Automotive Aerodynamics & Body Engineering

Unit I & II

Introduction To Aerodynamics

T. E. (Automobile)(2015Course) Semester – II

Code	Subject	Teaching Scheme (Hrs/Week)			Examination Scheme					Total	Credit
		Lect.	Tut.	Pract.	In-Sem	ESE	TW	PR	OR		
302047	Numerical Methods and Optimization*	4	--	2	30	70	--	50	--	150	5
316484	Design of Engine Components	4	--	2	30@	70@	25	--	25	150	5
316485	Automotive Transmission	3	--	2	30	70	--	--	25	125	4
316486	Automotive Aerodynamics and body Engineering	3	1	--	30	70	--	--	25	125	4
302051	Manufacturing Process-II*	3	--	--	30	70	--	--	--	100	3
302052	Machine Shop-II*	--	--	2	--	--	50	--	--	50	1
302053	Seminar*	--	--	2	--	--	25	--	25#	50	1
302054	Audit Course*	--	--	--	--	--	--	--	--	--	--

Savitribai Phule Pune University, Pune Third Year of Automobile Engineering(2015 Course) 316486: Automotive Aerodynamics and body Engineering		
Teaching Scheme: TH: 03 hrs/week Tut: 01 hrs/week	Credits: TH: 03 Tut: 01	Examination Scheme: In-Sem: 30 End-Sem: 70 OR: 25

Course Objectives:-

1. Identify various forces and moments associated with aerodynamics.
2. Gain thorough understanding of the different types of vehicles.
3. To understand the physics of fluid flow over vehicle body and its optimization techniques.
4. State and illustrate applications of ergonomics and safety in the designing of vehicle body.
5. To select appropriate process for designing of vehicle body with aesthetic appearance.

Course Contents		
Unit - I	**Fundamental of Vehicle Aerodynamics**	**6 hours**
Scope of study, History of vehicle aerodynamics, Present and future trends, Flow phenomenon related to vehicle: external and internal flow, Development of drag & lift on Aerofoil, Aerodynamic drag and its types and various forces and moments, Resistance to vehicle motion, the passenger car as bluff body, Flow field around car, Analysis of drag: Possible approaches, Physical mechanisms, Local origins, Drag & Lift.		
Unit - II	**Vehicle Aerodynamics and Shape Optimization**	**6 hours**
Drag fractions and their local origins: optimization of car bodies for low drag, Aerodynamics performance improvement using front and rear end modification, windshield and A-pillar, roof, spoilers, Wheel & wheel housings, attachments. Strategies for body shape development: Objectives, Detail Optimization, Shape optimization, Facelift, Adaptation of attachments, Forecasting and expert systems. Water and dirt accumulation on vehicle.		
Unit-III	**Wind Tunnels and Wind Noise**	**7 hours**
Scope, Fundamentals of wind tunnel technique, Limitations of Simulation, Tests with reduced scale models, Existing Automobile Wind tunnels. Introduction to CFD methodology – Application to vehicle aerodynamics. Wind noise: Mechanism of generation and transmission, Design features.		

Unit-IV	Car and Bus Body Details	8 hours
Car body: Types- Saloon, Convertibles, Limousine, Estate Van, Racing and sport cars. Regulations, Drivers visibility, Tests for visibility, Methods of improving visibility, Space in cars, safety design, car body construction, front assembly, Roof Assembly, Under floor, bonnet etc. **Bus body**: Types - Mini Bus, Single Dekker, double Dekker, two levels, split level and articulated bus. Bus body layout – floor height, Engine Locations, Entrance cum exit location, Seating dimensions, seating layouts, passenger comfort. Construction details: frame construction, double skin construction, types metal sections used – regulations, conventional & integral type construction, Emergency door location, luggage space location.		
Unit - V	**Commercial Vehicle Body Details**	**5 hours**
Types of bodies: - flat platform, drop side, fixed side, tipper body, tanker body. Light construction vehicle body types, dimensions of driver seat in relation to control, driver cabin design, design of chassis frame.		
Unit- VI	**Body Loads & Ergonomics**	**6 hours**
Idealized structure, structural surfaces, shear panel method, symmetric & asymmetric vertical loads in car, longitudinal load and load distribution on vehicle structure. Ergonomics and anthropometry, Drivers work station- Design of driver seat for comfort and safety, Types of seat used in automobiles, Types of safety belts, Use of energy absorbing system in automobiles, Impact protection from steering controls, Importance of Bumper in automobile.		

