6 Fuselage design

In conventional aircraft the fuselage serves to accommodate the payload. The wings are used to store fuel and are therefore not available to accommodate the payload. The payload of civil aircraft can consist of passengers, baggage and cargo. The passengers are accommodated in the cabin and the cargo in the cargo compartment. Large items of baggage are also stored in the cargo compartment, whereas smaller items are taken into the cabin as carry-on baggage and stowed away in overhead stowage compartments above the seats. The cockpit and key aircraft systems are also located in the fuselage.

6.1 Fuselage cross-section and cargo compartment

Today's **passenger aircraft** have a **constant fuselage cross-section** in the central section. This design reduces the production costs (same frames; simply instead of doubly curved surfaces, i.e. a sheet of metal can be unwound over the fuselage) and makes it possible to construct aircraft variants with a lengthened or shortened fuselage. In this section we are going to examine the cross-section of this central fuselage section.

In order to accommodate a specific number of passengers, the fuselage can be long and narrow or, conversely, short and wide. As the fuselage contributes approximately 25% to 50 % of an aircraft's total drag, it is especially important to ensure that it has a low-drag shape. A fuselage fineness ratio l_F / d_F of approximately 6 provides the smallest tube drag[1]. However, as a longer fuselage leads to a longer tail lever arm, and therefore to smaller empennages and lower tail drag, a **fineness ratio of 8 is seen as the ideal** according to [ROSKAM III]. Stretched versions of an aircraft can have fineness ratios of 14, and shorter versions will scarcely be less than 5. If one opts for a fineness ratio of 8 for the first version of a new type of aircraft, one obtains a low-drag fuselage that leaves the option open of constructing shorter or stretched versions at a later stage. The average fineness ratio for passenger planes is about 9.

If we work on the basis of this average fineness ratio, the number of seats abreast is as shown in equation (6.1). **Fig. 6.1** also gives the **number of seats per row** for other fineness ratios.

$$n_{SA} = 0.45 \cdot \sqrt{n_{PAX}} \quad . \qquad \textbf{(6.1)}$$

A **circular** or near-circular **cross-section** is suitable for a **pressure cabin** for reasons of strength. If no baggage is to be transported under the cabin floor, the fuselage can be flattened out at the bottom (Fokker 50, for example). The fuselage cross-section can also be composed of two overlapping circular cross-sections. Thus, special requirements in terms of the ratio of

[1] This only applies to the subsonic range. In the case of supersonic passenger aircraft, the fineness ratio must be just as large as necessary to provide acceptable passenger comfort. Concorde has a fineness ratio of 16.7.

dimensions for the cabin and cargo compartment can be met. The two circles can be on top of each other or next to each other. Such a fuselage cross-section is called a *double bubble*. An alternative to the *double bubble* is an oval fuselage. For an aircraft **without a pressure cabin,** a **rectangular cross-section** is cheaper to produce. Furthermore, in small aircraft, a rectangular cross-section also provides more space for passengers sitting in the window seats (Shorts 330 and 360, for example).

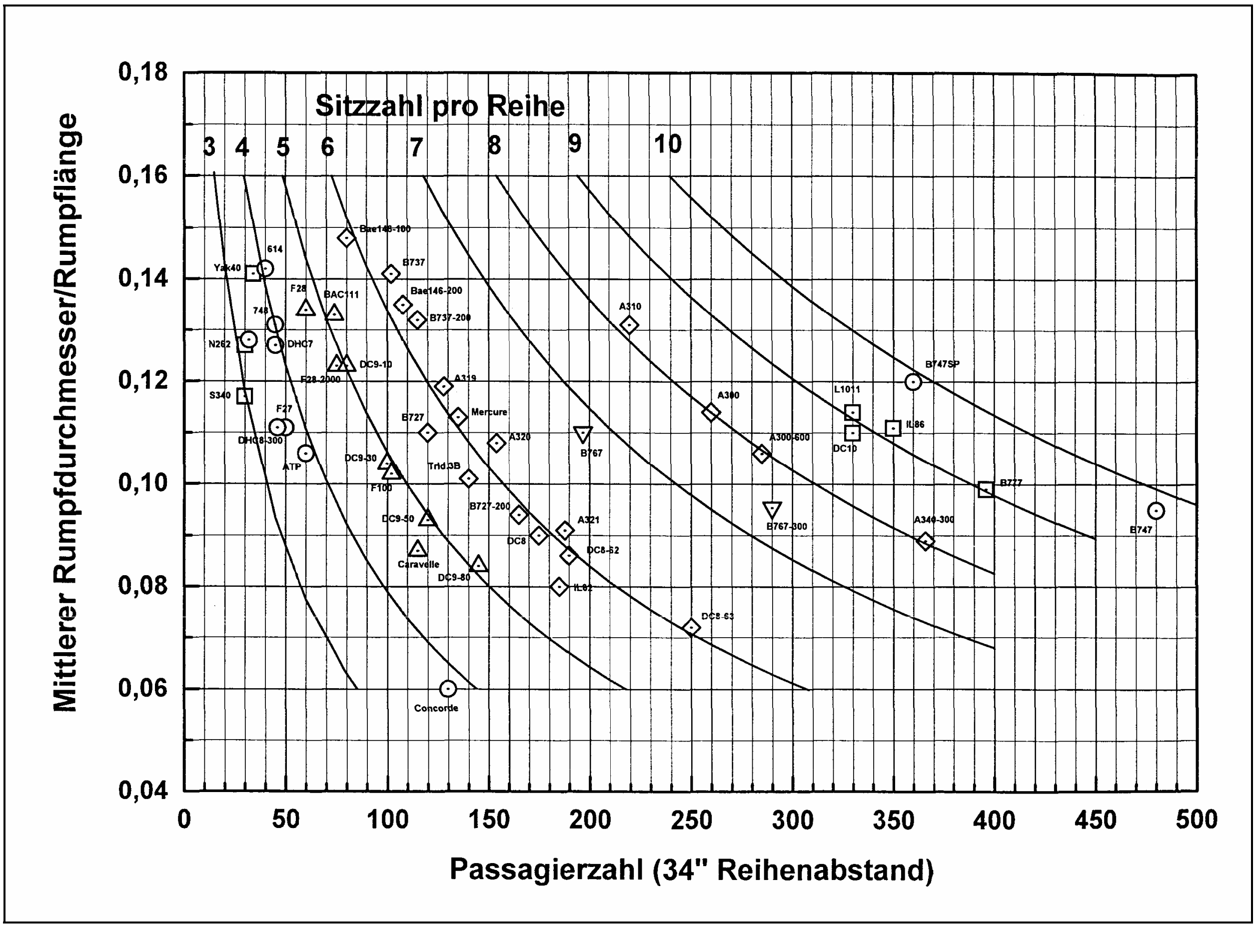


Fig. 6.1: Number of seats per row as a function of passenger numbers and the fineness ratio of the fuselage [MARCKWARDT 98a]

Cabin dimensions are defined in **Fig. 6.2. Fig. 6.3** and **Fig. 6.4** give typical values for cabins and seat dimensions. As cabin dimensions are stated in inches internationally (1 inch = 2.54 cm), it is easier to note characteristic values in this unit and convert them as required.

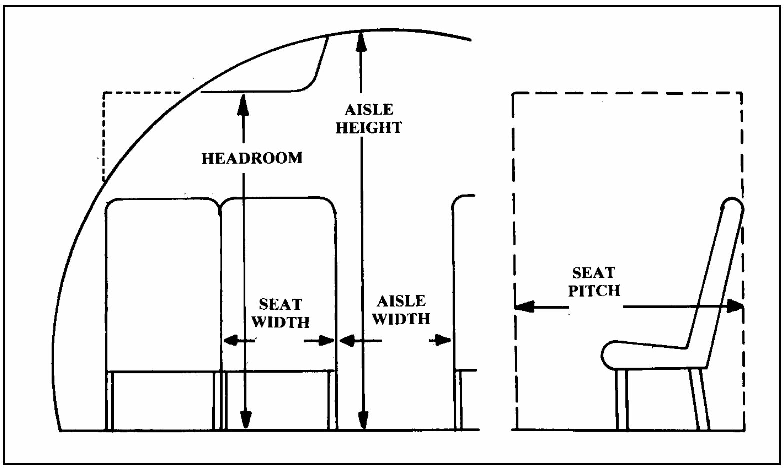


Fig. 6.2:
Definition of key cabin and seat dimensions
[RAYMER 89]

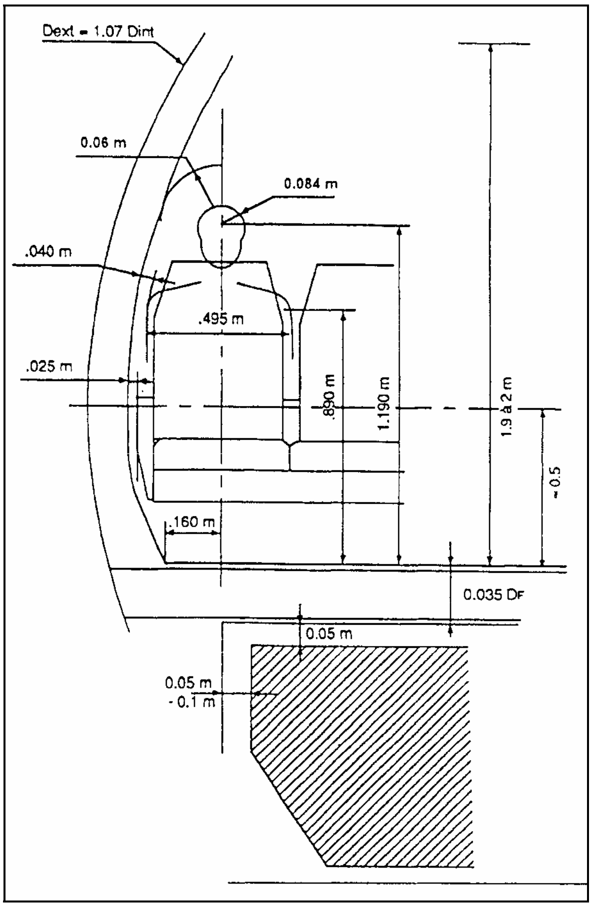


Fig. 6.3:
Some key dimensions for passengers, seats, cabin and cargo compartment.
[SCHMITT 98]

	First class	Economy	High density/ small aircraft
Seat pitch (in.)	38–40	34–36	30–32
Seat width (in.)	20–28	17–22	16–18
Headroom (in.)	>65	>65	–
Aisle width (in.)	20–28	18–20	≥12
Aisle height (in.)	>76	>76	>60
Passengers per cabin staff (international-domestic)	16–20	31–36	≤50
Passengers per lavatory (40″ × 40″)	10–20	40–60	40–60
Galley volume per passenger (ft^3/pass)	5–8	1–2	0–1

Fig. 6.4:
Typical cabin and seat dimensions according to [RAYMER 89]

The certification regulations define minimum requirements for the **width and number of aisles**. However, the figures in the certification regulations should be seen as minimum safety standards, which are, for example, intended to allow successful emergency evacuation. Today's comfort standards require larger aisle widths and fewer seats at the aisles than prescribed.

