ARCH 5605
KIRSTEN TUDOR

TOPIC

Vertical Circulation: Stairs & Elevators

STAIRS

Leon Alberti and Andrea Palladio were among the first to give architectural treatises in regards to the design of stairs. Development of the different types of stairs continued through the Renaissance, Gothic, Baroque, Classical ages all the way to the 19th century where stair construction primarily consisted of wood, stone, and iron. These three methods evolved into wood, concrete, and steel in the 20th century. The first International Building Code was published in 1997 giving the first code requirements for stairs. The following information is to be used to help design and size stairs, exit stairs, and elevators for high rise construction, while giving a brief overview of stairs in general.

STAIRS					
Construction Type	Used in	Materials	Methods	Benefits	Downfalls
Timber Stairs	Houses, Historic preservation	Pine, Spruce, Maple, Beech, Oak, Ash	Hand-crafted, For Manufacturing & Large Projects: Robot technology, Laser Projection Systems	• affordable • renewable resource • load bearing qualities • relatively lightweight • visually appealing material	• combustible • Hand-craftsmanship can take more time
Concrete Stairs	High Rise, Hotel, Apartment, Health Care, Education, Fire Stairs	Concrete, Reinforced Concrete	Solid Concrete, Prefabricated Reinforced Concrete	• Favorable because of fire resistance • Prefabrication allows increased precision and higher surface quality to be achieved • Coloring of aggregates and surface treatments can be easily made	• Requires sound insulation
Steel Stairs	Historic preservation, High Rise, Appartment, Hotel, Health Care, Fire Stairs	Iron, Steel, Stainless Steel	Prefabricated, Machine produced from shop drawings	• Large load bearing capacity condensed into smallest dimensions • manufacturing precision available • non-flammable qualities • high structural efficiency • option of transparent design • can be combined with concrete, concrete blocks, stone, timber, and glass. • Quick assembly	• if used on exterior, corrosion can be a problem • requires metal, plastic, or paint to give weather protection

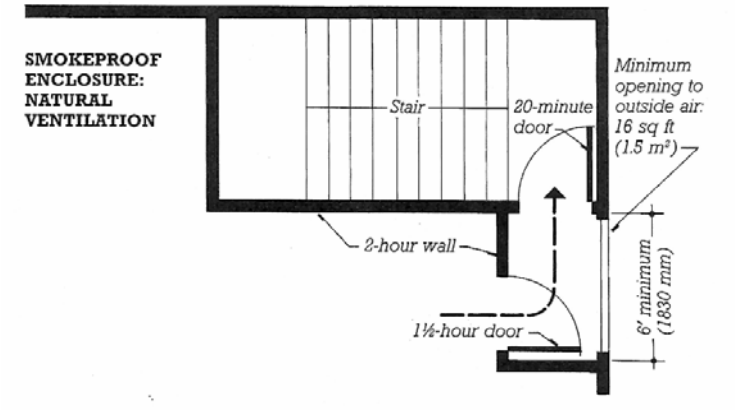
Exit Stairways

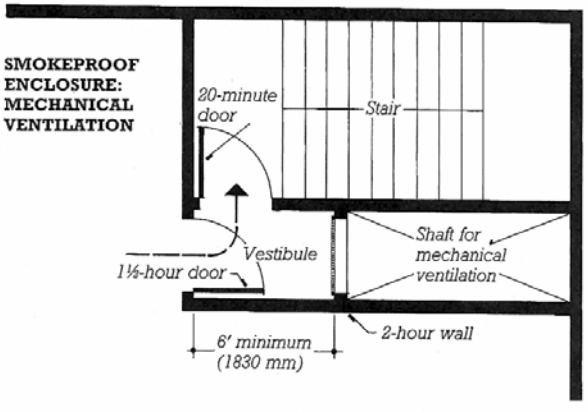
Usually, each floor of a building must have at least two exits and not less than the minimum listed in the following table

Occupant Load	Min Number of Exits
500 or fewer persons	2
501 to 1000	3
More than 1000	4

The IBC requires stairway enclosures serving four stories or more to be built of 2-hour construction with 1 ½ hour self closing doors. In an exit enclosure serving an occupant load of more than 50 the door is requires to swing in the direction of egress travel. Dimensions and typical designs for stairways and stair enclosures are given in a table at the end of this paper. Egress widths are based on the occupant load of the largest single floor served. Occupant loads do not normally accumulate from one floor to the next. Where mezzanines discharge through a floor below, egress components serving that floor are sized for the combined occupant load of the floor and the mezzanine. In general, escalators and elevators are not used as required exits. In the IBC, however, elevators in a smokeproof shaft can be permitted to serve as a means of egress for disabled persons.

