MECH3422 Building Services Engineering I

http://me.hku.hk/bse/MECH3422/

Lift and Escalators: Operation and Safety

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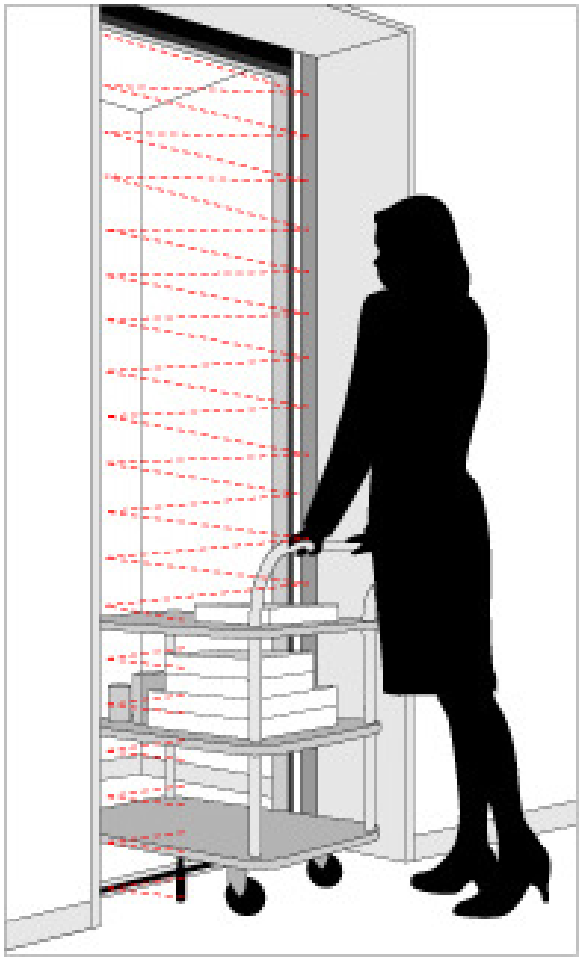
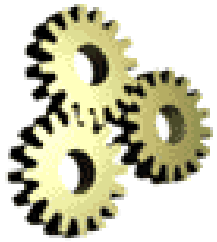
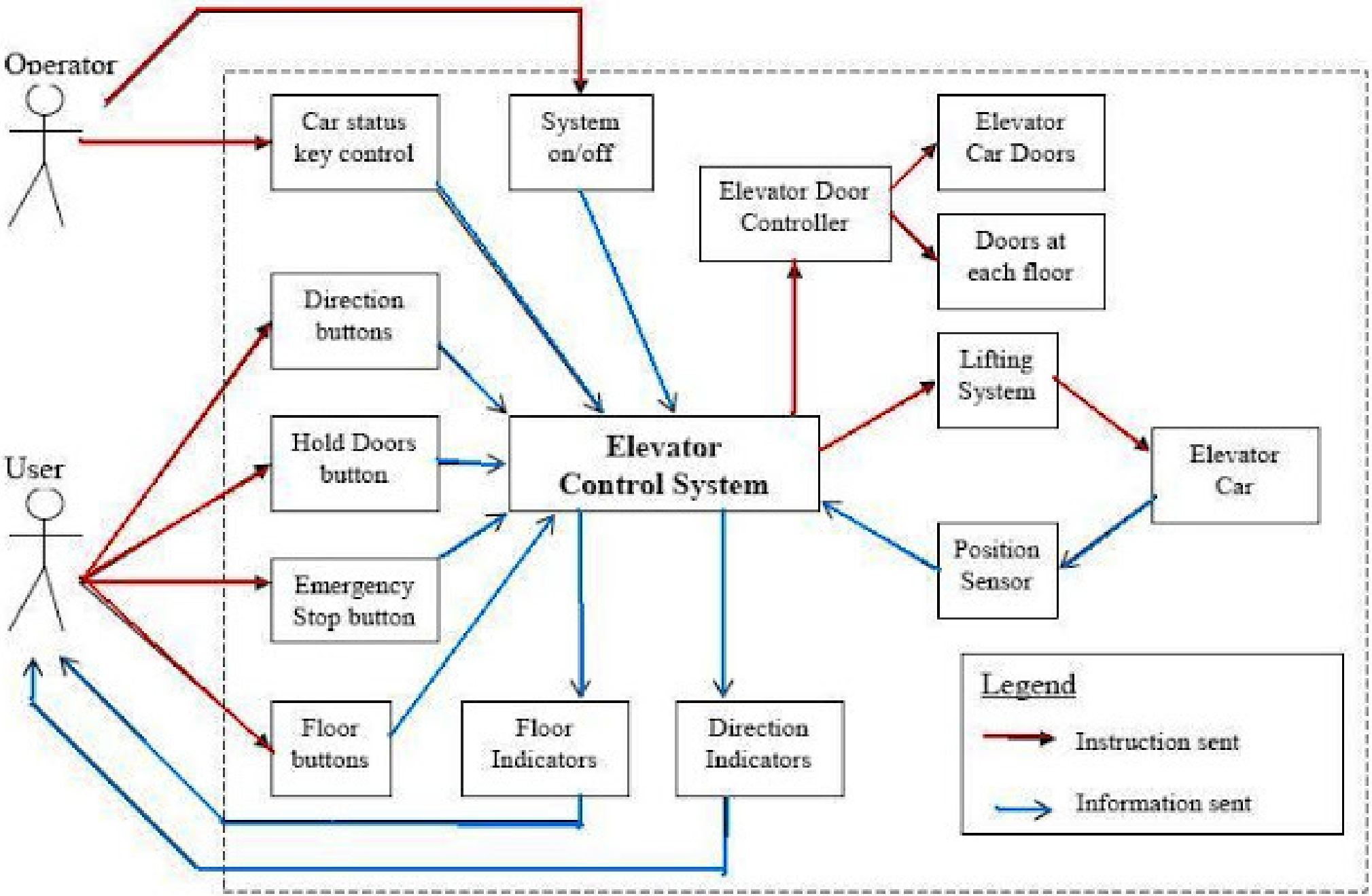


Lift Drive Operation



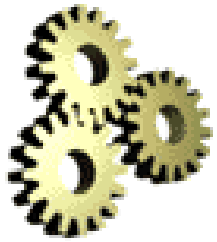
- Lift controllers
  - Power control: car motion, door
  - Traffic control: passenger demand
  - Controller input
    - Car calls, landing calls, door safety device, lift well safety, passenger detection device
  - Controller output
    - Door control signals, life drive control signals, passenger signalling
  - Lift control options: normal & various operation modes
  - Fail-safe operation: to ensure safety

Simple lift/elevator control system inputs and outputs



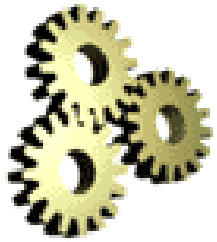
[Source: http://www.electrical-knowhow.com/2012/04/elevator-control-system.html]

Lift Drive Operation



- Lift control system
  - Coordinating all aspects of lift service e.g. travel, speed, accelerating, decelerating, door opening speed and delay, leveling and hall lantern signals
- Main aims of lift control system:
  - To bring the lift car to the correct floor
  - To minimize travel time and maximize passenger comfort by providing a smooth ride
  - To accelerate, decelerate and travel within safe speed limits

Lift Drive Operation



- Controller technology
  - Electromechanical switching
    - Electromagnetic relays & mechanically driven selectors
    - Limited operation life, maintenance problems, noisy
  - Solid-state logic technology
    - Discrete transistors circuits & integrated circuit boards
    - Improved reliability, lower power consumption & easier fault detection
  - Computer-based (‘intelligent’) systems
    - Enable complex & adaptable functions

Controller cabinets

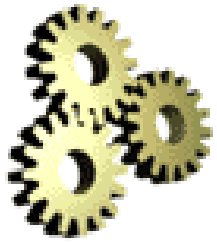
Relay based controller

Solid-State Logic Technology

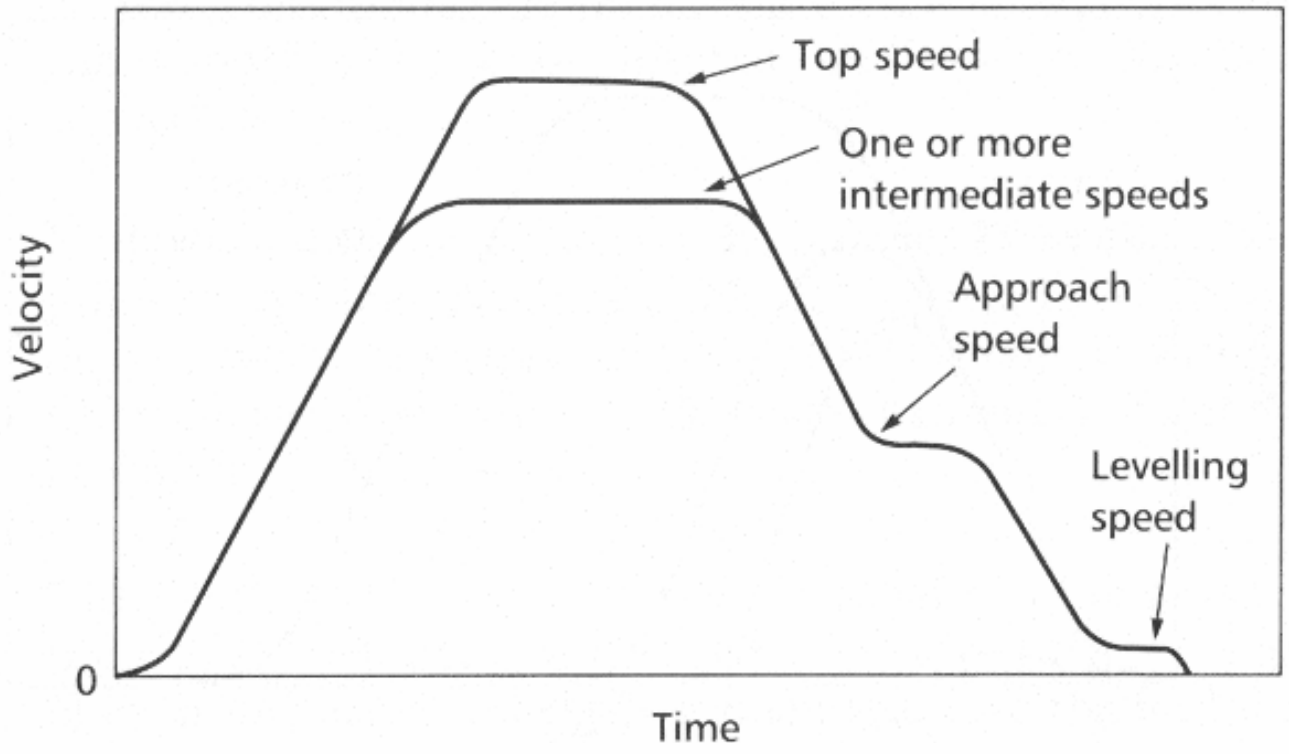
computer based technology

[Source: http://www.electrical-knowhow.com/2012/04/elevator-control-system-part-two.html]