JAR 25.815 **Width of aisle**
The passenger aisle width at any point between seats must equal or exceed the values in the following table:

Passenger seating capacity	Minimum passenger aisle width (inches)	
	Less than 25 inches from floor	25 inches and more from floor
10 or less	12 *	15
11 to 19	12	20
20 or more	15	20
	* A narrower width not less than 9 inches may be approved when substantiated by tests found necessary by the authority.	

A trolley has a width of approximately 12 inches. If the width of the aisle is 24 inches, it is possible to steer the trolley past a person standing in the aisle. This increases passenger comfort.

JAR 25.817 **Maximum number of seats abreast**
On aeroplanes having only one passenger aisle, no more than 3 seats abreast may be placed on each side of the aisle in any one row.

JAR 25.817 says:

$n_{SA} \leq 6$: one aisle

$6 < n_{SA} \leq 12$: two aisles

Current **comfort requirements** are stated in **Fig. 6.4, Fig. 6.5** and **Table 6.1**.

		SR Kurzstrecke SR ≤ 3000 nm	MR Mittelstrecke 3000 nm < MR < 5500 nm		LR Langstrecke LR ≥ 5500 nm		
		YC	FC	YC	FC	BC	YC
Sitze	Sitze in %	100	8 - 10	90 - 92	5 - 7	18 - 20	73 - 77
	Sitzabstand [inch]	32	40	32	60	38	32
	Sitzlehnenneigung [inch]	5	7.5	5	15	7	5
	Sitzbreite (2er Bank)	40	48	40	53	50	40
Kabinenpersonal pro Pax		1 / 45	1 / 8	1 / 35	1 / 8	1 / 20	1 / 35
Toiletten pro Pax		1 / 60	1 / 14	1 / 45	1 / 14	1 / 25	1 / 45
Galley / Trolleys [Tabletts / Pax]		1.7	9	2.3	9	7	2.7
Mantelstauraum [inch / Pax]		Nein	1.5	Nein	1.5	1.5	Nein

Fig. 6.5: Definition of cabin standards [SCHMITT 98]

Table 6.1: Definition of cabin standards (Airbus Industrie)

	Economy Class	Business Class	First Class
3-er Bank mit Lehne	60	72	-
2-er Bank mit Lehne	40	48	50
Einzelsitz mit Lehne	21	25	25.5

This data makes it possible to draw the cross-section through the cabin. **Fig. 6.7** to **Fig. 6.11** show **examples of fuselage cross-sections**.

It is immediately noticeable that the cabin floor (with a thickness of approximately 0.2 m) is located below the center line of the fuselage. The typical values for this **lowering of the cabin floor** in relation **to the center line** are 0 m to 1 m, and the average is 0.6 m. With **Fig. 6.6** or equation (6.2) the outer diameter $d_{F,O}$ of the cabin can be deduced from the inner diameter $d_{F,I}$:

$$\Delta d = d_{F,O} - d_{F,I} = 0.084\,\mathrm{m} + 0.045 \cdot d_{F,I} \quad . \tag{6.2}$$

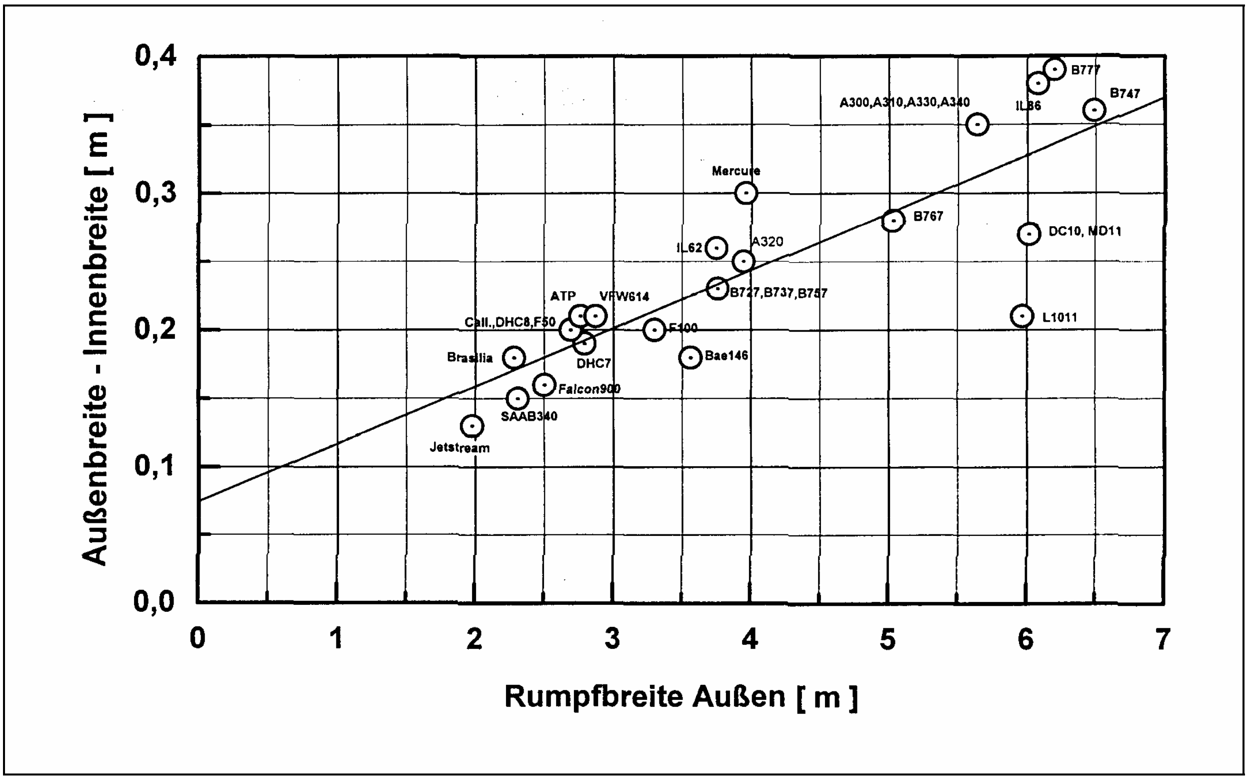


Fig. 6.6: Calculation of the outer width of the fuselage from the inner width [MARCKWARDT 98a]

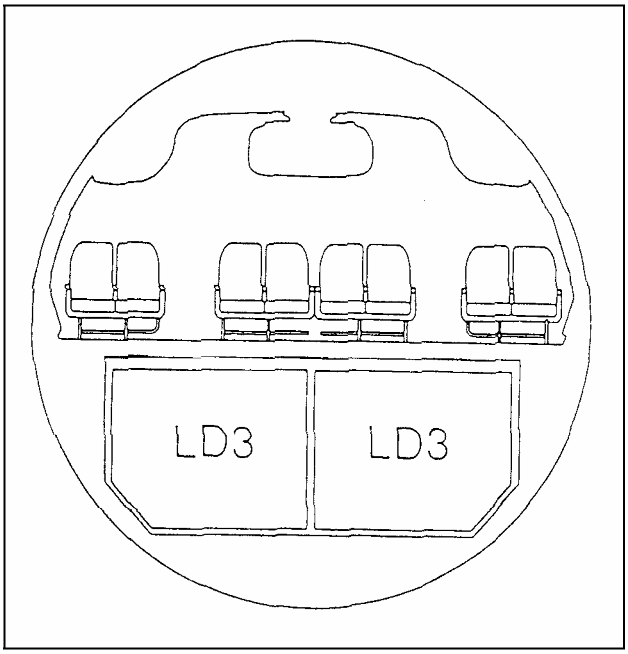


Fig. 6.7:
Airbus A340, twin aisle, widebody aircraft [SCHMITT 98]