Term Work:
Any six experiments from Sr.No 1-7 and Sr.No 8 and 9 are compulsory. 1. Demonstration of Car body construction with sketches. 2. To study the construction of typical truck body and draw sketches. 3. Demonstration of passenger seat position, requirement and construction by using standard dimension of bus. 4. Study of effect of different shapes, styles and exterior objects on drag force 5. Measurement of drag, lift force of a scaled model in wind tunnel. 6. To demonstrate constructional and operational features of mechanical and power window mechanism. 7. Study and analysis of flow conditions over the vehicle with the help of CFD software. 8. Prepare the layouts of intercity and luxury bus by using any drafting software as well as manually. 9. Visit to Automotive body building workshop.

Books:

Text Book:

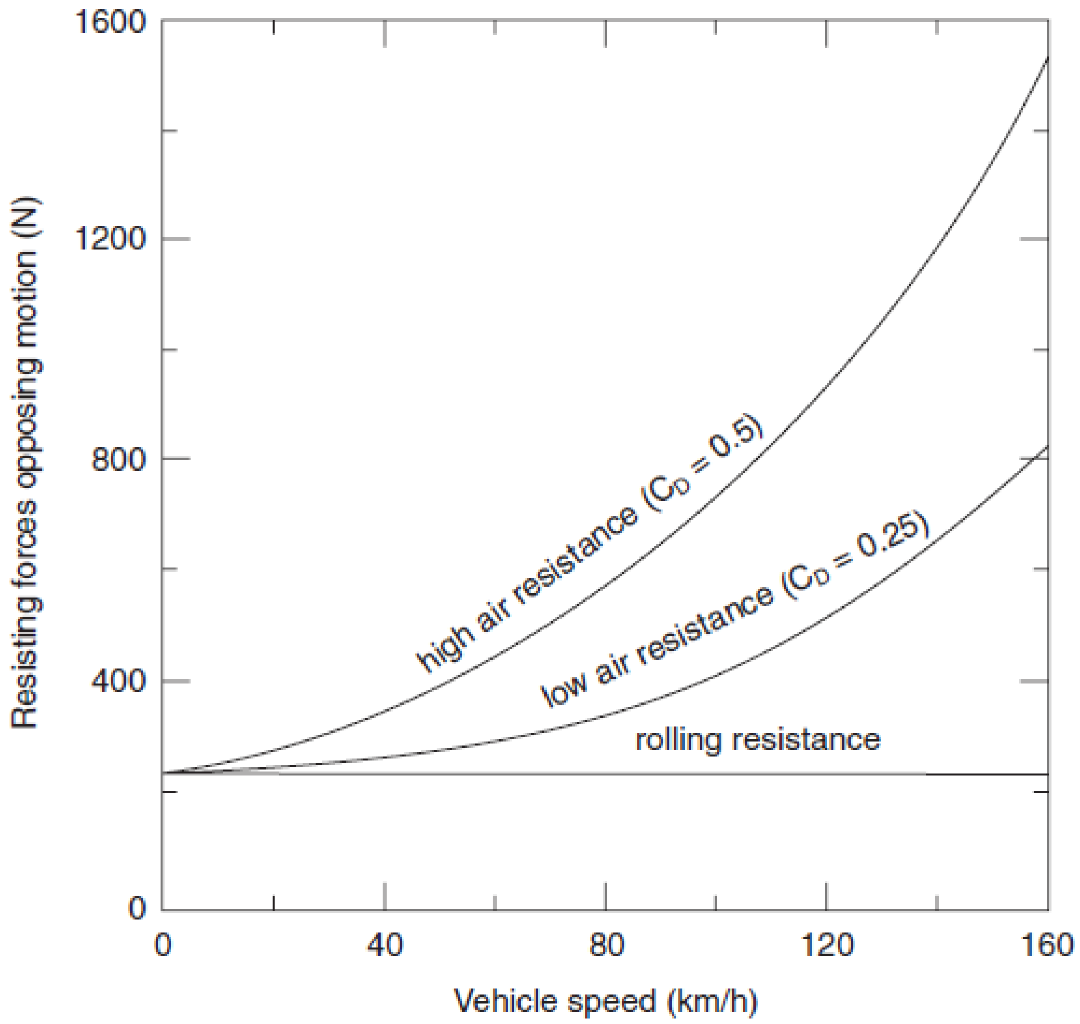
1. J. Powloski, "Vehicle Body Engineering", Business Books Ltd., London.
2. W.H. Hucho, "Automotive aerodynamics"