Lift Drive Operation

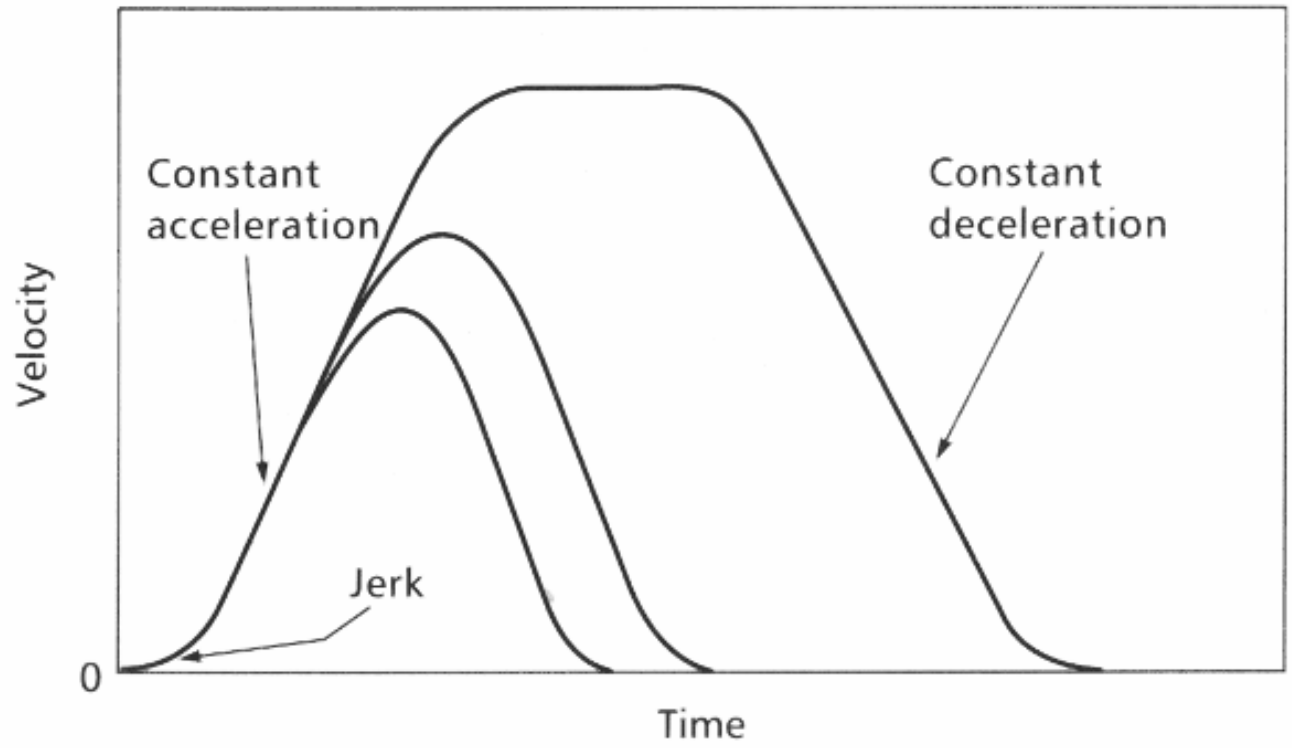


- Types of lift drive control
  - Motor speed reference
    - Time-based speed reference
    - Distance-based speed reference
  - Protection against failure of feedback systems
  - DC motor control, e.g. static convertors
  - AC motor control: variable voltage/frequency
  - Control of hydraulic lifts
- Control of door operators (DC/AC)



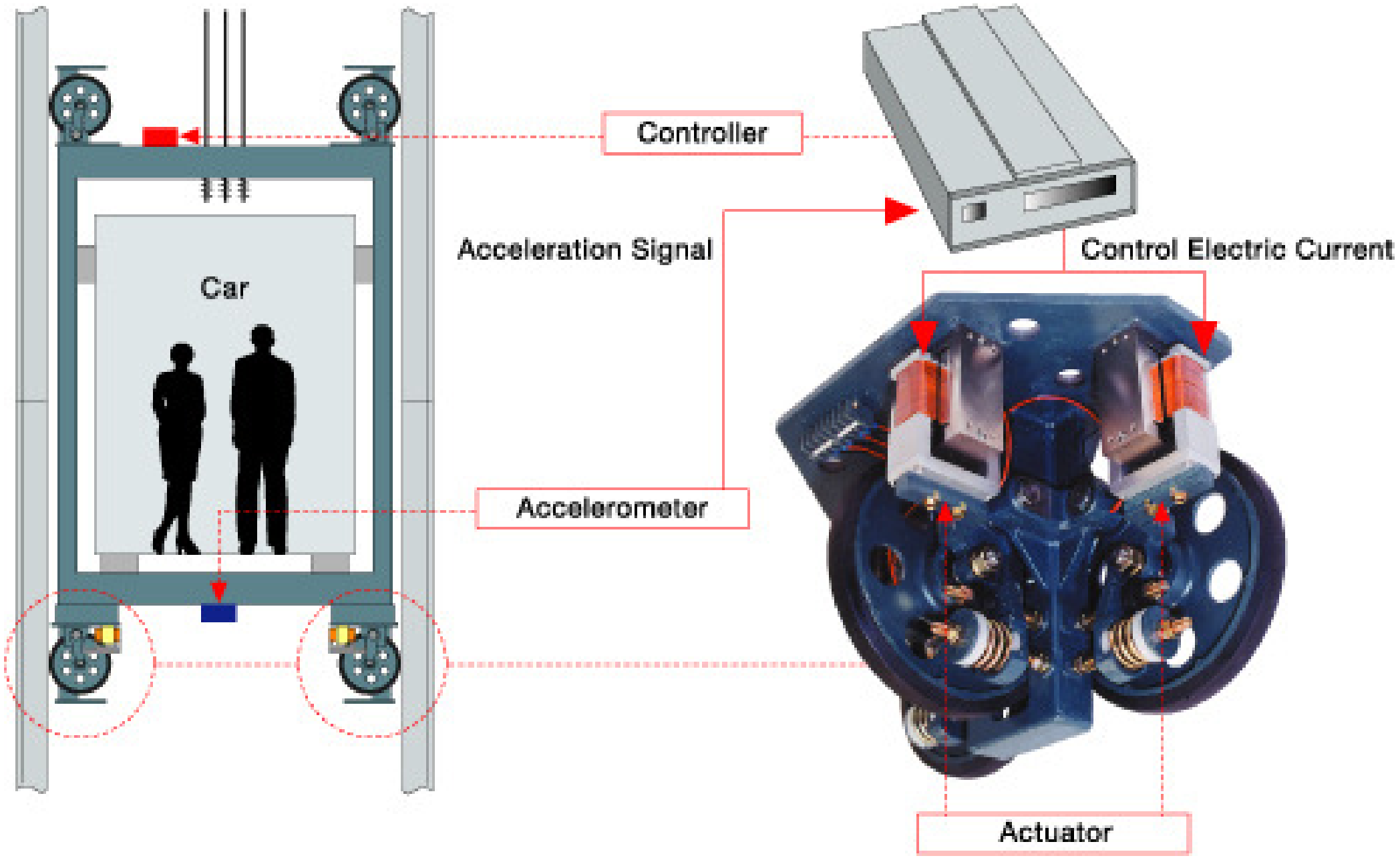
Time-based speed reference

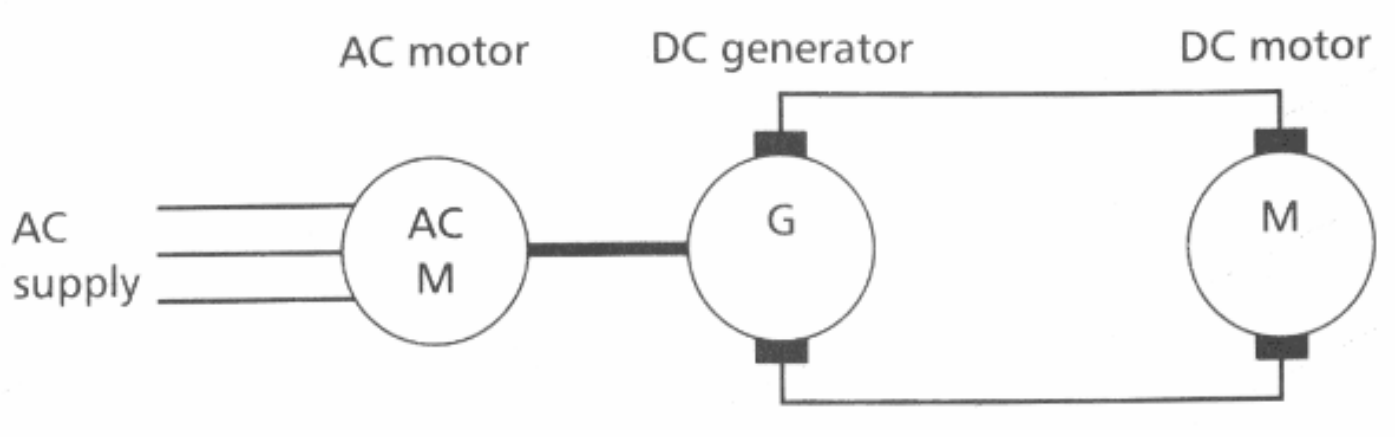
Do you feel comfortable when travelling on a lift?

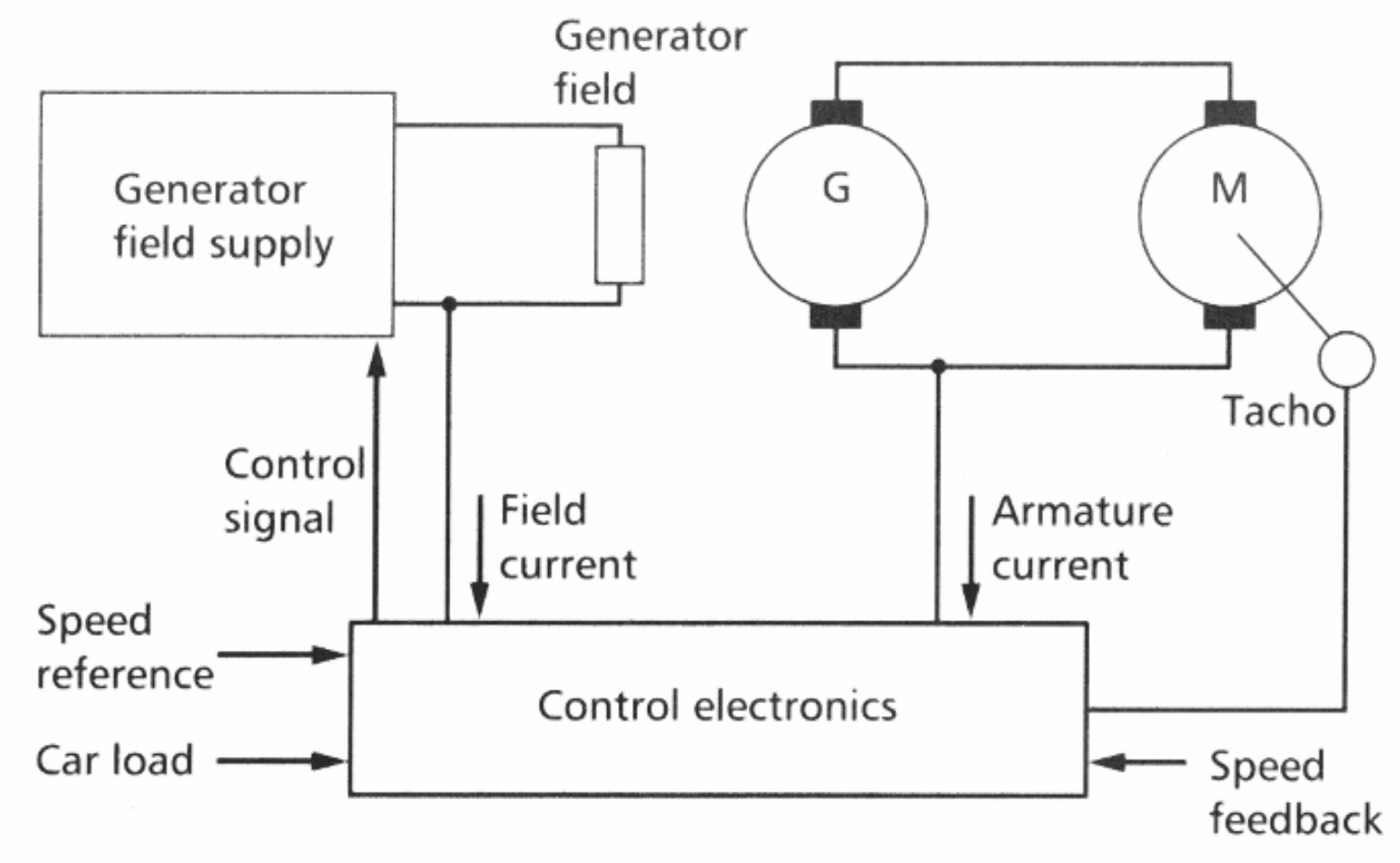


Distance-based speed reference

[Source: CIBSE Guide D]