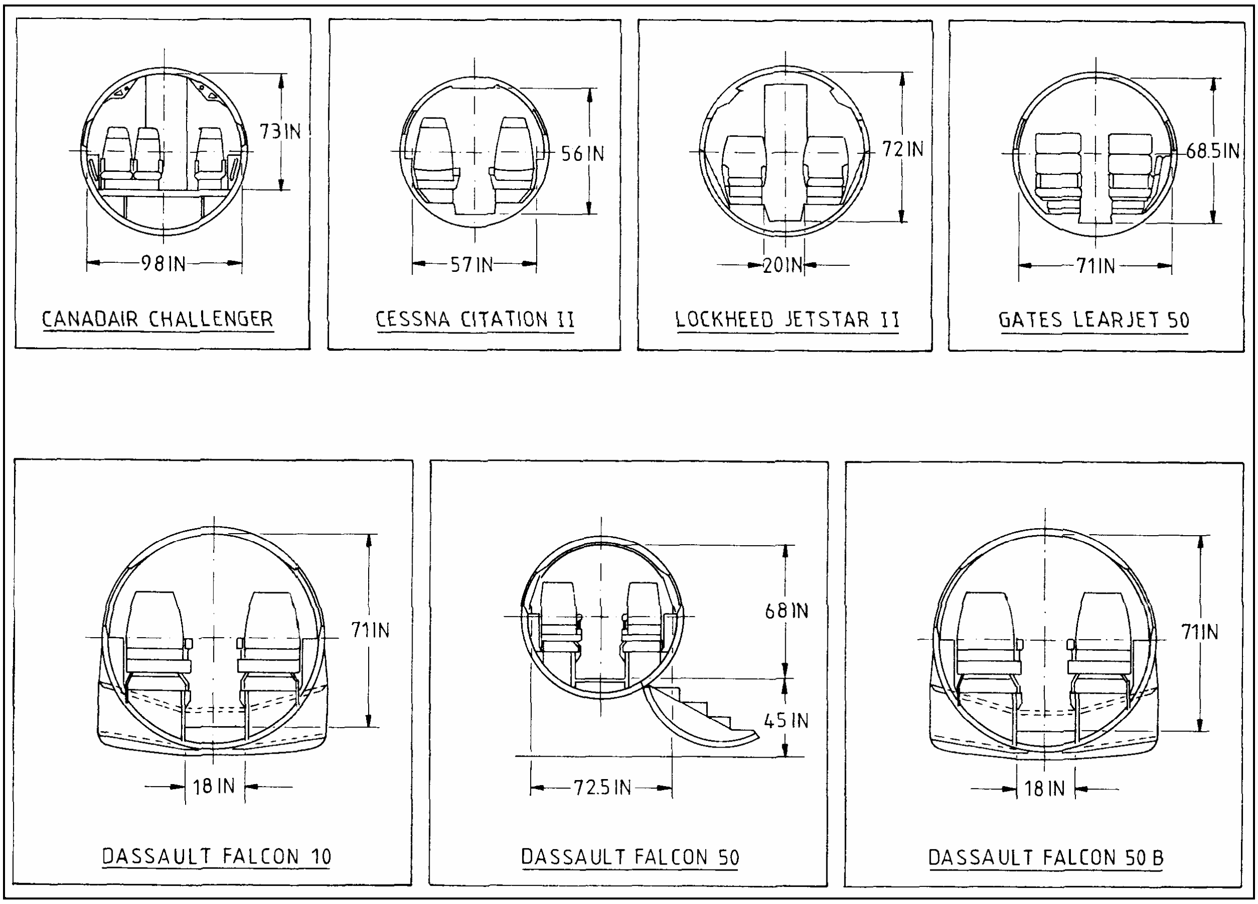


Fig. 6.8: Fuselage cross-sections according to [ROSKAM III]

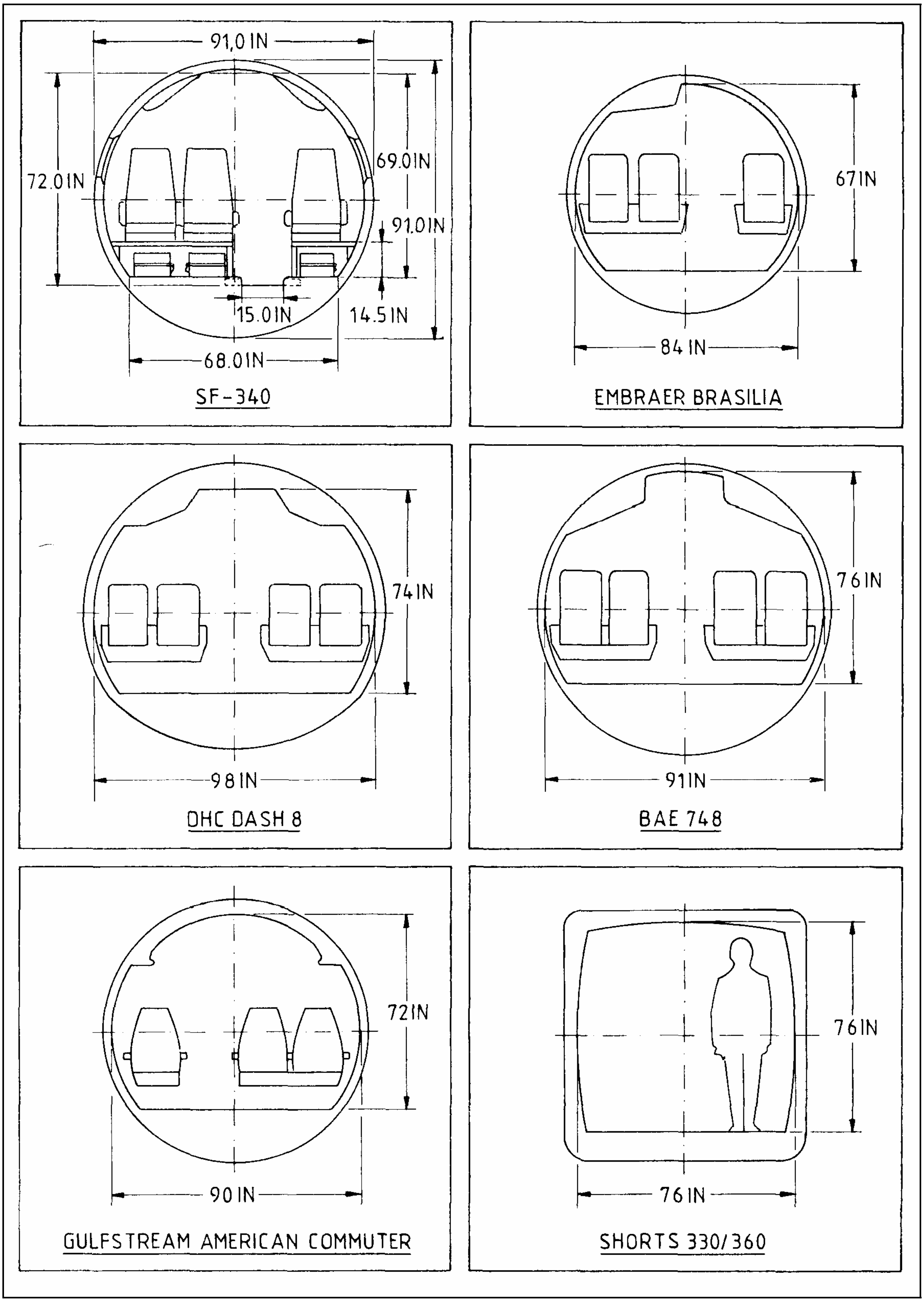


Fig. 6.9: Fuselage cross-sections according to [ROSKAM III]

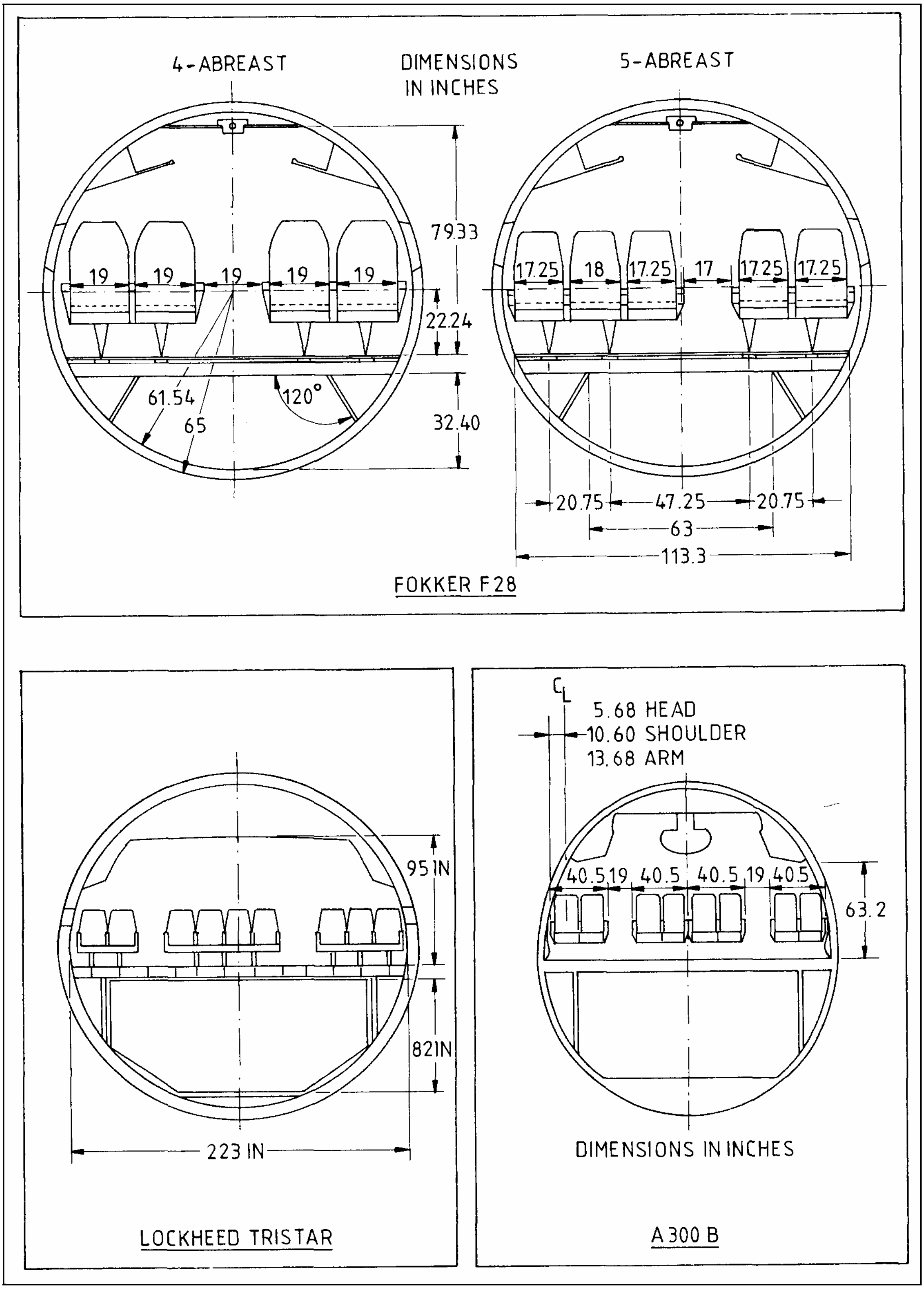


Fig. 6.10: Fuselage cross-sections according to [ROSKAM III]

