet steel. The crimped seam was not considered as watertight as the *Stannos* wire used in England, which had a soldered sheath.

A somewhat similar system called "concentric wiring" was introduced in the United States around 1905. In this system, an insulated copper wire was wrapped with copper tape which was then soldered, forming the grounded (return) conductor of the wiring system. The bare metal sheath, at earth potential, was considered safe to touch. While companies such as General Electric manufactured fittings for the system, and a few buildings were wired with it, it was never adopted into the US National Electrical Code. Drawbacks of the system were that special fittings were required, and that any defect in the connection of the sheath would result in the sheath becoming energized.

Other historical wiring methods

Other methods of securing wiring that are now obsolete include:

- Re-use of existing gas pipes for electric lighting. Insulated conductors were pulled into the pipes feeding gas lamps.
- Wood mouldings with grooves cut for single conductor wires, covered by a wooden cap strip. These were prohibited in North American electrical codes by 1928. Wooden moulding was also used to some degree in England, but was never permitted by German and Austrian rules.
- A system of flexible twin cords supported by glass or porcelain buttons was used near the turn of the 20th century in Europe, but was soon replaced by other methods.
- During the first years of the 20th century various patented forms of wiring system such as Bergman and Peschel tubing were used to protect wiring; these used very thin fibre tubes or metal tubes which were also used as return conductors.
- In Austria, wires were concealed by embedding a rubber tube in a groove in the wall, plastering over it and then removing the tube and pulling in wires in the cavity.

Metal moulding systems, with a flattened oval section consisting of a base strip and a snap-on cap channel, were more costly than open wiring or wooden moulding, but could be easily run on wall surfaces. Similar systems are still available today.

Cables

Wiring in extremely-wet conditions

Armoured cables with two rubber-insulated conductors in a flexible metal sheath were used as early as 1906, and were considered at the time a better method than open knob-and-tube wiring, although much more expensive.

The first polymer-insulated cables for building wiring were introduced in 1922. These were two or more solid copper wires, with rubber insulation, woven cotton cloth over each conductor for protection of the insulation, with an overall woven jacket, usually impregnated with tar as a protection from moisture. Waxed paper was used as a filler and separator.

Rubber-insulated cables become brittle over time because of exposure to oxygen, so they must be handled with care, and should be replaced during renovations. When switches, outlets or light fixtures are replaced, the mere act of tightening connections may cause

insulation to flake off the conductors. Rubber was hard to separate from bare copper, so copper was tinned, causing slightly more resistance.

Three-phase copper cable TN-S 16mm² (5AWG) with PVC insulation

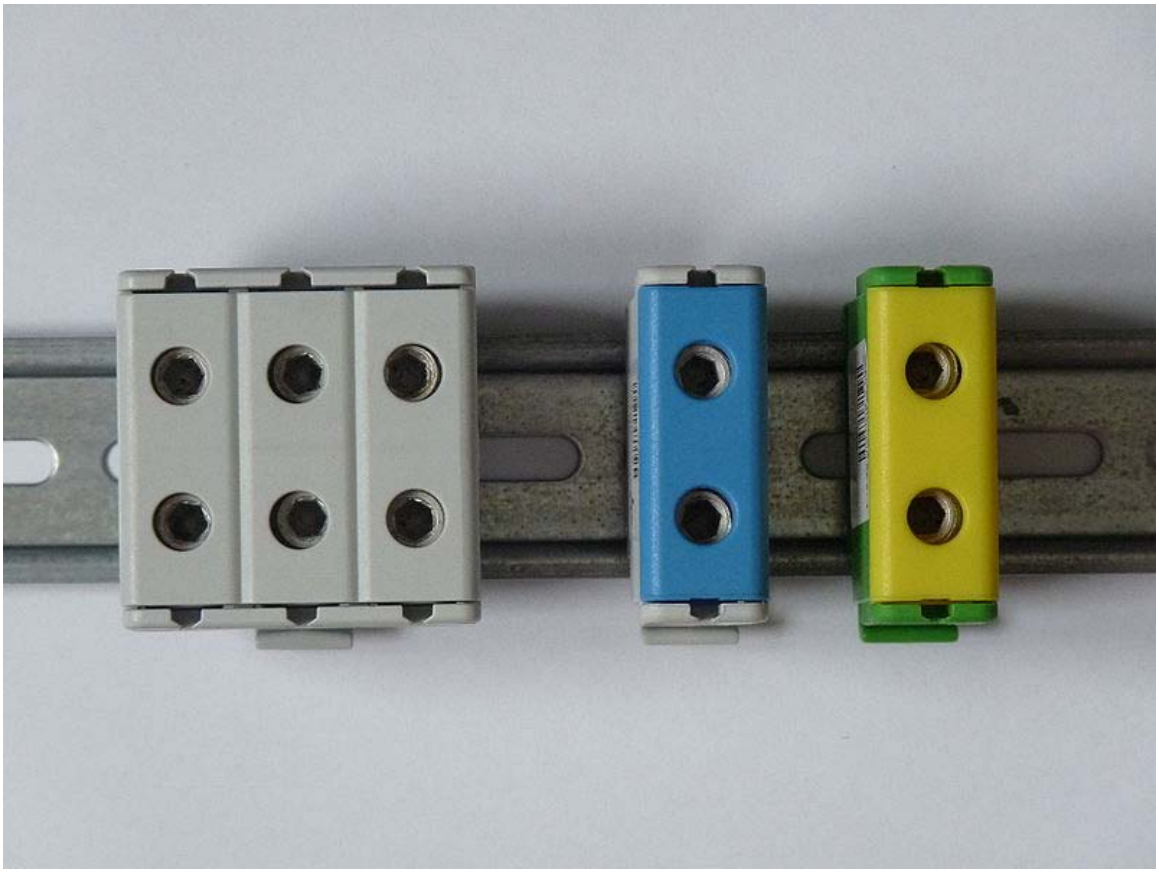
About 1950, PVC insulation and jackets were introduced, especially for residential wiring. About the same time, single conductors with a thinner PVC insulation and a thin nylon jacket became common.

The simplest form of cable has two insulated conductors twisted together to form a unit; such unjacketed cables with two or three conductors are used for low-voltage signal and control applications such as doorbell wiring. In North American practice, an overhead cable from a transformer on a power pole to a residential electrical service consists of

three twisted (triplexed) wires, often with one being a bare copper wire (protective earth/ground) and the other two being insulated for the line voltage (hot/live wire and neutral wire).

Aluminium conductors

Aluminium wire was common in North American residential wiring from the late 1960s to mid 1970s due to the rising cost of copper. Because of its greater resistivity, aluminium wiring requires larger conductors than copper. For instance, instead of 14 AWG (American wire gauge) for most lighting circuits, aluminium wiring would be 12 AWG on a typical 15 ampere circuit, though local building codes may vary.



Terminal blocks for joining aluminium and copper conductors. The terminal blocks may be mounted on a DIN rail.

Aluminium conductors were originally used with wiring devices intended for copper wires. This can cause defective connections unless the aluminium was one of a special alloy, or all devices — breakers, switches, receptacles, splice connectors, i.e., wire nuts, etc. — were designed to address problems with junctions between dissimilar metals, oxidation on metal surfaces and mechanical effects that occur as different metals expand at different rates with increases in temperature. Unlike copper, aluminium has a tendency to cold-flow under pressure, so screw clamped connections may get loose over time. This

can be mitigated by using spring-loaded connectors that apply constant pressure, applying high pressure cold joints in splices and termination fittings, and torquing the bolted connection. Unlike copper, aluminium forms an insulating oxide layer on the surface. This is sometimes addressed by coating aluminium wires with an antioxidant paste at joints, or applying a mechanical termination designed to break through the oxide layer during installation.

Because of improper design and installation, some junctions to wiring devices overheated under heavy current load and caused fires. Revised standards for wiring devices (such as the CO/ALR "copper-aluminium-revised" designation) were developed to reduce these problems. Nonetheless, aluminium wiring for residential use has acquired a poor reputation and has fallen out of favor.

Aluminium conductors are still used for power distribution and large feeder circuits, because they cost less than copper wiring, and weigh less, especially in the large sizes needed for heavy current loads. Aluminium conductors must be installed with compatible connectors.

Modern wiring materials

An electrical "3G" power cable found commonly in modern European houses. The cable consists of 3 wires (2 wires + 1 grounding in case if cable has "3G" name) and is double-insulated.

Modern nonmetallic sheathed cables (NMC), like (U.S. and Canadian) Type NM, consist of two to four wires covered with thermoplastic insulation and a bare wire for grounding (bonding) surrounded by a flexible plastic jacket. Some versions wrap the individual conductors in paper before the plastic jacket is applied. It is often called **Romex™** cable, since the first of its type was manufactured by Rome Cable Division of Cyprus Mines, Rome, New York. The trade name has been owned by Southwire since it purchased the electrical building wire assets of General Cable in 2001.

Rubber-like synthetic polymer insulation is used in industrial cables and power cables installed underground because of its superior moisture resistance.

Insulated cables are rated by their allowable operating voltage and their maximum operating temperature at the conductor surface. A cable may carry multiple usage ratings for applications, for example, one rating for dry installations and another when exposed to moisture or oil.

Generally, single conductor building wire in small sizes is solid wire, since the wiring is not required to be very flexible. Building wire conductors larger than 10 AWG (or about 6 mm^2) are stranded for flexibility during installation, but not stranded enough to be flexible enough to use as appliance cord.

Cables for industrial, commercial, and apartment buildings may contain many insulated conductors in an overall jacket, with helical tape steel or aluminium armour, or steel wire armour, and perhaps as well an overall PVC or lead jacket for protection from moisture and physical damage. Cables intended for very flexible service or in marine applications may be protected by woven bronze wires. Power or communications cables (e.g., computer networking) that are routed in or through air-handling spaces (plenums) of office buildings are required under the model code to be either encased in metal conduit or rated for low flame and smoke production.

For some industrial uses in steel mills and similar hot environments, no organic material gives satisfactory service. Cables insulated with compressed mica flakes are sometimes used. Another form of high-temperature cable is a mineral insulated cable, with individual conductors placed within a copper tube, and the space filled with magnesium oxide powder. The whole assembly is drawn down to smaller sizes, thereby compressing the powder. Such cables have a certified fire resistance rating, are more costly than non-fire rated cable, and have less flexibility.

Mineral insulated cables at a panel board

Because multiple conductors bundled in a cable cannot dissipate heat as easily as single insulated conductors, those circuits are always rated at a lower "ampacity". Tables in electrical safety codes give the maximum allowable current for a particular size of conductor, for the voltage and temperature rating at the surface of the conductor for a given physical environment, including the insulation type and thickness. The allowable current will be different for wet or dry, for hot (attic) or cool (underground) locations. In a run of cable through several areas, the most severe area will determine the appropriate rating of the overall run.

Cables usually are secured by special fittings where they enter electrical apparatus; this may be a simple screw clamp for jacketed cables in a dry location, or a polymer-gasketed cable connector that mechanically engages the armour of an armoured cable and provides a water-resistant connection. Special cable fittings may be applied to prevent explosive gases from flowing in the interior of jacketed cables, where the cable passes through areas where inflammable gases are present. To prevent loosening of the connections of individual conductors of a cable, cables must be supported near their entrance to devices and at regular intervals through their length. In tall buildings special designs are required to support the conductors of vertical runs of cable. Usually, only one cable per fitting is allowed unless the fitting is otherwise rated.

Special cable constructions and termination techniques are required for cables installed in ocean-going vessels; in addition to electrical safety and fire safety, such cables may also be required to be pressure-resistant where they penetrate bulkheads of a ship.

Raceways

Electrical Conduit risers, seen inside fire-resistance rated shaft, as seen entering bottom of a firestop. The firestop is made of firestop mortar on top, rockwool on the bottom. Raceways are used to protect cables from damage.

Insulated wires may be run in one of several forms of a raceway between electrical devices. This may be a pipe, called a conduit, or in one of several varieties of metal (rigid steel or aluminum) or non-metallic (PVC or HDPE) tubing. Rectangular cross-section metal or PVC wire troughs (North America) or trunking (UK) may be used if many circuits are required. Wires run underground may be run in plastic tubing encased in concrete, but metal elbows may be used in severe pulls. Wiring in exposed areas, for example factory floors, may be run in cable trays or rectangular raceways having lids.

Where wiring, or raceways that hold the wiring, must traverse fire-resistance rated walls and floors, the openings are required by local building codes to be firestopped. In cases where the wiring has to be kept operational during an accidental fire, fireproofing must be applied to maintain circuit integrity in a manner to comply with a product's certification listing. The nature and thickness of any passive fire protection materials used

in conjunction with wiring and raceways has a quantifiable impact upon the ampacity derating.

A cable tray can be used in stores and dwellings

Cable trays are used in industrial areas where many insulated cables are run together. Individual cables can exit the tray at any point, simplifying the wiring installation and reducing the labour cost for installing new cables. Power cables may have fittings in the tray to maintain clearance between the conductors, but small control wiring is often installed without any intentional spacing between cables.

Since wires run in conduits or underground cannot dissipate heat as easily as in open air, and adjacent circuits contribute induced currents, wiring regulations give rules to establish the current capacity (ampacity).

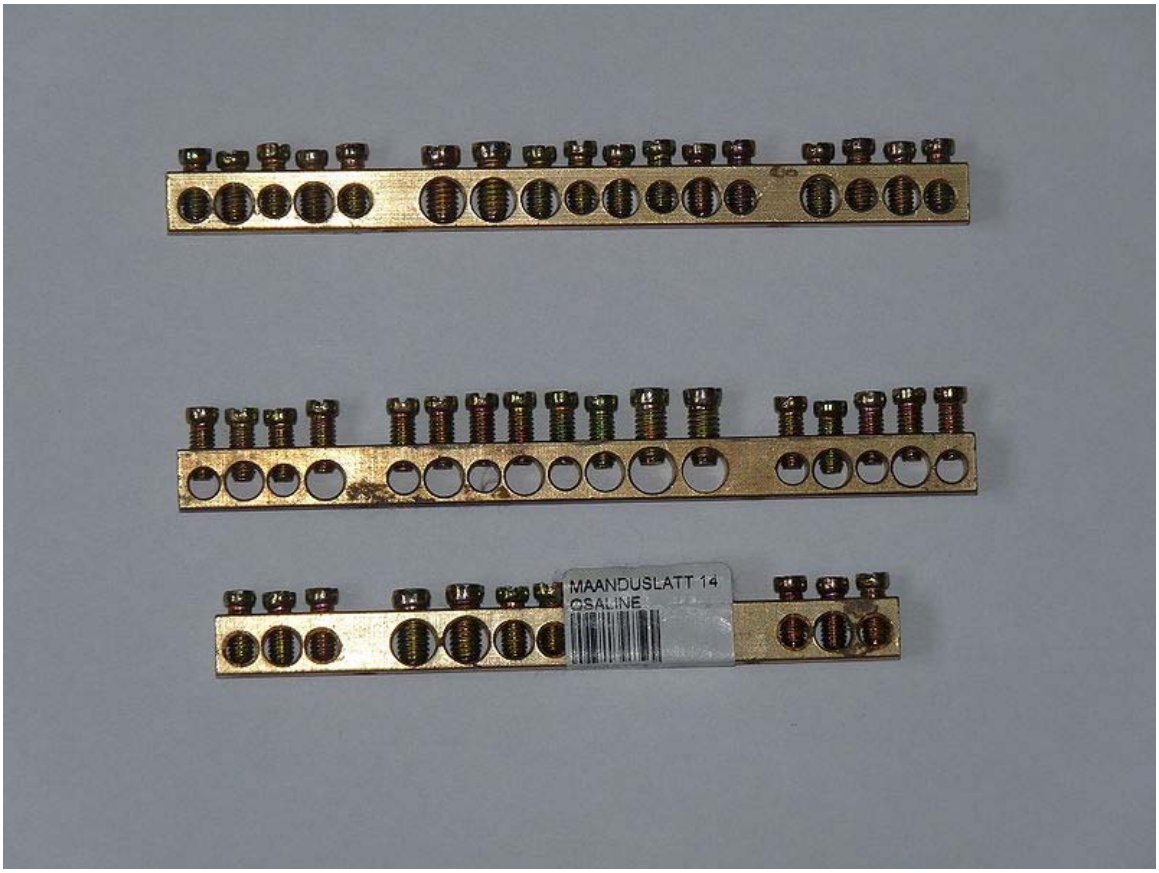
Special fittings are used for wiring in potentially explosive atmospheres.

Bus bars, bus duct, cable bus

Topside of firestop with penetrants consisting of electrical conduit on the left and a bus duct on the right. The firestop consists of firestop mortar on top and rockwool on the bottom, for a 2 hour fire-resistance rating.

For very heavy currents in electrical apparatus, and for heavy currents distributed through a building, bus bars can be used. Each live conductor of such a system is a rigid piece of copper or aluminium, usually in flat bars (but sometimes as tubing or other shapes). Open bus bars are never used in publicly accessible areas, although they are used in manufacturing plants and power company switch yards to gain the benefit of air cooling. A variation is to use heavy cables, especially where it is desirable to transpose or "roll" phases.

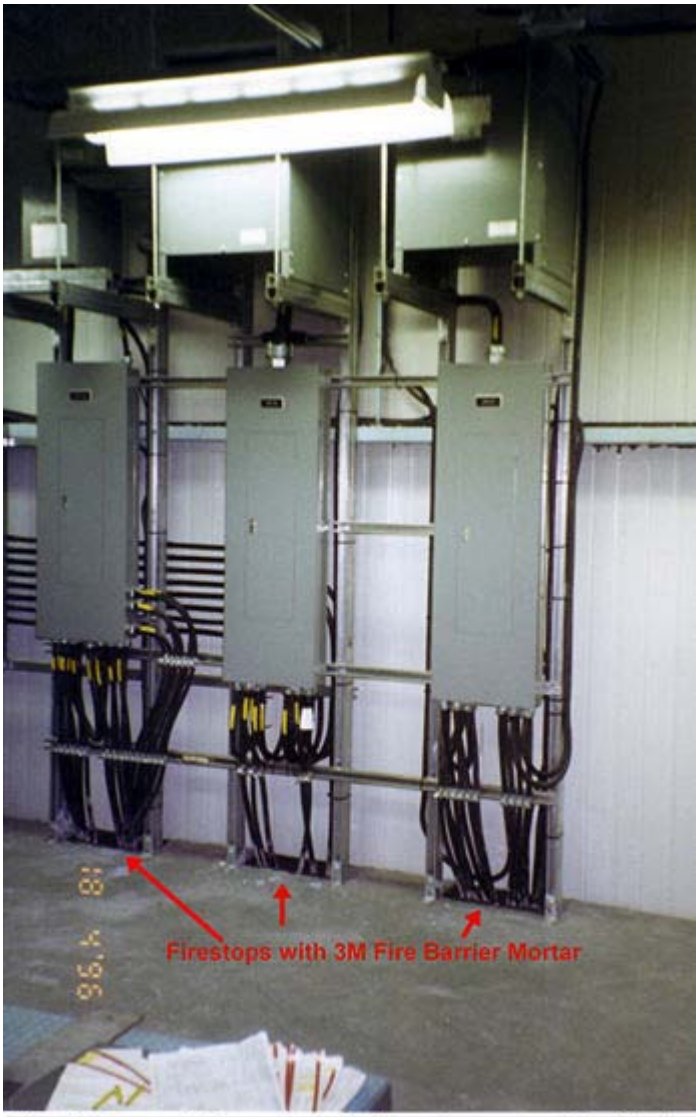
In industrial applications, conductor bars are assembled with insulators in grounded enclosures. This assembly, known as bus duct or busway, can be used for connections to large switchgear or for bringing the main power feed into a building. A form of bus duct known as plug-in bus is used to distribute power down the length of a building; it is constructed to allow tap-off switches or motor controllers to be installed at definite places along the bus. The big advantage of this scheme is the ability to remove or add a branch circuit without removing voltage from the whole duct.



Busbars for distributing PE (ground)

Bus ducts may have all phase conductors in the same enclosure (non-isolated bus), or may have each conductor separated by a grounded barrier from the adjacent phases (segregated bus). For conducting large currents between devices, a cable bus is used. For very large currents in generating stations or substations, where it is difficult to provide circuit protection, an isolated-phase bus is used. Each phase of the circuit is run in a separate grounded metal enclosure. The only fault possible is a phase-to-ground fault, since the enclosures are separated. This type of bus can be rated up to 50,000 amperes and up to hundreds of kilovolts (during normal service, not just for faults), but is not used for building wiring in the conventional sense.