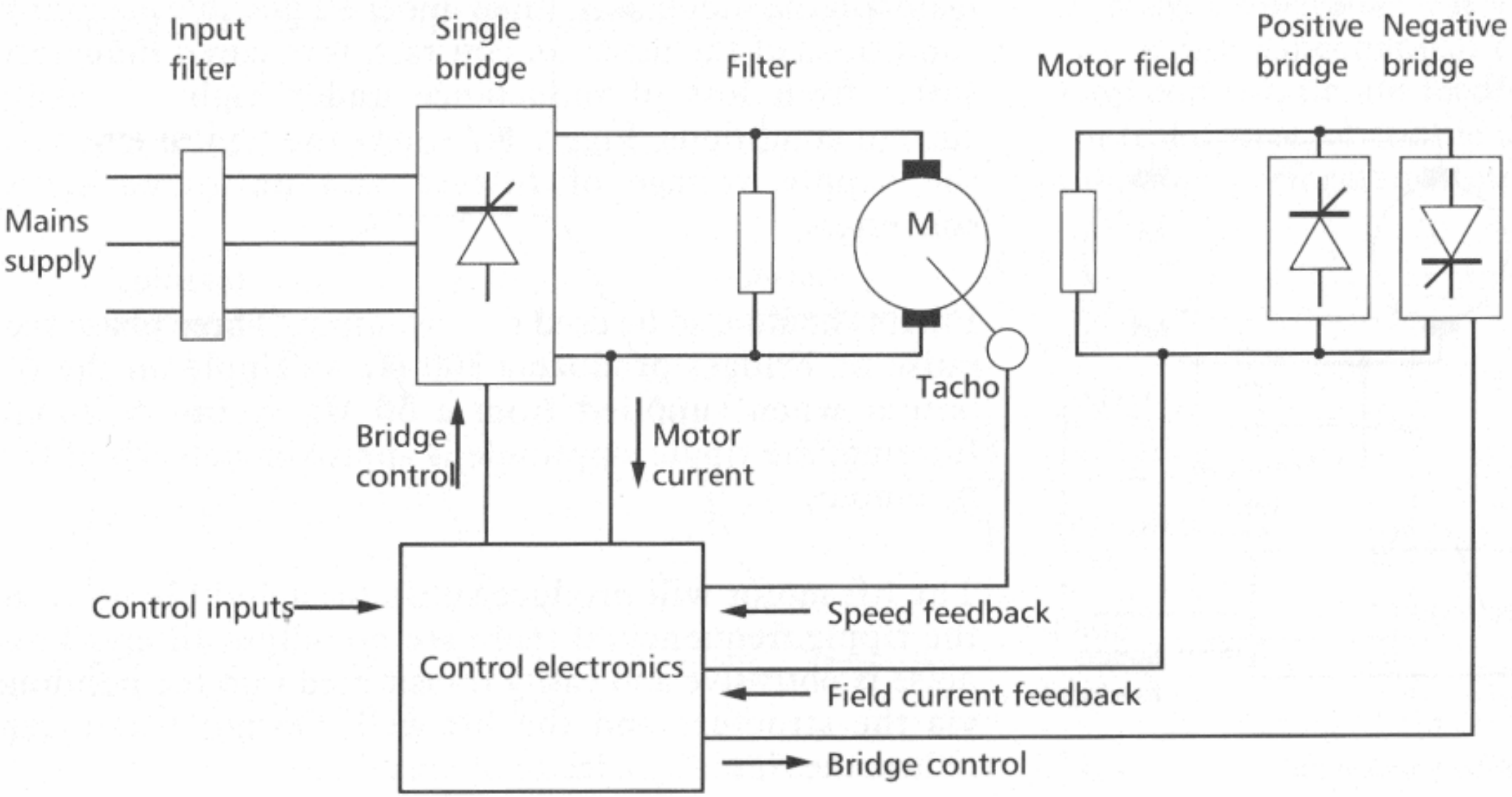

Car
Controller
Acceleration Signal
Control Electric Current
Accelerometer
Actuator





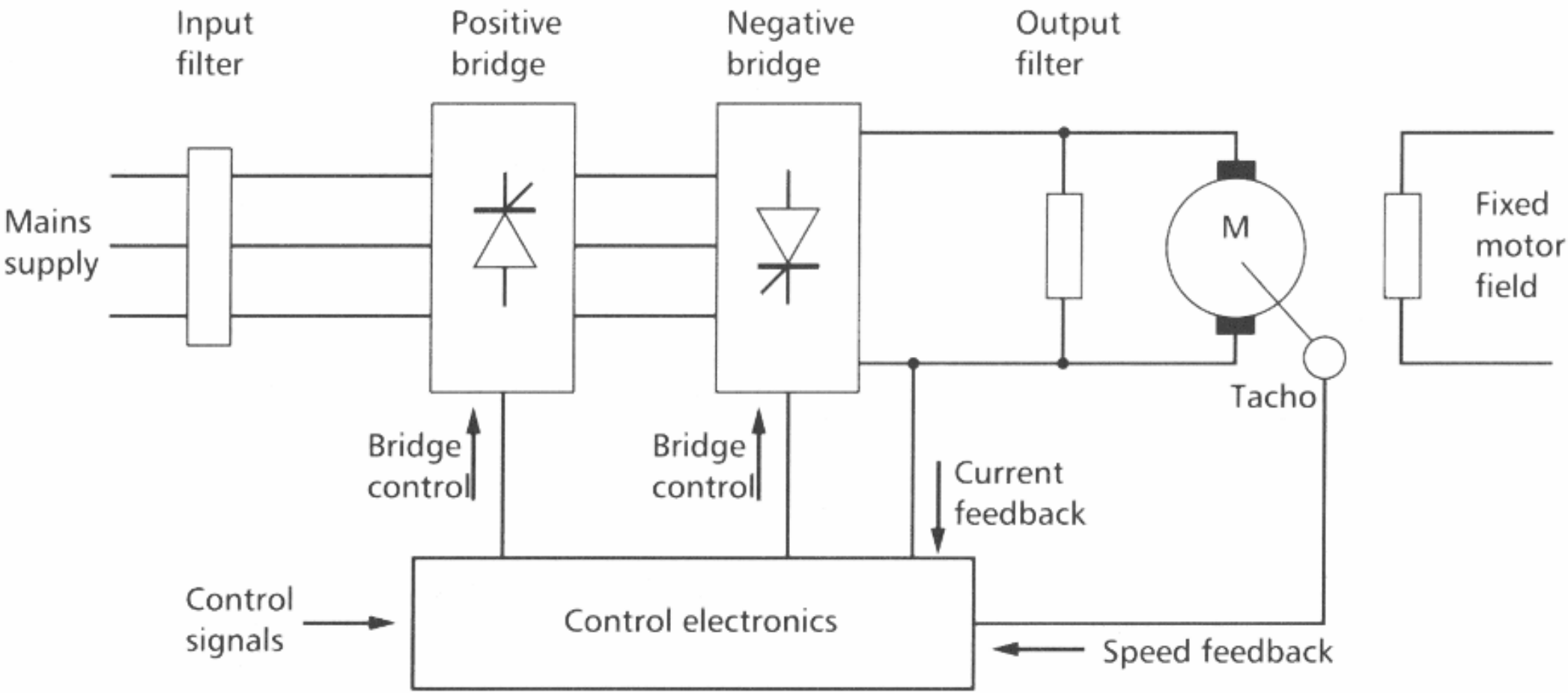
Generator control using feedback techniques

[Source: CIBSE Guide D]



Schematic of single-bridge static converter with motor field control

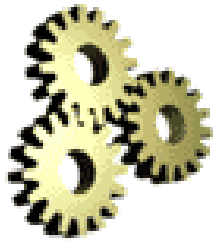
[Source: CIBSE Guide D]



Schematic of two-bridge static converter with fixed motor field

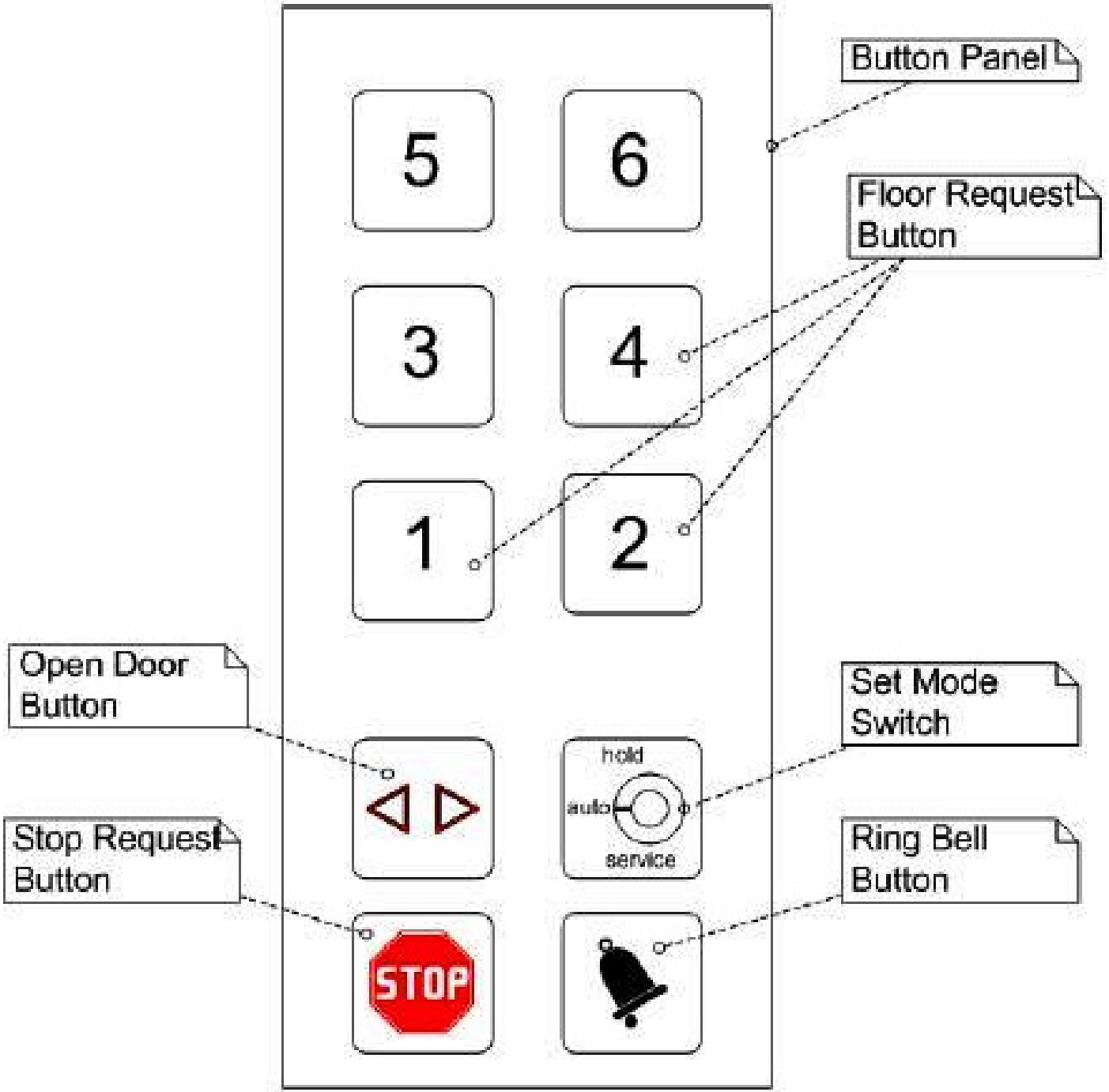
[Source: CIBSE Guide D]

Lift Drive Operation



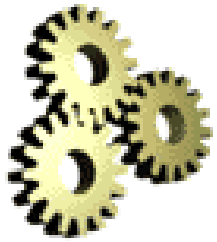
- Monitoring of lift operation
  - Basic information
    - Lift position, actual & intended travel direction, lift-in use indication
  - Other features, e.g.
    - Fault detection & diagnosis
    - Statistics on call handling & lift usage
    - Communication capability (transmit info to remote pt.)
    - Video monitor displays of real-time lift operation
    - Voice annunciation of lift position & other messages

Car operating panel (COP) buttons



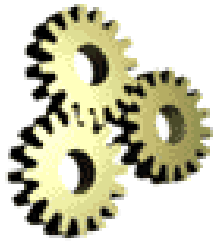
[Source: http://www.electrical-knowhow.com/2012/04/elevator-control-system-part-two.html]