Exit stair enclosures, as required by most building codes, are designed as smoke proof enclosures to provide a higher degree of protection against the movement of smoke into a stairway during a fire emergency. The IBC requires smokeproof stair enclosures in a building with occupied floors greater than 75 ft above the lowest level of fire department vehicle access, which includes most high-rise buildings. One can either use a smokeproof stair with natural ventilation or mechanical. Examples are given in the following diagrams.





New developments since the September 11th World Trade Center incident have made vertical circulation safer and more accessible, especially to those in the fire safety industry. The requirements are as follows:

- An additional exit stairway for buildings more than 420-feet high.
- A minimum of one fire service access elevator for buildings more than 120-feet high.
- Luminous markings showing the exit path in buildings more than 75-feet high to facilitate rapid egress and full building evacuation.

*Note: curved stairways and spiral stairways may not serve as required exist in any building other than a residential muti-family (R2) and one- and two-family (R3) types.

Example of Determining Egress Exit Widths

Problem: Design an exit for a department store basement, sprinklered, dimensions 105 by 292.55 ft.

Solution:

1 – Determine the occupancy group.
Department store belongs under group M.

2 – Multiply dimensions of the building floor to get gross area
105 X 292.55 = 30,720

3 – Determine the occupancy load based on Table 10041.1 on page 204 of the IBC 2006.
IBC says that 30 sq. ft. per occupant is allowed for mercantile buildings.
30,720 / 30 = 1024 people

4- Look at the minimum number of exits table on the previous page to determine how many exits are needed
1000+ people = 4 exits

5 – Divide occupancy by the number of exits
1024 / 4 = 256 people per exit

6 – Look in the width per occupant table to find the percentage of how much width must be provided for doorways and stairs. This table is included at the end of the stairs section in this paper or can be found in the 2006 IB on page 205 Table 1005.1.
.15 in of width must be provided per occupant in corridors and doorways
.2 in per occupant in stairways

7 – Using the Egress widths chart from the IBC included at the end of this section read horizontally from the occupancy to the width per occupant line then downward to find the width of the corridor, doors, and stairway.
From the 256 occupant line to the .15 diagonal, move downward to find that the length of the corridor is 38" which is rounded up to 44" based on IBC minimum clear corridor width.

Extending the line downward you will see that you can select either two 3-ft doors or a single 4-ft door or a pair of 3-ft doors without a center mullion
From the 256 occupant line to the .2 in diagonal, move downward to arrive at a stair width of 52-in.