Reference Books:

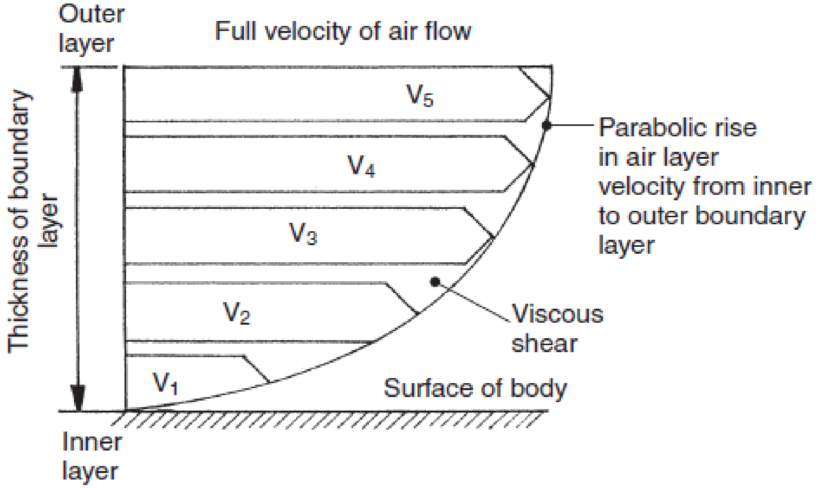
1. John Fenton, "Vehicle Body Layout & Analysis", Hutchinson, London.
2. Sydney F. Page, "Body Engineering", Chapman & Hill Ltd., London, 3rd Edition
3. J.G. Giles, "Body Construction and Design", Vol. 6, llefe Books/Butterworth & Co. London
4. P. L. Kohli, "Automotive Chassis & Body", Papyrus Publishing House, New Delhi.
5. Dr. V. Sumantran and Dr. Gino Sovram, Vehicle Aerodynamics Published by SAE International, USA
6. John Fenton, "Handbook of Automotive Body Construction and Design Analysis" Professional Engineering Publishing.

Introduction :

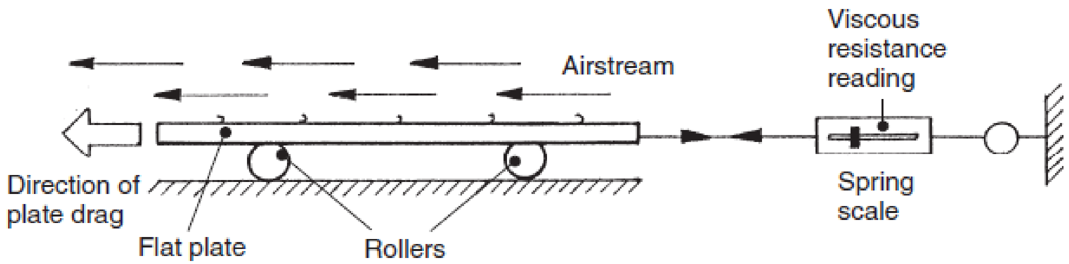
- **The power delivered by the engine is finally made available at the drive wheels as propulsive force.**
- **The propulsive force or tractive effort, available at the contact between the driving wheels and road should be more than the total resistance for the motion of a vehicle**
- **The surplus tractive effort contribute for acceleration, climbing gradient, etc.**



