Chapter 3: Elevator “muscle power”

Summary: Elevator "muscle power" controls how swift a car can move between floors including the times for closing and opening of doors. Door to Door Flight Times (DDFT’s) define the "muscle power" of each elevator. DDFT’s can be measured easily and facilitate the comparison of the "muscle power" of different types or brands of elevators.

“Muscle power”

Each elevator drive system has characteristics that determines the minimum car flight time over a specific floor distance. The door drive also has a minimum time for door closing and door opening. These minimum times define the maximum “muscle power” of an elevator. “Muscle power” can be defined as follows:

Door to Door Flight Time (DDFT)

The DDFT is the time period from the moment the doors start to close till the moment the doors are fully open on the next target floor.

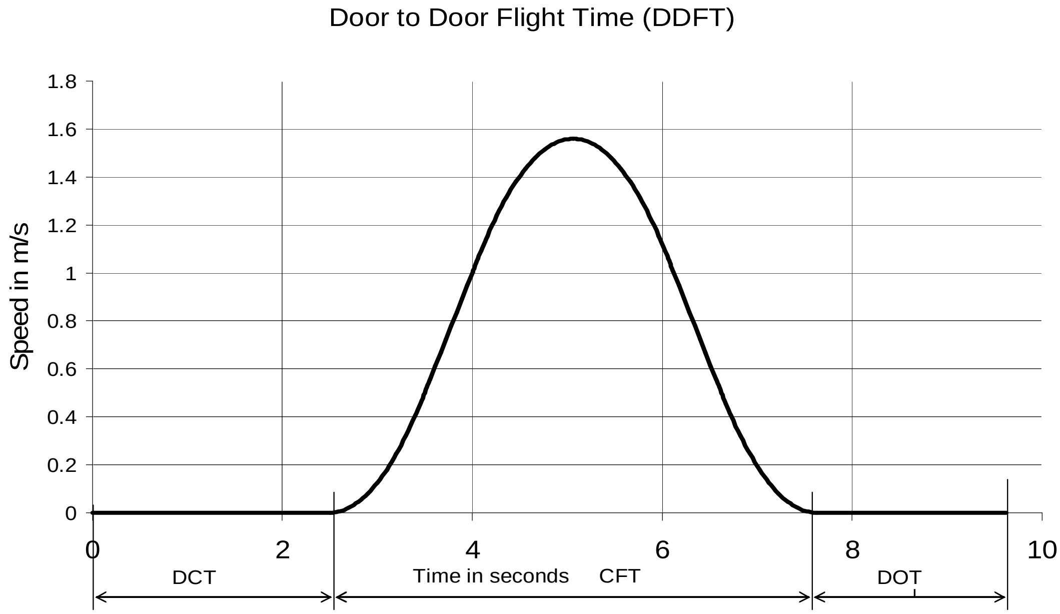
To compare the **maximum “muscle power”** of two brands of elevators, A and B, it is sufficient to compare their **minimum DDFT’s** over a specific floor distance. If elevator A has a shorter minimum DDFT over this distance than B, the minimum DDFT’s of elevator A over all distances will be shorter than those of elevator B. Reason: The shorter DDFT of A is caused by a differential in the characteristics of A and B, that control the minimum DDFT’s over each and every distance.

Elevators should not operate with maximum “muscle power” at all times; however, the ability to apply more “muscle power” during periods of PEAK traffic is a desirable feature for "intelligent elevators".

Elevator contracts and specifications usually do not mention data for DDFT’s although these data are of great interest. For example: The DDFT of a modern high speed elevator over a floor distance of 4 meters is approximately 10 seconds. This time can be easily checked by a building manager and provide him with an immediate information about the “muscle power” performance of this elevator! Automatic monitoring of DDFT’s is of course a “must” for "intelligent elevators".

The maximum or **contract speed** is usually the only reference to “muscle power” in an elevator quotation or contract. However, the car of an elevator with a contract speed of 2.5 m/s requires a non-stop travel distance of approximately 9 meters to momentarily reach contract speed. DDFT’s for short distances are controlled by the rates for **acceleration, deceleration and jerk** and the **door opening and closing times**. Tables 1 and 2 in the Appendix to this chapter demonstrate their influence. Detailed information about the above mentioned rates and door times (minima and maxima) should be a standard element of all elevator specifications.