Width per Occupant			
For Doors, Corridors, and Ramps		**For Stairs**	
Unsprinklered	**Sprinklered**	**Unsprinklered**	**Sprinklered**
0.2" (5 mm)	0.15" (4 mm)	0.3" (8 mm)	0.2" (5 mm)
0.2" (5 mm)	0.15" (4 mm)	0.3" (8 mm)	0.2" (5 mm)
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0.2" (5 mm)	0.2" (5 mm)	0.4" (10 mm)	0.3" (8 mm)
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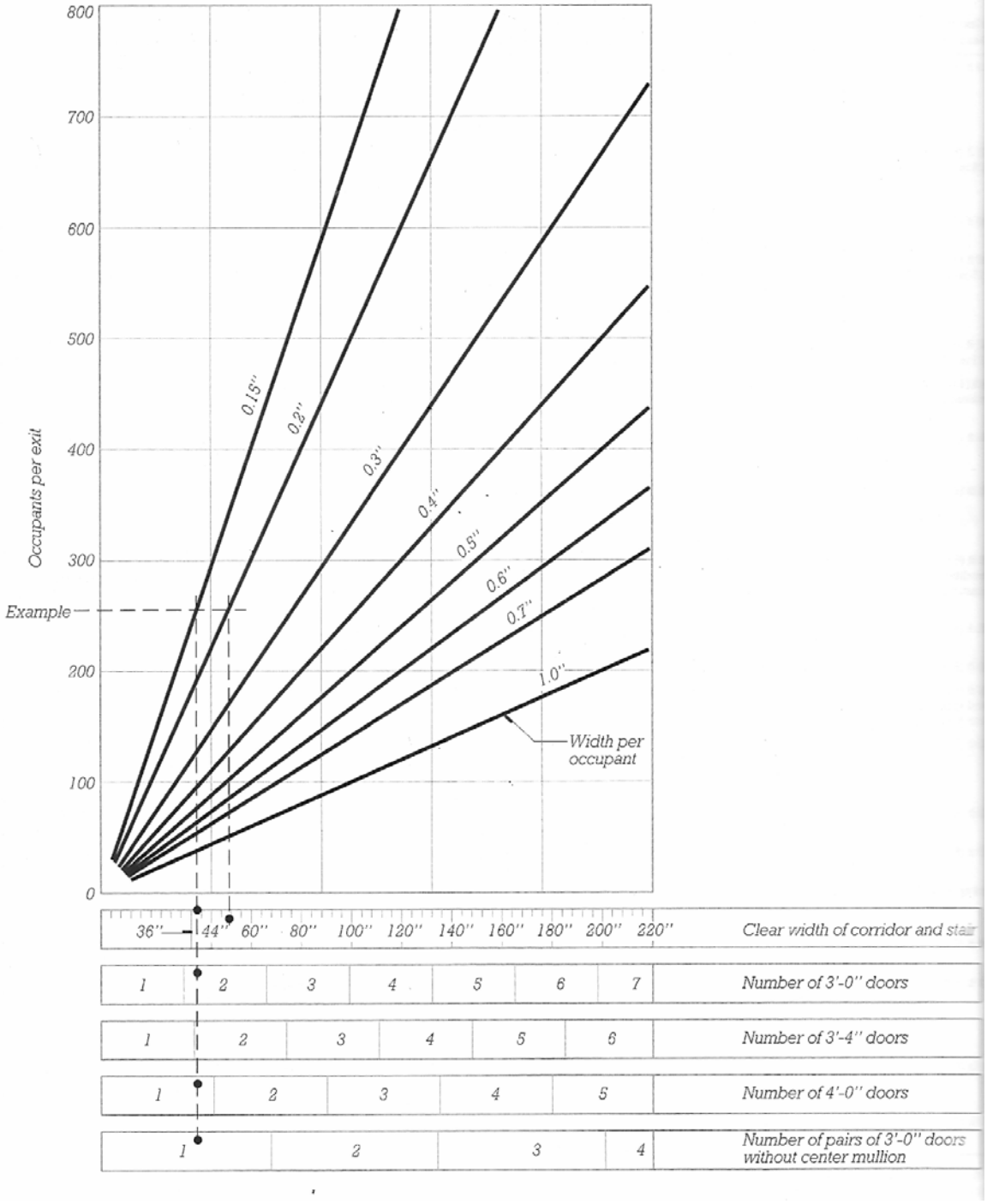
EGRESS WIDTHS: INTERNATIONAL BUILDING CODE