Comparison of low and high aerodynamic drag forces with rolling resistance



Boundary layer velocity gradient



Apparatus to demonstrate viscous drag

Introduction :

- The total resistance to the motion of a vehicle is by Air resistance & Rolling resistance
- The vehicle drag is a force which resists motion and is due to ;
  - a) the deformation of the wheel and the ground
  - b) aerodynamic effects of air flow over the vehicle
- Deformation of the wheel
  - - the pneumatic Tyres are most suitable for road transport vehicles.
  - - the deformation of Tyres account for 90 to 95 % of the rolling resistance of the vehicle

Introduction :

- - the distortion of the tyre tread as it passes through the contact area results in a hysteresses loss manifests itself as heat & rise in temperature of tyre
- - The hysteresses loss is primarily a function of deflection caused by the load it carries
- Other parameters affecting rolling resistance are;
  - tyre temp., inflation pressure, tread thickness,
  - no. of plies, rubber quality, level of torque
  - transmitted and vehicle speed

Introduction :

- - The Rolling resistance expressed in terms of non- dimensional rolling coefficient, α as
  - Rr = α . W where; W - weight of vehicle
- - The relationship between rolling resistance and vehicle weight is more complex and require a detailed knowledge of the soil and ground material,etc.

Introduction :

- Aerodynamic effects of air flow over the vehicle
- - A moving vehicle, in displacing the surrounding air, has a resultant resisting force called aerodynamic drag or simply air resistance.
- - It can be expressed as resistive force opposing the motion of a vehicle through the air and the work done in overcoming the force is dissipated as energy lost to the air flow.
- - The amount of drag depends on the vehicle shape and varies with the speed of the vehicle.

Introduction :

- Aerodynamic effects of air flow over the vehicle
- - A low-drag body allows vehicle to reach higher speeds for a given power output. Conversely, reducing the power consumption at any particular speed makes it available for acceleration.
- - Reducing power requirement improves fuel consumption thereby reducing on-board fuel carrying requirements. This can contribute towards reducing laden weight of the vehicle

Introduction :

- Aerodynamic effects of air flow over the vehicle
- - Motor vehicles have demonstrated strong aerodynamic influence upon their design.
- - Until recently flowing lines on vehicle body were primarily a statement of style and fashion with little regard for economic / environmental benefits.
- - Rising fuel prices, triggered by fuel crisis in 1970s and now the environmental concerns have provided serious attention towards aerodynamic designs.

Introduction :

- **Aerodynamic effects of air flow over the vehicle**
- **- Aerodynamic research focused upon ;**
  - **drag reduction : for fuel efficiency & emission**
  - **lift & side forces : vehicle stability**
- *low drag shapes reduce stability when driven in cross-wind conditions*
- **-**Understanding of Aerodynamics of vehicle is highly complex as unsteady flows are associated with it.
- - Experimental and Computational flow prediction methods still require substantial developments

Introduction :

- Aerodynamic effects of air flow over the vehicle
- - Significance of Aerodynamic Study
  - 1. Reduction of drag force and achieve maximum speed & acceleration for the same power output
  - 2. Reduction of drag force improves fuel economy
  - 3. Good aerodynamic design gives better appearance and styling
  - 4. Good stability and safety can be provided by reducing various forces and moments subjected to by the vehicle
  - 5. This helps to understand the dirt flow, exhaust gas flow patterns, etc.
  - 6. Good aerodynamic design provide proper ventilation, reduce noise, etc.