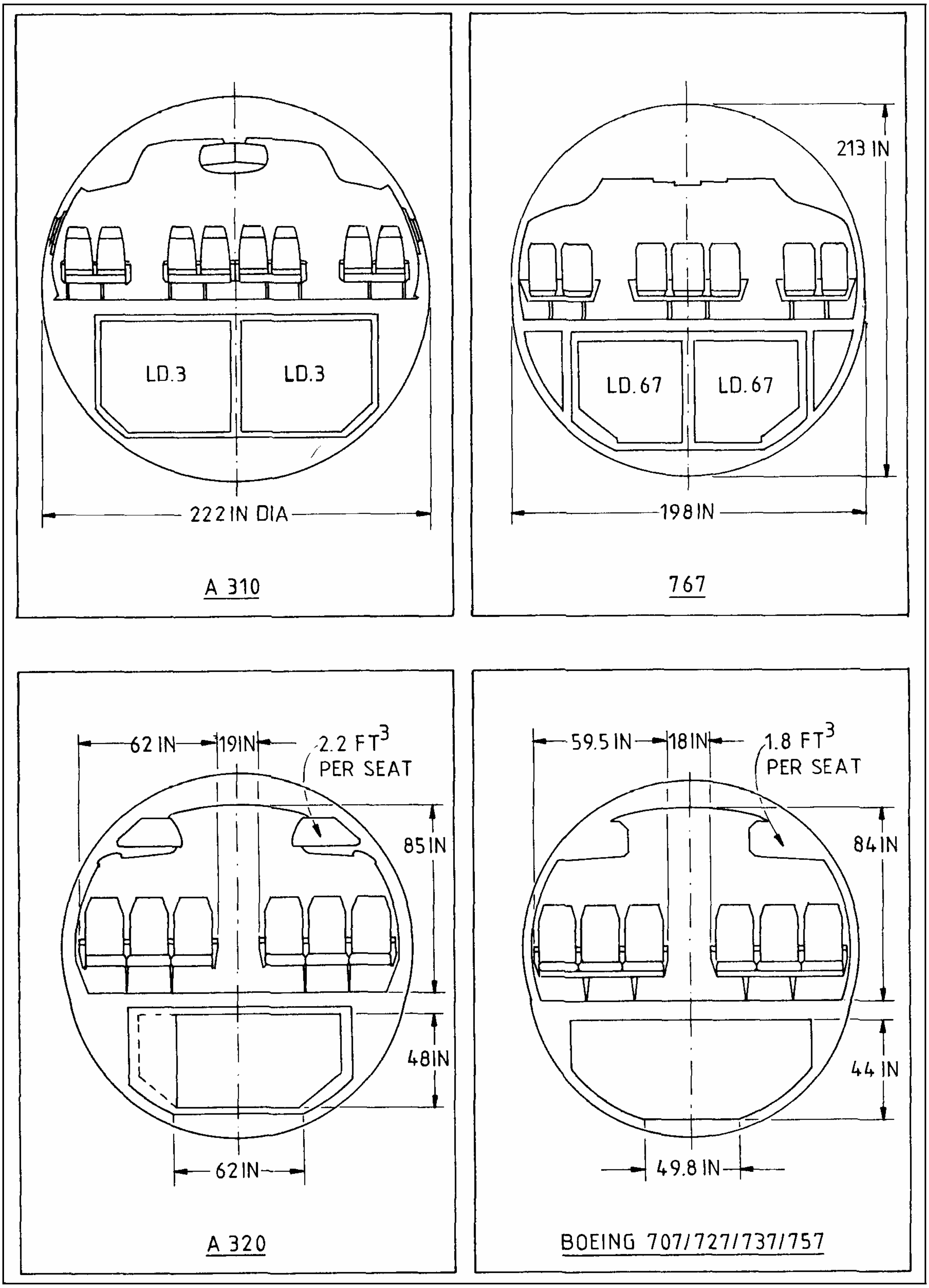


Fig. 6.11: Fuselage cross-sections according to [ROSKAM III]

The fuselage must have adequate volume to accommodate baggage and cargo in addition to passengers. After the cabin cross-section has been drawn, the **volume of the cargo compartment** can be checked:

1.) The necessary volume can be calculated from the required mass of the cargo and the baggage (see Table 3.3) with the aid of the density. **Average densities** according to [TORENBEEK 88] are:

- Baggage: 170 kg/m³,
- Cargo: 160 kg/m³.

2.) On more modern planes, 0.05 m³ to 0.065 m³ per passenger is available for carry-on baggage, in the form of overhead stowage compartments. In practice it has been shown that this volume is in fact utilized because especially business passengers insist on taking their baggage into the cabin with them. The *required* cargo compartment volume $V_{CARGO\_COMPARTMENT}$ is consequently calculated from the required volume for baggage and cargo $\left(V_{BAGGGAGE} + V_{CARGO}\right)$ minus the volume of the overhead stowage compartments $V_{OVERHEAD\_STOWAGE}$

$$V_{CARGO\_COMPARTMENT} \geq \left(V_{BAGGAGE} + V_{CARGO}\right) - V_{OVERHEAD\_STOWAGE} \quad . \qquad \textbf{(6.3)}$$

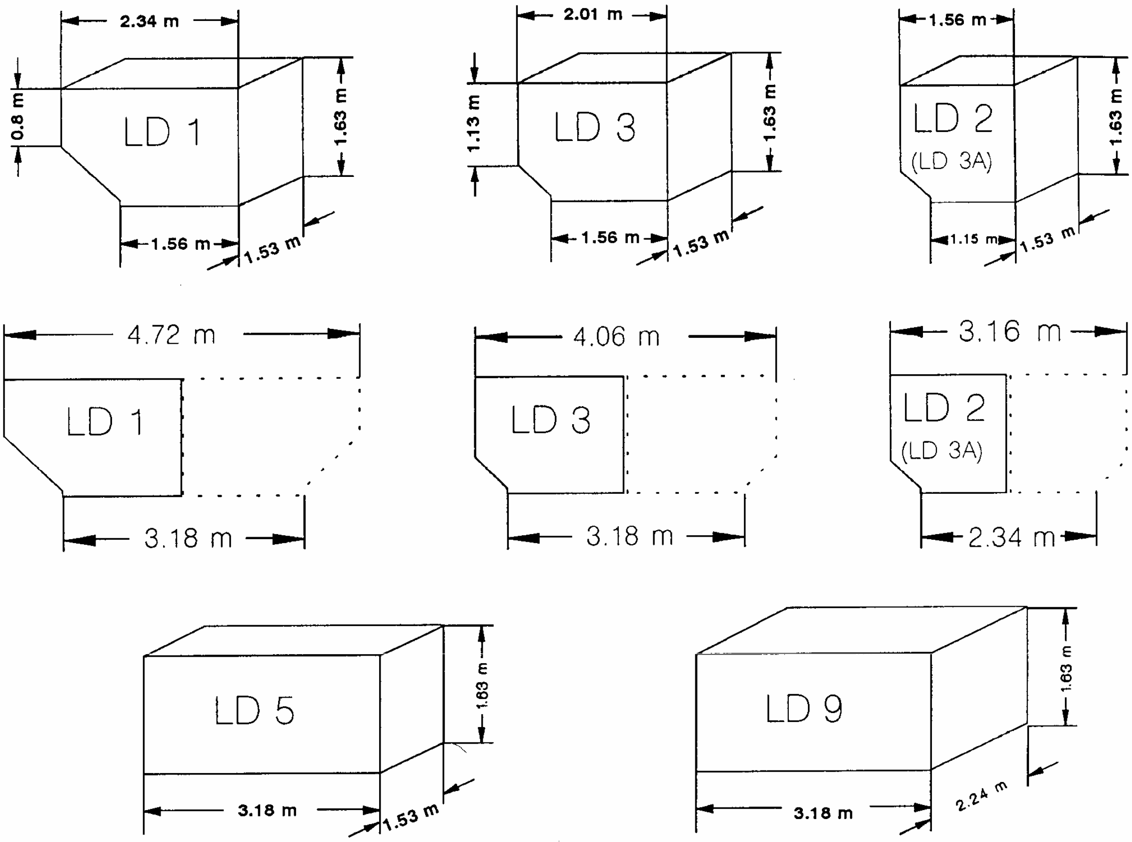
3.) The *available* cargo compartment volume can be roughly calculated. The following applies:

$$V_{CARGO\_COMPARTMENT} = d_F \cdot \frac{l_F}{d_F} \cdot S_{CARGO\_COMPARTMENT} \cdot k_{CARGO\_COMPARTMENT} \quad . \qquad \textbf{(6.4)}$$

$S_{CARGO\_COMPARTMENT}$ is the usable cross-section area of the cargo compartment, measured according to the drawn fuselage cross-section.

$k_{CARGO\_COMPARTMENT}$ defines how much of the total length of the fuselage can be used as a cargo compartment. $k_{CARGO\ COMPARTMENT}$ assumes values of between 0.35 and 0.55. The smaller value applies to regional planes and the larger values to widebody airliners.

4.) To permit fast loading and unloading, standardized **containers (Fig. 6.12)** should be used wherever possible. Therefore, the shape of the cargo compartments is important in addition to their volume. The drawn cabin cross-section must consequently be adapted to allow the use of standard containers (as far as possible).



	Nutzvolumen in [m]^3	Eigenmasse in [kg]
LD 1	4.9	75
LD 3	4.5	70
LD 2	3.4	60
LD 5	6.9	180
LD 9	9.9	200

Übliche Paletten	
m x m	inch x inch
2.24 x 1.38	88 x 54
2.24 x 2.75	88 x 108
2.24 x 3.18	88 x 125
2.44 x 3.18	96 x 125

Fig. 6.12: Dimensions of containers and pallets [MARCKWARDT 98a]

If the cargo compartment is not the required size (or the cargo is less dense), the maximum payload might be limited by the available volume instead of by the MTOW or MZFW. This is a situation that should be avoided.

6.2 Cockpit, cabin and fuselage tail section

The **cockpit** must provide sufficient space for the pilot and any additional crew. The rough layout of the cockpit can be shown in a view according to **Fig. 6.13**. Information on the layout of the cockpit is contained in [ARP 4101] (Aerospace Recommended Praxis (ARP) No. 4101 of the Society of Automotive Engineers (SAE)).