ONE-FLIGHT STAIR: ENGLISH UNITS

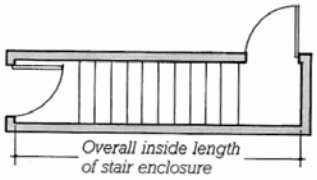
Floor-to-Floor Height (ft-in.)	Number of Risers	Riser Height (in.)	Tread Depth (in.)	Overall Inside Length of Stair Enclosure (ft-in.)				
				36" Width	44" Width	56" Width	66" Width	88" Width
1-8	3	6.67	11	7-10	9-2	11-2	12-10	16-6
2-0	4	6.00	11	8-9	10-1	12-1	13-9	17-5
2-4	4	7.00	11	8-9	10-1	12-1	13-9	17-5
2-8	5	6.40	11	9-8	11-0	13-0	14-8	18-4
3-0	6	6.00	11	10-7	11-11	13-11	15-7	19-3
3-4	6	6.67	11	10-7	11-11	13-11	15-7	19-3
3-8	7	6.29	11	11-6	12-10	14-10	16-6	20-2
4-0	7	6.86	11	11-6	12-10	14-10	16-6	20-2
4-4	8	6.50	11	12-5	13-9	15-9	17-5	21-1
4-8	8	7.00	11	12-5	13-9	15-9	17-5	21-1
5-0	9	6.67	11	13-4	14-8	16-8	18-4	22-0
5-4	10	6.40	11	14-3	15-7	17-7	19-3	22-11
5-8	10	6.80	11	14-3	15-7	17-7	19-3	22-11
6-0	11	6.55	11	15-2	16-6	18-6	20-2	23-10
6-4	11	6.91	11	15-2	16-6	18-6	20-2	23-10
6-8	12	6.67	11	16-1	17-5	19-5	21-1	24-9
7-0	12	7.00	11	16-1	17-5	19-5	21-1	24-9
7-4	13	6.77	11	17-0	18-4	20-4	22-0	25-8
7-8	14	6.57	11	17-11	19-3	21-3	22-0	26-7
8-0	14	6.86	11	17-11	19-3	21-3	22-11	26-7
8-4	15	6.67	11	18-10	20-2	22-2	23-10	27-6
8-8	15	6.93	11	18-10	20-2	22-2	23-10	27-6
9-0	16	6.75	11	19-9	21-1	23-1	24-9	28-5
9-4	16	7.00	11	19-9	21-1	23-1	24-9	28-5
9-8	17	6.82	11	20-8	22-0	24-0	25-8	29-4
10-0	18	6.67	11	21-7	22-11	24-11	26-7	30-3
10-4	18	6.89	11	21-7	22-11	24-11	26-7	30-3
10-8	19	6.74	11	22-6	23-10	25-10	27-6	31-2
11-0	19	6.95	11	22-6	23-10	25-10	27-6	31-2
11-4	20	6.80	11	23-5	24-9	26-9	28-5	32-1
11-8	20	7.00	11	23-5	24-9	26-9	28-5	32-1
12-0	21	6.86	11	24-4	25-8	27-8	29-4	33-0

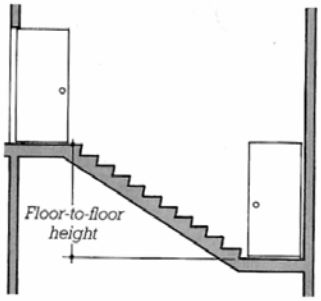
Stairway widths may be determined rapidly by using the tables and graphs on pages 268–271 and 276–277.

EXIT STAIRWAY DESIGN TABLES

ONE-FLIGHT STAIR: METRIC UNITS (280-MM TREAD, 180-MM RISER)