Electrical panels



Electrical panels in an electrical service room at St. Mary's Pulp and Paper, Sault Ste. Marie, Ontario, Canada, April 1996

Electrical panels, cables and firestops in an electrical service room at St. Mary's Pulp and Paper, a paper mill in Sault Ste. Marie, Ontario, Canada.

Electrical panels are easily accessible junction boxes used to reroute and switch electrical services.

Chapter- 3

Fireplace

A **fireplace** is an architectural structure to contain a fire for heating and, especially historically, for cooking. A fire is contained in a firebox or firepit; a chimney or other flue directs gas and particulate exhaust to escape. Fireplaces are a central household feature, as the flames and crackling sounds are comforting, even when not necessary for heat or cooking. Fireplace mantels are a focus for interior decoration.

Wood-burning fireplace

Types of fireplace

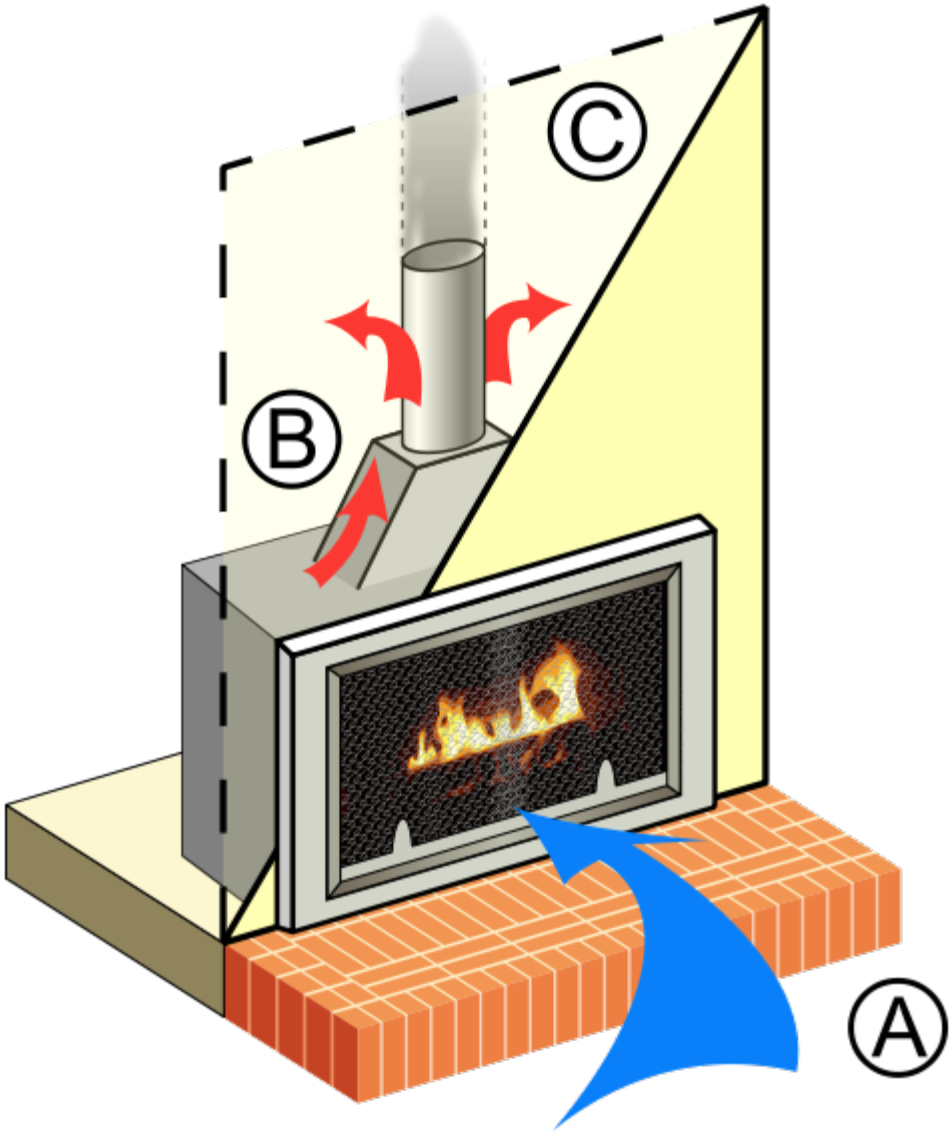


Diagram of a fireplace.
A. Cool air enters.
B. The cool air is heated and is released.
C. Smoke is released.

A fireplace may have: a foundation, a hearth, a firebox, a fireplace mantel, an ashdump door, a chimney crane, a cleanout door, a grate, a lintel, a lintel bar, overmantel, a chimney breast, a damper, a smoke chamber, a throat, a flue, a chimney chase, a crown, a cap, a shroud, or a spark arrestor.

Fireplace types:

- Masonry (brick or stone fireplaces and chimneys.
- Manufactured ("prefab") fireplaces with sheet metal fire boxes.

Masonry and prefab fireplaces can be fueled with wood, natural gas, biomass and lp/propane fuel sources.

- Ventless Fireplaces (duct free/room-venting fireplaces) that are fueled by either gel, LP/bottled gas or natural gas. In the US, some states and local counties have laws and ordinances regarding these types of fireplaces. They require the least installation and are the most efficient fireplace. The gas burning version of a vent free fireplace while using less fuel, burns that fuel at close to 100% efficiency. They must be sized appropriately to the area to be heated. Aside from the heat output there are also air quality control problems due to the amount of moisture they release into the room air, and oxygen sensor and carbon monoxide sensors are safety essentials.

Chimney/flue types:

- Masonry (brick or stone fireplaces and chimneys) with or without tile lined flue.
- Reinforced concrete chimneys. Fundamental flaws (the difference in thermal expansion rates between steel rebar and concrete which caused the chimney flues to crack when heated) bankrupted the US manufacturers and obsoleted the technique. This is evidenced by vertical cracks on the exterior of the chimney.
- Metal-lined flue: Double or triple walled metal pipe running up inside a new or existing wood framed or masonry chase

Newly constructed flues may feature a chase cover, a cap, and a spark arrestor at the top to keep small animals out and sparks from exiting the chimney cavity.

History

An outdoor fireplace

Ancient fire pits were sometimes built in the ground in the center of a hut or dwelling. Smoke escaped through holes in the roof. Smoke would be blown outside or back into the room. Chimneys, invented much later, partially fixed this problem, venting smoke outside.

In 1678 Prince Rupert, nephew of Charles I, raised the grate of the fireplace, improving the airflow and venting system. The 18th century saw two important developments in the history of fireplaces. Ben Franklin developed a convection chamber for the fireplace that greatly improved the efficiency of fireplaces and wood stoves. He also improved the airflow by pulling air from a basement and venting out a longer area at the top. In the later 18th century, Count Rumford designed a fireplace with a tall, shallow firebox that was better at drawing the smoke up and out of the building. The shallow design also improved greatly the amount of radiant heat projected into the room. Rumford's design is the foundation for modern fireplaces.

One famous tradition in the United States during the Great Depression was President Franklin Delano Roosevelt's "fireside chats", weekly radio addresses in which he made use of the family gathering time to state his views.

Many homes no longer have open fireplaces, they are often replaced by what is considered to be more efficient ways of heating, such as central heating, or electric heaters. The social function of the fireplace is often substituted by the home entertainment center. Some fireplaces have been closed off not allowing them to be used. Some have been made unable to be used by feeding a telephone, television antenna, cable TV or satellite TV wire down them. For homeowners that want the ambiance of a fireplace without the fire, there are several alternatives. One is to install a 'fake fire' or gas fireplace, which offers the fireplace effect. For people with existing fireplaces, the alternative to simply closing them up is to install a gas, wood or biomass fireplace insert. Some governments have a partial ban on solid fuel burning fireplaces due to air pollution. Ventless fireplaces have received attention recently: they are free standing, requiring no chimney and no hearth. Prefabricated fireplaces are popular because of their lower construction cost and some considered them to be safer and more reliable. Brick or stone fireplaces can be designed to meet exact specifications for opening size, depth, and facing material. The open brick or stone fireplaces can cost more to build and usually require regular cleaning or maintenance.

Heating efficacy

The heating effect of a fireplace is largely due to radiative heating, by which objects surrounding the fireplace are heated up, and some of this heat is transferred to the air. It is a common misconception that a fireplace leads to energy savings by reducing the heating load on a home. In fact, a fireplace moves large amounts of air out of the home which must be replaced by outside air. The outside air, presumably at a lower temperature, must be heated by the home's HVAC system. Some fireplace units incorporate a blower which aims to transfer more of the fireplace's heat to the air via convection, resulting in a more homogenously heated space and a lower heating load.

Fireplace with decorative screen.

Accessories

A wide range of accessories are used with **fireplaces**, which vary between countries and regions, and historical periods. For the interior, common in recent Western cultures are grates, fireguards, logboxes, andirons, pellet baskets, and fire dogs, all of which cradle fuel and accelerate burning. Heavy metal firebacks are sometimes used to capture and reradiate heat, to protect the back of the fireplace, and as decoration.

Fireplace with tubular grate heater, with a high surface area in its heat exchanger and a lift out ash tray to simplify cleanup.

In the last several decades tubular grate heaters have become an increasingly popular accessory to significantly increase the efficiency of a fireplace and hence the amount of heat that makes it from the fireplace out into the home. They work by having a naturally convected or fan forced tubular metal heat exchanger that is heated by the coals and or fire. They draw in cold air from the floor and blow heated air back out into your home. This adds an element of conductive and convective heating to the radiant heat typical of a basic fireplace. Grate Heaters have been called many things; heatilator, hearth heater, fireplace blower, fireplace grate heater, etc...

For fireplace tending, tools include pokers, bellows, tongs, shovels, brushes and toolstands.

Chapter- 4

Flooring

An example of a flooring job

Levelling of ceramic tiles floor with a laser device

Flooring is the general term for a permanent covering of a floor, or for the work of installing such a floor covering. **Floor covering** is a term to generically describe any finish material applied over a floor structure to provide a walking surface. Both terms are used interchangeably but floor covering refers more to loose-laid materials.

Materials almost always classified as floor covering include carpet, area rugs, and resilient flooring such as linoleum or vinyl flooring. Materials commonly called flooring include wood flooring, ceramic tile, stone, terrazzo, and various seamless chemical floor coatings.

Subfloor

The floor under the flooring is called the subfloor. This provides the support for the flooring. Special purpose subfloors like floating floors, raised floors or sprung floors may be laid upon another underlying subfloor which provides the structural strength.

Flooring materials

The choice of material for floor covering is affected by factors such as cost, endurance, noise insulation, comfort and cleaning effort. Some types of flooring must not be installed below grade (lower than ground level), and laminate or hardwood should be avoided where there may be moisture or condensation.

The sub-floor may be finished in a way that makes it usable without any extra work, see:

- Earthen floor adobe or clay floors
- Solid ground floor cement screed or granolithic

Soft coverings

Carpet is a floor covering woven or felted from natural or man-made fibers. Fitted carpet is attached to the floor structure, extends wall-to-wall, and cannot be moved from place to place. An underlay can extend carpet life and improve comfort.

Rugs are also woven or felted from fibers, but are smaller than the room in which they are located, have a finished edge, and usually lie over another finished floor such as wood flooring. Rugs may either be temporarily attached to the flooring below by adhesive tape or other methods to prevent creep, or may be loose-laid.

Wood flooring

Many different species of wood are fabricated into wood flooring in two primary forms: plank and parquet. Hardwoods are typically much more durable than softwoods. Reclaimed lumber has a unique appearance and is green.

Laminate is a floor covering that appears similar to hardwood but is made with a plywood or medium density fiberboard ("MDF") core with a plastic laminate top layer. HDF laminate consists of high density fiberboard topped by one or more layers of decorative paper and a transparent protective layer. Laminate may be more durable than hardwood, but cannot be refinished like hardwood. Laminate flooring is available in many different patterns which can resemble different woods or even ceramic tile. It usually locks or taps together.

Bamboo flooring is a floor manufactured from the bamboo plant and is a type of hardwood flooring, though technically not a wood. Bamboo is known to be durable and environmentally friendly. It is available in many different patterns, colors, and textures.

Cork Flooring is a flooring material manufactured from the by-product of the cork oak tree. Cork floors are considered to be eco-friendly since the cork oak tree bark is stripped every nine to ten years and doesn't damage the tree. Cork flooring comes in both tiles and planks, and can have glue or glues-less installation. Cork floors are very durable due to

their honeycomb cellular structure, allowing compress up to 40% and then returning back to its normal shape.

Resilient flooring

Resilient flooring is made of material that has some elasticity. It includes many different manufactured products including linoleum, sheet vinyl, vinyl composition tile (VCT), cork (sheet or tile), rubber, and others. Performance surfaces used for dance or athletics are made of either wood or resilient flooring.

Hard flooring

Ceramic tiles flooring in Istanbul street

Ceramic tile includes a wide variety of clay products fired into thin units which are set in beds of mortar or mastic with the joints between tiles grouted. Varieties include quarry tile, porcelain tile, terracotta tile, and others.

Many different natural stones are cut into a variety of sizes, shapes, and thicknesses for use as flooring. Stone flooring is usually set in mortar and grouted similar to ceramic tile. Slate and marble are popular types of stone flooring.

New technologies are emerging since 2004 to produce hard floorings having the ability to light up when needed. These security glazing materials contain transparent LED embedded films laminated between glass:

Terrazzo consists of marble or other stone aggregate set in mortar and ground and polished to a smooth surface.

A Mosaic consists of many small pieces of stone arranged to form a design or picture and are common in cultural and religious centers.

Seamless chemical flooring

Many different seamless flooring materials are available. These are usually latex, polyester, urethane or epoxy compounds which are applied in liquid form to provide a completely seamless floor covering. These are usually found in wet areas such as laboratories or food processing plants. These may have granular or rubberized particles added to give better traction.

Sustainable flooring

Sustainable flooring is produced from sustainable materials (and by a sustainable process) that reduces demands on ecosystems during its life-cycle. Some think that sustainable flooring creates safer and healthier buildings and guarantees a future for traditional producers of renewable resources that many communities depend on.

Flooring tools

Special tools used for flooring include:

- Flooring clamp, a clamp for tongue-and-groove floors while nailing
- Knee kicker, used to stretch carpets flat
- Concrete moisture meter used to check a concrete floor before laying flooring on top

Floor features

There are a number of special features that may be used to ornament a floor or perform a useful service:

- Floor medallions decorative centerpieces of a floor design
- Doormats to help keep a floor clean
- Gratings used to drain water or to rub dirt off shoes
- Tactile or rumble strips to warn of for instance a wheelchair ramp, these would normally also be distinctively colored or patterned.
- Light strips to show an escape route out, especially on airplanes.

- Moldings or baseboards to decorate the sides of a floor or to cover the edge of a floating floor.
- Anti-Slip Devices The addition of either granular or rubberized particles that will allow wheels, shoes, or feet better traction.

Floor Cleaning

Floor cleaning is a major occupation throughout the world. Cleaning is essential to prevent injuries due to slips and to remove dirt. Floors are also treated to protect or beautify the surface. The correct method to clean one type of floor can often damage another, so it is important to use the correct treatment.

Issues with floors

Wood floors, particularly older ones, will tend to 'squeak' in certain places. This is caused by the wood rubbing against other wood, usually at a joint of the subfloor. Firmly securing the pieces to each other with screws or nails will remove this problem.

Floor vibration is a particularly annoying problem with floors. Wood floors tend to pass sound, particularly heavy footsteps and low bass frequencies. Floating floors can reduce or eliminate this problem. Concrete floors are usually so solid they do not have this problem, but are also much more expensive to construct, and much heavier, resulting in further requirements regarding the structure of the building.

The flooring may need protection sometimes (e.g., a gym floor used for a graduation ceremony). A Gym floor cover can be used to reduce the need to satisfy incompatible requirements.

Chapter- 5

Light Fixture

A wide array of light fixtures

A **light fixture**, **light fitting**, or **luminaire** is an electrical device used to create artificial light and/or illumination, by use of an electric lamp. All light fixtures have a fixture body, a light socket to hold the lamp and allow for its replacement—which may also have a switch to operate the fixture, and also require an electrical connection to a power source, often by using electrical connectors (e.g. plugs) with portable fixtures. Light fixtures may also have other features, such as reflectors for directing the light, an aperture (with or without a lens), an outer shell or housing for lamp alignment and protection, and an electrical ballast and/or power supply. A wide variety of special light fixtures are created for use in the automotive lighting industry, aerospace, marine and medicine.

The use of the word "lamp" to describe light fixtures is common slang for an all-in-one luminary unit, usually portable "fixtures" such as a **table lamp** or **desk lamp** (in contrast

to a true fixture, which is fixed in place with screws or some other semi-permanent attachment). In technical terminology, a lamp is the light source, what is typically called the light bulb.

Light fixtures are classified by how the fixture is installed, the light function or lamp type.

Light fixture is US usage; in British English it is called a light fitting. However, luminaire is the International Electrotechnical Commission (IEC) terminology for technical use.

Fixture types

Free-standing or portable

Tiffany dragonfly desk lamp with pigeon sculptures

- Table lamp fixtures, standard lamp fixtures, and office task light luminaries.
  - Balanced-arm lamp is a spot light with an adjustable arm such as anglepoise or Luxo L1.
  - Gooseneck lamp
  - Nightlight

Fixed

- Recessed light — the protective housing is concealed behind a ceiling or wall, leaving only the fixture itself exposed. The ceiling-mounted version is often called a downlight.
    - "Cans" with a variety of lamps — this term is jargon for inexpensive downlighting products that are recessed into the ceiling, or sometimes for uplights placed on the floor. The name comes from the shape of the housing. The term "pot lights" is often used in Canada and parts of the US.
    - Troffer light — recessed fluorescent lights (the word comes from the combination of trough and coffer).
    - Cove light — recessed into the ceiling in a long box against a wall.
    - Torch lamp, torchière, or floor lamp.

A chandelier light fixture

- Surface-mounted light — the finished housing is exposed, not flush with surface
    - Chandelier
    - Pendant light — suspended from the ceiling with a chain or pipe

- Sconce — provide up or down lights; can be used to illuminate artwork, architectural details; commonly used in hallways and/or as an alternative to overhead lighting.
- Track lighting fixture — individual fixtures ("track heads") can be positioned anywhere along the track, which provides electric power.
- Under-cabinet light — mounted below kitchen wall cabinets
- Emergency lighting or exit light — connected to a battery backup or to an electric circuit that has emergency power if the mains power fails
- High- and low-bay lighting — typically used for general lighting for industrial buildings and often big-box stores
- Strip lights or industrial lighting — often long lines of fluorescent lamps used in a warehouse or factory

A decorative outdoor lamp at Leeds Town Hall

A garden solar lamp is an example of landscape lighting

- Outdoor lighting — used to illuminate walkways, parking lots, roadways, building exteriors, landscape, and architectural details.
    - Pole- or stanchion-mounted — for landscape, roadways, and parking lots
    - Pathway lighting — typically mounted in the ground at low levels for illuminating walkways
    - Bollard — A type of architectural outdoor lighting that is a short, upright ground-mounted unit typically used to provide cutoff type illumination for egress lighting, to light walkways, steps, or other pathways.
    - Sign light — used to light building signs or walls

- Street light
- Yard light
- Garden light
- Solar lamp

Special-purpose lights

- Accent light — Any directional light which highlights an object or attracts attention to a particular area
- Background light — for use in video production
- Blacklight
- Flood light
- Safelight (for use in a darkroom)
- Safety lamp (for use in coal mines)
- Searchlight (for military and advertising use)
- Security lighting
- Step light
- Strobe light
- Theatrical
  - Stage lighting instrument
  - Intelligent lighting
  - Followspot
- Wallwasher

Lamp types

- **Fuel lamps**

  Betty lamp, butter lamp, carbide lamp, gas lighting, kerosene lamp, oil lamp, rush light, torch, candle, Limelight, gas mantle
  Safety lamps: Davy lamp & Geordie lamp

- **Arc lamps**

  Xenon arc lamp, Yablochkov candle

- **Incandescent lamp**

  A-lamp, Parabolic aluminized reflector lamp (PAR), reflector lamp (R), bulged reflector lamp (BR) (refer to lamp shapes)

  - Obsolete types: limelight, carbon button lamp, Mazda (light bulb), Nernst glower
  - Novelty: Lava lamp
  - Special purpose: heat lamp, Globar, gas mantle

- **Halogen** – special class of incandescent lamps
- **Gas-discharge lamp** and high-intensity discharge lamp (HID)

Mercury-vapor lamp, Metal-halide (HMI, HQI, CDM), Sodium vapor or "high-pressure sodium"

    - Neon sign,

- **Plasma lamp**
- **Fluorescent**

  Linear fluorescent, compact fluorescent lamp (CFL), blacklight. 1939 New York World's Fair for the first fluorescent light displayed to the commercial public.