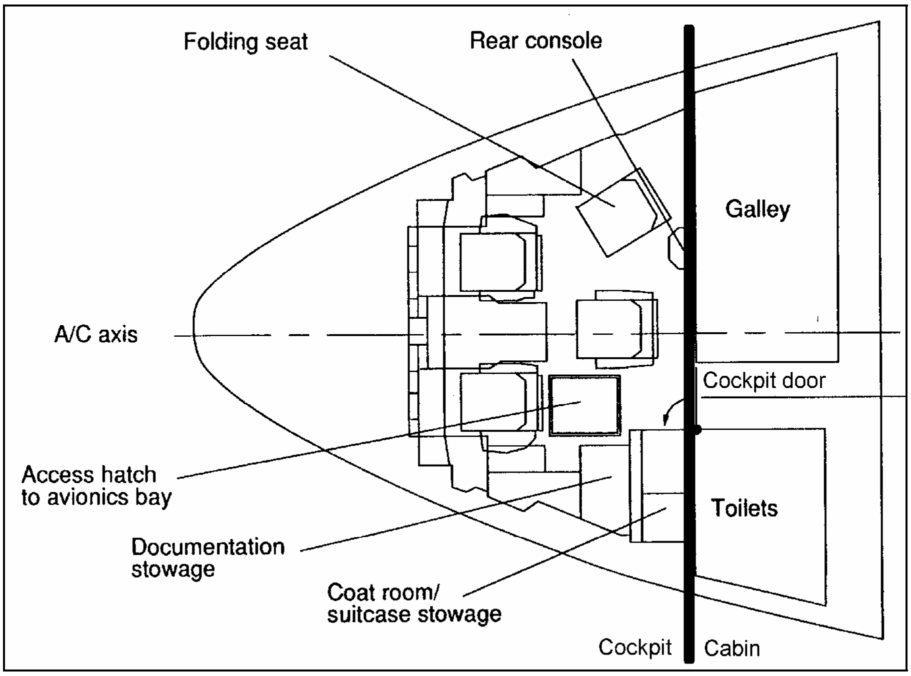


Fig. 6.13:
Airbus A340,
View of the cockpit
(Airbus Industrie)

JAR 25.771	Pilot compartment
(b)	The primary controls ... must be located with respect to the propellers so that **no member of** the minimum **flight crew** ... or part of the controls, **lies in the region** between the plane of rotation of any inboard propeller and the surface generated by a line passing through the centre of the propeller hub making an angle of **5º forward or aft of the plane of rotation of the propeller**.

According to JAR 25.771, the pilots' seats in propeller aircraft should not be at rotor level.

The **cockpit windows** must provide pilots with an adequate view to the outside:

JAR 25.773	**Pilot compartment view**
(a)	Non-precipitation conditions...
(1)	Each pilot compartment must be arranged to give the pilots a **sufficiently extensive, clear, and undistorted view**, to enable them to safely perform any manoeuvres within the operating limitations of the aeroplane, including taxying, take-off, approach and landing.

[ARP 4101/2] defines what a “sufficiently extensive view” means. Each pilot must have a view to the outside from the design eye position, encompassing a certain angle range upwards, downwards, to the left and to the right. **Fig. 6.14** defines the necessary angle. **Fig. 6.15** shows how this requirement was met in the Airbus A340.

The following also applies according to [ARP 4101/2]:

3.3	Impairments: **Impairments to Vision** within the Vision area ... , when using arnbinocular Vision shall meet the following requirements: NO obstructions to vision between 20 degrees right and 20 degrees left. It must be possible for the pilot to eliminate any obstruction to Vision using arnbinocular vision with head movement of 32 mr;i (1.25 in) left and right.

Therefore, the pilot’s view must not be inadmissibly restricted by struts between the cockpit windows.

The cockpit windows should produce as streamlined a fuselage contour as possible, but they should not be flatter than approximately 30° because the pilot’s vision might otherwise be impaired due to reduced transparency and potential reflections from the instruments. Flat cockpit windows are cheaper than curved cockpit windows, but curved ones produce less drag.

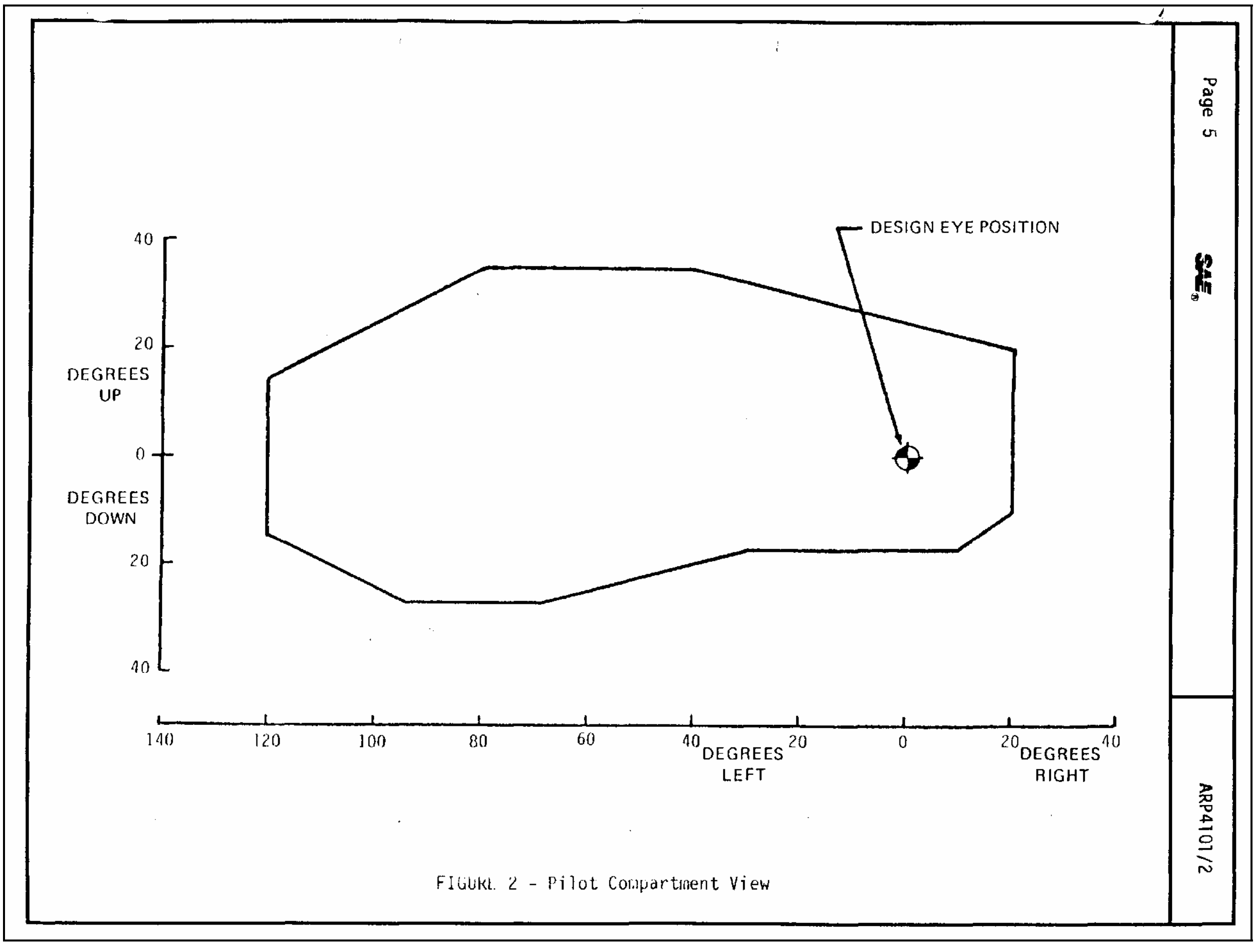


Fig. 6.14: Pilot’s required field of vision according to ARP 4101/2

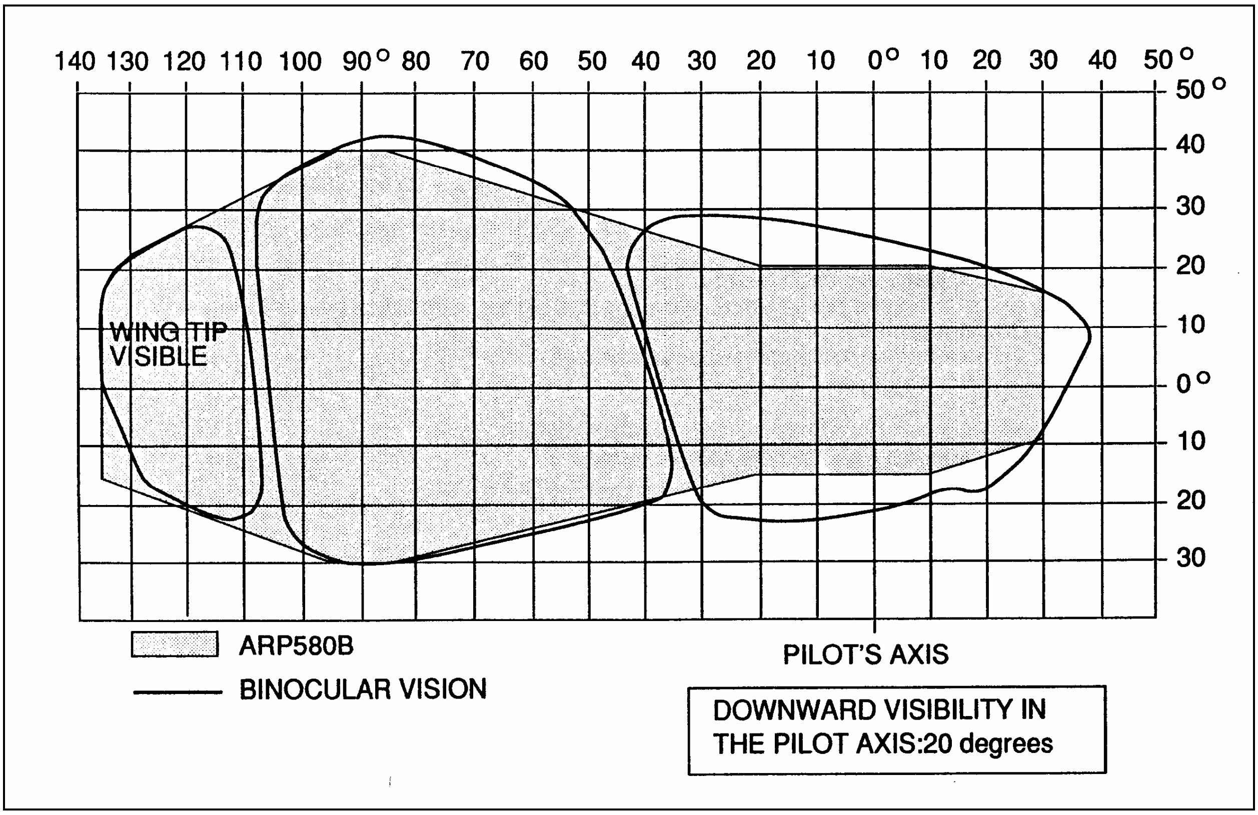


Fig. 6.15: The pilot's field of vision from the cockpit of an Airbus A340 (Airbus Industrie). Please note: ARP580B no longer exists. The necessary field of vision is defined in ARP 4101/2, see Fig. 6.14

The cabin must accommodate the following items:

- seats for passengers and flight attendants,
- lavatories,
- galleys,
- wardrobes.