The DDFT definition is depicted below in the form of a DDFT graph that is typical for a one floor trip of a modern high speed elevator.



Elevator data

Contract speed	2.5	m/s	DDFT	9.6	seconds
Acceleration	1	m/s^2	DCT	2.5	seconds
Deceleration	1	m/s^2	CFT	5.1	seconds
Jerk rate	1	m/s^3	DOT	2.0	seconds
Floor distance	4	m			

The above graph consists of **3 phases**:

- DCT = Door Closing Time
- CFT = Car Flight Time
- DOT = Door opening time

An additional phase that may be used in performance calculations is the **“Time gain for advanced door opening”**. When regulations permit to start door opening before the car is completely level with the target floor a small time saving is possible. All Door to Door Flight Times (DDFT)’s in this book ignore this very small time saving because it does not affect the performance comparisons of this book.

Each one of the 3 phases mentioned above deserves further attention.

Door Closing Time (DCT)

During the DCT the elevator controls execute several tasks:

- start and control door closing
- measure the load in the car
- build the motor field to hold car in position during brake opening
- lock the doors
- open the brake of the drive system

The last two tasks are split second operations that take place during the last phase of door closing and are timed to allow the car to start moving immediately after the landing doors are locked. In this book a standard DCT of 2.5 seconds is assumed and car movement starts immediately after the DCT ends. All DDFT's mentioned in this book are calculated on this basis.

To achieve short DDFT's it is obvious that the DCT should be as short as possible; however, a short DCT implies a high door closing speed. A high door closing speed may be uncomfortable or even dangerous if impact with a passenger occurs. For this reason regulations about maximum permissible impact forces exist and this means that maximum door speed and the weight of door panels are interdependent.

Car Flight Time (CFT)

Modern high speed elevators have speed control systems that deliver optimal CFT's over any floor distance.

The optimal CFT and the maximum speed reached over a specific floor distance are determined by and can be calculated on the basis of the following characteristics:

- contract speed
- acceleration in m/s^2
- deceleration in m/s^2
- jerk rate in m/s^3

CFT's are calculated in accordance with standard mathematical formulas. Readers may obtain CFT's for various distances and speeds from the DDFT's stated in the **Appendix**. The CFT equals the DDFT less the time for door closing and opening (DCT + DOT).

The jerk rate is the rate of change of acceleration and deceleration. The name "jerk rate" is rather appropriate because the jerk rate determines **ride comfort,** together with the mechanical systems of an individual elevator.

The maximum rate of acceleration is of particular interest to the elevator buyer and planners, because a higher rate of acceleration enables "intelligent" drive controls to achieve shorter DDFT's during PEAK traffic periods. A higher maximum rate of acceleration requires a more powerful drive system and this affects costs.

A high speed elevator should have an acceleration rate of at least 1 m/s^2. The maximum rate of acceleration for elevators is usually 1.2 m/s^2.

A higher rate of deceleration does not cause extra costs; however, it usually does not exceed 1.4 m/s^2 for the sake of comfort. Table 1 of the Appendix shows how DDFT's and ride comfort vary in relation to acceleration, deceleration and jerk rates.

The low maximum speeds achieved during short trips imply that a high maximum speed will have very little influence on the performance of a group of low rise elevators. For this reason high speeds are not recommended for low rise elevators.

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All DDFT’s and other data in this book are calculated with acceleration and deceleration rates of 1 m/s^2 and jerk rates of 1 m/s^3.

Door Opening Time (DOT)

The DOT is usually shorter than the DCT, because the danger of impact with passengers does not exist.

All DDFT calculations in this book assume a DOT of 2.0 seconds.

"Muscle power" of intelligent elevators.

Intelligent elevators will have lists that state their DDFT’s for all possible travel distances. They are likely to have a DDFT list for each of the following traffic densities: Heavy-, Medium- and Light traffic. These lists enable intelligent destination groups to adjust acceleration, deceleration and the door opening and closing times relative to anticipated traffic densities.

Intelligent elevators continuously monitor their DDFT’s and will report deviations from correct values.