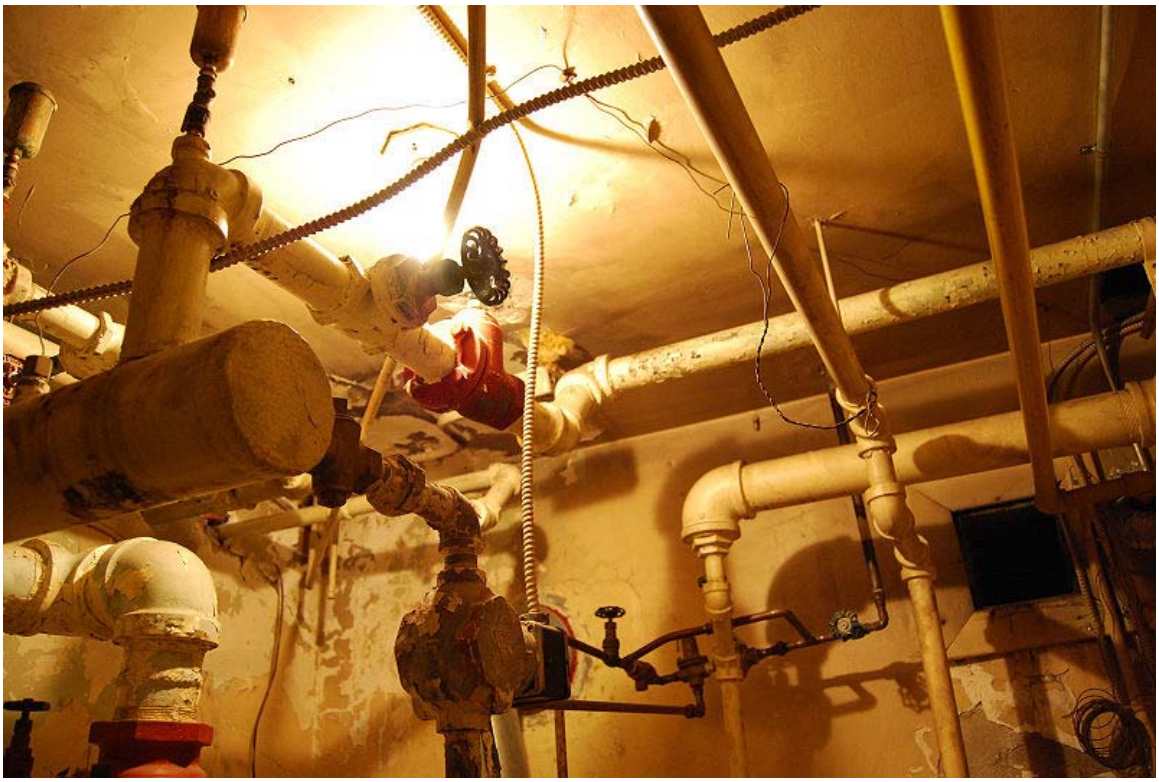
- Cold cathode
- Fiber optics
- Induction lamp
- Light-emitting diode (LED) (solid-state lighting)
- **Nuclear:** self-powered lighting

Light-fixture controls

- Light switch (often part of the light socket or power cord on portable fixtures)
- Dimmer
- Motion detector
- Timer
- Touch

Chapter- 6

Plumbing



A complex arrangement of rigid steel piping, stop valves regulate flow to various parts of the building.

Water and sewage pipes of a Jerusalem building built around 1930

Plumbing (from the Latin *plumbum* for lead, as pipes were once made from lead) is the skilled trade of working with pipes, tubing and plumbing fixtures for drinking water systems and the drainage of waste. A **plumber** is someone who installs or repairs piping systems, plumbing fixtures and equipment such as water heaters. The plumbing industry is a basic and substantial part of every developed economy due to the need for clean water, and proper collection and transport of wastes.

Plumbing also refers to a system of pipes and fixtures installed in a building for the distribution of potable water and the removal of waterborne wastes. Plumbing is usually distinguished from water and sewage systems, in that a plumbing system serves one building, while water and sewage systems serve a group of buildings or a city.

History

Roman lead pipe with a folded seam, at the Roman Baths in Bath, England

Plumbing was extremely rare until the growth of modern cities in the 19th century. At about the same time public health authorities began pressing for better waste disposal systems to be installed. Earlier, the waste disposal system merely consisted of collecting waste and dumping it on ground or into a river. Standardized earthen plumbing pipes with broad flanges making use of asphalt for preventing leakages appeared in the urban settlements of the Indus Valley Civilization by 2700 B.C. Plumbing originated during the ancient civilizations such as the Greek, Roman, Persian, Indian, and Chinese civilizations as they developed public baths and needed to provide potable water, and drainage of

wastes. The Romans used lead pipe inscriptions to prevent water theft. Improvement in plumbing systems was very slow, with virtually no progress made from the time of the Roman system of aqueducts and lead pipes until the 19th century. Eventually the development of separate, underground water and sewage systems eliminated open sewage ditches and cesspools. Most large cities today pipe solid wastes to treatment plants in order to separate and partly purify the water before emptying into streams or other bodies of water. The use of lead for potable water declined sharply after World War II because of the dangers of lead poisoning. At this time, copper piping was introduced as a better and safer alternative to lead pipes.

Another material used for plumbing pipes, particularly water main, was hollowed wooden logs wrapped in steel banding. Logs used for water distribution were used in England close to 500 years ago. The US cities began using hollowed logs in the late 18th through the 19th centuries.

Materials

Water systems of ancient times relied on gravity for the supply of water, using pipes or channels usually made of clay, lead, bamboo wood or stone. Present-day water-supply systems use a network of high-pressure pumps, and pipes are now made of copper, brass, plastic, or other nontoxic material. Present-day drain and vent lines are made of plastic, steel, cast-iron, and lead. Lead is not used in modern water-supply piping due to its toxicity.

The "straight" sections of plumbing systems are of **pipe** or **tube**. A pipe is typically formed via casting or welding, where a tube is made through extrusion. Pipe normally has thicker walls and may be threaded or welded, where tubing is thinner-walled and requires special joining techniques such as "brazing", "compression fitting", "crimping", or for plastics, "solvent welding".

Fittings and valves

Piping being placed for a sink

In addition to the straight pipe or tubing, many fittings are required in plumbing systems, such as valves, elbows, tees, and unions. The piping and plumbing fittings and valves articles discuss these features further.

Fixtures

Plumbing fixtures are designed for the end-users. Some examples of fixtures include water closets (also known as toilets), urinals, bidets, showers, bathtubs, utility and

kitchen sinks, drinking fountains, ice makers, humidifiers, air washers, fountains, and eye wash stations.

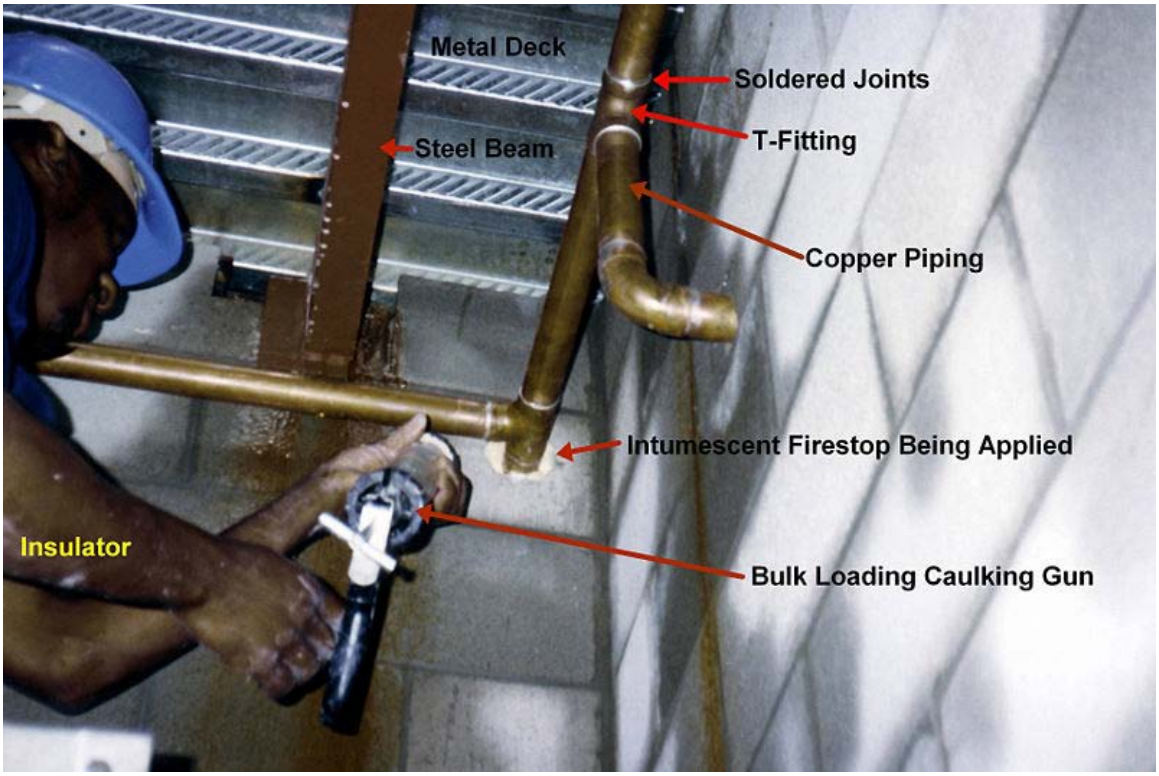
Equipment

A plumber wrench for working on pipes and fittings

Plumbing equipment, not present in all systems, include, for example, water meters, pumps, expansion tanks, backflow preventers, filters, water softeners, water heaters, wrenches, heat exchangers, flaring pliers, gauges, and control systems.

Now there is more equipment that is technologically advanced and helps plumbers fix problems without the usual hassles. For example, plumbers use video cameras for inspections of hidden leaks or problems, they use hydro jets, and high pressure hydraulic pumps connected to steel cables for trench-less sewer line replacement.

Systems



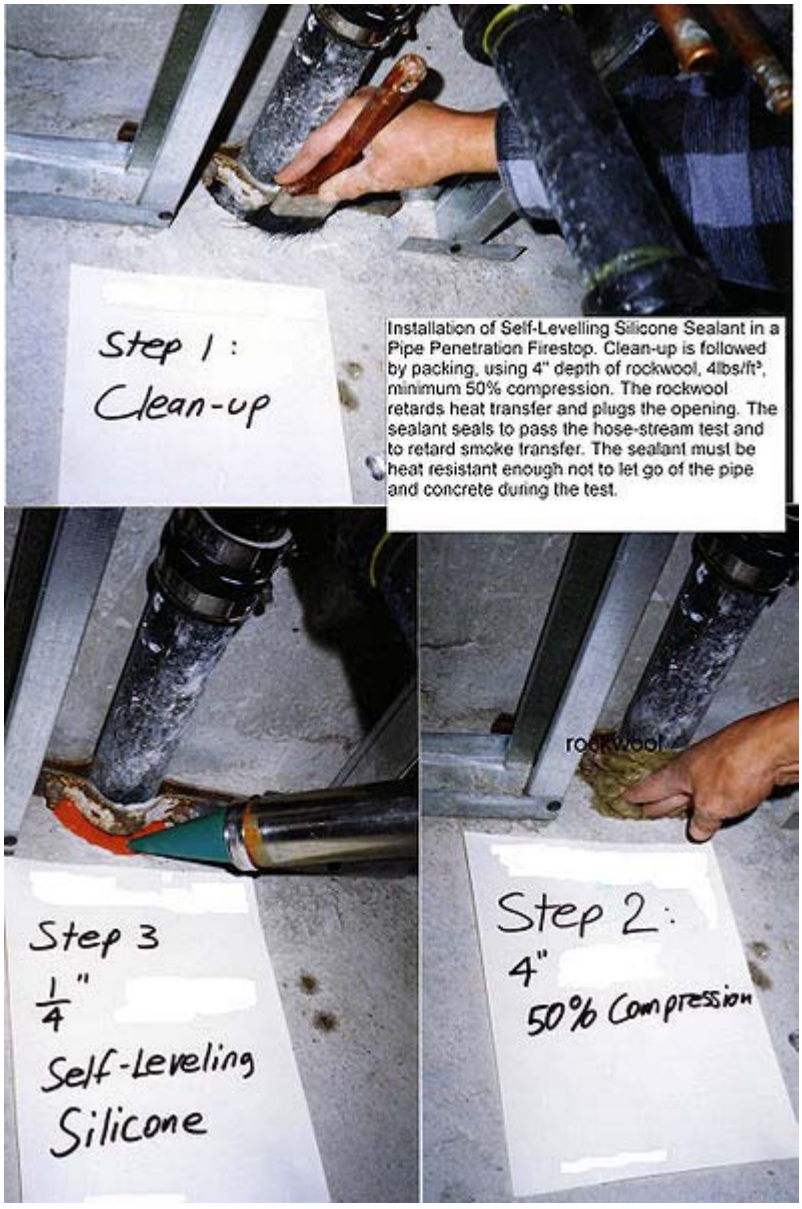
Copper **piping** system in a building with intumescent firestop being installed by an insulator, Vancouver, British Columbia, Canada.

The major categories of plumbing systems or subsystems are:

- Potable cold and hot water supply
- Traps, drains, and vents
- Septic systems
- Rainwater, surface, and subsurface water drainage
- Fuel gas piping

For their environmental benefit and sizable energy savings hot water heat recycling units are growing in use throughout the residential building sectors. Further ecological concern has seen increasing interest in grey-water recovery and treatment systems.

Firestopping



Self-levelling silicone firestop installation in mechanical service penetration in 2 hour rated concrete floor.

Firestopping is required where mechanical penetrants traverse fire-resistance rated wall and floor assemblies, or membranes thereof. This work is usually done worldwide by the insulation trade and/or specialty firestop sub-contractors.

Regulation

Much of the plumbing work in populated areas is regulated by government or quasi-government agencies due to the direct impact on the public's health, safety, and welfare. Plumbing installation and repair work on residences and other buildings generally must be done according to plumbing and building codes to protect the inhabitants of the buildings and to ensure safe, quality construction to future buyers. If permits are required for work, plumbing contractors typically secure them from the authorities on behalf of home or building owners. In the United Kingdom the professional body is the newly Chartered Institute of Plumbing and Heating Engineering (educational charity status) and it is true that the trade still remains virtually ungoverned; there are no systems in place to monitor or control the activities of unqualified plumbers or those home owners who choose to undertake installation and maintenance works themselves, despite the health and safety issues which arise from such works when they are undertaken incorrectly; *Health Aspects of Plumbing (HAP)* published jointly by the World Health Organization (WHO) and the World Plumbing Council (WPC). WPC has subsequently appointed a representative to the World Health Organization to take forward various projects related to Health Aspects of Plumbing.

Chapter- 7

Roof

The roofs of Olomouc, Czech Republic

Roofs of Antananarivo, Madagascar

The roofs of San Cristobal de las Casas, Mexico

The roofs of Vietnam

A **roof** is the covering on the uppermost part of a building. A roof protects the building and its contents from the effects of weather. Structures that require roofs range from a letter box to a cathedral or stadium, dwellings being the most numerous.

In most countries a roof protects primarily against rain. Depending upon the nature of the building, the roof may also protect against heat, sunlight, cold, snow and wind. Other types of structure, for example, a garden conservatory, might use roofing that protects against cold, wind and rain but admits light. A verandah may be roofed with material that protects against sunlight but admits the other elements.

The characteristics of a roof are dependent upon the purpose of the building that it covers, the available roofing materials and the local traditions of construction and wider concepts of architectural design and practice and may also be governed by local or national legislation.

The elements in the design of a roof are:

- the material
- the construction
- the durability

The **material** of a roof may range from banana leaves, wheaten straw or seagrass to lamininated glass, aluminium sheeting and precast concrete. In many parts of the world ceramic tiles have been the predominant roofing material for centuries.

The **construction** of a roof is determined by its method of support and how the underneath space is bridged and whether or not the roof is *pitched*. The *pitch* is the angle at which the roof rises from its lowest to highest point. Most domestic architecture, except in very dry regions, has roofs that are sloped, or *pitched*. The pitch is partly dependent upon stylistic factors, but has more to do with practicalities. Some types of roofing, for example thatch, require a steep pitch in order to be waterproof and durable. Other types of roofing, for example pantiles, are unstable on a steeply pitched roof but provide excellent weather protection at a relatively low angle. In regions where there is little rain, an almost flat roof with a slight run-off provides adequate protection against an occasional downpour.

The **durability** of a roof is a matter of concern because the roof is often the least accessible part of a building for purposes of repair and renewal, while its damage or destruction can have serious effects.

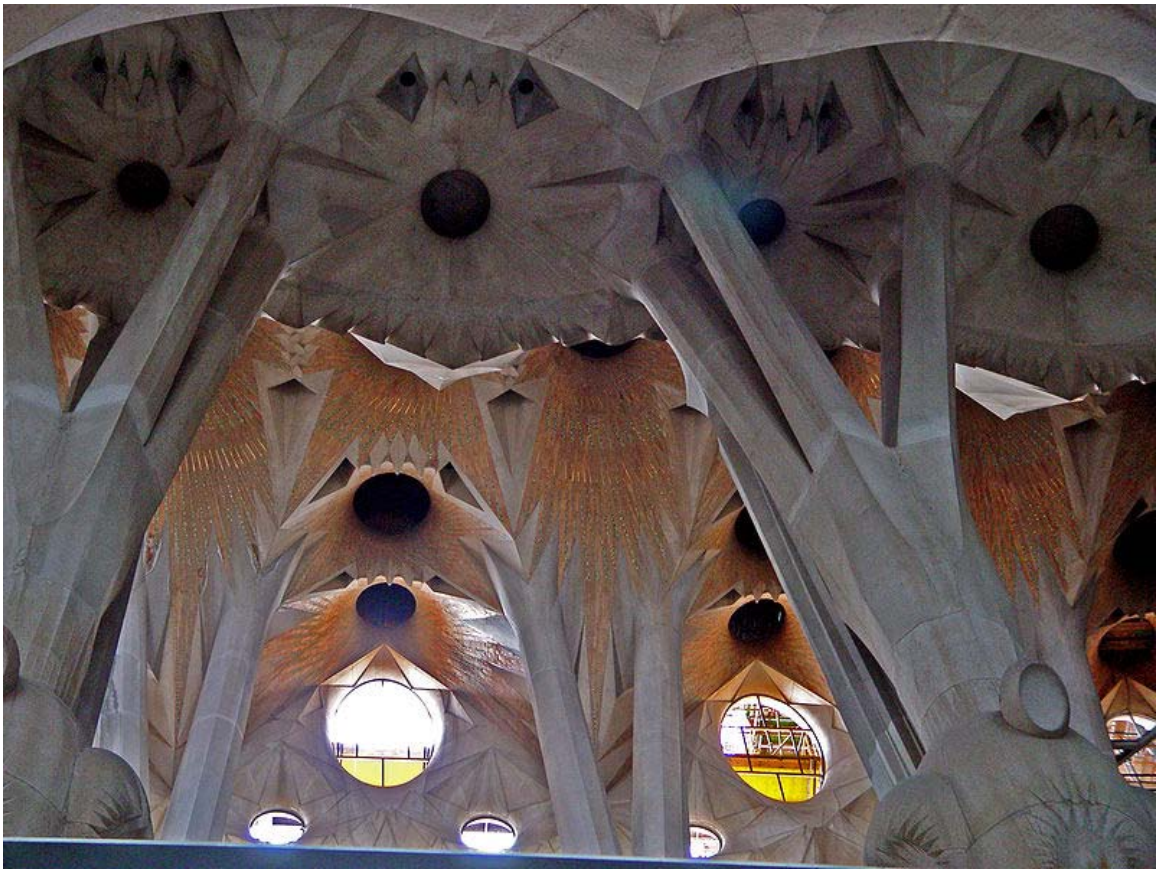
Parts of a roof

There are two parts to a roof, its supporting structure and its outer skin, or uppermost weatherproof layer. In a minority of buildings, the outer layer is also a self-supporting structure.