For a given fuselage cross-section, the length of the cabin l_{CABIN} is calculated from the sum of the areas of all the parts to be accommodated. An initial estimate is provided by $k_{CABIN} \approx 1.0\text{m} \ldots 1.1\text{m}$ for single-class seating.

$$l_{CABIN} = k_{CABIN} \cdot \frac{n_{PAX}}{n_{SA}} \quad . \qquad (6.5)$$

According to Fig. 6.5, the total number of passengers n_{PAX} is split into the classes FC, BC and YC. The required area (or length) for all **passenger seats** in the cabin is determined from the distance between the seats in these categories. It is important to bear in mind that the distance between the seats and the dividing walls (which are used to separate individual classes) must be greater because the foot space under the seat in front that would otherwise be available is missing.

The **seats of flight attendants** are designed as folding seats to save space. They are preferably placed near (emergency) exits. The details can be found in [ARP 583]. The number of flight attendants, as employed in practice, can be found in Fig. 6.4 and Fig. 6.5. The minimum number of flight attendants is specified in JAR-OPS and FAR Part 91. At least one flight attendant is required per 50 passengers, or fraction of 50, on board.

JAR - OPS 1.990 Number and composition of Cabin Crew
(a) An operator shall not operate an aeroplane with a maximum approved passenger seating configuration of more than 19, when carrying one or more passengers, unless at least one cabin crew member is included in the crew for the purpose of performing duties, specified in the Operations Manual, in the interests of the safety of passengers.
(b) When complying with sub-paragraph (a) above, an operator shall ensure that the minimum number of cabin crew is the greater of:
(1) **One cabin crew member for every 50**, or fraction of 50, **passenger** seats installed on the same deck of the aeroplane; ...

FAR 91.533 Flight attendant requirements.
(a) No person may operate an airplane unless at least the following number of flight attendants are on board the airplane:
(1) For airplanes having more than 19 but less than 51 passengers on board, one flight attendant.
(2) For airplanes having more than 50 but less than 101 passengers on board, two flight attendants.
(3) For airplanes having more than 100 passengers on board, two flight attendants plus **one additional flight attendant for each** unit (or part of a unit) of **50 passengers** above 100.

The number of **lavatories** required is also stated in Fig. 6.4 and Fig. 6.5. The floor space taken up by one lavatory is:

- [RAYMER 89] : 1.03 m²,
- [MARCKWARDT 98a] : 1.20 m².

The required floor space for the galleys is [MARCKWARDT 98a]

$$S_{GALLEY} = k_{GALLEY} \cdot \frac{n_{PAX}}{1000} + \frac{1}{2} \mathrm{m}^2 \qquad \textbf{(6.6)}$$

with k_{GALLEY} from Table 6.2.

Table 6.2: Factor k_{GALLEY} for estimating the floor space of the galleys as a function of the routes on which the aircraft is operated

Routes	k_{GALLEY} [m²]
Südatlantik, Fernost, Südafrika	41
Nordatlantik, Nahost	32
Europa	23
Innerdeutsch und Nachbarschaft	16

According to [MARCKWARDT 98a] the floor space of the wardrobes is approximately

$$S_{WARDROBE} = 0.03\,\mathrm{m}^2 \cdot \left(1 - 3 \cdot \frac{n_{AISLE}}{n_{PAX}}\right) \cdot n_{PAX} \quad . \qquad \textbf{(6.7)}$$

The number of emergency exits is stipulated by JAR 25.809 as follows:

JAR 25.807 **Emergency exits**

(a) Type. For the purpose of this JAR-25, the **types of exits are defined** as follows:

(1) **Type I**. This type is a **floor level exit** with a rectangular opening of not less than **24 inches** (609·6mm) wide **by 48 inches** (1·219 m) high, with corner radii not greater than one-third the width of the exit.

(2) **Type II**. This type is a rectangular opening of not less than **20 inches** (508 mm) wide **by 44 inches** (1·12 m) high, with corner radii not greater than one-third the width of the exit. Type II exits must be **floor level exits** unless located over the wing, in which case they may not have a step-up inside the aeroplane of more than 10 inches (254 mm) nor a step-down outside the aeroplane of more than 17 inches (431·8 mm).

(3) **Type III**. This type is a rectangular opening of not less than **20 inches** (508 mm) wide **by 36 inches** (914·4 mm) high, with corner radii not greater than one-third the width of the exit, and with a step-up inside the aeroplane of not more than 20 inches (508 mm). If the exit is located over the wing, the step-down outside the aeroplane may not exceed 27 inches (685·8 mm).

(4) **Type IV**. This type is a rectangular opening of not less than **19 inches** (482·6 mm) wide **by 26 inches** (660·4 mm) high, with corner radii not greater than one-third the width of the exit, located **over the wing**, with a step-up inside the aeroplane of not more than 29 inches (736·6 mm) and a step-down outside the aeroplane of not more than 36 inches (914·4 mm).

(5) **Ventral**. This type is an exit from the passenger compartment through the pressure shell and the bottom fuselage skin. The dimensions and physical configuration of this type of exit must allow at least the same rate of egress as a Type I exit with the aeroplane in the normal ground attitude, with landing gear extended.

(6) **Tail cone**. This type is an aft exit from the passenger compartment through the pressure shell and through an openable cone of the fuselage aft of the pressure shell. The means of opening the tail cone must be simple and obvious and must employ a single operation.

(7) **Type A**. This type is a **floor level exit** with a rectangular opening of not less than **42 inches** (1·067 m) wide by **72 inches** (1·829 m) high with corner radii not greater than one-sixth of the width of the exit.

(b) **Step down distance**. Step down distance, as used in this paragraph, means the actual distance between the bottom of the required opening and a usable foot hold, extending out from the fuselage, that is large enough to be effective without searching by sight or feel.

(c) **Over-sized exits**. Openings larger than those specified in this paragraph, whether or not of rectangular shape, may be used if the specified rectangular opening can be inscribed within the opening and the base of the inscribed rectangular opening meets the specified step-up and step-down heights.

(d) Passenger emergency exits. Except as provided in sub-paragraphs (d)(3) to (7) of this paragraph, **the minimum number and type of passenger emergency exits is as follows:**

(1) For passenger seating configurations of **1 to 299 seats** - Passenger seating Emergency exits for each side of the fueslage configuration (crewmember seats not included)

Passenger seat configuration (crew member seats not included)	**Emergency exits for each side of the fuselage**			
	Type I	Type II	Type III	Type IV
1 to 9				1
10 to 19			1	
20 to 39		1	1	
40 to 79	1		1	
80 to 109	1		2	
110 to 139	2		1	
140 to 179	2		2	

Additional exits are required for passenger seating configurations greater than 179 seats in accordance with the following table:

Additional emergency exits (each side of fuselage)	Increase in passenger seating configuration allowed
Type A	110
Type I	45
Type II	40
Type III	35

(2) For **passenger seating configurations greater than 299 seats**, each emergency exit in the side of the fuselage must be either a Type A or a Type I. A passenger seating configuration of 110 seats is allowed for each pair of Type A exits and a passenger seating configuration of 45 seats is allowed for each pair of Type I exits.

(3) **If a passenger ventral or tail cone exit is installed** and that exit provides at least the same rate of egress as a Type III exit with the aeroplane in the most adverse exit opening condition that would result from the collapse of one or more legs of the landing gear, an increase in the passenger seating configuration beyond the limits specified in sub-paragraph (d)(1) or (2) of this paragraph may be allowed as follows:

(i) For a ventral exit, 12 additional passenger seats.

(ii) For a tail cone exit incorporating a floor level opening of not less than 20 inches (508 mm) wide by 60 inches (1·524 m) high, with corner radii not greater than one-third the width of the exit, in the pressure shell and incorporating an approved assist means in accordance with JAR 25.809(h), 25 additional passenger seats.

(iii) For a tail cone exit incorporating an opening in the pressure shell which is at least equivalent to a Type III emergency exit with respect to dimensions, step-up and step-down distance, and with the top of the opening not less than 56 inches (1·422 m) from the passenger compartment floor, 15 additional passenger seats.

(4) **For aeroplanes on which the vertical location of the wing does not allow the installation of over-wing exits**, an exit of at least the dimensions of a Type III exit must be installed instead of each Type IV exit required by sub-paragraph (1) of this paragraph.

(5) ...

(6) ...

(7) For an aeroplane that is required to have more than one passenger emergency exit for each side of the fuselage, **no passenger emergency exit shall be more than 60 feet** (18·288 m) **from any adjacent passenger emergency exit** on the same side of the same deck of the fuselage, as measured parallel to the aeroplane's longitudinal axis between the nearest exit edges.

(e) **Ditching emergency exits for passengers**. Ditching emergency exits must be provided in accordance with the following requirements whether or not certification with ditching provisions is requested:

(1) For aeroplanes that have a passenger seating configuration of nine seats or less, excluding pilots seats, one exit above the waterline in each side of the aeroplane, meeting at least the dimensions of a Type IV exit.

(2) For aeroplanes that have a passenger seating configuration of 10 seats or more, excluding pilots seats, one exit above the waterline in a side of the aeroplane, meeting at least the dimensions of a Type III exit for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, [with one on each side of the aeroplane. The passenger seat/exit ratio may be increased through the use of larger exits, or other means, provided it is shown that the evacuation capability during ditching has been improved accordingly.

(3) If it is impractical to locate side exits above the waterline, the side exits must be replaced by an equal number of readily accessible overhead hatches of not less than the dimensions of a Type III exit, except that for aeroplanes with a passenger configuration of 35 seats or less, excluding pilots seats, the two required Type III side exits need be replaced by only one overhead hatch.