Floor-to-Floor Height (m)	Number of Risers	Riser Height (mm)	Tread Depth (mm)	Overall Inside Length of Stair Enclosure (m)				
				900-mm Width	1100-mm Width	1400-mm Width	1650-mm Width	2200-mm Width
0.5	3	167	280	2.36	2.76	3.36	3.86	4.96
0.6	4	150	280	2.64	3.04	3.64	4.14	5.24
0.7	4	175	280	2.64	3.04	3.64	4.14	5.24
0.8	5	160	280	2.92	3.32	3.92	4.42	5.52
0.9	5	180	280	2.92	3.32	3.92	4.42	5.52
1.0	6	167	280	3.20	3.60	4.20	4.70	5.80
1.1	7	158	280	3.48	3.88	4.48	4.98	6.08
1.2	7	172	280	3.48	3.88	4.48	4.98	6.08
1.3	8	163	280	3.76	4.16	4.76	5.26	6.36
1.4	8	175	280	3.76	4.16	4.76	5.26	6.36
1.5	9	167	280	4.04	4.44	5.04	5.54	6.64
1.6	9	178	280	4.04	4.44	5.04	5.54	6.64
1.7	10	170	280	4.32	4.72	5.32	5.82	6.92
1.8	10	180	280	4.32	4.72	5.32	5.82	6.92
1.9	11	173	280	4.60	5.00	5.60	6.10	7.20
2.0	12	167	280	4.88	5.28	5.88	6.38	7.48
2.1	12	175	280	4.88	5.28	5.88	6.38	7.48
2.2	13	170	280	5.16	5.56	6.16	6.66	7.76
2.3	13	177	280	5.16	5.56	6.16	6.66	7.76
2.4	14	172	280	5.44	5.84	6.44	6.94	8.04
2.5	14	179	280	5.44	5.84	6.44	6.94	8.04
2.6	15	174	280	5.72	6.12	6.72	7.22	8.32
2.7	15	180	280	5.72	6.12	6.72	7.22	8.32
2.8	16	175	280	6.00	6.40	7.00	7.50	8.60
2.9	17	171	280	6.28	6.68	7.28	7.78	8.88
3.0	17	177	280	6.28	6.68	7.28	7.78	8.88
3.1	18	173	280	6.56	6.96	7.56	8.06	9.16
3.2	18	178	280	6.56	6.96	7.56	8.06	9.16
3.3	19	174	280	6.84	7.24	7.84	8.34	9.44
3.4	19	179	280	6.84	7.24	7.84	8.34	9.44
3.5	20	175	280	7.12	7.52	8.12	8.62	9.72
3.6	20	180	280	7.12	7.52	8.12	8.62	9.72
3.7	21	177	280	7.40	7.80	8.40	8.90	10.00





	Max travel distance from most remote point to nearest exit enclosure		Max travel distance to two independent egress paths	Largest rom that may have only one door	Max length of a dead end corridor	Max clear corridor width	Min net clear egress door width	Min stair width
	Unsprinklered	Sprinklered						
B: Business	200'	300'	75' unsprinklered, 100' sprinklered, 100' for tenant spaces with occupancy of 30 or less	50 occupants	20' unsprinklered, 50' sprinklered	44" for more than 50 occupants	32"	44" for more than 50 occupants
R1: Hotels, Residential	200'	250'	75'	10 occupants	20'	44" for more than 50 occupants, 36" within dwelling units	32"	44" for more than 50 occupants
M: Mercantile	200'	250'	75'	50 occupants	20'	44" for more than 50 occupants	32"	44" for more than 50 occupants
P: Parking Garage	300'	400'	75' unsprinklered, 100' sprinklered, 100' for tenant spaces with occupancy of 30 or less	30 occupants	20'	44" for more than 50 occupants	32"	44" for more than 50 occupants, 36" for attendent-only areas in open garages

Stairs Other Than Residential				
	Max Riser Height	Min Riser Height	Min Tread Depth	Max Rise Between Landings
IBC	7"	4"	11"	12'

ELEVATORS

Because of its many complexities, elevator systems are usually designed by elevator consultants or the engineering department of an elevator manufacturer. The charts titled "Approximate Numbers of Elevator Shafts" and "Elevator Dimensions" included at the end of this section, can be used to approximate the number of elevators and sizes of the cars. In high rise buildings the number of shafts can be reduced somewhat with schemes of express and local elevators. Local elevators in high zones of the building can even run in the same shaft to save floor space. Two-story elevators served by two-story lobbies can reduce the number of shafts up to one-third. Walking distance to the elevator lobby should not exceed 150-ft.

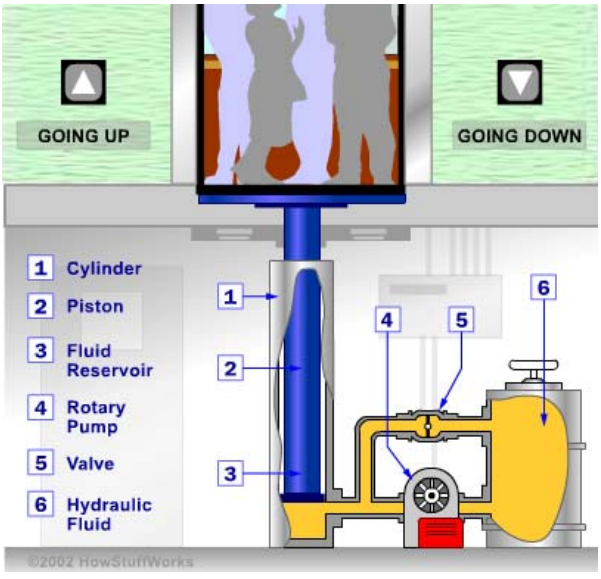
Elevators serving the same zone should be arranged in banks. Banks of three elevators in a row is the largest desirable configuration. In a high-rise building, four is acceptable. The minimum width of an elevator lobby serving a single bank of elevators is 8-ft and for a lobby with banks of elevators on both sides is 10-ft. Shafts should not be located next to occupied space for the are noisy.