Aerodynamic effects of air flow over the vehicle

- - The composition of Aerodynamic drag is due to
  - I) The air flow in the boundary layer resulting in the loss of momentum of the main stream and is called 'skin friction drag'.
  - - A component from the downstream of the trailing vortices behind the vehicle is called 'Induced drag'
  - - The 'normal pressure drag' is found out by integration of the product (normal pressure x area) around the vehicle. This produces net force

Introduction :

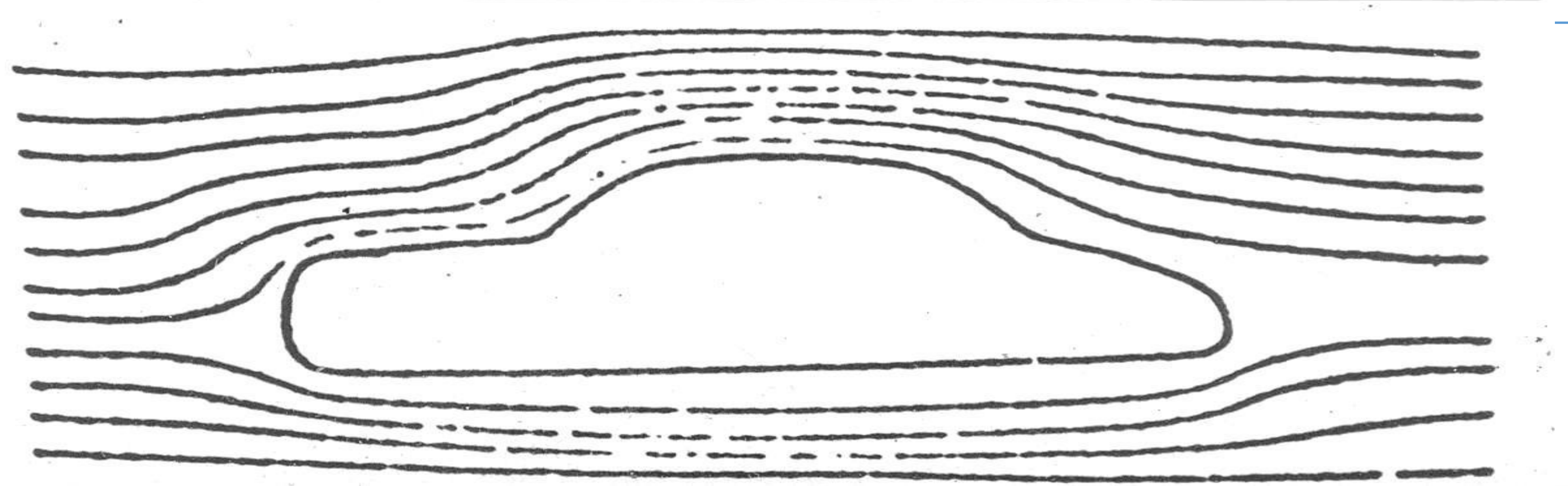
- Aerodynamic effects of air flow over the vehicle
- opposing the motion of the vehicle because separation of flow at rear of the vehicle results in lowering of pressure on rearward facing surfaces.
- - The skin friction drag and the induced drag are usually small in comparison to normal pressure drag.

Aerodynamic Forces and Moments :

- The profile of the vehicle is the principle component of aerodynamic drag and is governed by the way in which vehicle disturbs the air stream.
- Its behavior has been found not to accord with established aerodynamic theory evolved in aviation since vehicle has to maintain contact with the ground.
- The importance of a good aerodynamic parameters in the design of a vehicle is being increasingly recognized. The designer must have a knowledge of the forces and the laws governing them in order to

Aerodynamic Forces and Moments :