Lift Drive Operation



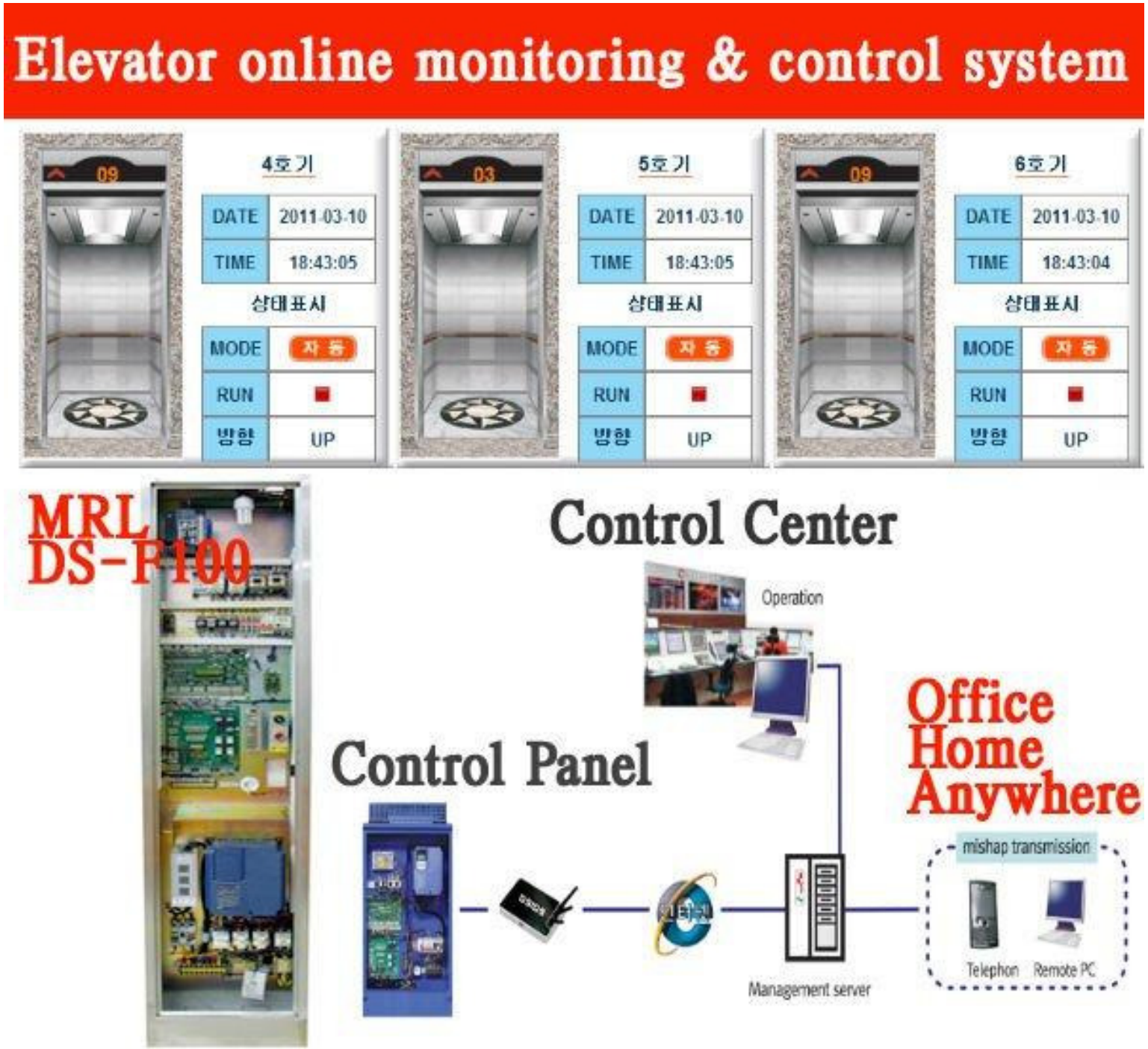
- Other lift operation features
  - Loaded car bypass
  - Automatic dispatching of loaded car
  - Emergency fire services operation
  - Nudging (to push gently)
  - Anti-nuisance operation
  - Preferential service operation
  - Auto adjustment of door open hold time
  - Learning function

Lift Drive Operation



- Other lift operation features (cont'd)
  - Emergency hospital operation
  - Earthquake emergency operation
  - Hoistway access operation
  - Card reader access
  - VIP operation
  - Freight service operation
  - Audio visual (info) system
  - Remote monitoring & interfacing with BAS/BMS

Supervisory control panel with remote online monitoring and control



[Source: http://www.electrical-knowhow.com/2012/04/elevator-control-system-part-two.html]

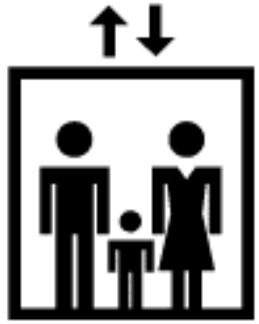
"Lift operator"

Generations of lift traffic control

Era	Dates	Traffic control type
I	1850-1890	Simple mechanical control (mechanical)
II	1890-1920	Attendant and electrical car switch control (electro-mechanical)
III	1920-1950	Attendant/dispatcher and pushbutton control (electro-mechanical)
IV	1950-1975	Group control: (electrical) IVa scheduled traffic control to 1960 IVb demand traffic control from 1960
V	1975-	Computer group control (electronic)

[Source: Barney, G., 2003. *Elevator Traffic Handbook*]

Lift Traffic Control



- Lift (group) control arrangements
  - Operator
  - Single automatic
  - Down or up collective
  - Directional (up & down) collective
  - Group collective
  - Programmed control
  - AI (artificial intelligence) assisted control

Single automatic control

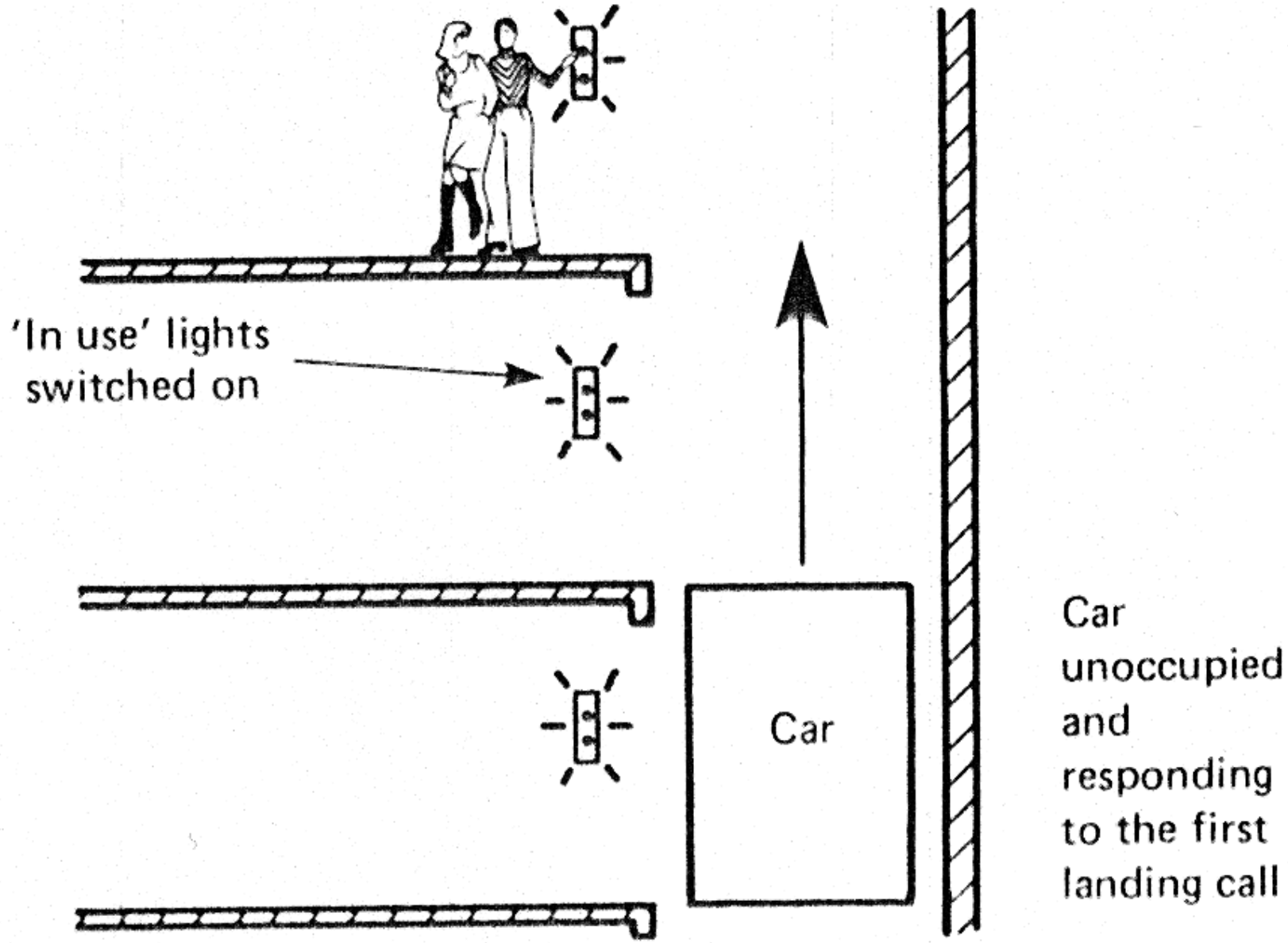


Fig 14 Lift car called to a floor. 'In use' lights switched on

[Source: Hall, F. and Greeno, R., 2005. *Building Services Handbook*]

Single automatic control

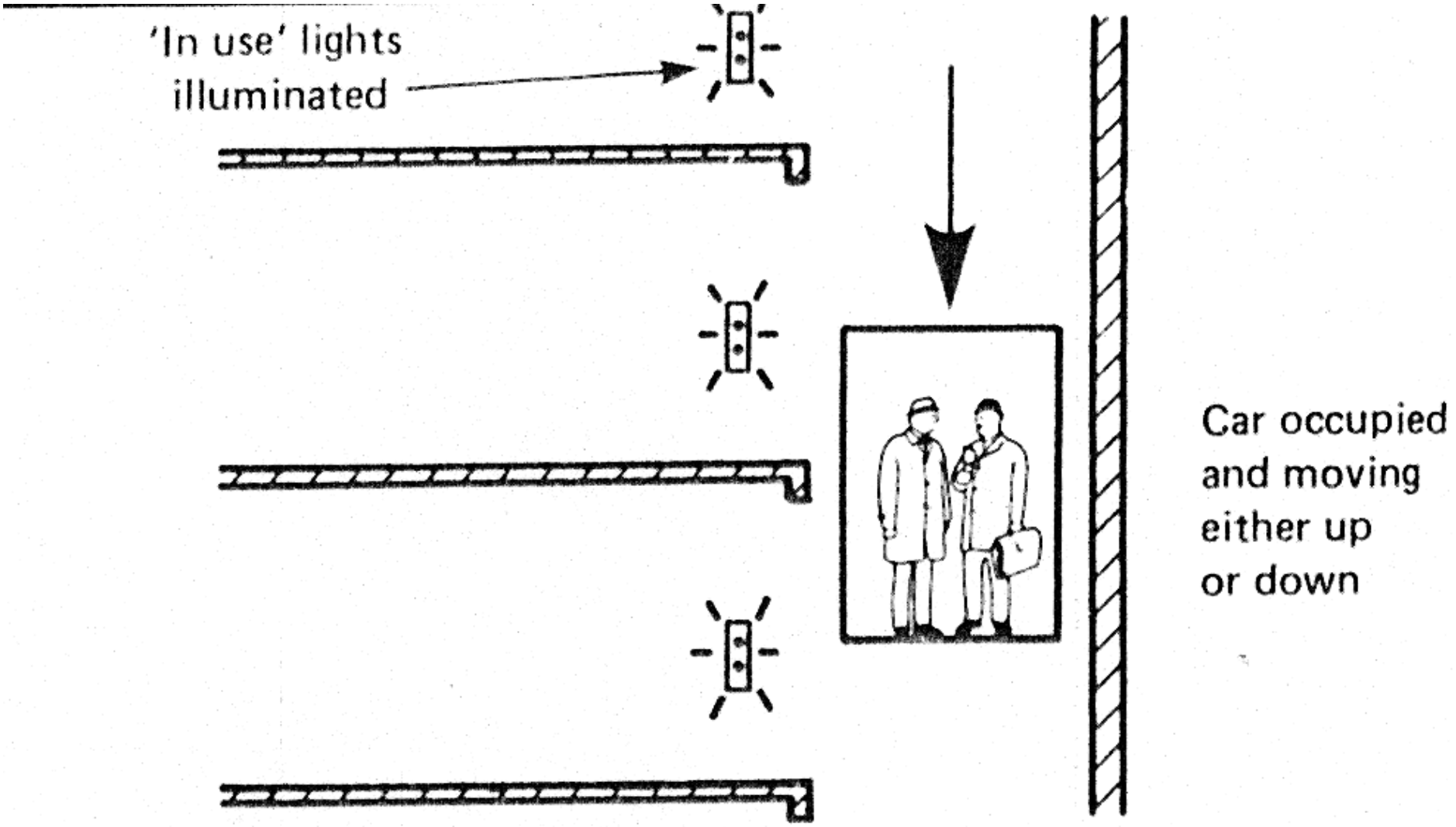


Fig 15 Lift car in control of occupant and cannot be called by other passengers

[Source: Hall, F. and Greeno, R., 2005. *Building Services Handbook*]