The roof structure is generally supported upon walls, although some building styles, for example, geodesic and A-frame, blur the distinction between wall and roof.

Support

The roof of a library, Sweden



Tree-like supporting pillars of roof (Sagrada Família, Barcelona)

The supporting structure of a roof usually comprises beams that are long and of strong, fairly rigid material such as timber, and since the mid 19th century, cast iron or steel. In countries that use bamboo extensively, the flexibility of the material causes a distinctive curving line to the roof, characteristic of Oriental architecture.

Timber lends itself to a great variety of roof shapes. The timber structure can fulfil an aesthetic as well as practical function, when left exposed to view.

Stone lintels have been used to support roofs since prehistoric times, but cannot bridge large distances. The stone arch came into extensive use in the ancient Roman period and in variant forms could be used to span spaces up to 140 feet (43 m) across. The stone arch or vault, with or without ribs, dominated the roof structures of major architectural works for about 2,000 years, only giving way to iron beams with the Industrial Revolution and the designing of such buildings as Paxton's Crystal Palace, completed 1851.

With continual improvements in steel girders, these became the major structural support for large roofs, and eventually for ordinary houses as well. Another form of girder is the reinforced concrete beam, in which metal rods are encased in concrete, giving it greater strength under tension.

Outer layer

This part of the roof shows great variation dependent upon availability of material. In simple vernacular architecture, roofing material is often vegetation, such as thatches, the most durable being sea grass with a life of perhaps 40 years. In many Asian countries bamboo is used both for the supporting structure and the outer layer where split bammboo stems are laid turned alternately and overlapped. In areas with an abundance of timber, wooden shingles are used, while in some countries the bark of certain trees can be peeled off in thick, heavy sheets and used for roofing.

The 20th century saw the manufacture of composition shingles which can last from a thin 20-year shingle to the thickest which are limited lifetime shingles, the cost depending on the thickness and durability of the shingle. When a layer of shingles wears out, they are usually stripped, along with the underlay and roofing nails, allowing a new layer to be installed. An alternative method is to install another layer directly over the worn layer. While this method is faster, it does not allow the roof sheathing to be inspected and water damage, often associated with worn shingles, to be repaired. Having multiple layers of old shingles under a new layer causes roofing nails to be located further from the sheathing, weakening their hold. The greatest concern with this method is that the weight of the extra material could exceed the dead load capacity of the roof structure and cause collapse.

Slate is an ideal, and durable material, while in the Swiss Alps roofs are made from huge slabs of stone, several inches thick. The slate roof is often considered the best type of roofing. A slate roof may last 75 to 150 years, and even longer. However, slate roofs are often expensive to install – in the USA, for example, a slate roof may have the same cost as the rest of the house. Often, the first part of a slate roof to fail is the fixing nails; they corrode, allowing the slates to slip. In the UK, this condition is known as "nail sickness". Because of this problem, fixing nails made of stainless steel or copper are recommended, and even these must be protected from the weather.

Asbestos, usually in bonded corrugated panels, has been used widely in the 20th century as an inexpensive, non-flammable roofing material with excellent insulating properties. Health and legal issues involved in the mining and handling of asbestos products means that it is no longer used as a new roofing material. However, many asbestos roofs continue to exist, particularly in South America and Asia.

Roofs made of cut turf (modern ones known as Green roofs, traditional ones as sod roofs) have good insulating properties and are increasingly encouraged as a way of "greening" the Earth. Adobe roofs are roofs of clay, mixed with binding material such as straw or animal hair, and plastered on lathes to form a flat or gently sloped roof, usually in areas of low rainfall.

In areas where clay is plentiful, roofs of baked tiles have been the major form of roof. The casting and firing of roof tiles is an industry that is often associated with brickworks. While the shape and colour of tiles was once regionally distinctive, now tiles of many

shapes and colours are produced commercially, to suit the taste and pocketbook of the purchaser.

Sheet metal in the form of copper and lead has also been used for many hundreds of years. Both are expensive but durable, the vast copper roof of Chartres Cathedral, oxidised to a pale green colour, having been in place for hundreds of years. Lead, which is sometimes used for church roofs, was most commonly used as flashing in valleys and around chimneys on domestic roofs, particularly those of slate. Copper was used for the same purpose.

In the 19th century, iron, electroplated with zinc to improve its resistance to rust, became a light-weight, easily-transported, waterproofing material. Its low cost and easy application made it the most accessible commercial roofing, world wide. Since then, many types of metal roofing have been developed. Steel shingle or standing-seam roofs last about 50 years or more depending on both the method of installation and the moisture barrier (underlayment) used and are between the cost of shingle roofs and slate roofs. In the 20th century a large number of roofing materials were developed, including roofs based on bitumen (already used in previous centuries), on rubber and on a range of synthetics such as thermoplastic and on fibreglass.

Insulation

Some roofing materials, particularly those of natural fibrous material, such as thatch, have excellent insulating properties. For those that do not, extra insulation is often installed under the outer layer. In developed countries, the majority of dwellings have a ceiling installed under the structural member of the roof. The purpose is to insulate against heat and cold, noise, dirt and often from the droppings and lice of birds who frequently choose roofs as nesting places.

Other forms of insulation are felt or plastic sheeting, sometimes with a reflective surface, installed directly below the tiles or other material; synthetic foam batting laid above the ceiling and recycled paper products and other such materials that can be inserted or sprayed into roof cavities.

So called Cool roofs are becoming increasingly popular, and in some cases are mandated by local codes. Cool roofs are defined as roofs with both high reflectivity and high emissivity.

Drainage

The primary job of most roofs is to keep out water. The large area of a roof repels a lot of water, which must be directed in some suitable way, so that it does not cause damage or inconvenience.

Flat roof of adobe dwellings generally have a very slight slope. In a Middle Eastern country, where the roof may be used for recreation, it is often walled, and drainage holes

must be provided to stop water from pooling and seeping through the porous roofing material.

Similar problems, although on a very much larger scale, confront the builders of modern commercial properties which often have flat roofs. Because of the very large nature of such roofs, it is essential that the outer skin is of a highly impermeable material. Most industrial and commercial structures have conventional roofs of low pitch.

In general, the pitch of the roof is proportional to the amount of precipitation. Houses in areas of low rainfall frequently have roofs of low pitch while those in areas of high rainfall and snow, have steep roofs. The longhouses of Papua New Guinea, for example, being roof-dominated architecture, the high roofs sweeping almost to the ground. The high steeply-pitched roofs of Germany and Holland are typical in regions of snowfall. In parts of North America such as Buffalo, USA or Montreal, Canada, there is a required minimum slope of 6 inches in 12 inches, a pitch of 30 degrees.

There are regional building styles which contradict this trend, the stone roofs of the Alpine chalets being usually of gentler incline. These buildings tend to accumulate a large amount of snow on them, which is seen as a factor in their insulation. The pitch of the roof is in part determined by the roofing material available, a pitch of 3/12 or greater slope generally being covered with asphalt shingles, wood shake, corrugated steel, slate or tile.

The water repelled by the roof during a rainstorm is potentially damaging to the building that the roof protects. If it runs down the walls, it may seep into the mortar or through panels. If it lies around the foundations it may cause seepage to the interior, rising damp or dry rot. For this reason most buildings have a system in place to protect the walls of a building from most of the roof water. Overhanging eaves are commonly employed for this purpose. Most modern roofs and many old ones have systems of valleys, gutters, waterspouts, waterheads and drainpipes to remove the water from the vicinity of the building. In many parts of the world, roofwater is collected and stored for domestic use.

Areas prone to heavy snow benefit from a metal roof because their smooth surfaces shed the weight of snow more easily and resist the force of wind better than a wood shingle or a concrete tile roof.

Solar roofs

Newer systems include solar shingles which generate electricity as well as cover the roof. There are also solar systems available that generate hot water or hot air and which can also act as a roof covering. More complex systems may carry out all of these functions: generate electricity, recover thermal energy, and also act as a roof covering.

Solar systems can be integrated with roofs by:

- integration in the covering of pitched roofs, e.g. solar shingles.

- mounting on an existing roof, e.g. solar panel on a tile roof.
- integration in a flat roof membrane using heat welding, e.g. PVC.
- mounting on a flat roof with a construction and additional weight to prevent uplift from wind.

Roof shapes

- Flat roof
  - Terrace - a flat roof with balustrade, used as a living space
- Arched Roof
  - Barrel-arched
  - Catenary
- Circular
  - Domical
  - Conical
- Pyramidal
  - Pyatthat
  - Helm Roof - Rhenish helm - a pyramidal roof with gable ends found on church towers
- Pitched or gabled
  - Asian traditional style
  - Crow-stepped gable (also called corbie step) gable
  - Dutch gable – a hybrid of hipped and gable
  - Shaped gable
  - Salt-box
  - Outshot or catslide, a pitched extension of the main roof
  - Saddleback – a gabled roof atop a tower
- Hip roof
  - Half-hipped
  - Dutch gable
- Mansard – with the pitch divided into a shallow slope above a steeper slope
  - Gambrel – as a mansard, but on only two sides of the roof
  - Bell-cast – as a mansard, but with the shallow slope below the steeper slope
- Skillion roof single-sloped or shed roof
  - Lean-to
- Saw-tooth - admits natural light into a factory. The vertical surfaces are glazed and face away from the equator. The sloping surfaces are opaque, shielding the workers and machinery from direct sunlight.

Roof shapes

Flat roof, Western Australia

Mansard roof on a county jail, Mount Gilead, Ohio

Temple roof Chang Mai, Thailand with a decorated gable end and ceramic tile covering.

Commercially available roofing materials

The weather proofing material is the topmost or outermost layer, exposed to the weather. Many materials have been used as weather proofing material:

- Thatch is roofing made of plant material, in overlapping layers.
  - Wheat Straw, widely used in England, France and other parts of Europe.
  - Seagrass, used in coastal areas where there are estuaries such as Scotland. Has a longer life than straw. Claimed to have a life in excess of 60 years.
- Shingles, Wood shingles longer than 16" are called *shakes* in North America. *Shingles* is the generic term for a roofing material that is in many overlapping sections, regardless of the nature of the material.
  - Red cedar. Life expectancy, up to 30 years. However, young growth red cedar has a short life expectancy. High cost. Should be allowed to breathe, usually installed on lath strip for this purpose. The lath may rest on a roof deck with underlayment or be fastened directly to the rafters.
  - Hardwood. Very durable roofing found in Colonial Australian architecture, its use now limited to restorations.

    - Slate. Higher cost with a life expectancy of 50 to 200 years depending on the thickness and type of slate used. Being a heavy material, the supporting structure must be rated to support the weight load.
    - Ceramic tile. High cost, life of 20–100 years.
        - Imbrex and tegula, style dating back to ancient Greece and Rome.
        - Monk and Nun, a style similar to Imbrex and tegula, but basically using two Imbrex tiles.
    - Mangalore clay tiles low cost, life of 20–80 years, used in India.
    - Metal shakes or shingles. Long life. High cost, suitable for roofs of 4/12 pitch or greater. Because of the flexibility of metal, they can be manufactured to lock together, giving durability and reducing assembly time.
    - Mechanically seamed metal. Long life. High cost, suitable for roofs of low pitch such as 0.5/12 to 3/12 pitch.
    - Concrete, usually reinforced with fibres of some sort. Not suitable in climates that experience many freeze/thaw cycles during a year which will cause this type of material to form cracks and fail.
    - Asphalt shingle, made of bitumen embedded in an organic or fiberglass mat, usually covered with colored, man-made ceramic grit. Cheaper and lighter than slate or tiles. Life expectancies vary from 20 to 50 years depending on the product. Sun is the enemy of asphalt shingles so longer life can be expected in cloudier locations or at higher latitudes.
    - Asbestos shingles. Lifespans vary. Fireproof. Rarely used anymore because of health concerns. Abatement costs can be high when the old roof needs to be replaced and is subject to additional state and local environmental regulation and oversight.
- Membrane. membrane roofing is in large sheets, generally fused in some way at the joints to form a continuous surface.
    - Thermosetting plastic (e.g. EPDM rubber). Synthetic rubber sheets adhered together with contact adhesive or tape. Primary application is big box store with large open areas and little vertical protrusions.
    - Thermoplastic (e.g. PVC, TPO, CSPE). Plastic sheets welded together with hot air creating one continuous sheet membrane. Can be re-welded with the exception of CSPE. Lends itself well to both big box and small roof application because of its hot air weldability.
    - Modified bitumen – heat welded, asphalt adhered or installed with adhesive. Asphalt is mixed with polymers such as APP or SBS, then applied to fiberglass and/or polyester mat, seams sealed by locally melting the asphalt with heat, hot mopping of asphalt, or adhesive. Lends itself well to all applications.
    - Built-Up Roof – Multiple plies of asphalt saturated organic felt or coated fiberglass felts. Plies of felt are adhered with hot asphalt, coal tar pitch or adhesive.
    - Sprayed-in-Place Polyurethane Foam (SPUF) – Foam sprayed in-place on the roof, then coated with a wide variety of coatings, or in some instances, covered with gravel.

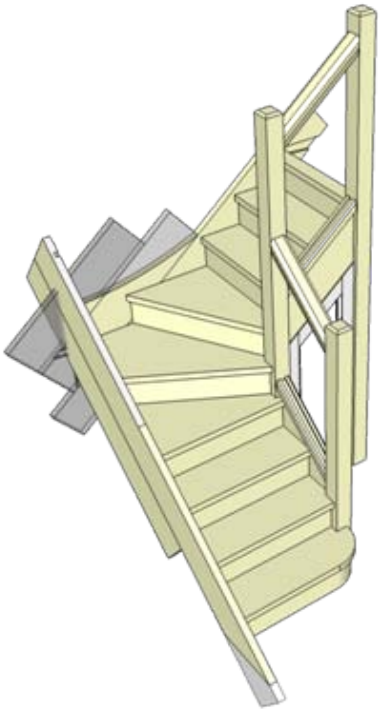
    - Fabric.
        - Polyester.
        - PTFE, (synthetic fluoropolymer) embedded in fibreglass.
- Metal roofing. Generally a relatively inexpensive building material.
    - Galvanised steel frequently manufactured with wavy corrugations to resist lateral flexing and fitted with exposed fasteners. Widely used for low cost and durability. Sheds are normally roofed with this material. Known as *Gal iron* or *Corro*, it was the most extensively used roofing material of 20th century Australia, now replaced in popularity by steel roofing coated with an alloy of zinc and aluminium, claimed to have up to four times the life of galvanized steel.
    - Standing-seam metal with concealed fasteners.
    - Mechanically seamed metal with concealed fasteners contains sealant in seams for use on very low sloped roofs.
    - Flat-seam metal with soldered seams.

Chapter- 8

Stairway

A straight stairway with tiled treads, a double railing and two landings in the "Porta Garibaldi" station, Milan

A Stairway with a landing in the middle



Example of Winder Stairs

Staircase between levels at Cabot Circus shopping centre, Bristol, England, United Kingdom. A sitting area is provided on the right of the staircase proper.

Stairway, **staircase**, **stairwell**, **flight of stairs** or simply **stairs** are names for a construction designed to bridge a large vertical distance by dividing it into smaller vertical distances, called **steps**. Stairways may be straight, round, or may consist of two or more straight pieces connected at angles.

Special stairways include escalators and ladders. Alternatives to stairways are elevators, stairlifts and inclined moving sidewalks as well as stationary inclined sidewalks.

Components and terminology

Step

The step is composed of the tread and riser.

Tread
: The part of the stairway that is stepped on. It is constructed to the same specifications (thickness) as any other flooring. The tread "depth" is measured from the outer edge of the step to the vertical "riser" between steps. The "width" is measured from one side to the other.

Riser
: The vertical portion between each tread on the stair. This may be missing for an "open" stair effect.

Nosing
: An edge part of the tread that protrudes over the riser beneath. If it is present, this means that, measured horizontally, the total "run" length of the stairs is not simply the sum of the tread lengths, as the treads actually overlap each other slightly.

Starting step or Bullnose
: Where stairs are open on one or both sides, the first step above the lower floor may be wider than the other steps and rounded. The balusters typically form a semicircle around the circumference of the rounded portion and the handrail has a horizontal spiral called a "volute" that supports the top of the balusters. Besides the cosmetic appeal, starting steps allow the balusters to form a wider, more stable base for the end of the handrail. Handrails that simply end at a post at the foot of the stairs can be less sturdy, even with a thick post. A **double bullnose** can be used when both sides of the stairs are open.

Stringer, Stringer board or sometimes just String
: The structural member that supports the treads and risers. There are typically two stringers, one on either side of the stairs; though the treads may be supported many other ways. The stringers are sometimes notched so that the risers and treads fit into them. Stringers on open-sided stairs are often open themselves so that the treads are visible from the side. Such stringers are called "cut" stringers. Stringers on a closed side of the stairs are closed, with the support for the treads routed into the stringer.

Winders
: Winders are steps that are narrower on one side than the other. They are used to change the direction of the stairs without landings. A series of winders form a

circular or spiral stairway. When three steps are used to turn a 90° corner, the middle step is called a **kite winder** as a kite-shaped quadrilateral.

Trim

Trim (e.g. quarter-round or baseboard trim) is normally applied where walls meet floors and often underneath treads to hide the reveal where the tread and riser meet. **Shoe moulding** may be used between where the lower floor and the first riser meet. Trimming a starting step is a special challenge as the last riser above the lower floor is rounded. Flexible, plastic trim is available for this purpose, however wooden mouldings are still used and are either cut from a single piece of rounded wood, or bent with laminations **Scotia** is concave moulding that is underneath the nosing between the riser and the tread above it.

The railing system

The balustrade is the system of railings and balusters that prevents people from falling over the edge.

Banister, Railing or Handrail

The angled member for handholding, as distinguished from the vertical balusters which hold it up for stairs that are open on one side; there is often a railing on both sides, sometimes only on one side or not at all, on wide staircases there is sometimes also one in the middle, or even more. The term "banister" is sometimes used to mean just the handrail, or sometimes the handrail and the balusters or sometimes just the balusters.

Volute

A handrail end element for the bullnose step that curves inward like a spiral. A volute is said to be right or left-handed depending on which side of the stairs the handrail is as one faces up the stairs.

Turnout

Instead of a complete spiral volute, a turnout is a quarter-turn rounded end to the handrail.

Gooseneck

The vertical handrail that joins a sloped handrail to a higher handrail on the balcony or landing is a gooseneck.

Rosette

Where the handrail ends in the wall and a half-newel is not used, it may be trimmed by a rosette.

Easings

Wall handrails are mounted directly onto the wall with *wall brackets*. At the bottom of the stairs such railings flare to a horizontal railing and this horizontal portion is called a "starting easing". At the top of the stairs, the horizontal portion of the railing is called a "over easing".

Core rail

Wood handrails often have a metal core to provide extra strength and stiffness, especially when the rail has to curve against the grain of the wood. The archaic term for the metal core is "core rail".

Baluster

A term for the vertical posts that hold up the handrail. Sometimes simply called *guards* or *spindles*. Treads often require two balusters. The second baluster is closer to the riser and is taller than the first. The extra height in the second baluster is typically in the middle between decorative elements on the baluster. That way the bottom decorative elements are aligned with the tread and the top elements are aligned with the railing angle.

Newel

A large baluster or post used to anchor the handrail. Since it is a structural element, it extends below the floor and subfloor to the bottom of the floor joists and is bolted right to the floor joist. A *half-newel* may be used where a railing ends in the wall. Visually, it looks like half the newel is embedded in the wall. For open landings, a newel may extend below the landing for a decorative *newel drop*.

Baserail or Shoerail

For systems where the baluster does not start at the treads, they go to a baserail. This allows for identical balusters, avoiding the second baluster problem.

Fillet

A decorative filler piece on the floor between balusters on a balcony railing.

Handrails may be *continuous* (sometimes called *over-the-post*) or *post-to-post* (or more accurately "newel-to-newel"). For continuous handrails on long balconies, there may be multiple newels and *tandem caps* to cover the newels. At corners, there are *quarter-turn caps*. For post-to-post systems, the newels project above the handrails.

Another, more classical, form of handrailing which is still in use is the tangent method. A variant of the Cylindric method of layout, it allows for continuous climbing and twisting rails and easings. It was defined from principles set down by architect Peter Nicholson in the 18th century.

Other terminology

Historical photo of a staircase in the Ford plant in Los Angeles with a double bullnose and two volutes. The photo also shows an **intermediate landing** as part of this U-shaped stair.