(f) **Flight crew emergency exits**. For aeroplanes in which the proximity of passenger emergency exits to the flight crew area does not offer a convenient and readily accessible means of evacuation of the flight crew, and for all aeroplanes having a passenger seating capacity greater than 20, flight crew exits shall be located in the flight crew area. Such exits shall be of sufficient size and so located as to permit rapid evacuation by the crew. One exit shall be provided on each side of the aeroplane; or, alternatively, a top hatch shall be provided. Each exit must encompass an unobstructed rectangular opening of at least 19 by 20 inches (482·6 by 508 mm) unless satisfactory exit utility can be demonstrated by a typical crew member.

The emergency exits must not be obstructed by seats. Therefore, the distance between the seats may have to be increased in the area of the emergency exits.

The design of the cabin can be drawn with the data now available. **Fig. 6.16** and **Fig. 6.17** give examples.

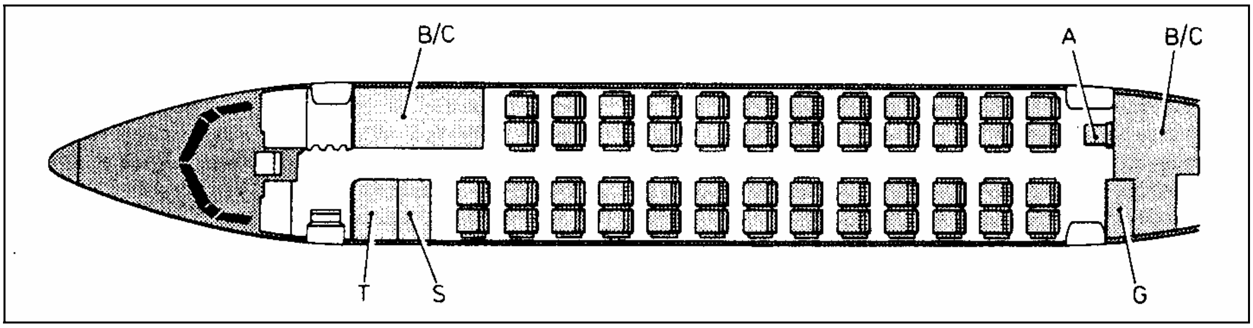


Fig. 6.16: Cabin design of the Fokker 50. Baggage and cargo are also accommodated in the cabin. A: attendant seat, B: baggage, C: cargo, G: galley, S: stowage, wardrobe, T: toilet. [LAMBERT 93]

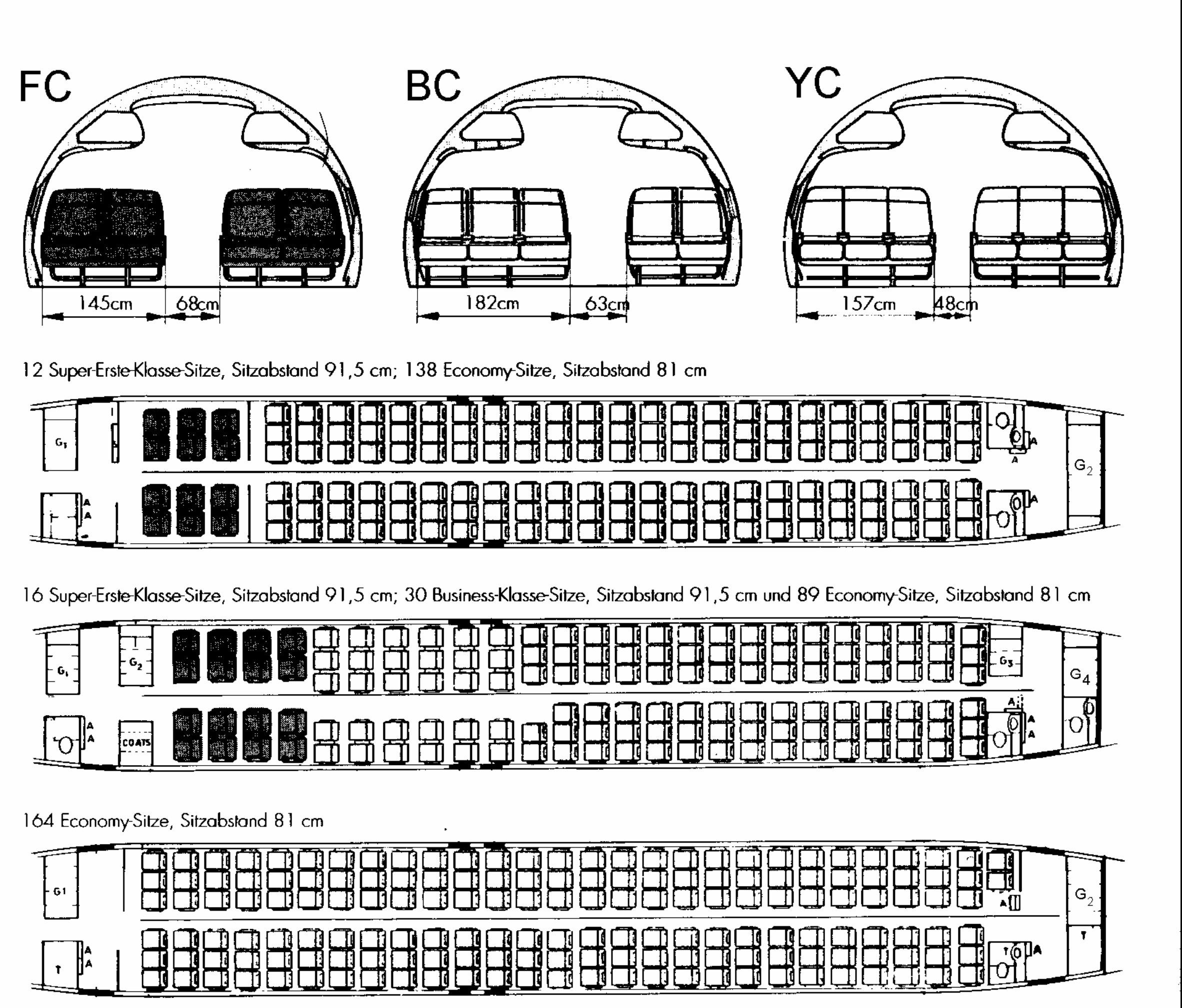


Fig. 6.17: Three different cabin designs of the Airbus A320.
A: attendant seat, G: galley, T: toilet. [GREEN 88]

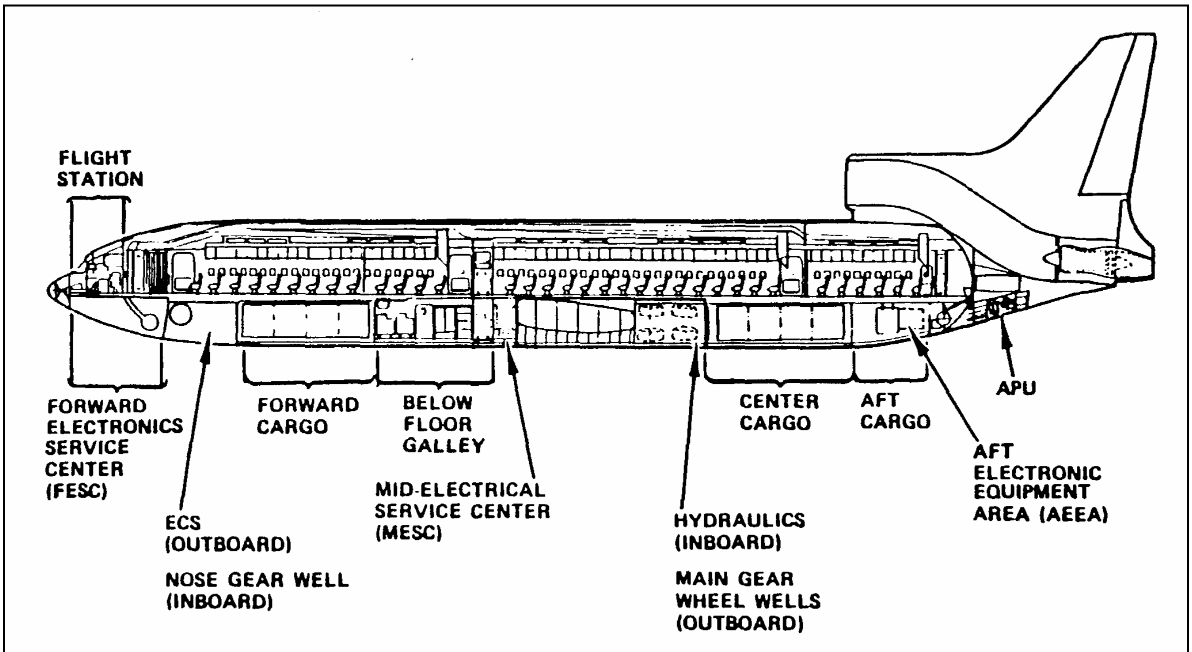


Fig. 6.18: Lockheed L-1011. Distribution and use of the fuselage [Wild 90]

Fig. 6.18 shows how the cabin and the underfloor area are utilized based on the example of the Lockheed L-1011. The rear cargo compartment in the area leading to the tail cannot be loaded with containers, but is only available for loose baggage items. Other underfloor areas are occupied by aircraft systems. By moving galleys or crew rest facilities to the underfloor area, space is created in the cabin for additional passenger seats.