Chapter 13: “Transparent performance calculations“ states DDFT’s for speeds up to 10 meters/second and travel distances up to 100 meter in Appendix 6.

Appendix

Table 1 shows, for a small range of short distances, the DDFT and the maximum speed reached with different rates for acceleration, deceleration and jerks and how different rates affect ride comfort. Please note that the DDFT’s for short distances may vary considerably. These DDFT reductions affect each and every trip and for this reason "intelligent elevators" may use different settings for light, medium and heavy traffic.

Table 2 shows, for **contract speeds up to 10.0 m/s**, the minimum travel distance to **momentarily reach the contract speed** and the relevant DDFT. This table facilitates calculation of DDFT’s for long distances.

Appendix

Table 1

Door to Door Flight Times (DDFT'S) and maximum speed reached (Vmax) over various floor distances, for elevators with contract speed 2.5 m/sec.								
Floor distance in meters	acceleration 0.8 m/s^2 deceleration 0.8 m/s^2 jerk rate 0.8 m/s^3		acceleration 1.0 m/s^2 deceleration 1.0 m/s^2 jerk rate 1.0 m/s^3		acceleration 1.2 m/s^2 deceleration 1.2 m/s^2 jerk rate 1.5 m/s^3		acceleration 1.2 m/s^2 deceleration 1.4 m/s^2 jerk rate 2.0 m/s^3	
	DDFT in seconds	Vmax m/sec.	DDFT in seconds	Vmax m/sec.	DDFT in seconds	Vmax m/sec.	DDFT in seconds	Vmax m/sec.
4	10.1	1.4	9.6	1.6	9.0	1.8	8.7	1.9
5	10.6	1.6	10.1	1.8	9.5	2.0	9.1	2.2
6	11.1	1.8	10.5	2.0	9.8	2.2	9.5	2.4
7	11.5	2.0	10.9	2.2	10.2	2.5	9.9	2.5
8	11.9	2.2	11.2	2.4	10.6	2.5	10.3	2.5
9	12.3	2.3	11.6	2.5	11.0	2.5	10.7	2.5
								Ch3dia1
	Ride quality characteristics							
	Movement of car hardly noticeable		very good		good		less comfortable	
Assumptions for door times:								
Door Closing Time (DCT)			2.5	seconds				
Door opening Time (DOT)			2.0	seconds				
Time Gain Advanced Opening			0	seconds				

Table 2

Minimum DDFT's and minimum Travel Distances for momentary reaching contract speed								
Contract speed in m/sec.	acceleration 0.8 m/s^2 deceleration 0.8 m/s^2 jerk rate 0.8 m/s^3		acceleration 1.0 m/s^2 deceleration 1.0 m/s^2 jerk rate 1.0 m/s^3		acceleration 1.2 m/s^2 deceleration 1.2 m/s^2 jerk rate 1.5 m/s^3		acceleration 1.2 m/s^2 deceleration 1.4 m/s^2 jerk rate 2.0 m/s^3	
	DDFT in seconds	Tr. Dist. in m to reach contr. speed	DDFT in seconds	Tr. Dist. in m to reach contr. speed	DDFT in seconds	Tr. Dist. in m to reach contr. speed	DDFT in seconds	Tr. Dist. in m to reach contr. speed
2.5	12.8	10.3	11.5	8.8	10.3	7.2	9.7	6.4
3.0	14.0	14.3	12.5	12.0	11.1	9.9	10.4	8.9
3.2	14.4	15.6	12.8	13.1	11.4	10.8	10.7	9.7
4.0	16.5	24.0	14.5	20.0	12.8	16.5	12.0	15.0
5.0	19.0	36.3	16.5	30.0	14.4	24.8	13.5	22.6
6.0	21.5	51.0	18.5	42.0	16.1	34.8	15.1	31.7
7.0	24.0	68.3	20.5	56.0	17.8	46.4	16.6	42.4
8.0	26.5	88.0	22.5	72.0	19.4	59.7	18.2	54.7
10.0	31.5	135.0	26.5	110.0	22.8	91.3	21.3	83.8
								Ch3dia2
Ride quality characteristics:			See Table 1 above.					
Assumptions for door times:			See Table 1 above.					