Balcony

For stairs with an open concept upper floor or landing, the upper floor is functionally a balcony. For a straight flight of stairs, the balcony may be long enough to require multiple newels to support the length of railing. In modern homes, it is common to have hardwood floors on the first floor and carpet on the second. The homeowner should consider using hardwood nosing in place of carpet. Should the carpet be subsequently replaced with hardwood, the balcony balustrade may have to be removed to add the nosing.

Flight
: A flight is an uninterrupted series of steps.

Floating stairs
: A flight of stairs is said to be "floating" if there is nothing underneath. The risers are typically missing as well to emphasize the open effect. There may be only one stringer or the stringers otherwise minimized. Where building codes allow, there may not even be handrails.

Landing or Platform
: A landing is the area of a floor near the top or bottom step of a stair. An intermediate landing is a small platform that is built as part of the stair between main floor levels and is typically used to allow stairs to change directions, or to allow the user a rest. As intermediate landings consume floor space they can be expensive to build. However, changing the direction of the stairs allows stairs to fit where they would not otherwise, or provides privacy to the upper level as visitors downstairs cannot simply look up the stairs to the upper level due to the change in direction.

Runner
: Carpeting that runs down the middle of the stairs. Runners may be directly stapled or nailed to the stairs, or may be secured by specialized bar that holds the carpet in place where the tread meets the riser.

Spandrel
: If there is not another flight of stairs immediately underneath, the triangular space underneath the stairs is called a "spandrel". It is frequently used as a closet.

Staircase
: This term is often reserved for the stairs themselves: the steps, railings and landings; though often it is used interchangeably with "stairs" and "stairway". In the UK, however, the term "staircase" denotes what in the U.S. is called "stairway", but usually includes the casing – the walls, bannisters and underside of the stairs or roof above.

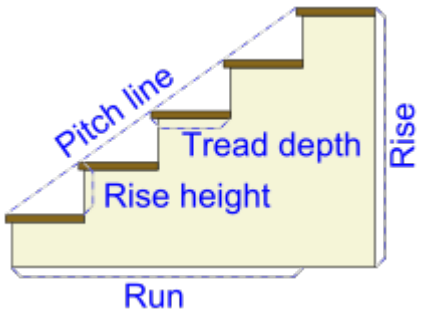
Stairway
: This term is often reserved for the entire stairwell and staircase in combination; though often it is used interchangeably with "stairs" and "staircase".

Stairwell
: The spatial opening, usually a vertical shaft, containing an indoor stairway; by extension it is often used as including the stairs it contains.

Measurements

The measurements of a stair, in particular the rise height and going of the steps, should remain the same along the stairs – with an obvious exception for winders.

The following stair measurements are important:



- The **rise height** or **rise** of each step is measured from the top of one tread to the next. It is not the physical height of the riser; the latter excludes the thickness of the tread. A person using the stairs would move this distance vertically for each step he takes.
- The **tread depth** of a step is measured from the edge of the nosing to the vertical riser; if the steps have no nosing, it is the same as the going; otherwise it is the going plus the extent of one nosing.
- The **going** of a step is measured from the edge of the nosing to the edge of nosing in plan view. A person using the stairs would move this distance forward with each step they take.
- To avoid confusion, the **number of steps** in a set of stairs is always the number of risers, not the number of treads.
- The **total run** or **total going** of the stairs is the horizontal distance from the first riser to the last riser. It is often not simply the sum of the individual tread lengths due to the nosing overlapping between treads. If there are N steps, the total run equals $N-1$ times the going: the tread of the last step is part of a landing and is not counted.
- The **total rise** of the stairs is the height between floors (or landings) that the flight of stairs is spanning. If there are N steps, the total rise equals N times the rise of each step.
- The **slope** or **pitch** of the stairs is the ratio between the rise and the going (not the tread depth, due to the nosing). It is sometimes called the **rake** of the stairs. The **pitch line** is the imaginary line along the tip of the nosing of the treads. In the UK, stair pitch is the angle the pitch line makes with the horizontal, measured in degrees. The value of the slope, as a ratio, is then the tangent of the pitch angle.
- **Headroom** is the height above the nosing of a tread to the ceiling above it.
- **Walkline** – for curved stairs, the inner radius of the curve may result in very narrow treads. The "walkline" is the imaginary line some distance away from the inner edge on which people are expected to walk. Building code will specify the distance. Building codes will then specify the minimum tread size at the walkline.

The easiest way to calculate the rise and run is to use a stair stringer calculator.

Ergonomics and building code requirements

Ergonomically and for safety reasons, stairs have to have certain measurements in order for people to comfortably use them. Building codes will typically specify certain measurements so that the stairs are not too steep or narrow. Building codes will specify:

- Minimum tread length, typically 9 inches (230 mm) excluding the nosing for private residences. However, most human feet are longer than this, thus people's feet don't actually fit on the tread of the step.
- Maximum riser height, typically 8.25 inches (210 mm). Note that by specifying the maximum riser height and minimum tread length, a maximum slope is established. Residential building codes will typically allow for steeper stairs than public building codes.
- Minimum riser height: Some building codes also specify a minimum riser height, often 5 inches (130 mm).
- Riser-Tread formula: Sometimes the stair parameters will be something like riser + tread equals 17–18 inches (430–460 mm); another formula is 2 times riser + tread equals 24.6 inches (625 mm), the length of a stride. Thus a 7 inches (178 mm) rise and a 10.6 inches (269 mm) tread exactly meets this code. If only a 2 inches (51 mm) rise is used then a 20.6 inches (523 mm) tread is required. This is based on the principle that a low rise is more like walking up a gentle incline and so the natural swing of the leg will be longer. This makes low rise stairs very expensive in terms of the space consumed. Such low rise stairs were built into the Winchester Mystery House to accommodate the infirmities of the owner, Sarah Winchester, before the invention of the elevator. These stairways, called "Easy Risers" consist of five flights wrapped into a multi-turn arrangement with a total width equal to more than four times the individual flight width and a depth roughly equal to one flight's run plus this width. The flights have varying numbers of steps.
- Slope: A value for the rise-to-tread ratio of $17/29 \approx 0.59$ is considered optimal; this corresponds to a pitch angle of about 30°.
- Variance on riser height and tread depth between steps on the same flight should be very low. Building codes require variances no larger than 0.1875 inches (4.76 mm) between depth of adjacent treads or the height of adjacent risers; within a flight, the tolerance between the largest and smallest riser or between the largest and smallest tread can not exceed 0.375 inches (9.5 mm). The reason is that on a continuous flight of stairs, people get used to a regular step and may trip if there is a step that is different, especially at night. The general rule is that all steps on the same flight must be identical. Hence, stairs are typically custom made to fit the particular floor to floor height and horizontal space available. Special care must be taken on the first and last risers. Stairs must be supported directly by the subfloor. If thick flooring (e.g. thick hardwood planks) are added on top of the subfloor, it will cover part of the first riser, reducing the effective height of the first step. Likewise at the top step, if the top riser simply reaches the subfloor and thick flooring is added, the last rise at the top may be higher than the last riser.

The first and last riser heights of the rough stairs are modified to adjust for the addition of the finished floor.
- Maximum nosing protrusion, typically 1.25 inches (32 mm) to prevent people from tripping on the nosing.
- Height of the handrail. This is typically between 34 and 38 inches (860 and 970 mm), measured to the nose of the tread. The minimum height of the handrail for landings may be different and is typically 36 inches (910 mm).
- Handrail diameter. The size has to be comfortable for grasping and is typically between 1.25 and 2.675 inches (32 and 67.9 mm).
- Maximum space between the balusters of the handrail. This is typically 4 inches (100 mm).
- Openings (if they exist) between the bottom rail and treads are typically no bigger than 6 inches (150 mm).
- Headroom: At least 83 inches (210 cm).
- Maximum vertical height between floors or landings. This allows people to rest and limits the height of a fall.
- Mandate handrails if there is more than a certain number of steps (typically 2 risers)
- Minimum width of the stairway, with and without handrails
- Not allow doors to swing over steps; the arc of doors must be completely on the landing/floor.
- A stairwell may be designated as an area of refuge as well as a fire escape route, due to its fire-resistance rated design and fresh air supply.

Jacques-François Blondel in his 1771 **Cours d'architecture** was the first known person to establish the ergonomic relationship of tread and riser dimensions. He specified that 2 x riser + tread = step length.

It is estimated that a noticeable mis-step occurs once in 7,398 uses and a minor accident on a flight of stairs occurs once in 63,000 uses. Some people choose to live in residences without stairs so that they are protected from injury.

Stairs are not suitable for wheelchairs and other vehicles. A stairlift is a mechanical device for lifting wheelchairs up and down stairs. For sufficiently wide stairs, a rail is mounted to the treads of the stairs. A chair is attached to the rail and the person on the chair is lifted as the chair moves along the rail.

UK Building Regulations

(overview of Approved document K - Stairs Ramps and Guards)

Approved document K categorises stairs as ‘Private’, ‘Institutional or assembly’ and ‘other’

When considering stairs for **private dwellings**

Building regulations are required for stairs used where the difference of level is greater than 600mm

Steepness of stairs – Rise and Going - Any rise between 155mm and 220mm used with any going between 245mm and 260mm or any rise between 165mm and 200mm used with any going between 223mm and 300mm

Maximum Rise 220mm and Minimum Going 220mm remembering that the maximum pitch of private stairs is 42^0. The normal relationship between dimensions of the rise and going is that twice the rise plus the going (2R + G) should be between 550mm and 700mm

Construction of steps - Steps should have level treads, they may have open risers but if so treads should overlap at least 16mm. Domestic private stairs are likely to be used by children under 5 years old so they should be constructed so that a 100mm diameter sphere cannot pass though the opening in the risers.

Headroom - A headroom of 2m is adequate.

Width of flights - No recommendations are given for stair widths in the Approved document K for stairs but designer's attention is drawn to approved document B: fire safety.

Length of flights - The approved document refers to 16 risers (steps) for stairs in shops or assembly building. There is no requirement for private stairs. In practice there will be less than 16 steps as 16 x 220mm gives over 3.5m total rise which is way above that in a domestic situation.

Landings - Level, unobstructed landings should be provided at the top and bottom of every flight. The width and length being at least that of the width of the stairs and can include part of the floor. A door may swing across the landing at the bottom of the flight but must leave a clear space of at least 400mm across the whole landing

Tapered steps - There are special rules for stairs with tapered steps as shown in the image Example of Winder Stairs above

Alternate tread stairs can be provide in space saving situations

Guarding - Flights and landings must be guarded at the sides where the drop is more than 600mm. As domestic private stairs are likely to be used by children under 5 the guarding must be constructed so that a 100mm diameter sphere cannot pass through any opening or constructed so that children will not be able to climb the guarding. The height for internal private stairs should be at least 900mm and be able to withstand a horizontal force of 0.36 kN/m

Forms

Stairs can take a large number of forms, combining winders and landings.

The simplest form is the straight flight of stairs, with neither winders nor landings. It is not often used in modern homes because:

- the upstairs is directly visible from the bottom of a straight flight of stairs.
- it is potentially more dangerous in that a fall is not interrupted until the bottom of the stairs.
- a straight flight requires enough space for the entire run of the stairs.

However, a straight flight of stairs is easier to design and construct than one with landings. Additionally, the rhythm of stepping is not interrupted in a straight run, which may offset the increased fall risk by helping to prevent a misstep in the first place.

Most modern stairs incorporate at least one landing. "L" shaped stairways have one landing and usually change in direction by 90 degrees. "U" shaped stairs may employ a single wider landing for a change in direction of 180 degrees, or 2 landings for two changes in direction of 90 degrees each. Use of landings and a possible change of direction have the following effects:

- The upstairs is not directly visible from the bottom of the stairs, which can provide more privacy for the upper floor.
- A fall can be arrested at the landing.
- Though the landings consume total floor space, there is no requirement for a large single dimension, allowing more flexible floorplan designs.
- For larger stairs, particularly in exterior applications, a landing can provide a place to rest the legs.

Spiral and helical stairs

Spiral stairs wind around a newel (also the central pole). They typically have a handrail on the outer side only, and on the inner side just the central pole. A squared spiral stair assumes a square stairwell and expands the steps and railing to a square, resulting in unequal steps (larger where they extend into a corner of the square). A pure spiral assumes a circular stairwell and the steps and handrail are equal and positioned screw-symmetrically. A tight spiral stair with a central pole is very space efficient in the use of floor area. Spiral stairs have the disadvantage of being very steep. Unless the central column is very large, the circumference of the circle at the walk line will be small enough that it will be impossible to maintain a normal going and a normal rise without compromising headroom before reaching the upper floor. To maintain headroom most spiral stairs have very high rises and a very short going. Most building codes limit the use of spiral stairs to small areas or secondary usage.

The term "spiral" is used incorrectly for a staircase from a mathematical viewpoint, as a mathematical spiral lies in a single plane and moves towards or away from a central point. A spiral staircase by the mathematical definition therefore would be of little use as it would afford no change in elevation. The correct mathematical term for motion where the locus remains at a fixed distance from a fixed line whilst moving in a circular motion about it is "helix". The presence or otherwise of a central pole does not affect the terminology applied to the design of the structure.

Spiral stairs in medieval times were generally made of stone and typically wound in a clockwise direction (from the ascendor's point of view), in order to place at a disadvantage attacking swordsmen (who were most often right-handed). This asymmetry forces the right-handed swordsman to engage the central pike and degrade his mobility compared with the defender who is facing down the stairs. Extant 14th to 17th century examples of these stairways can be seen at Muchalls Castle, Crathes Castle and Myres Castle in Scotland. Exceptions to the rule exist, however, as may be seen in the above image of the Scala of the Palazzo Contarini del Bovolo, which winds up anti-clockwise.

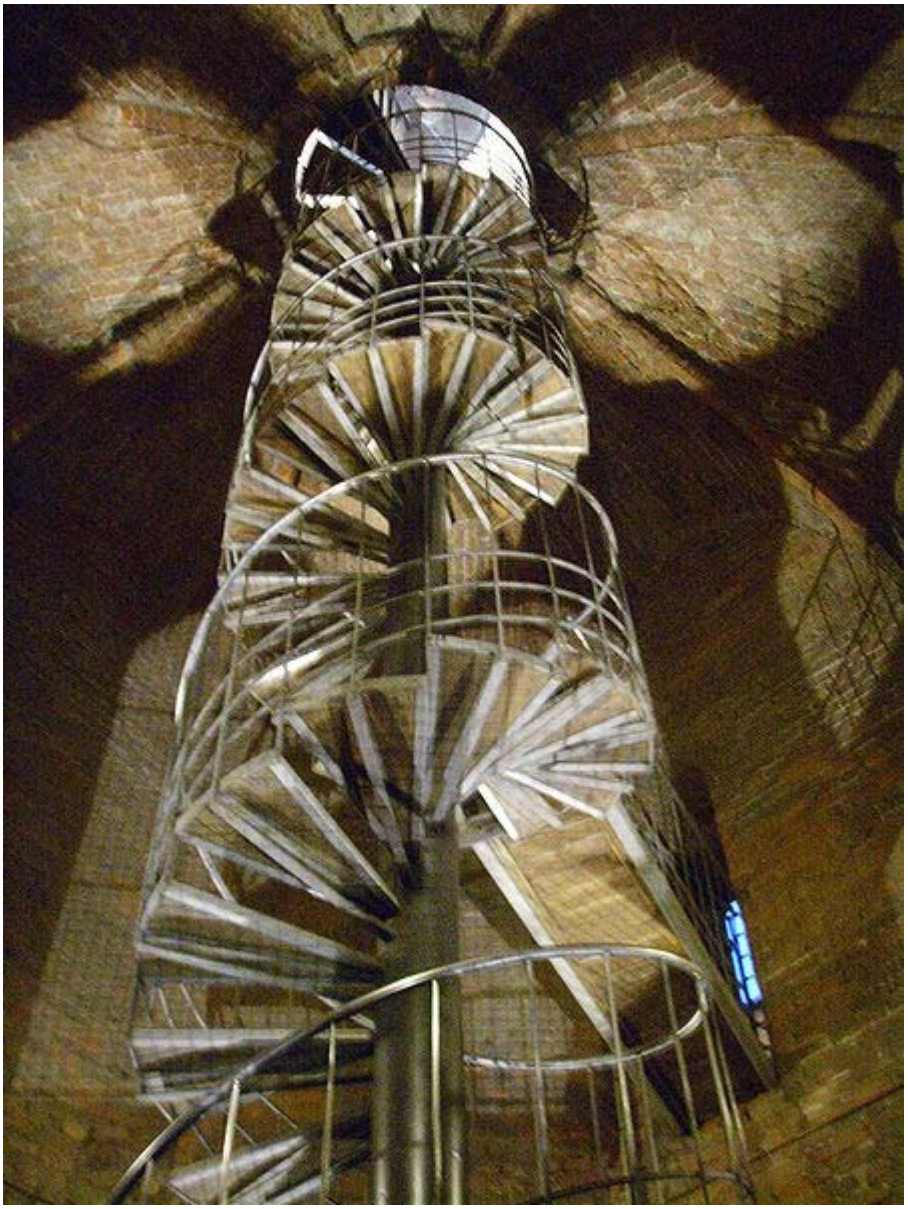
Developments in manufacturing and design have led to the introduction of kit form spiral stair. Steps and handrails can be bolted together to form a complete unit. These stairs can be made out of steel, timber, concrete or a combination of materials.

Helical or circular stairs do not have a central pole and there is a handrail on both sides. These have the advantage of a more uniform tread width when compared to the spiral staircase. Such stairs may also be built around an elliptical or oval planform. A double helix is possible, with two independent helical stairs in the same vertical space, allowing one person to ascend and another to descend, without ever meeting if they choose different helixes (examples : Château de Chambord, Château de Blois, Crédit Lyonnais headquarters in Paris). Fire escapes, though built with landings and straight runs of stairs, are often functionally double helixes, with two separate stairs intertwinned and occupying the same floor space. This is often in support of legal requirements to have two separate fire escapes.

Both spiral and helical stairs can be characterized by the number of turns that are made. A "quarter-turn" stair deposits the person facing 90 degrees from the starting orientation. Likewise there are half-turn, three-quarters-turn and full-turn stairs. A continuous spiral may make many turns depending on the height. Very tall multi turn spiral staircases are usually found in old stone towers within fortifications, churches and in lighthouses.

Winders may be used in combination with straight stairs to turn the direction of the stairs. This allows for a large number of permutations.

There is no newel at Loretto Chapel's spiral staircase (the "Miracle stair") in Santa Fe, New Mexico, USA.



A spiral staircase inside Cremona's Torrazzo, Italy

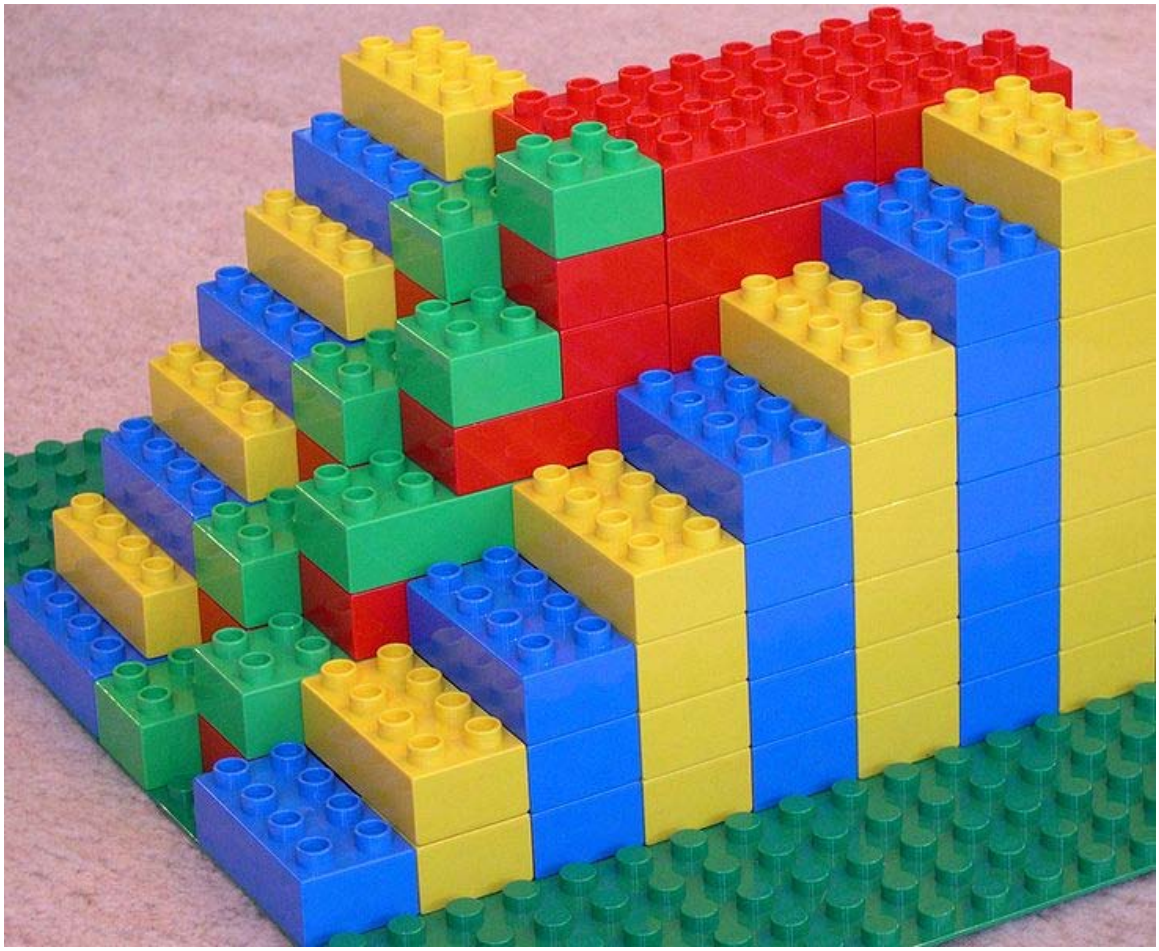
Upward view of the Tulip Stairs & lantern at the Queen's House, Greenwich, United Kingdom.