Elevators usually have doors that open only to one side, although elevators with doors that open on both sides are available. Note that the shafts with elevators that have doors on two sides are slightly wider than normal to allow for the counterweights to be placed next to the side of the car. Service elevators should open to separate service rooms or workrooms. Mailrooms, receiving rooms, maintenance, and housekeeping should all be closely stationed near service elevators.

TYPES OF ELEVATORS

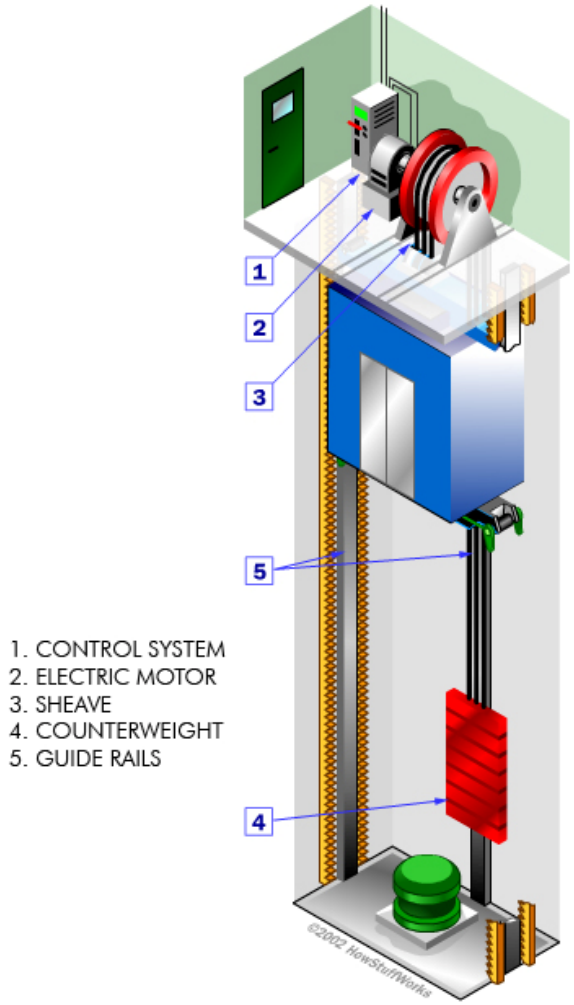
Hydraulic Elevator

The hydraulic elevator runs on a pumping system which pumps oil (or any other incompressible fluid) through a piston enclosed in a cylinder to raise the elevator to the appropriate floor. To lower the elevator, the fluid is released into the reservoir tank until the car has reached its desired destination. There are three configurations of hydraulic elevators: direct plunger (shown in the diagram), roped pluncher, and holeless.