Single automatic control

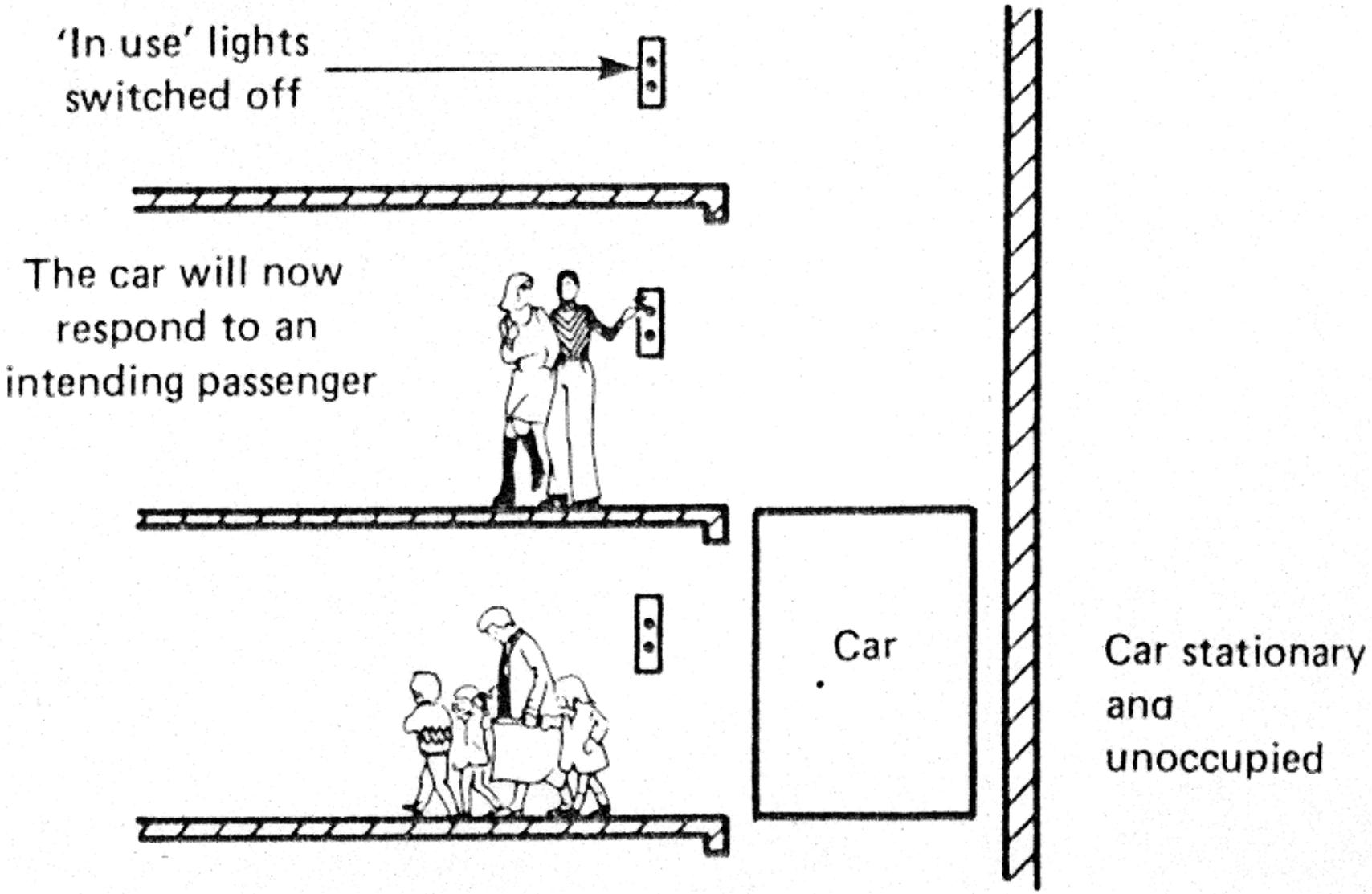


Fig 16 Lift car vacated. 'In use' lights switched off. Lift can now be called by other passengers

[Source: Hall, F. and Greeno, R., 2005. *Building Services Handbook*]

Down collective control

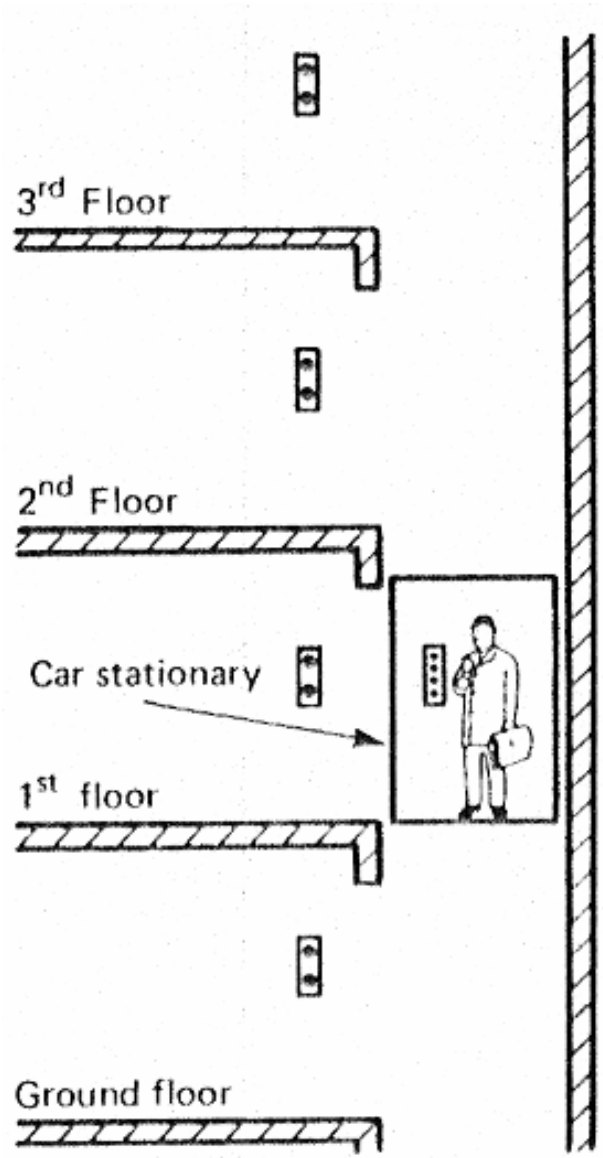


Fig 17 Passengers enter the car and press buttons to travel upwards

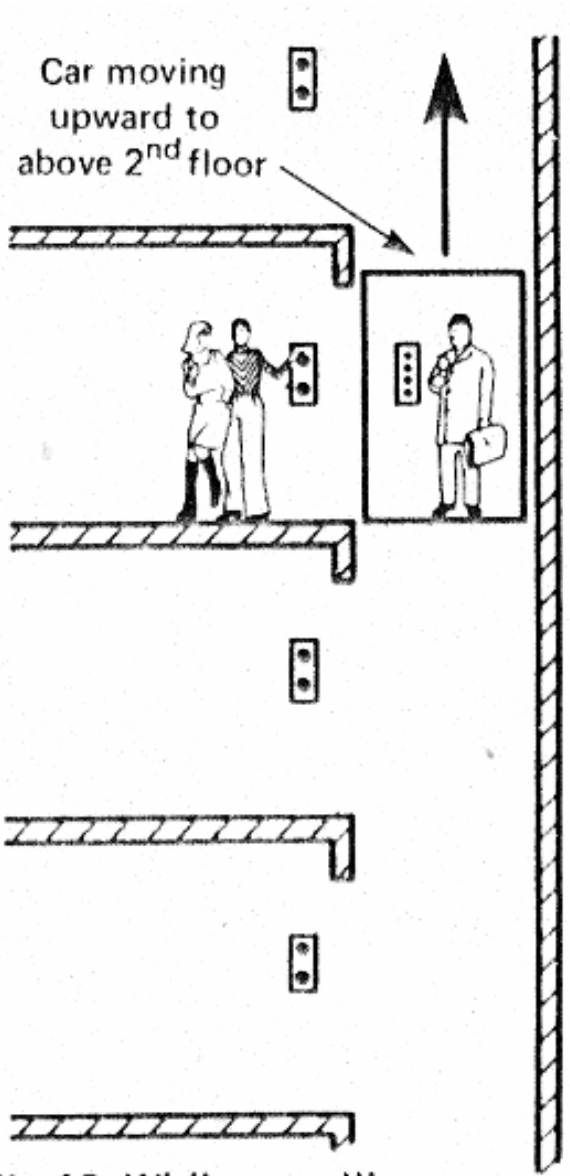


Fig 18 While travelling upwards all the landing calls are by-passed

[Source: Hall, F. and Greeno, R., 2005. *Building Services Handbook*]

Down collective control

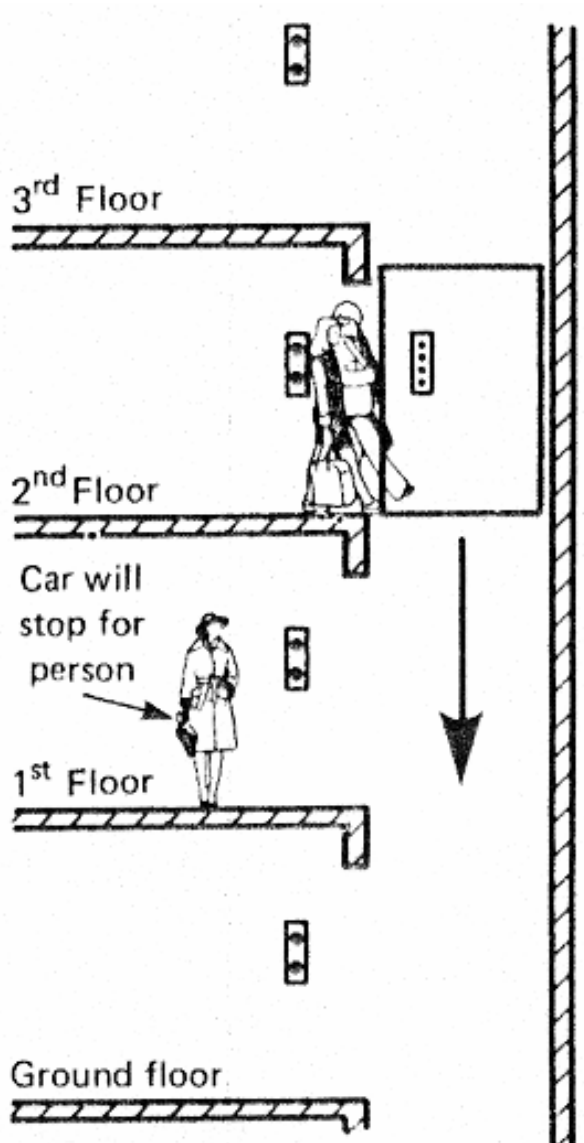


Fig 19 When the car moves down all landing calls are collected floor by floor

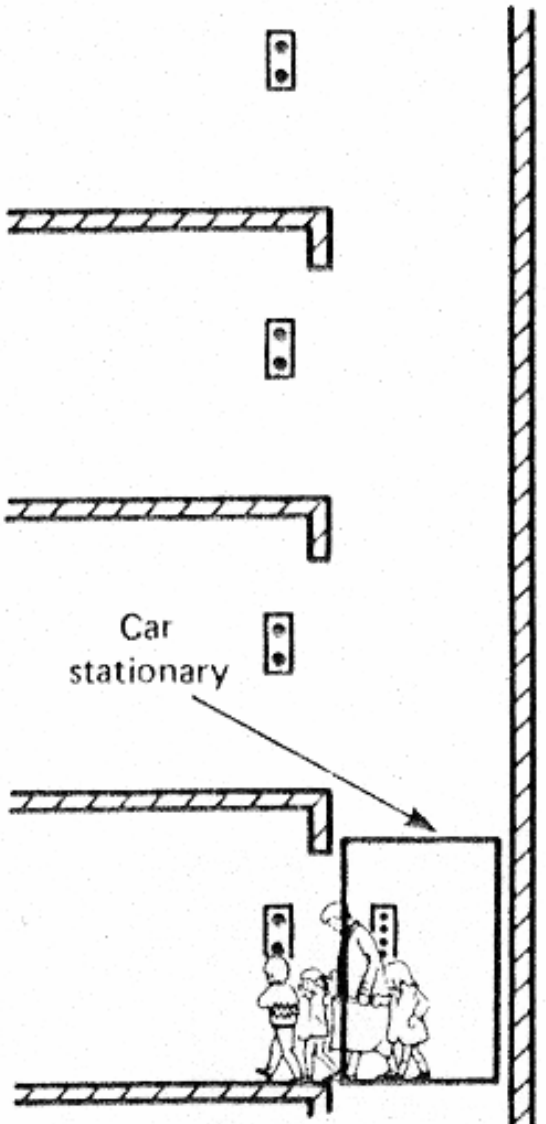
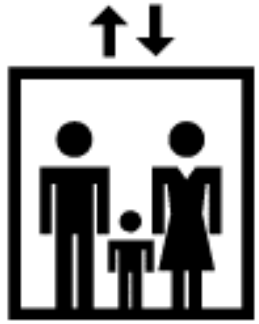


Fig 20 Passengers leave the car.