Spiral stairway seen from below; Melk Abbey, Austria.

History

The earliest spiral staircases appear in Temple A in the Greek colony Selinunte, Sicily, to both sides of the cella. The temple was constructed around 480–470 BC.

Alternating tread stairs



An alternating Duplo tread stair (center) between a half-width stair (left) and full-width stair (right)

An alternating tread stair climbing the steep slope of a pinnacle in Pinnacles National Monument, California, United States.

Where there is insufficient space for the full run length of normal stairs, alternating tread stairs may be used. Alternating tread stairs allow for safe forward-facing descent of very steep stairs. The treads are designed such that they alternate between treads for each foot: one step is wide on the left side; the next step is wide on the right side. There is insufficient space on the narrow portion of the step for the other foot to stand, hence the person must always use the correct foot on the correct step. The slope of alternating tread stairs can be as high as 65 degrees as opposed to standard stairs which are almost always less than 45 degrees. The advantage of alternating tread stairs is that people can descend face forward. The only other alternative in such short spaces would be a ladder which requires backward-facing descent. Alternating tread stairs may not be safe for small

children, the elderly or the physically challenged. Building codes typically classify them as ladders and will only allow them where ladders are allowed, usually basement or attic utility or storage areas not frequently accessed.

The image on the right illustrates the space efficiency gained by an alternating tread stair. The alternating tread stair appearing on the image's center, with green-colored treads. The alternating stair requires one unit of space per step: the same as the half-width step on its left, and half as much as the full-width stair on its right. Thus, the horizontal distance between steps is in this case reduced by a factor of two reducing the size of each step.

The horizontal distance between steps is reduced by a factor less than two if for constructional reasons there are narrow "unused" steps.

There is often (here also) glide plane symmetry: the mirror image with respect to the vertical center plane corresponds to a shift by one step.

Alternating tread stairs have been in use since at least 1888.

Notable stairways

The world's longest stairway at the Niesenbahn funicular in Switzerland has 11,674 steps

- The longest stairway is listed by Guinness Book of Records as the service stairway for the Niesenbahn funicular railway near Spiez, Switzerland, with 11,674 steps and a height of 1669 m (5476 ft). The stairs are employee-only.
- A flight of 7,200 steps (including inner temple Steps), with 6,293 Official Mountain Walkway Steps, leads up the East Peak of Mount Tai in China.
- The Haʻikū Stairs, on the island of Oʻahu, Hawaiʻi, are approximately 4,000 steps which climb nearly 1/2 of a mile. Originally used to access longwire radio radio antennas which were strung high above the Haʻikū Valley, between Honolulu and Kāneʻohe, they are closed to hikers.
- The Flørli stairs, in Lysefjorden, Norway, have 4,444 wooden steps which climb from sea level to 740 meters. It is a maintenance stairway for the water pipeline to the old Flørli hydro plant. The hydro plant is now closed down, and the stairs are open to the public. The stairway is claimed to be the longest wooden stairway in the world.
- The CN Tower's staircase reaches the main deck level after 1,776 steps and the Sky Pod above after 2,579 steps; it is the tallest metal staircase on Earth.
- The Penrose stairs, devised by Lionel and Roger Penrose, are a famous impossible object. The image distorts perspective in such a manner that the stairs appear to be never-ending, a physical impossibility. The image was adopted by M. C. Escher in his iconic lithograph *Ascending and Descending*.

Image in art

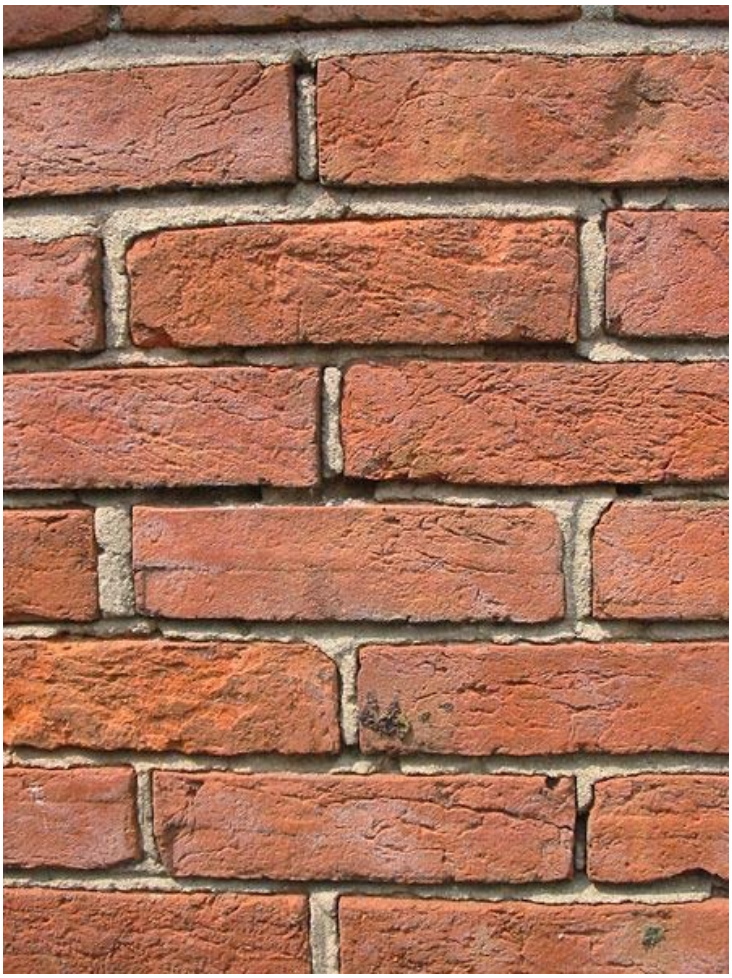
Stairway is a metaphor of achievement or loss of a position in the society, a metaphor of hierarchy (e.g. Jacob's Ladder, The Battleship Potemkin).

Staircase art

Staircase art is an art form practiced by a few devoted individuals around the world. A small vignette exists describing the art form here.

Chapter- 9

Wall



A brick wall

A **wall** is a usually solid structure that defines and sometimes protects an area. Most commonly, a wall delineates a building and supports its superstructure, separates space in buildings into rooms, or protects or delineates a space in the open air. There are three principal types of structural walls: building walls, exterior boundary walls, and retaining walls.

Building walls

Building walls have one main purpose: to support roofs and ceilings. Such walls most often have three or more separate components. In today's construction, a building wall will usually have the structural elements (such as 2×4 studs in a house wall), insulation, and finish elements or surface (such as drywall or panelling). In addition, the wall may house various types of electrical wiring or plumbing. Electrical outlets are usually mounted in walls.

Building walls frequently become works of art externally and internally, such as when featuring mosaic work or when murals are painted on them; or as design foci when they exhibit textures or painted finishes for effect.

On a ship, the walls separating compartments are termed "bulkheads", whilst the thinner walls separating cabins are termed "partitions".

In architecture and civil engineering, the term curtain wall refers to the facade of a building which is not load-bearing but functions as decoration, finish, front, face, or history preservation.

Partition wall

A partition wall is a wall for the purpose of separating rooms, or dividing a room. Partition walls are usually not load-bearing.

Partition walls may be constructed with bricks or blocks from clay, terra-cotta or concrete, reinforced, or hollow. Glass blocks may also be used.

They may also be constructed from sheet glass. Glass partition walls are a series of individual toughened glass panels, which are suspended from or slide along a robust aluminium ceiling track. The system does not require the use of a floor guide, which allows easy operation and an uninterrupted threshold.

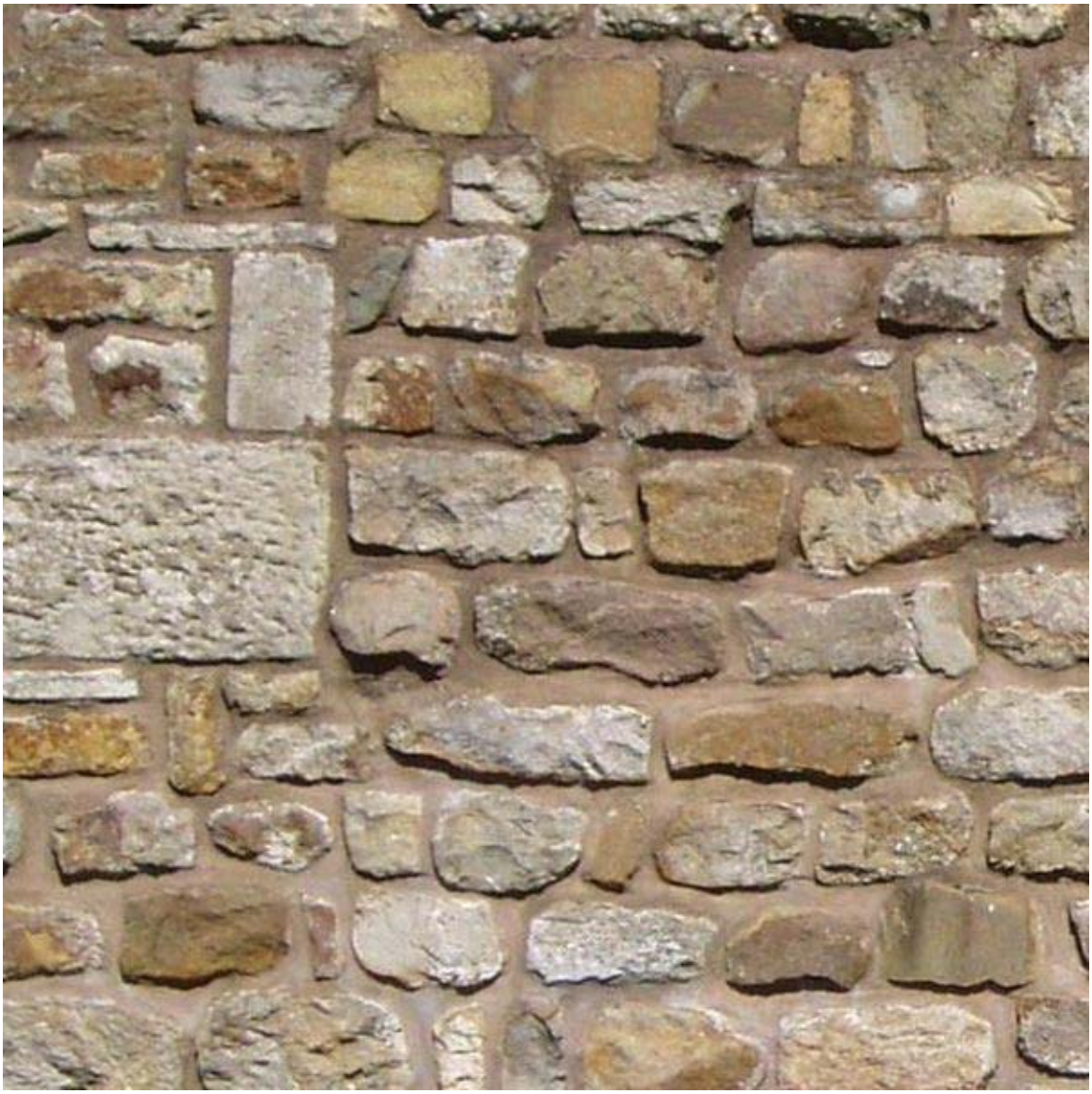
Timber may be used. This type of partition consists of a wooden framework either supported on the floor below or by side walls. Metal lath and plaster, properly laid, forms a reinforced partition wall, which is thin, strong, durable, and fire-resistant. Partition walls constructed from fibre cement sheeting are popular as bases for tiling in kitchens or in wet areas like bathrooms. Galvanized sheet fixed to wooden or steel members are mostly adopted in works of temporary character. Plain or reinforced partition walls may also be constructed from concrete, including precast concrete blocks.

Movable Partitions

Movable partitions are used where the walls of a room are frequently opened to form one large floor area. In this system, there are three types of partitions:

- Sliding: Sliding partitions consists of series of panels that slide in tracks fixed to the floor and ceiling. The machine if the partition is similar to those of sliding doors.
- Sliding & folding: Sliding and folding partitions operate in a similar manner to sliding folding doors. They are normally used for smaller spans.
- Screens: Screens are usually constructed of a metal or timber frame. It is fixed with plywood and chipboard inside. The screen supported with legs for free standing and easy movement.

Boundary walls



Stone wall of an English barn

Boundary walls include privacy walls, boundary-marking walls on property, and town walls. These intergrade into fences; the conventional differentiation is that a fence is of minimal thickness and often is open in nature, while a wall is usually more than a nominal thickness and is completely closed, or opaque. More to the point, if an exterior structure is made of wood or wire, it is generally referred to as a fence, while if it is made of masonry, it is considered a wall. A common term for both is barrier, convenient if it is partly a wall and partly a fence, for example the Berlin Wall. Another kind of wall/fence ambiguity is the ha-ha which is set below ground level, so as not to interrupt a view yet acting as a barrier to cattle for example.

An old Italian wall surrounded by flowers

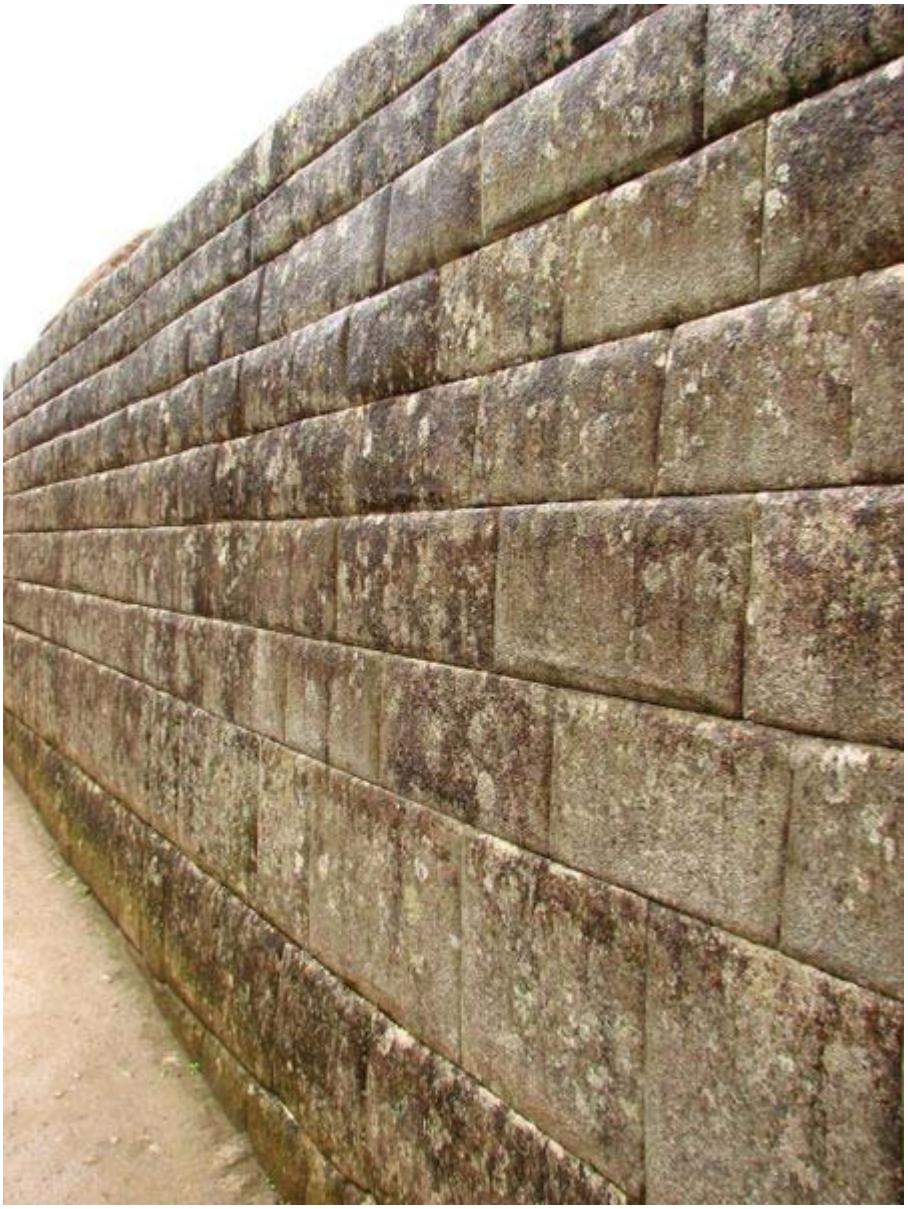
Before the invention of artillery, many of the world's cities and towns, particularly in Europe and Asia, had protective walls (also called town walls or city walls). In fact, the English word "wall" is derived from Latin *vallum*, which was a type of fortification wall. Since they are no longer relevant for defense, such cities have grown beyond their walls, and many of the walls, or portions thereof, have been torn down, for example in Rome, Italy and in Beijing, China. Examples of protective walls on a much larger scale include the Great Wall of China and Hadrian's Wall.

Separation walls

Some walls are designed to formally separate one population from another. A example was the Berlin Wall, which divided East and West Berlin.

Retaining walls

Dry-stone wall - Grendon



Ashlar wall - Inca wall at Machu Picchu, Peru

In areas of rocky soils around the world, farmers have often pulled large quantities of stone out of their fields to make farming easier and have stacked those stones to make walls that either mark the field boundary, or the property boundary, or both.

Retaining walls are a special type of wall, that may be either external to a building or part of a building, that serves to provide a barrier to the movement of earth, stone or water. The ground surface or water on one side of a retaining wall will be noticeably higher than on the other side. A dike is one type of retaining wall, as is a levee, a load-bearing foundation wall, and a sea wall.

Shared walls

Special laws often govern walls shared by neighbouring properties. Typically, one neighbour cannot alter the common wall if it is likely to affect the building or property on the other side. A wall may also separate apartment or hotel rooms from each other. Each wall has two sides and breaking a wall on one side will break the wall on the other side.