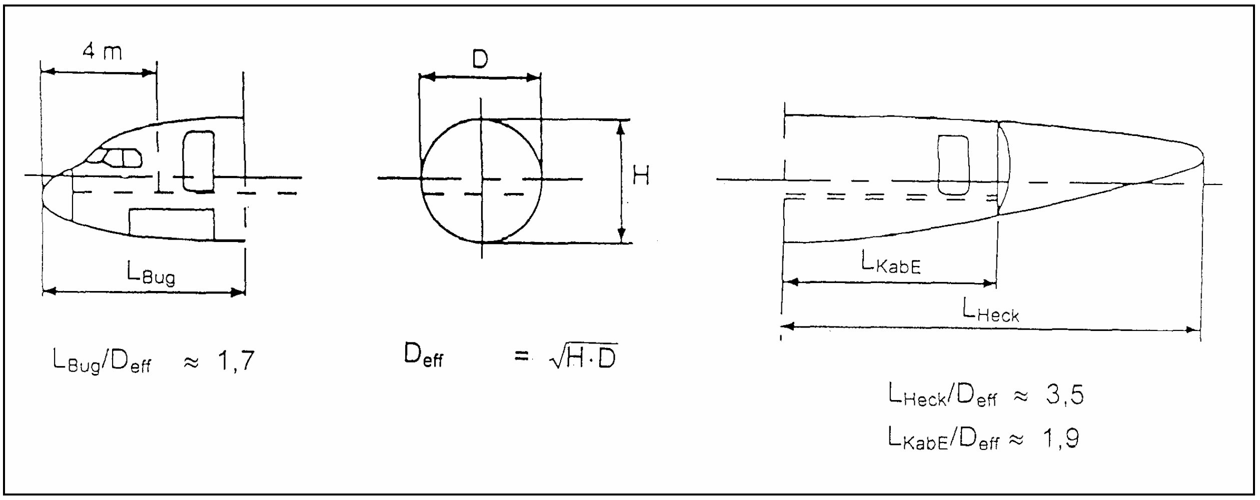


Fig. 6.19: The length of the cockpit, fuselage nose, cabin at the rear and the fuselage tail as a function of the fuselage diameter [SCHMITT 98]

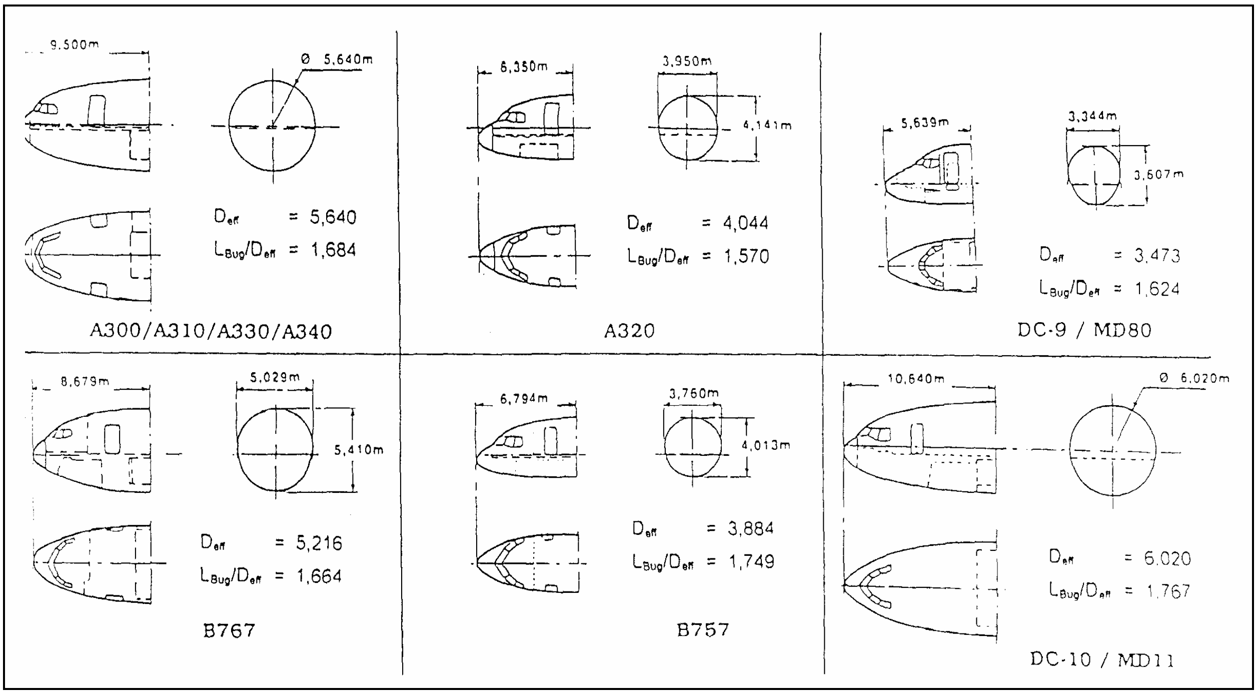


Fig. 6.20: Dimensions of nose sections according to [SCHMITT 98]

A side view of the fuselage can now also be drawn with the data from **Fig. 6.19** to **Fig. 6.22**. It is important to bear in mind that the cabin takes up space in the nose and in the tail. In other words (with the formula symbols of this lecture) Fig. 6.19 gives the total fuselage length as

$$l_F = l_{CABIN} + 1.6 \cdot d_F + 4\text{m} \quad . \qquad \textbf{(6.8)}$$

If the **length of the tail** is too short, this will result in additional drag. A longer tail is characterized by low drag, but such a long tail will increase the operating empty mass and thus lead to an increase in drag.

The **tail angle** must be chosen so that the aircraft achieves a sufficiently high angle of attack when rotating during take-off. Otherwise the take-off distance would increase. There would also be a danger of the tail hitting the runway (tail strike). When choosing the tail angle it is important to bear in mind that stretched versions might be developed at a later date. Therefore, the tail angle should still have some reserves for the future.

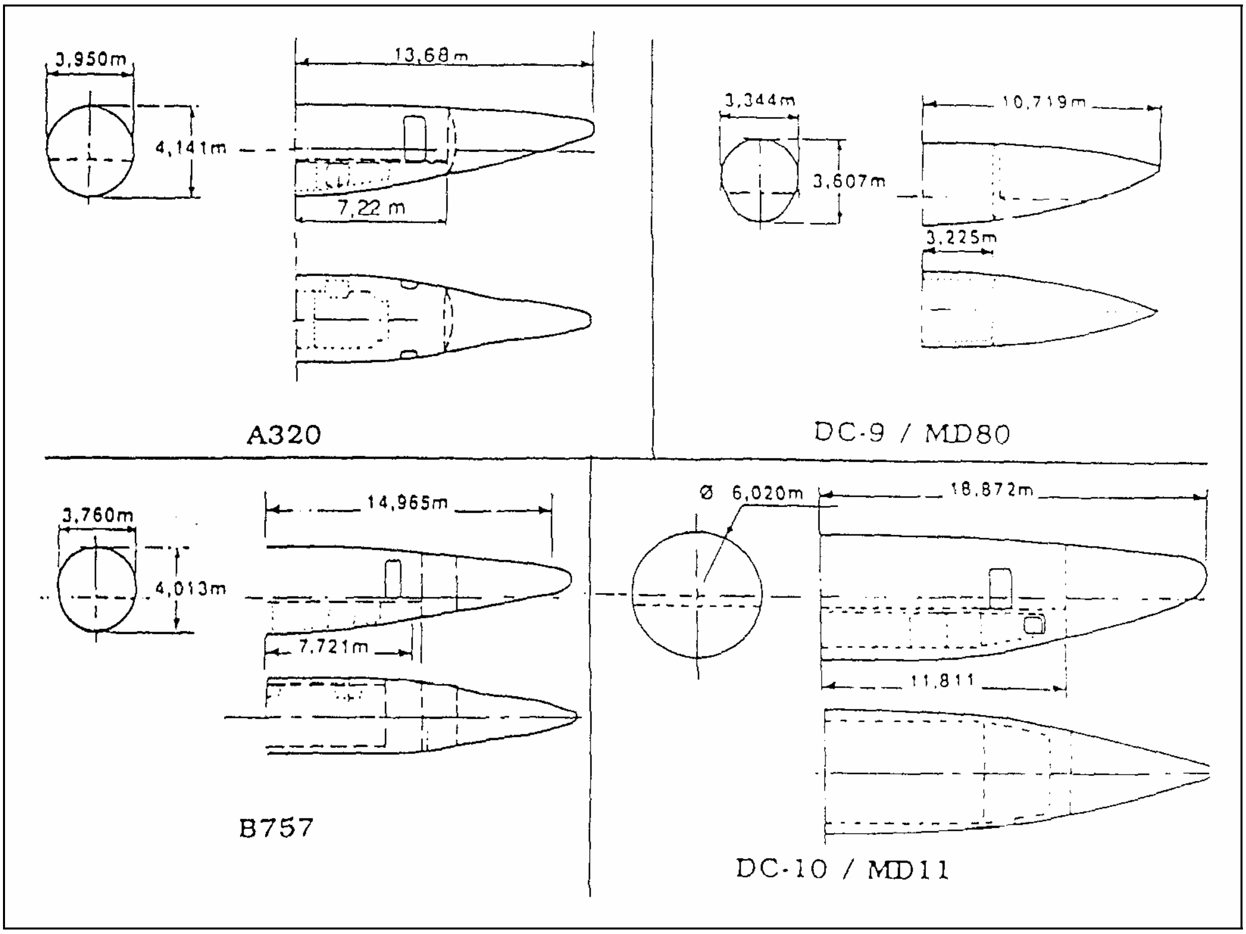
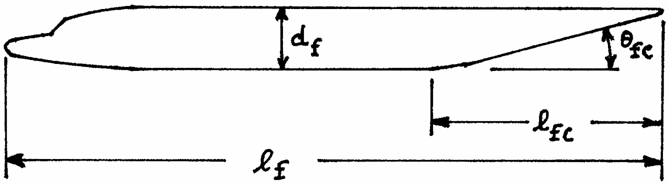


Fig. 6.21: Dimensions of tail sections according to [SCHMITT 98]



Definition of Geometric Fuselage Parameters

Currently Used Geometric Fuselage Parameters

Airplane Type	l_f/d_f	l_{fc}/d_f	θ_{fc} (deg)
Homebuilts	4 - 8	3	2 - 9
Single Engine	5 - 8	3 - 4	3 - 9
Twins	3.6 - 8	2.6 - 4	6 - 13
Agricultural	5 - 8	3 - 4	1 - 7
Business Jets	7 - 9.5	2.5 - 5	6 - 11
Regionals	5.6 - 10	2 - 4	15 - 19
Jet Transports	6.8 - 11.5	2.6 - 4	11 - 16
Mil. Trainers	5.4 - 7.5	3	up to 14
Fighters	7 - 11	3 - 5	0 - 8
Mil. Transports, Bombers and Patrol Airplanes	6 - 13	2.5 - 6	7 - 25
Flying Boats	6 - 11	3 - 6	8 - 14
Supersonics	12 - 25	6 - 8	2 - 9

Fig. 6.22: Fuselage dimensions according to [ROSKAM II]

Now that the side view of the fuselage, including the doors and emergency exits, has been drawn, the distribution of the underfloor area should be sketched in one section. This is the oportunity to recheck the volume of the cargo compartment, which has only been roughly estimated so far with equation (6.4).