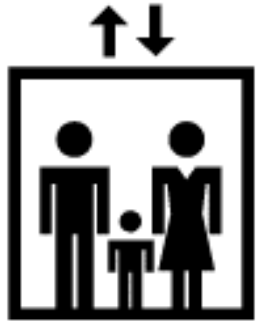
[Source: Hall, F. and Greeno, R., 2005. *Building Services Handbook*]

Lift Traffic Control



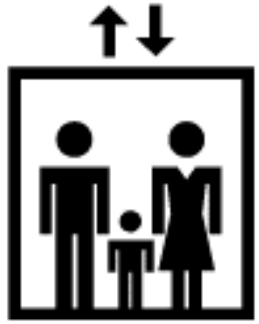
- Group of lifts
  - A number of lifts placed physically together, using a common signalling system and under the command of a group lift control system
- Group traffic control algorithms
  - From simple 2 lift control to very sophisticated
  - Landing call allocation: assign a lift to service a particular landing call

Lift Traffic Control



- Purpose:
  - To allocate the landing calls in an optimum way to individual lifts in the group
    - Minimise passenger waiting time
    - Minimise system response time
    - Minimise passenger journey time
    - Reduce ‘bunching’ (lifts move around together, instead of being evenly separated, e.g. by sudden heavy traffic)
    - Minimise the variation in passenger waiting time

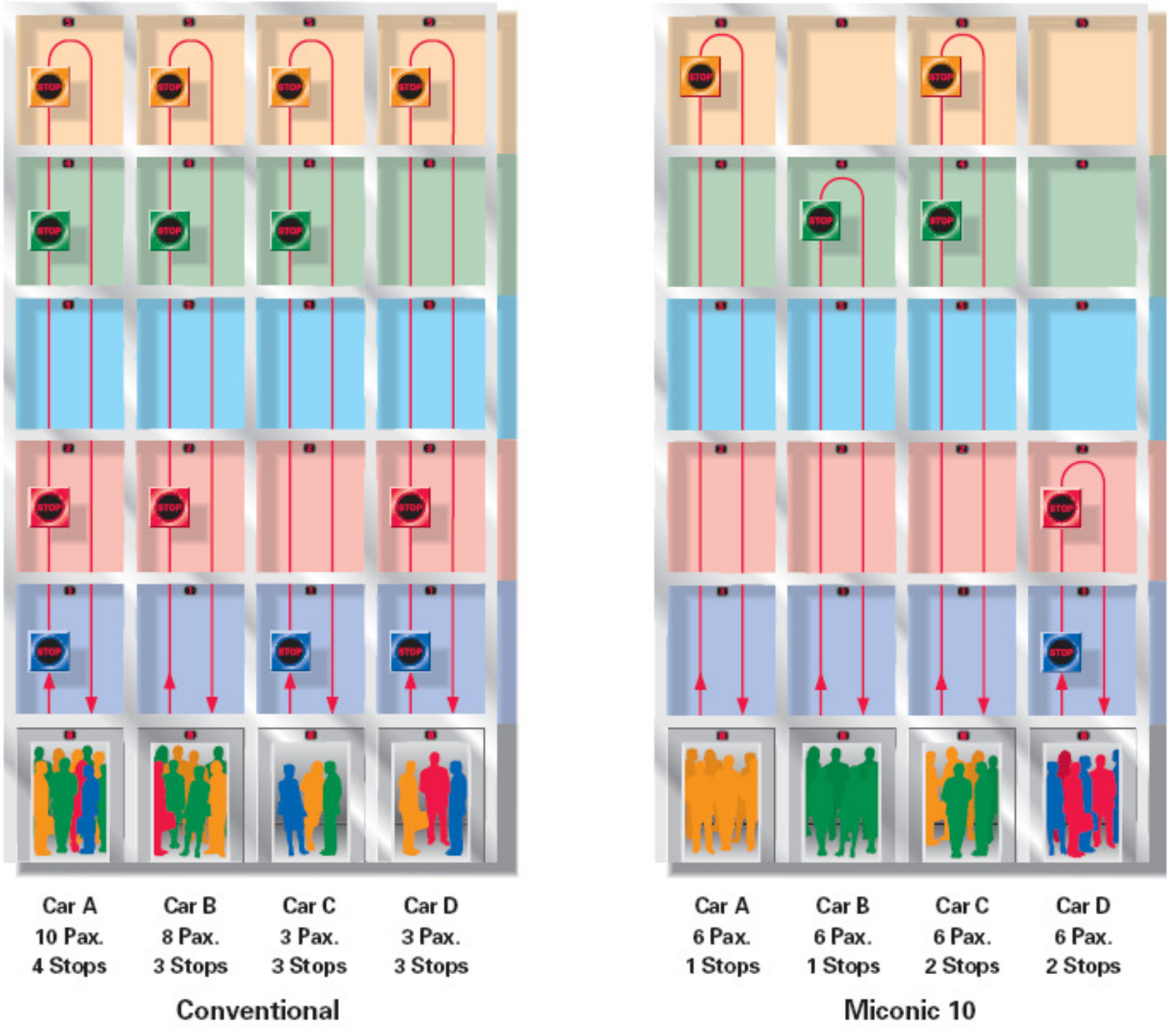
Lift Traffic Control



- Up peak service
  - Focus on main terminal; zone assignments; dynamic zoning
- Down peak service
  - Similar to up peak but down direction
- General group control
  - Static sectoring (assign & park car(s) to each building 'sector')
  - Dynamic sectoring (sectors change with position & direction of car)
  - Hall call allocation systems (every passenger register his/her call, an indication of which car is allocated, no car button)

Hall call allocation system

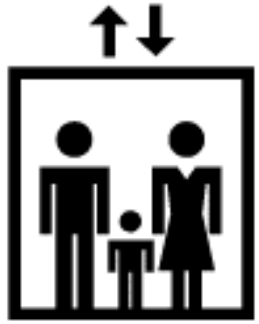
[Source: Schindler]



Hall call allocation system: comparison

[Source: Schindler]

Lift Traffic Control

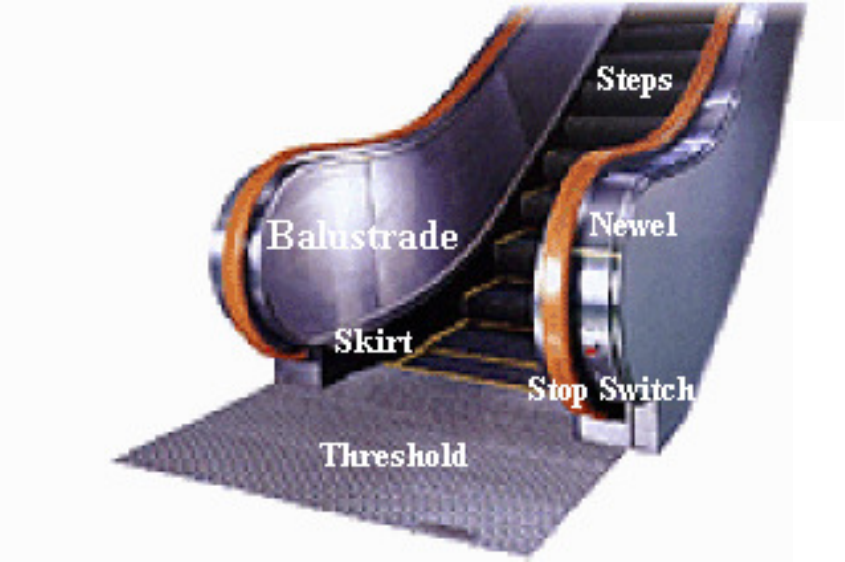


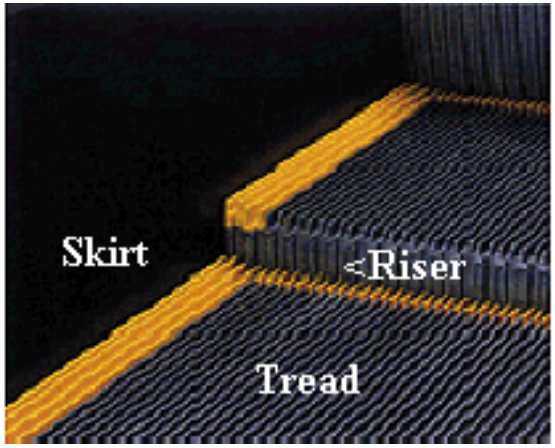
- Other features
  - Load bypass (when a lift fills up)
  - Heavy demand floors
  - Lobby & preferential floor
  - Lift parking (to main terminal)
  - Basement service
  - Car preference
  - Automatic shut down
- Future trends: use of artificial intelligence
  - Such as expert system control, fuzzy control, artificial neural network control, optimal variance method

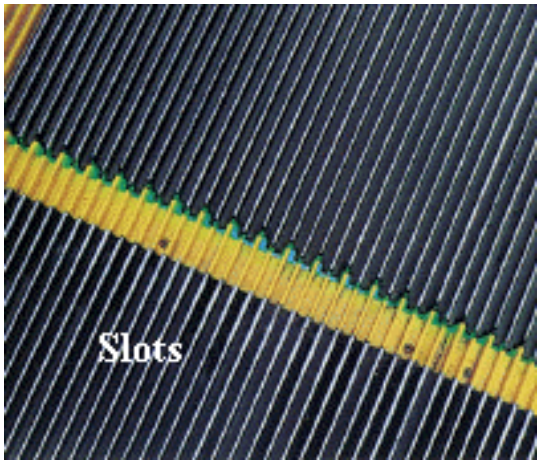
Operation of Escalators

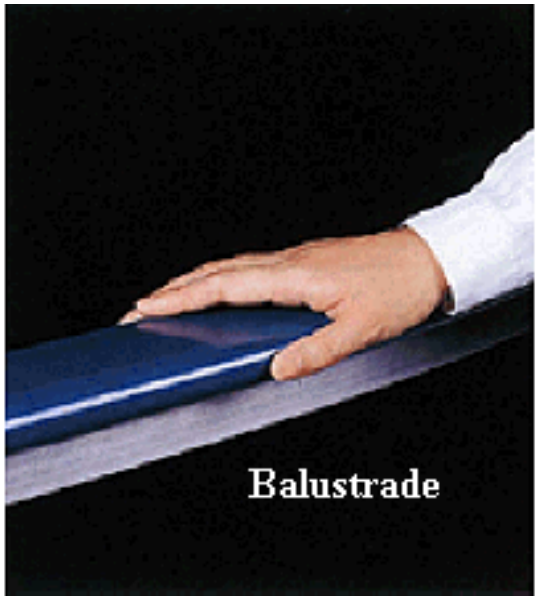
- Basic applications of escalators
  - Commercial (e.g. shopping centres)
  - Transportation (airport terminals, railway stations)
  - Mass transit (subway, MTR)
- Safety features
  - Yellow lines on steps
  - Brushguards
  - Yellow spots on handrails
  - Lighting at the landings