Portable walls

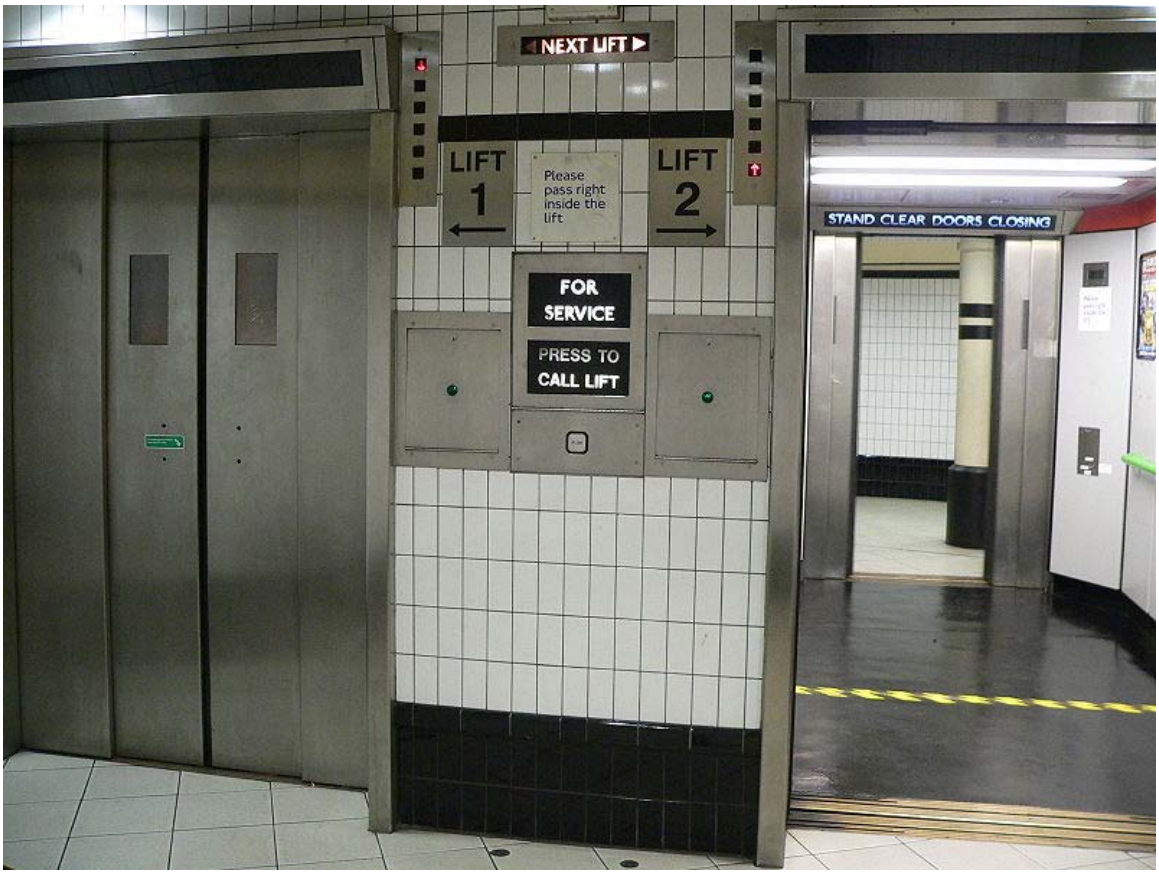
Portable walls, such as room dividers or portable partitions, are used to take a large open space and effectively divide it into smaller rooms. Portable walls can be static such as cubicle walls, or they can be wall panels mounted on casters to provide an easy way to reconfigure assembly space. They are often found inside schools, churches, convention centers, hotels and corporate facilities.

Etymology

It is notable that English uses the same word to refer to an external wall, and the internal sides of a room. This is by no means universal, and many languages distinguish between the two. In German, some of this distinction can be seen between *Wand* and *Mauer*, in Spanish between *pared* and *muro*.

Chapter- 10

Elevator



A set of lifts in the lower level of a London Underground station in the United Kingdom. The arrows indicate each lift's position and direction of travel.

This elevator to the Alexanderplatz U-Bahn station in Berlin is built with glass walls, exposing the inner workings.

An **elevator** (or **lift** in British English) is a vertical transport equipment that efficiently moves people or goods between floors (levels, decks) of a building, vessel or other structure. Elevators are generally powered by electric motors that either drive traction cables and counterweight systems like a hoist, or pump hydraulic fluid to raise a cylindrical piston like a jack.

Languages other than English may have loanwords based on either *elevator* (e.g., Korean & Japanese) or *lift* (e.g., Russian & Cantonese).

Because of wheelchair access laws, elevators are often a legal requirement in new multi-story buildings, especially where wheelchair ramps would be impractical.

Design

Some argue that lifts began as simple rope or chain hoists. A lift is essentially a platform that is either pulled or pushed up by a mechanical means. A modern day lift consists of a cab (also called a "cage" or "car") mounted on a platform within an enclosed space called a shaft or sometimes a "hoistway". In the past, lift drive mechanisms were powered by

steam and water hydraulic pistons or by hand. In a "traction" lift, cars are pulled up by means of rolling steel ropes over a deeply grooved pulley, commonly called a sheave in the industry. The weight of the car is balanced with a counterweight. Sometimes two lifts always move synchronously in opposite directions, and they are each other's counterweight.

The friction between the ropes and the pulley furnishes the traction which gives this type of lift its name.

Hydraulic lifts use the principles of hydraulics (in the sense of hydraulic power) to pressurize an above ground or in-ground piston to raise and lower the car. Roped hydraulics use a combination of both ropes and hydraulic power to raise and lower cars. Recent innovations include permanent magnet motors, machine room-less rail mounted gearless machines, and microprocessor controls.

The technology used in new installations depends on a variety of factors. Hydraulic lifts are cheaper, but installing cylinders greater than a certain length becomes impractical for very high lift hoistways. For buildings of much over seven stories, traction lifts must be employed instead. Hydraulic lifts are usually slower than traction lifts.

Lifts are a candidate for mass customization. There are economies to be made from mass production of the components, but each building comes with its own requirements like different number of floors, dimensions of the well and usage patterns.

Elevator doors

Elevator doors protect riders from falling into the shaft. The most common configuration is to have two panels that meet in the middle, and slide open laterally. In a cascading configuration (potentially allowing wider entryways within limited space), the doors run on independent tracks so that while open, they are tucked behind one another, and while closed, they form cascading layers on one side. This can be configured so that two sets of such cascading doors operate like the center opening doors described above, allowing for a very wide elevator cab. In less expensive installations the elevator can also use one large "slab" door: a single panel door the width of the doorway that opens to the left or right laterally. Some buildings have elevators with the single door on the shaft way, and double cascading doors on the cab.

Machine room-less

General

for a single or a group of elevators.

Machine room-less elevators are designed so that most of its components fit within the shaft containing the elevator car; and a small cabinet houses the elevator controller. Other

than the machinery being in the hoistway, the equipment is similar to a normal traction elevator.

This new design was first developed by Kone in 1996.

Benefits

- creates more usable space
- use less energy (70-80% less than hydraulic elevators)
- uses no oil
- all components are above ground similar to roped hydraulic type elevators (this takes away the environmental concern that was created by the hydraulic cylinder on direct hydraulic type elevators being stored underground)
- slightly lower cost than other elevators
- can operate at faster speeds than hydraulics but not normal traction units

Detriments

- Equipment can be harder to service and maintain.
- No code has been approved for the installation of Residential elevator Equipment.

Facts

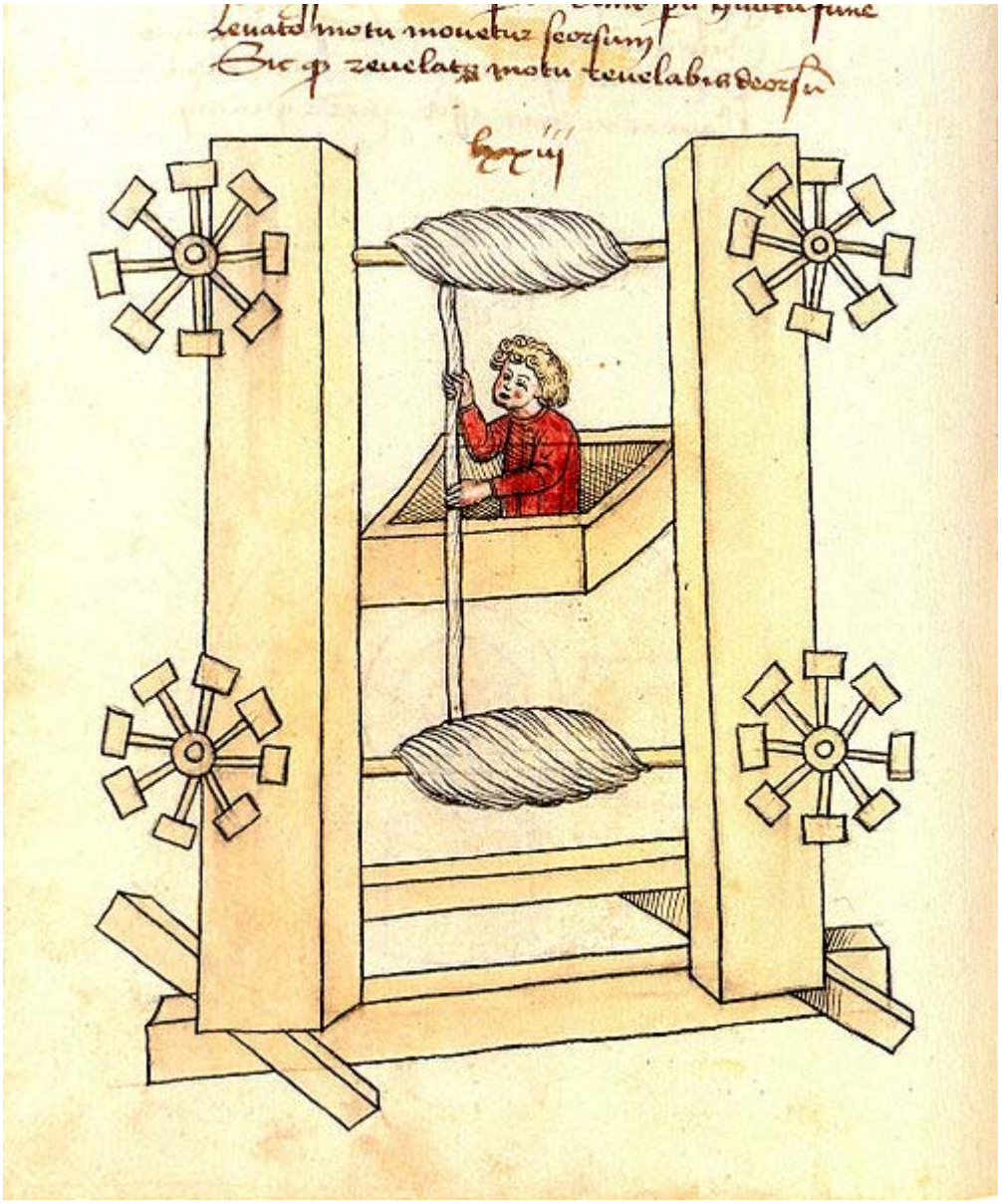
- Noise level is at 50-55 dBA (A-weighted decibels), which can be lower than some but not all types of elevators
- Usually used for low-rise to mid-rise buildings
- The motor mechanism is placed in the hoistway itself
- The US was slow to accept the commercial MRL Elevator because of codes

---national and local building codes did not address elevators without machine rooms. Residential MRL Elevators are still not allowed by the ASME A17 code in the US.

Elevator modernization

Most elevators are built to provide about 20 years of service, as long as service intervals specified and periodic maintenance/inspections by the manufacturer are followed. As the elevator ages and equipment become increasingly difficult to find or replace, along with code changes and deteriorating ride performance, a complete overhaul of the elevator may be suggested to the building owners.

History



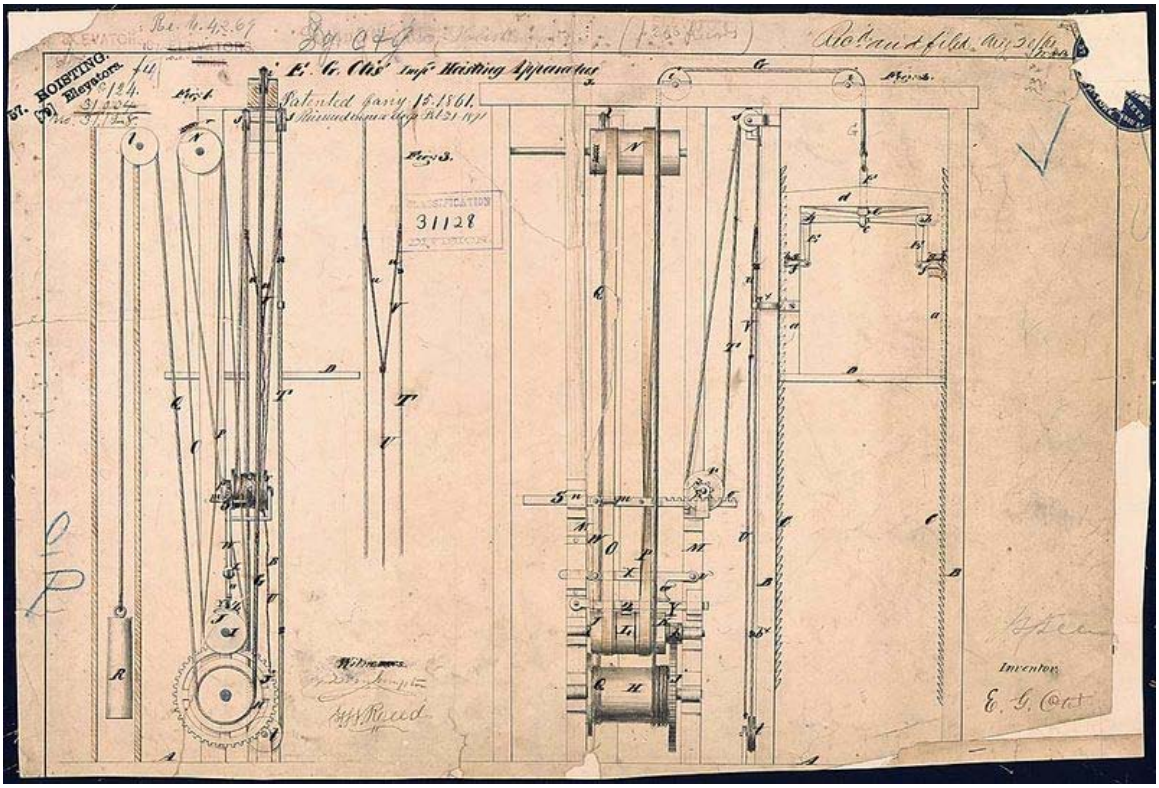
Elevator design by the German engineer Konrad Kyeser (1405)

The first reference to an elevator is in the works of the Roman architect Vitruvius, who reported that Archimedes (c. 287 BC – c. 212 BC) built his first elevator probably in 236 BC. In some literary sources of later historical periods, elevators were mentioned as cabs on a hemp rope and powered by hand or by animals. It is supposed that elevators of this type were installed in the Sinai monastery of Egypt.

In 1000, the *Book of Secrets* by Ibn Khalaf al-Muradi in Islamic Spain described the use of an elevator-like lifting device, in order to raise a large battering ram to destroy a

fortress. In the 17th century the prototypes of elevators were located in the palace buildings of England and France.

The ancient and medieval elevators used the drive system based on hoist. The invention of another system. based on the screw drive, was perhaps the most important step in elevator technology since ancient times, which finally led to the creation of modern passenger elevators. The first screw drive elevator was built by Ivan Kulibin and installed in Winter Palace in 1793, while several years later another Kulibin's elevator was installed in Arkhangelskoye near Moscow. In 1823, an "ascending room" made its debut in London.



Elisha Otis' elevator patent drawing, 15 January 1861.

In the middle 1800s, there were many types of crude elevators that carried freight. Most of them ran hydraulically. The first hydraulic elevators used a plunger below the car to raise or lower the elevator. A pump applied water pressure to a plunger, or steel column, inside a vertical cylinder. Increasing the pressure allowed the elevator to descend. The elevator also used a system of counter-balancing so that the plunger did not have to lift the entire weight of the elevator and its load. The plunger, however, was not practical for tall buildings, because it required a pit as deep below the building as the building was tall. Later a rope-geared elevator with multiple pulleys was developed.

Henry Waterman of New York is credited with inventing the "standing rope control" for an elevator in 1850.

In 1852, Elisha Otis introduced the safety elevator, which prevented the fall of the cab if the cable broke. The design of the Otis safety elevator is somewhat similar to one type still used today. A governor device engages knurled roller(s), locking the elevator to its guides should the elevator descend at excessive speed. He demonstrated it at the New York exposition in the Crystal Palace in a dramatic, death-defying presentation in 1854.

On March 23, 1857 the first Otis passenger elevator was installed at 488 Broadway in New York City. The first elevator shaft preceded the first elevator by four years. Construction for Peter Cooper's Cooper Union building in New York began in 1853. An elevator shaft was included in the design for Cooper Union, because Cooper was confident that a safe passenger elevator would soon be invented. The shaft was cylindrical because Cooper felt it was the most efficient design. Later Otis designed a special elevator for the school. Today the Otis Elevator Company, now a subsidiary of United Technologies Corporation, is the world's largest manufacturer of vertical transport systems.

The first electric elevator was built by Werner von Siemens in 1880. The safety and speed of electric elevators were significantly enhanced by Frank Sprague. The inventor Anton Freissler developed the ideas of von Siemens and built up a successful enterprise in Austria-Hungary.

The development of elevators was led by the need for movement of raw materials including coal and lumber from hillsides. The technology developed by these industries and the introduction of steel beam construction worked together to provide the passenger and freight elevators in use today.

In 1874, J.W. Meaker patented a method which permitted elevator doors to open and close safely. U.S. Patent 147,853

In 1882, when hydraulic power was a well established technology, a company later named the London Hydraulic Power Company was formed. It constructed a network of high pressure mains on both sides of the Thames which, ultimately, extended to 184 miles and powered some 8,000 machines, predominantly lifts (elevators) and cranes.

In 1929, Clarence Conrad Crispen, with Inclinator Company of America, created the first residential elevator. Crispen also invented the first inclined stairlift.

Elevator safety

Pneumatic vacuum elevators

Pneumatic or "Vacuum" elevators operate without cables and can be installed more easily and quickly than their alternatives since their housing comprises prefabricated sections which are considerably narrower than conventional lift shafts. These sections are often transparent and afford the passenger a near 360° view.

Cable-borne elevators

Statistically speaking, elevators are extremely safe. Their safety record is unsurpassed by any other vehicle system. In 1998, it was estimated that approximately eight 100-millionths of one percent (1 in 12 million) of elevator rides resulted in an anomaly, and the vast majority of these were minor things such as the doors failing to open. For all practical purposes, there are no cases of elevators simply free-falling and killing the passengers inside; of the 20 to 30 elevator-related deaths each year, most of them are maintenance-related - for example, technicians leaning too far into the shaft or getting caught between moving parts, and most of the rest are attributed to easily avoidable accidents, such as people stepping blindly through doors that open into empty shafts or being strangled by scarves caught in the doors. In fact, prior to the September 11th terrorist attacks, the only known free-fall incident in a modern cable-borne elevator happened in 1945 when a B-25 bomber struck the Empire State Building in fog, severing the cables of an elevator cab, which fell from the 75th floor all the way to the bottom of the building, seriously injuring (though not killing) the sole occupant - the female elevator operator. However, there was an incident in 2007 at a Seattle children's hospital, where a ThyssenKrupp ISIS machine room-less elevator free-fell until the safety brakes were engaged. This was due to a flaw in the design where the cables were connected at one common point, and the kevlar ropes had a tendency to overheat and cause slipping (or, in this case, a free-fall). While it is possible (though extraordinarily unlikely) for an elevator's cable to snap, all elevators in the modern era have been fitted with several safety devices which prevent the elevator from simply free-falling and crashing. An elevator cab is typically borne by six or eight hoist cables, each of which is capable on its own of supporting the full load of the elevator plus twenty-five percent more weight. In addition, there is a device which detects whether the elevator is descending faster than its maximum designed speed; if this happens, the device causes copper brake shoes to clamp down along the vertical rails in the shaft, stopping the elevator quickly, but not so abruptly as to cause injury. This device is called the governor, and was invented by Elisha Graves Otis. In addition, a hydraulic buffer is installed at the bottom of the shaft to cushion any impact somewhat.

Hydraulic elevators

Past problems with early hydraulic elevators meant those built prior to a code change in 1972 were subject to possible catastrophic failure. The code had previously required only single-bottom hydraulic cylinders. In the event of a cylinder breach, an uncontrolled fall of the elevator might result. Because it is impossible to verify the system completely without a pressurized casing (as described below), it is necessary to remove the piston to inspect it. The cost of removing the piston is such that it makes no economic sense to re-install the old cylinder; therefore it is necessary to replace the cylinder and install a new piston. Another solution to protect against a cylinder blowout is to install a "life jacket." This is a device which, in the event of an excessive downward speed, clamps onto the cylinder and stops the car. A device known as a rupture valve is often attached to the hydraulic inlet/outlet of the piston and can be adjusted for a maximum flow rate. If a pipe or hose were to break (rupture), the flow rate of the rupture valve will surpass a set limit

and mechanically stop the outlet flow of hydraulic fluid, thus stopping the piston and the car in the down direction.