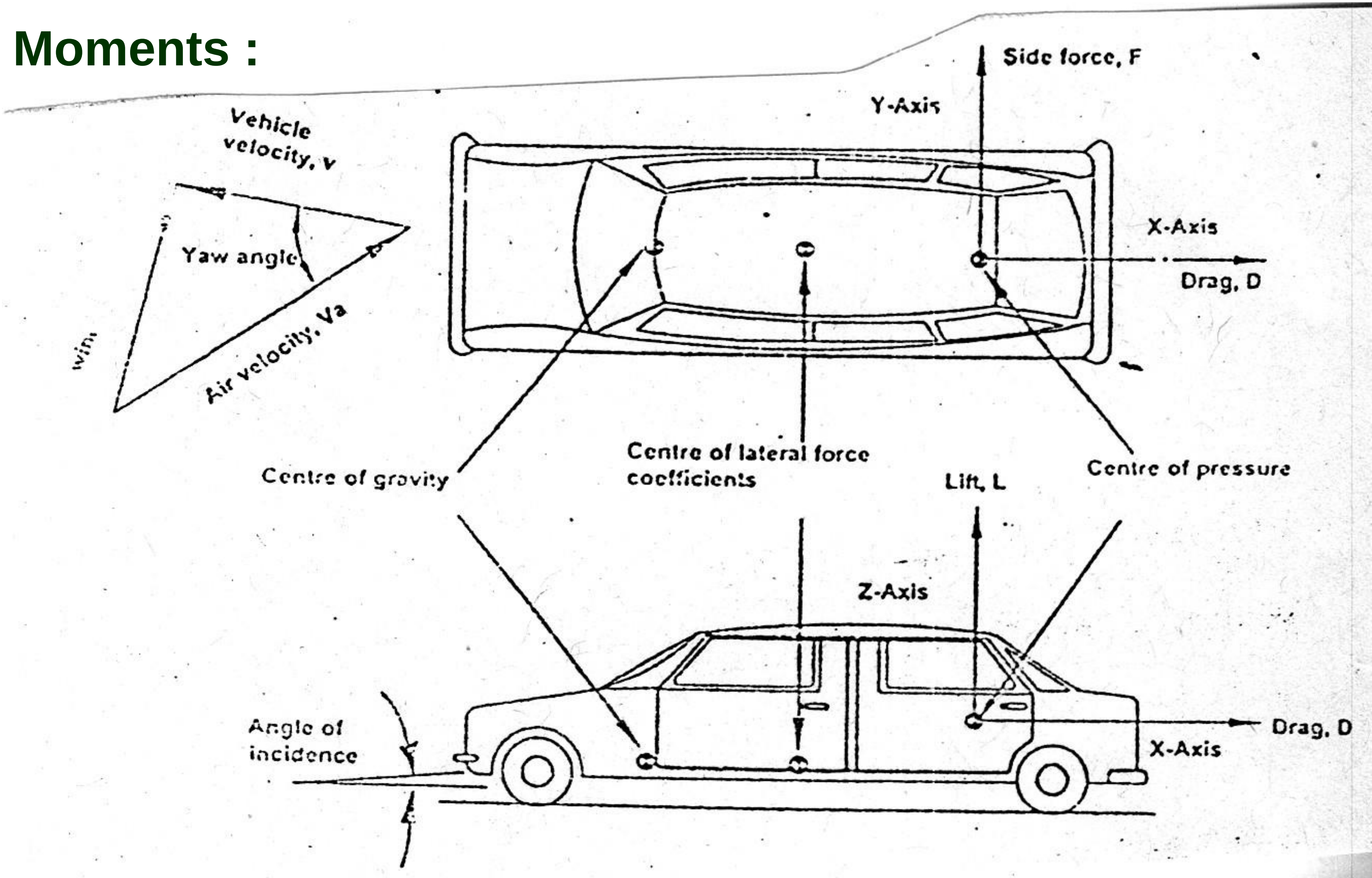
- produce body shapes which will have acceptable aerodynamic characteristics.
- Considering a car profile as an aerofoil the streamlines around a car body is as shown below



Aerodynamic Forces and Moments :

- The car body profile shown having smooth streamlines which are continuous and with no separation of boundary layers & vortices. However, like an aerofoil, the streamlines over the upper part have a higher velocity than the streamlines below the car.
- For complete description of aerodynamic effects on the motion of the vehicle it should be considered as a mass having six degree of freedom and the aerodynamic forces and moments acting on the vehicle are balanced by the wheel reactions.