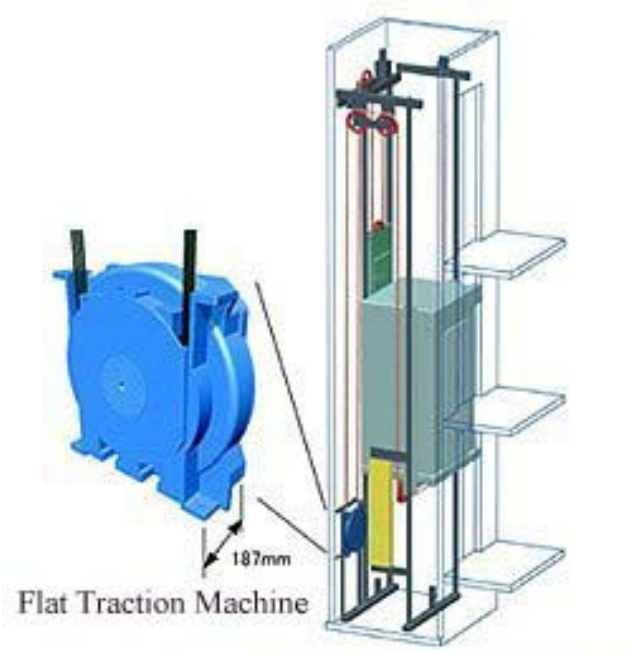
Traction Elevator

In a traction elevator, the car is raised and lowered by traction steel ropes hung from a sheave (a giant pulley with grooves) rather than pushed from below like a hydraulic elevator. The sheave is connected to an electric motor and when it turns one way the elevator is raised and when the motor turns the other way the elevator is lowered. In a gearless elevator, the motor turns the sheave directly. In a geared elevator, the motor turns a gear train that rotates the sheave. On the other side of the steel traction ropes hangs the counterweight. It weighs approximately the same as the car filled to 40% capacity. There are three different types of traction elevators. In the overhead traction elevator, the motor and sheave are placed in a mechanical room above the elevator car at the top of the shaft. In the basement traction elevator, the motor is located in a mechanical room in the basement with the sheave still above the car. In the underslung traction elevator, the motor is still located in the basement with the sheave above the car, but there is an extra system of gears that are located below the elevator to configure an alternate pulley system. Below is an example of an overhead traction elevator:



Machine Roomless Elevators (MRL)

The machine-room-less elevator is the result of technological advancements that often allow a significant reduction in the size of the electric motors used with traction equipment. These newly designed permanent magnet motors (PMM) allow the manufacturers to locate the machines in the hoistway overhead, thus eliminating the need for a machine room over the hoistway.



New Machine-Room-Less Elevator

ELEVATOR COMPARISON CHART			
	Hydraulic	Traction	MRL
Pro's	- Costs less to install - Shorter lead time - Shorter installation - No reactions at the top of the structure	- Higher speeds - Greater rise - Smooth ride quality	- Saves space and eliminates full machine room - Saves energy; uses 40-60% less than others - Eliminates Oil - Installation control - Reduces costs
Con's	- Higher noise level - Slow speeds - Poor ride quality - High energy consumption - Environmental concerns significant use of oil	- Higher installation cost - Longer lead times - Longer installation - Significant loads on top of structure - Penthouse requirements - Critical path	- Still new design - ASME 17.1 Code does not address MRL's - Until recently MRL was not more economical than traditional elevators - Each manufacturer has different limitations
Capacity	2000-3500 Passenger 4500-5000 Service	2100-4000 Passenger 4000-5000 Service	2000 to 5000 lbs
Rise (Travel)	60 ft	200-590 ft	230
Speed	150 ft per min	200-800 ft per min	200 to 500 ft per min
Max number of stops	7	63	36
Installation Cost	Low	High	Med
Energy Consumption	High	Med	Low
Maintenance	Low	High	Med
Works for What Building Type?	Low rise buildings	Medium to High Rise	Low to Medium Rise

In conclusion, a traction elevator system is the best solution for a high rise building.