In addition to the safety concerns for older hydraulic elevators, there is risk of leaking hydraulic oil into the aquifer and causing potential environmental contamination. This has led to the introduction of PVC liners (casings) around hydraulic cylinders which can be monitored for integrity.

In the past decade, recent innovations in inverted hydraulic jacks have eliminated the costly process of drilling the ground to install a borehole jack. This also eliminates the threat of corrosion to the system and increases safety.

Mine-shaft elevators

Safety testing of mine shaft elevator rails is routinely undertaken. The method involves destructive testing of a segment of the cable. The ends of the segment are frayed, then set in conical zinc molds. Each end of the segment is then secured in a large, hydraulic stretching machine. The segment is then placed under increasing load to the point of failure. Data about elasticity, load, and other factors is compiled and a report is produced. The report is then analyzed to determine whether or not the entire rail is safe to use.

Uses of elevators

A residential elevator in Singapore.

Passenger service

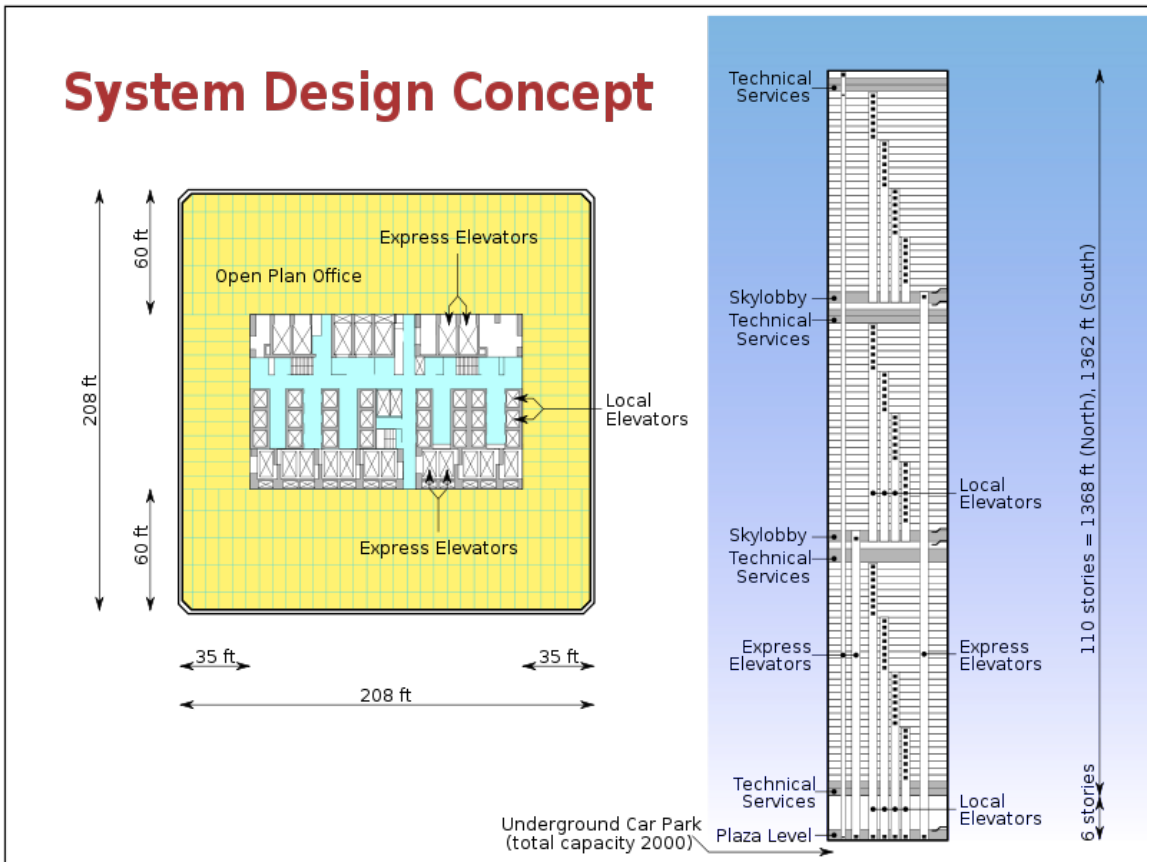
A passenger elevator is designed to move people between a building's floors.

Passenger elevators capacity is related to the available floor space. Generally passenger elevators are available in capacities from 1,000 to 6,000 pounds (450–2,700 kg) in 500 lb (230 kg) increments. Generally passenger elevators in buildings eight floors or less are hydraulic or electric, which can reach speeds up to 200 ft/min (1.0 m/s) hydraulic and up to 500 ft/min electric. In buildings up to ten floors, electric and gearless elevators are likely to have speeds up to 500 ft/min (2.5 m/s), and above ten floors speeds begin at 500 ft/min (2.5 m/s) up to 2000 ft/min (10 m/s).

Sometimes passenger elevators are used as a city transport along with funiculars. For example, there is a 3-station underground public elevator in Yalta, Ukraine, which takes passengers from the top of a hill above the Black Sea on which hotels are perched, to a tunnel located on the beach below. At Casco Viejo station in the Bilbao Metro, the elevator that provides access to the station from a hilltop neighborhood doubles as city

transportation: the station's ticket barriers are set up in such a way that passengers can pay to reach the elevator from the entrance in the lower city, or vice versa.

Types of passenger elevators



The former World Trade Center's twin towers used skylobbies, located on the 44th and 78th floors of each tower.

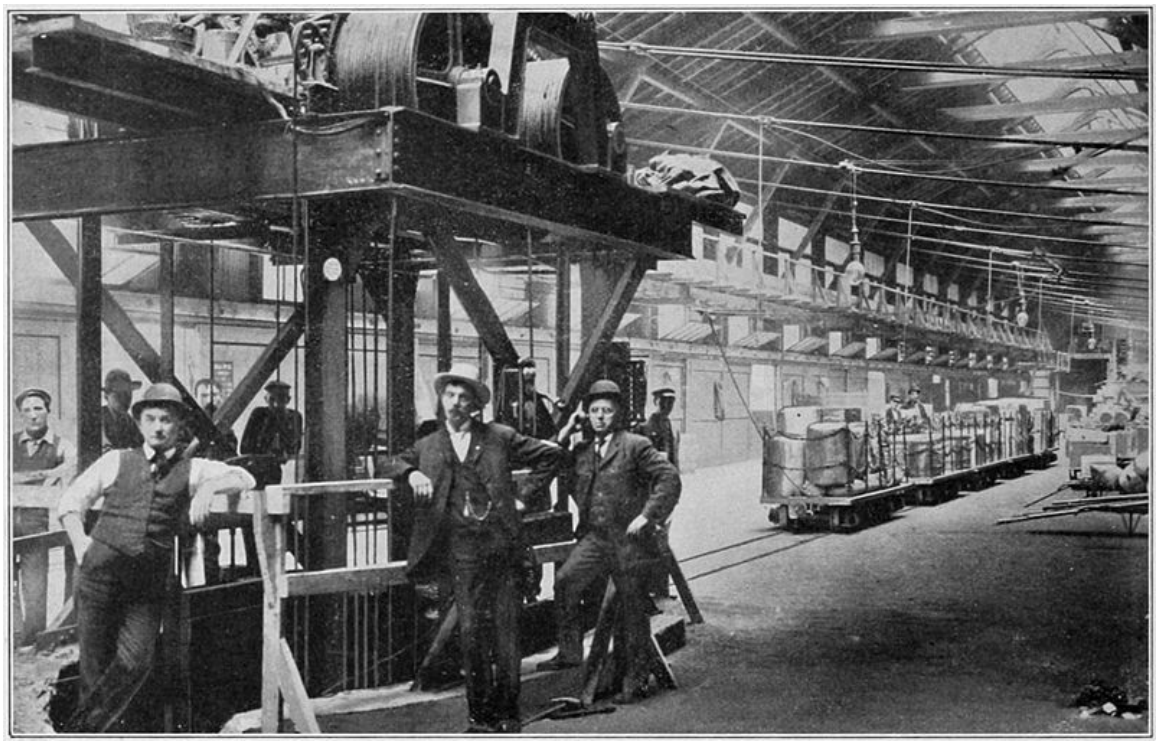
Passenger elevators may be specialized for the service they perform, including: hospital emergency (Code blue), front and rear entrances, a television in high rise buildings, double decker, and other uses. Cars may be ornate in their interior appearance, may have audio visual advertising, and may be provided with specialized recorded voice instructions.

An **express elevator** does not serve all floors. For example, it moves between the ground floor and a skylobby, or it moves from the ground floor or a skylobby to a range of floors, skipping floors in between. These are especially popular in eastern Asia.

Capacity

Residential elevators may be small enough to only accommodate one person while some are large enough for more than a dozen. Wheelchair, or platform lifts, a specialized type of elevator designed to move a wheelchair 6 ft (1.8 m) or less, often can accommodate just one person in a wheelchair at a time with a load of 1000 lb (450 kg).

Freight elevators

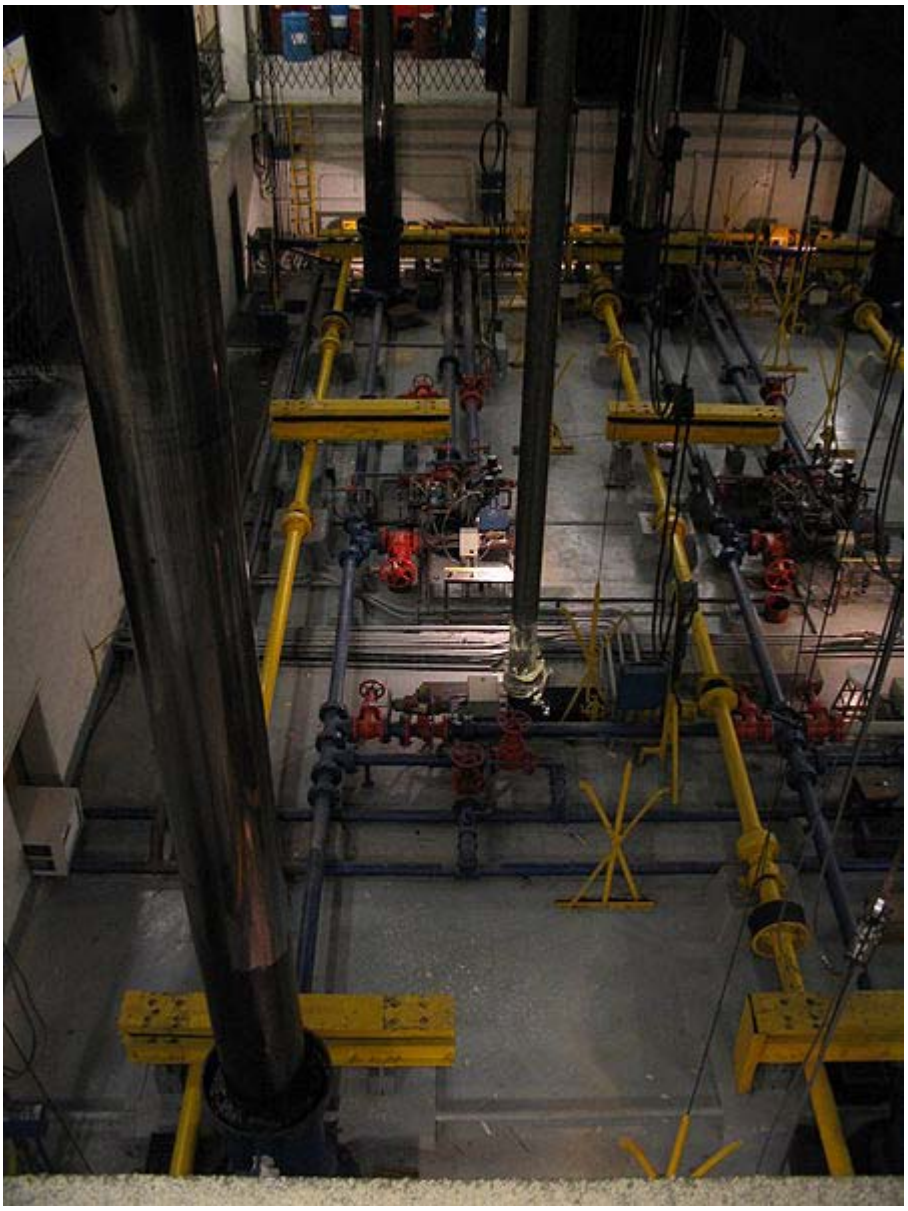


A specialized elevator from 1905 for lifting narrow gauge railroad cars between a railroad freight house and the Chicago Tunnel Company tracks below.

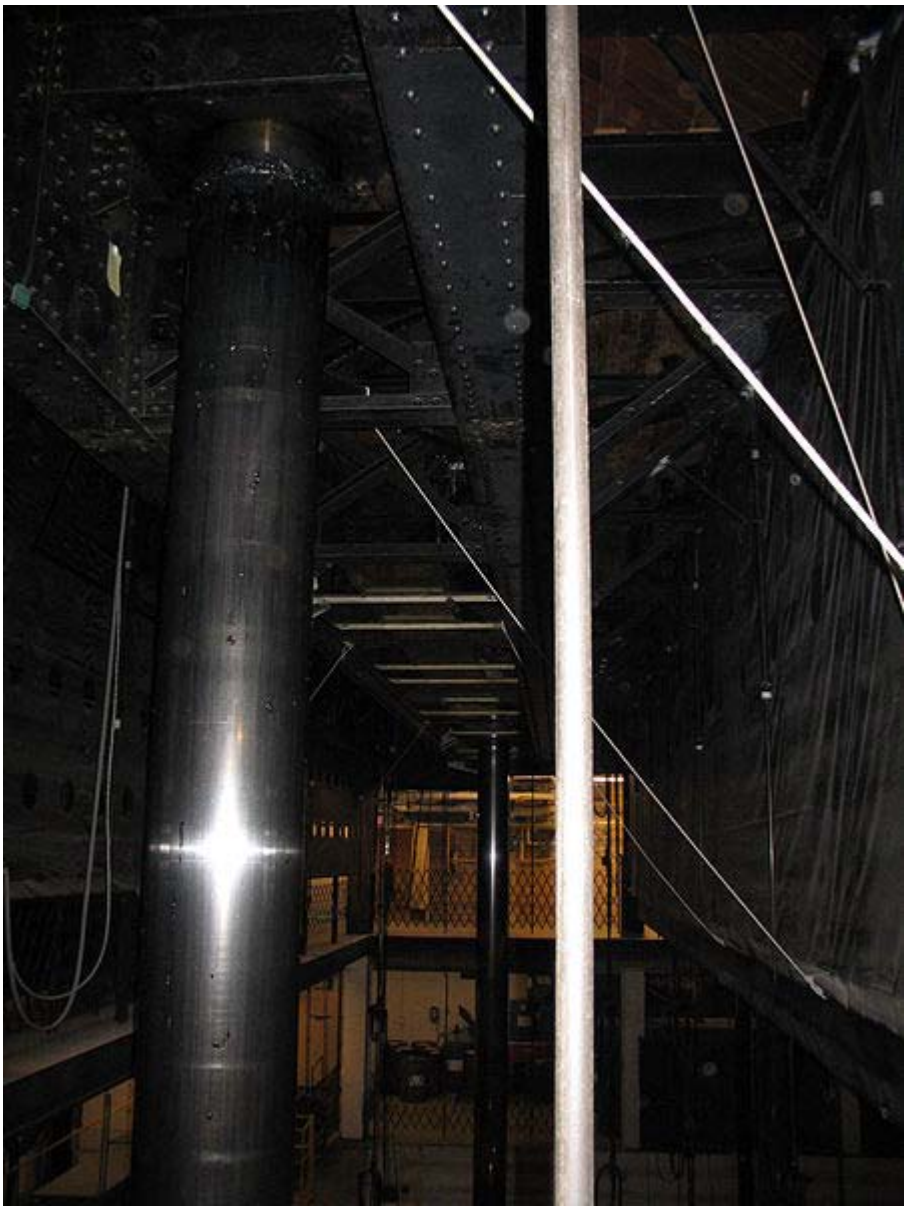
A freight elevator, or goods lift, is an elevator designed to carry goods, rather than passengers. Freight elevators are generally required to display a written notice in the car that the use by passengers is prohibited (though not necessarily illegal), though certain freight elevators allow dual use through the use of an inconspicuous riser. Freight elevators are typically larger and capable of carrying heavier loads than a passenger elevator, generally from 2,300 to 4,500 kg. Freight elevators may have manually operated doors, and often have rugged interior finishes to prevent damage while loading and unloading. Although hydraulic freight elevators exist, electric elevators are more energy efficient for the work of freight lifting.

Stage lifts

Stage and orchestra lifts are specialized lifts, typically powered by hydraulics, that are used to lift entire sections of a theater stage. For example, Radio City Music Hall has four such lifts: an "orchestra lift" that covers a large area of the stage, and three smaller lifts near the rear of the stage. In this case, the orchestra lift is powerful enough to raise an entire orchestra, or an entire cast of performers (including live elephants) up to stage level from below.



The pit beneath the orchestra lift at Radio City Music Hall



Orchestra lift at Radio City Music Hall as viewed from beneath the stage

Vehicle elevators

Vehicular elevators are used within buildings or areas with limited space (in lieu of ramps), typically to move cars into the parking garage or manufacturer's storage. Geared hydraulic chains (not unlike bicycle chains) generate lift for the platform and there are no counterweights. To accommodate building designs and improve accessibility, the platform may rotate so that the driver only has to drive forward. Most vehicle elevators have a weight capacity of 2 tons.

Rare examples of extra-heavy elevators for 20-ton lorries, and even for railcars (like one that was used at Dnipro Station of the Kiev Metro) also occur.

Boat elevators

In some smaller canals, boats and small ships can pass between different levels of a canal with a boat lift rather than through a canal lock.

Aircraft elevators

An F/A-18C on an aircraft elevator of the USS *Kitty Hawk*

On aircraft carriers, elevators carry aircraft between the flight deck and the hangar deck for operations or repairs. These elevators are designed for much greater capacity than other elevators, up to 200,000 pounds (90 tonnes) of aircraft and equipment. Smaller elevators lift munitions to the flight deck from magazines deep inside the ship.

On some passenger double-deck aircraft such as the Boeing 747, Lockheed L-1011 or other widebody aircraft, lifts transport flight attendants and food and beverage trolleys from lower deck galleys to upper passenger carrying decks.

Residential elevator

The residential elevator is often permitted to be of lower cost and complexity than full commercial elevators. They may have unique design characteristics suited for home furnishings, such as hinged wooden shaft-access doors rather than the typical metal sliding doors of commercial elevators. Construction may be less robust than in commercial designs with shorter maintenance periods, but safety systems such as locks on shaft access doors, fall arrestors, and emergency phones must still be present in the event of malfunction.

Limited Use / Limited Application

The limited-use, limited-application (LU/LA) elevator is a special purpose passenger elevator used infrequently, and which is exempt from many commercial regulations and accommodations. For example, a LU/LA is primarily meant to be handicapped accessible, and there might only be room for a single wheelchair and a standing passenger.

Dumbwaiter

Dumbwaiters are small freight elevators that are intended to carry food rather than passengers. They often link kitchens with rooms on other floors.

Paternoster

A paternoster in Berlin, Germany

A special type of elevator is the paternoster, a constantly moving chain of boxes. A similar concept, called the manlift or humanlift, moves only a small platform, which the rider mounts while using a handhold and was once seen in multi-story industrial plants.

Scissor lift

The scissor lift is yet another type of lift. As most of these lifts are self-contained, these lifts can be easily moved to where they are needed.

Rack-and-pinion lift

The rack-and-pinion lift is another type of lift. This lifts are simpler in construction, but noisy and slow. They are nonetheless the most used type of lift for buildings under construction (to move materials and tools up and down).

Material handling belts and belt elevators

A different kind of **elevator** is used to transport material. It generally consists of an inclined plane on which a conveyor belt runs. The conveyor often includes partitions to prevent the material from sliding backwards. These elevators are often used in industrial and agricultural applications. When such mechanisms (or spiral screws or pneumatic transport) are used to elevate grain for storage in large vertical silos, the entire structure is called a grain elevator.

There have occasionally been lift belts for humans; these typically have steps about every seven feet along the length of the belt, which moves vertically, so that the passenger can stand on one step and hold on to the one above. These belts are sometimes used, for example, to carry the employees of parking garages, but are considered too dangerous for public use.