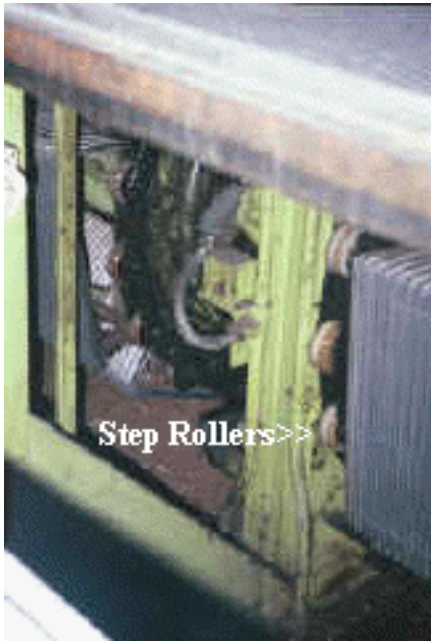
Terminal Railway Station









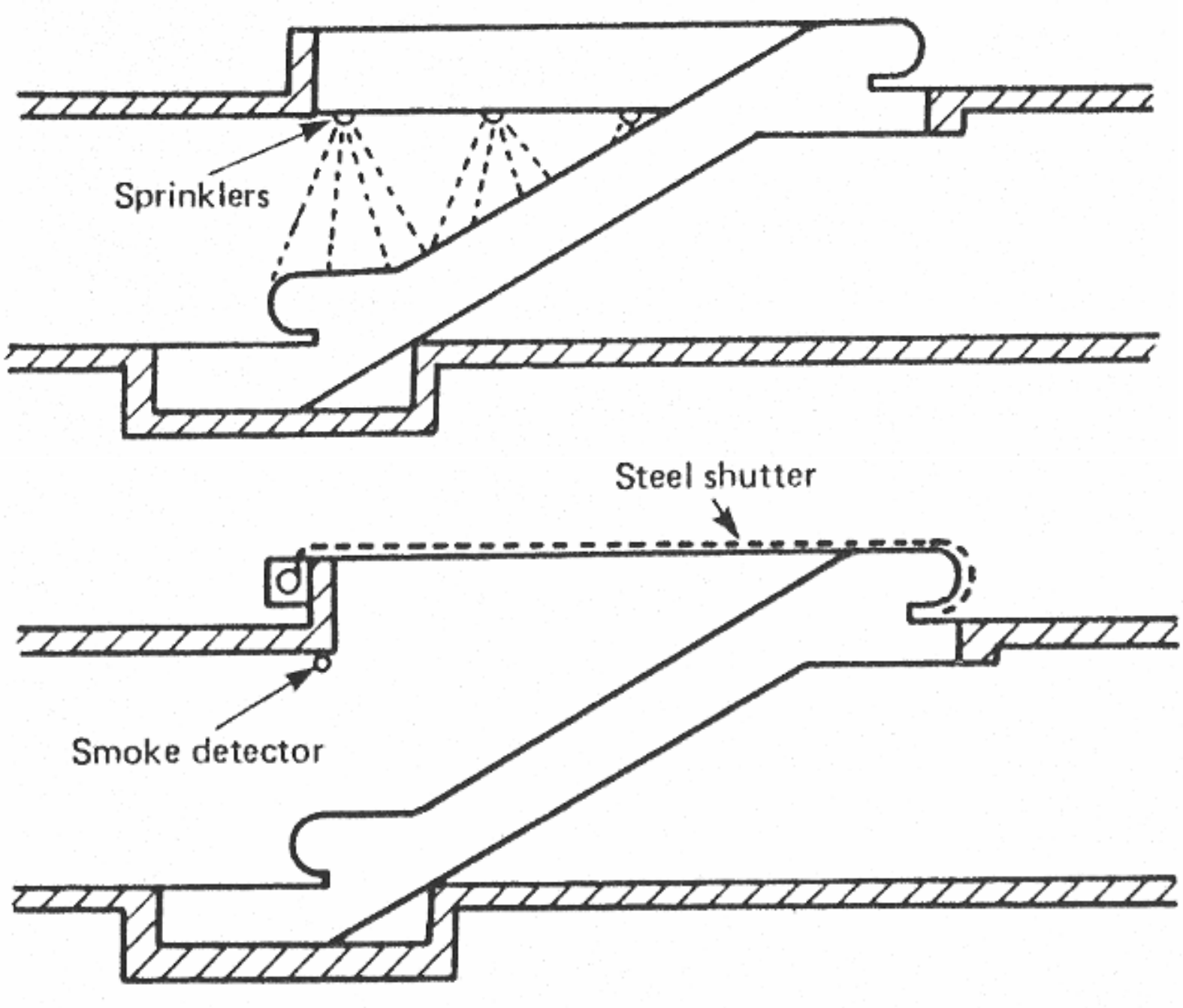


Escalator components (http://www.elevator-expert.com)

Operation of Escalators

- Prevent spread of fire
  - Void containing escalators encourage fire/smoke to spread
  - Precautions needed:
    - Sprinklers to provide a continuous water curtain
    - Fire curtains or shutter released by fusible smoke link or smoke relay to seal the top of the escalator shaft
    - Compartmentation or separation of escalators

Fire/Smoke precautions for escalators



[Source: Hall, F. and Greeno, R., 2005. *Building Services Handbook*]

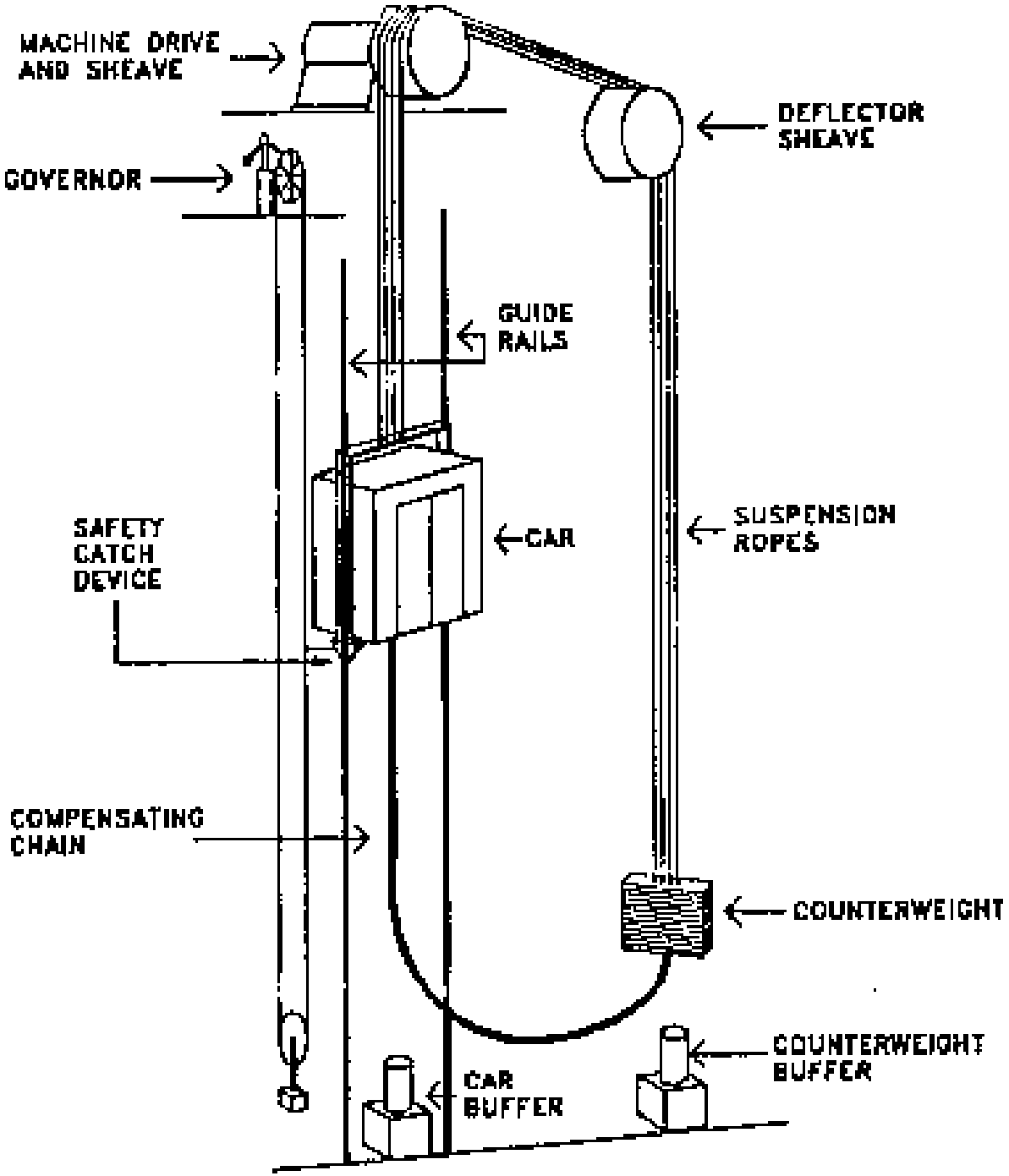
Operation of Escalators

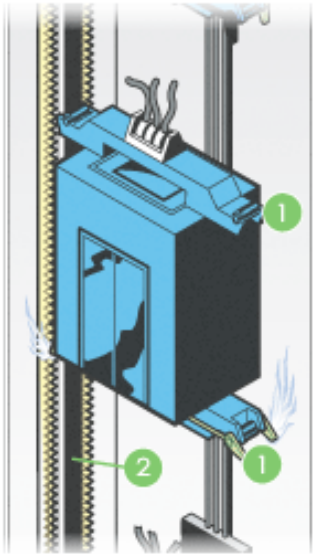
- Motor drives & methods of starting
  - Star delta starter
    - Requires a non-standard pole changing motor & high value of starting current
  - Soft start (by using thyristors)
  - Inverter start (standard motor can be used)
    - Also allow speed to be varied
  - Modular drives
    - Employ 2 or 3 motors coupled to the gear box

Safety Issues

- Relevant EMSD documents (available at http://www.emsd.gov.hk)
  - Guideline on Safe Use of Lift and Escalator 2003
  - Lift Owners' Guidebook 2003
  - Code of Practice for Lift Works and Escalator Works 2002
  - Code of Practice on the Design and Construction of Lifts and Escalators 2000

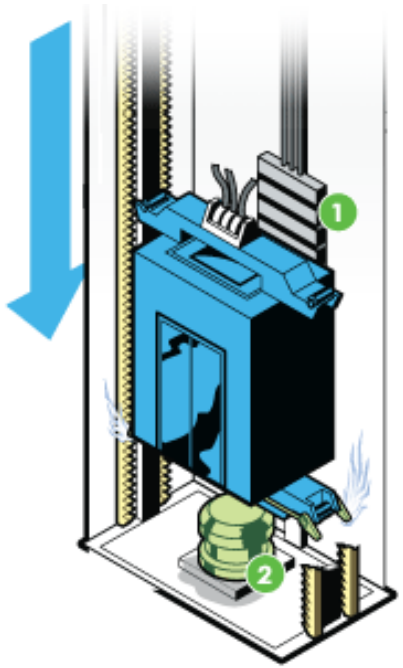
Lift safety systems and components





1 If the cables snap, the elevator's **safeties** would kick in. **Safeties** are braking systems on the elevator.

2 Some safeties clamp the **steel rails** running up and down the elevator shaft, while others drive a wedge into the notches in the **rails**.



1 The cables that lift the car are also connected to a **counterweight**, which hangs down on the other side of the sheave.

2 The built-in **shock absorber** at the bottom of the shaft - typically a piston in an oil-filled cylinder - helps cushion the imact in the event of snapping cables.