APPROXIMATE NUMBERS OF ELEVATOR SHAFTS

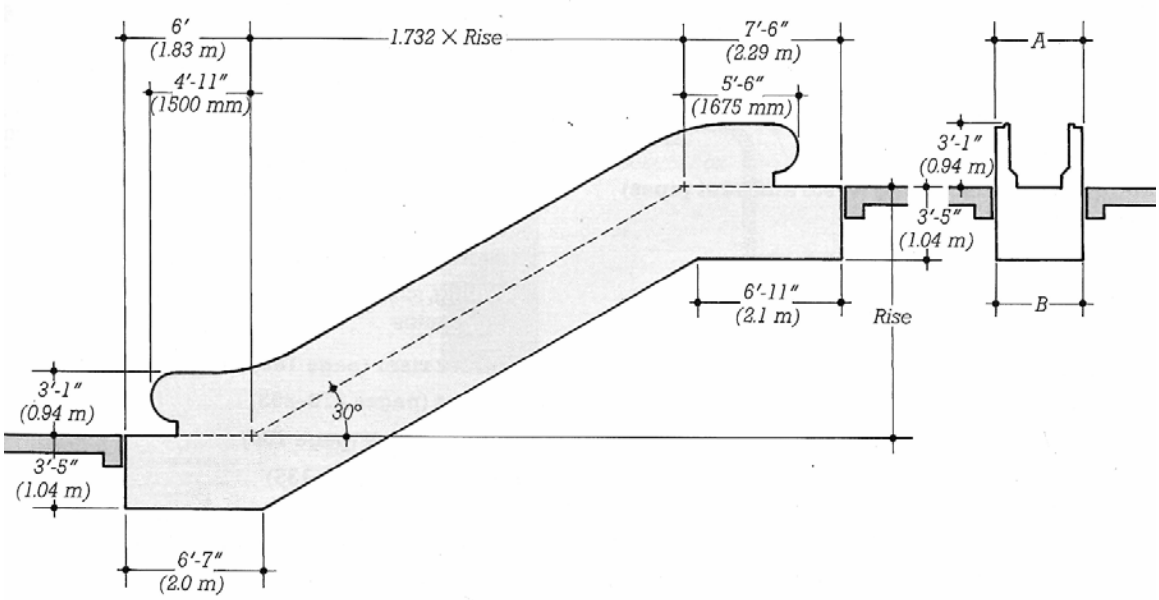
Use	Number of Shafts	Capacity of Elevator
Apartment Buildings	1 per 75 units, plus 1 service elevator for 300 units or more in a high-rise building	2000 lb to 2500 lb (900 kg to 1140 kg)
Hotels	1 per 75 rooms, plus 1 service elevator for up to 100 rooms and 1 service elevator for each additional 200 rooms	2500 lb to 3000 lb (1140 kg to 1360 kg)
Office Buildings	1 per 35,000 sq ft (3250 m^2) of area served, plus 1 service elevator per 265,000 sq ft (24,600 m^2) of area served	2500 lb to 3500 lb (1360 kg to 1590 kg)

ELEVATOR DIMENSIONS

Use	Capacity	Inside Car Dimensions	Inside Shaft Dimensions (width × depth)
Apartments, Hotels, Office Buildings, Stores	2000 lb (900 kg)	5'-8" × 4'-3" (1727 × 1295 mm)	6'-7" × 7'-4" (2006 × 2235 mm)
	2500 lb (1140 kg)	6'-8" × 4'-3" (2032 × 1295 mm)	8'-4" × 6'-8" (2540 × 2032 mm)
Office Buildings, Hotels, Stores	3000 lb (1360 kg)	6'-8" × 4'-9" (2032 × 1448 mm)	8'-4" × 7'-5" (2540 × 2261 mm)
Office Buildings, Stores	3500 lb (1590 kg)	6'-8" × 5'-5" (2032 × 1651 mm)	8'-4" × 8'-1" (2540 × 2464 mm)
Hospitals, Nursing Homes	6000 lb (2730 kg)	5'-9" × 10'-0" (1750 × 3050 mm)	8'-2" × 11'-9" (2490 × 3580 mm)
Freight, Service	4000 lb to 6000 lb (1820 kg to 2730 kg)	8'-4" × 10'-0" (2540 × 3050 mm)	10'-10" × 10'-8" (3300 × 3250 mm)

ESCALATORS

Escalators are useful in situations where large numbers of people wish to circulate among a small number of floors on a more or less continual basis. Escalators are useful for floors that have mezzanines and want to provide alternate transportation between floors other than stairs. An escalator can NOT be counted as a means of egress. The structural and mechanical necessities of an escalator are located in the integral box that lies under the moving stairway. Structural support is only required at the two ends of the unit. See the basic diagram and size chart below.



	32" Escalator	48" Escalator
A	3'-9" (1145 mm)	5'-1" (1550 mm)
B	3'-7" (1090 mm)	4'-11" (1500 mm)

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For Elevators & Escalators:

Architects Studio Companion. Third Edition. By Edward Allen and Joseph Iano
Vertical Transportation: Elevators and Escalators By George R. Strackosch
ASME A17 ELEVATOR CODE

Vendors:

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