[Source: http://www.msha.gov/S&HINFO/TECHRPT/HOIST/PAPER4.HTM and http://science.howstuffworks.com/]

Safety Issues

- Lift mechanical & electrical components:*
  - Rope brake, machine motor brake
  - Overspeed governor & counterweight
  - Machine & controller (stopping, levelling & braking + speed limiting control)
  - Deflector sheave & interlock
  - Car safety & structural steel car frame
  - Car & counterweight buffers
  - Lower stopping & reversal limits
  - Pit stop switch light switch & ladders

(* See also the lift components in the previous lecture)

Safety Issues

- Lift passenger safety devices:
  - Door operator (open/close car door, e.g. infrared)
  - Door protection (guard against door interference)
  - Emergency light & communication (intercom)
  - Interlock (ensures landing door is closed before car allowed to move)
  - Car position indicator
- Safety precautions for lift installation & maintenance works (e.g. prevent person falling)

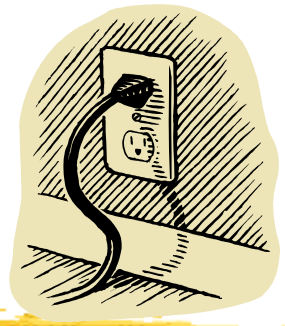
Safety Issues

- Escalator safety devices:
  - Handrail safety guard
  - Emergency stop button
  - Skirt guard obstruction device
  - Broken drive-chain safety device
  - Broken step chain safety device
  - Electric circuit protection device
  - Electromagnetic brake
  - Step upthrust safety device
  - Skirt guards
  - Fire shutter interlocked device

Safety Issues

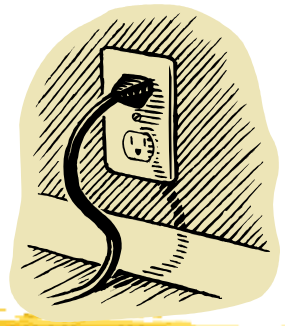
- Escalator safety devices: (cont'd)
  - Demarcation line
  - Reversal protection device
  - Governor (overspeed)
  - Comb impact switch
  - Handrail speed delay sensing device
  - Step sag safety device
  - Missing step device
  - Tandem operation interlock
  - Comb plate switch
  - Step obstruction device

Energy Efficiency



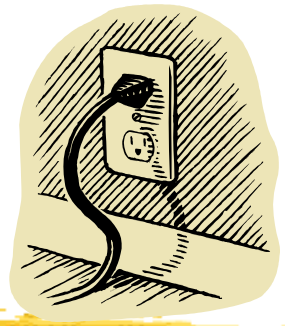
- Lifts & escalators are a major energy consumer in buildings
  - Typically consists 5-15% of electricity in high-rise commercial buildings
  - Also affects peak energy demand & power factor
- EMSD building energy code & guidelines:
  - Code of Practice for Energy Efficiency of Lift and Escalator Installations
  - Guidelines on Energy Efficiency of Lift and Escalator Installations

Energy Efficiency



- Requirements on lifts & escalators
  - Maximum allowable electrical power
  - Energy management of lift cars or escalators
  - Total harmonic distortion (motor drive)
  - Total power factor (motor drive)
- Recommendations on lifts
  - Handling capacity
  - Lift traffic design

Energy Efficiency



- General approach for lifts & escalators
  - Minimise friction losses & dynamic losses
  - Possible regeneration into the supply system
- General principles to energy efficiency
  - Specify energy efficiency equipment
  - Do not over design the system
  - Suitable zoning arrangement
  - Suitable control and energy management
  - Use light weight materials for lift car decoration
  - Good house keeping

Classification of energy efficiency of lifts

Energy efficiency class	Energy consumption per day (Wh)
A	$E_d \leq 0.72*Q*n_d*s_{av}/1000 + 50* t_{nr}$
B	$E_d \leq 1.08*Q*n_d*s_{av}/1000 + 100* t_{nr}$
C	$E_d \leq 1.62*Q*n_d*s_{av}/1000 + 200* t_{nr}$
D	$E_d \leq 2.43*Q*n_d*s_{av}/1000 + 400* t_{nr}$
E	$E_d \leq 3.65*Q*n_d*s_{av}/1000 + 800* t_{nr}$
F	$E_d \leq 5.47*Q*n_d*s_{av}/1000 + 1600* t_{nr}$
G	$E_d > 5.47*Q*n_d*s_{av}/1000 + 1600* t_{nr}$

E_d = Total daily energy consumption (Wh)
Q = Rated load (kg)
n_d = Number of trips per day
s_{av} = Average travel distance for target installation (m)
t_{nr} = Non running (idle and standby) time(s) per day (h)

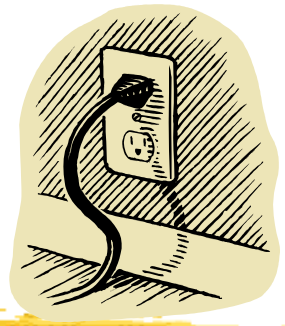
[Source: ISO 25745-2 Energy performance of lifts, escalators and moving walks, Part 2]

Guidelines for reducing energy consumption of escalators

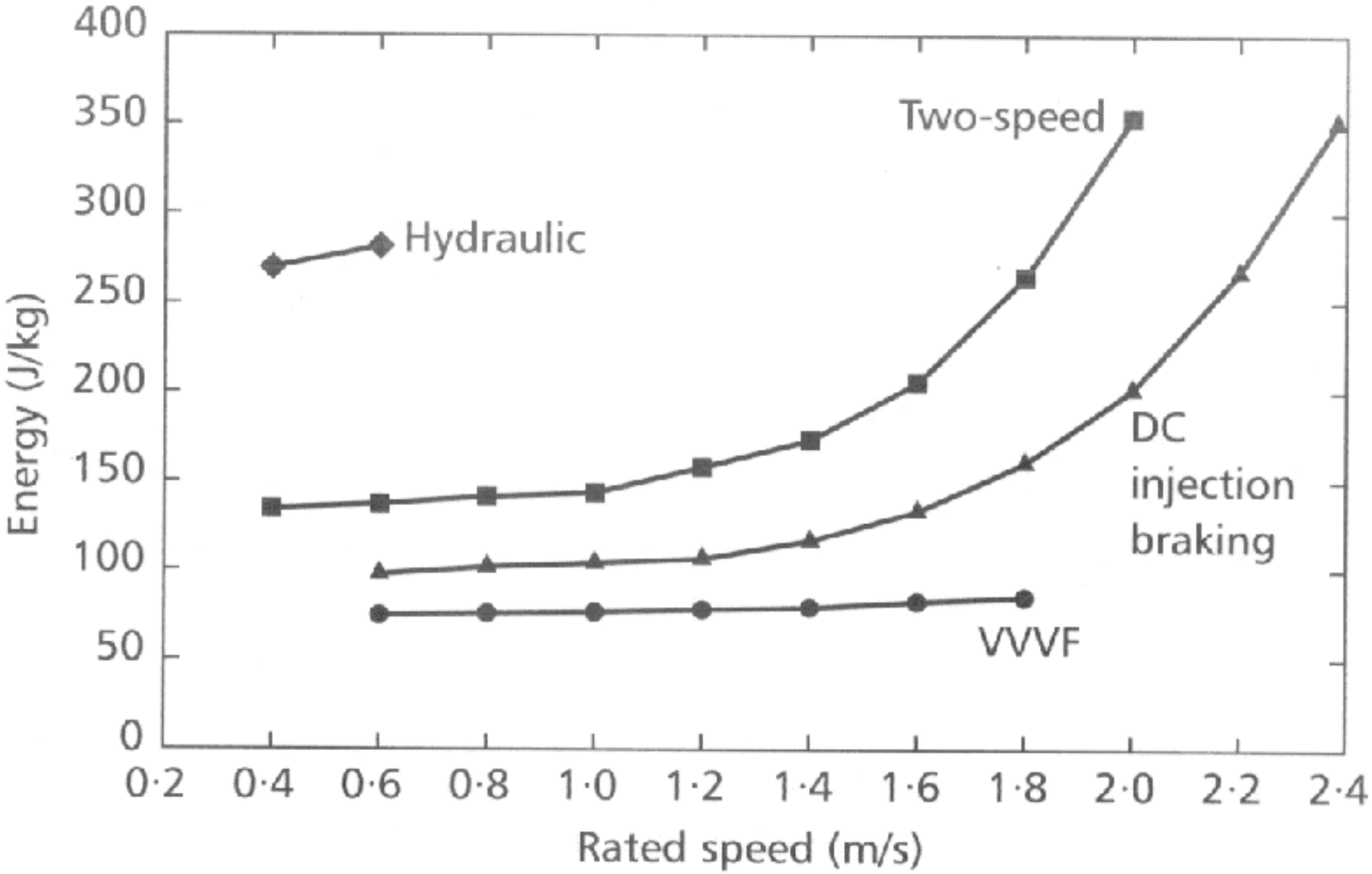
Measure	Description	Remark
Auto start	Stopping the unit in case of absence of passengers	Reduction by switching from $E_{no\ load}$ to $E_{stand\ by}$
Slow speed	Slow down the unit to slow speed in case of absence of passengers	Reduction by switching from $E_{no\ load}$ to $E_{slow\ speed}$
Power OFF	Switch off the main supply, e.g during night	Reduction by switching $E_{standby}$ off
Power OFF ancillary equipment	Switch off the ancillary equipment supply	Reduction by switching $E_{ancillary}$ off
Motor voltage control	Load depending voltage reduction, e.g. star delta switching, frequency converter, voltage control	Improvement of η of motor resulting in reduction of $E_{no\ load}$, $E_{slow\ speed}$ and partial load condition
Gear efficiency improvement	Usage of gear technologies with improved efficiency, e.g. helical gear	Improvement of η of gear resulting in reduction of $E_{no\ load}$, $E_{slow\ speed}$ and any load condition
Motor efficiency improvement	Usage of motor technologies with improved efficiency	Improvement of η of motor resulting in reduction of $E_{no\ load}$, $E_{slow\ speed}$ and any load condition
Handrail system efficiency improvement	Usage of low friction handrail components	Reduction of $E_{no\ load}$, $E_{friction}$, $E_{slow\ speed}$ and any load condition
Step/pallet chain system efficiency improvement	Usage of automatic lubrication system	Reduction of $E_{no\ load}$, $E_{friction}$, $E_{slow\ speed}$ and any load condition

[Source: ISO 25745-3 Energy performance of lifts, escalators and moving walks, Part 3]

Energy Efficiency



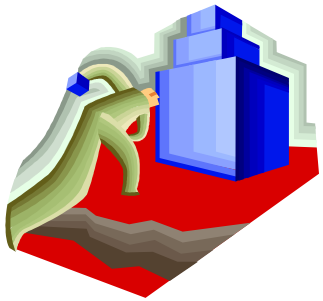
- Factors affecting energy consumption
  - Type of drive (hydraulic, two-speed, etc.)
  - Mechanical design (e.g. gearbox)
  - Efficiency of various components
  - Reduction of inertia (e.g. flywheel)
  - Type of gearing (if applicable)
  - Possibility of electricity regeneration
  - Running power factor
  - Loading (level of usage)



Energy consumption of various types of drives

[Source: CIBSE Guide D]

Lift Modernisation

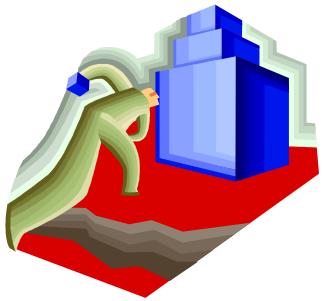


- Lift modernisation*
  - Refurbish, retrofit, renew lift system/components
- Purposes
  - For performance
  - For aesthetic
  - To meet code (e.g. for disabled)
- Consider together with the lift maintenance programme

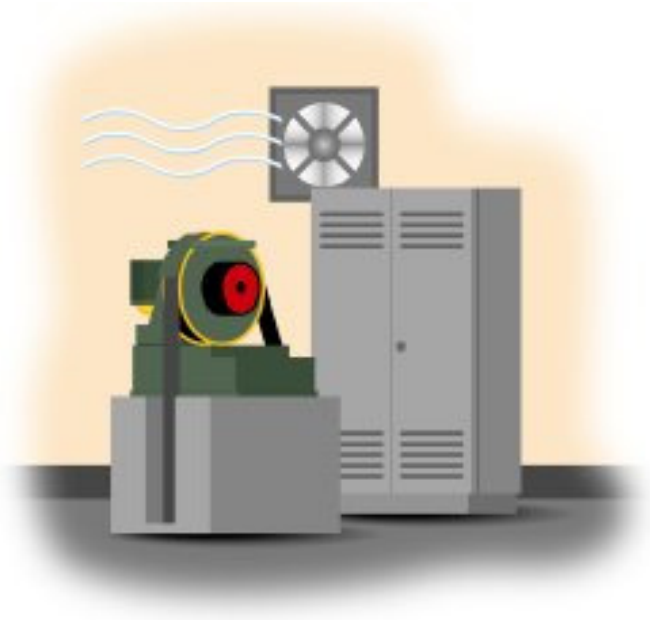
Why modernise the existing lifts?

(* See also EMSD Guidelines for Modernising Existing Lifts http://www.emsd.gov.hk/emsd/e_download/pps/le/Modernising_Lifts.pdf)

Lift Modernisation

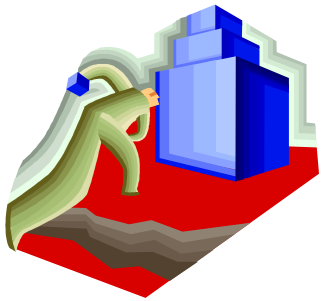


- Influencing factors
  - Type of installation
  - Original manufacturer
  - Budget provision
  - Building life cycle
  - Codes & standards



- Typical elements
  - Lift car, door equipment, control system, drive machinery, guide rails & fixings, pit equipment

Lift Modernisation



- Recommended work stages
  - 1. Pre-planning
  - 2. Design limitations
  - 3. Planned modernisation
  - 4. System design
  - 5. Specification
  - 6. Tender list
  - 7. Out to tender
  - 8. Post-tender evaluation
  - 9. Award of contract

(* See also http://www.theliftconsultancy.co.uk/topics-lift-modernisation)