Aerodynamic Forces and Moments :



Aerodynamic Forces and Moments :

- The aerodynamic forces on a vehicle act at the Center of Pressure and summarized as follows
  - - Px : force of air drag in the direction of motion (longitudinal)
  - - Py : side forces or cross wind forces (lateral)
  - - Pz : aerodynamic lift forces (vertical)
- As these forces are not acting at center of gravity, they cause moments as follows
  - - Mx : rolling moment caused by force,Py about the X-axis

Aerodynamic Forces and Moments :

- - My : Pitching moment caused by forces about the Y-axis
- - Mz : Yawing moment caused by the force, Py about the Z - axis
- Drag force, Px
  - - The air flow over a vehicle is complex and the aerodynamic drag is expressed by the semi - empirical equation to represent the aerodynamic effect. It is defined by the following equation.

Aerodynamic Forces and Moments :

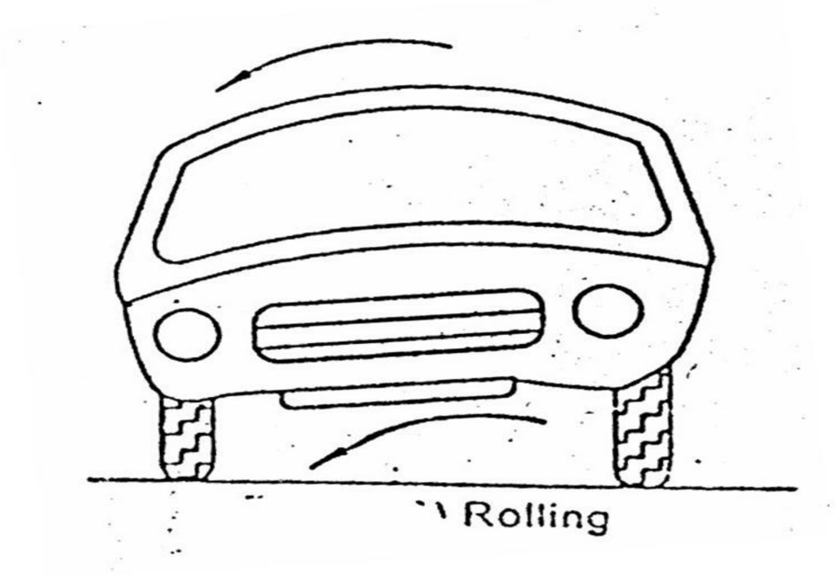
- DA = 1/2 ρ V^2 A Cd
- where ; DA = aerodynamic drag force (Px) , Kgf
- ρ = air density , Kgf. Sec^2 / m^4
  - V = velocity , m / sec
  - A = Frontal area of the vehicle , m^2
  - Cd = aerodynamic drag coefficient
- Lift force, Pz
  - The lift force is a result of the asymmetrical flow of air above and below the vehicle. The lift force

Aerodynamic Forces and Moments :

- affects the vehicle driving stability. The lift force is measured at the centerline of the vehicle at the center of the wheel base.
  - Pz = 1/2 ρ V^2 A Cz , Kgf
  - where ; Cz = Lift coefficient
- Side Force, Py
  - The side force is formed by the asymmetric flow of air around the body of the vehicle due to cross wind flow (forces). The lateral wind components impose a side force on the vehicle to change its direction .

Aerodynamic Forces and Moments :

- Side force acts on the body at the center of pressure
- $Py = 1/2\ \rho\ V^2\ A\ Cy$, Kgf
- where ; Cy = cross wind force coefficient
  - Rolling : The angular oscillation of the vehicle about longitudinal axis is called rolling as shown

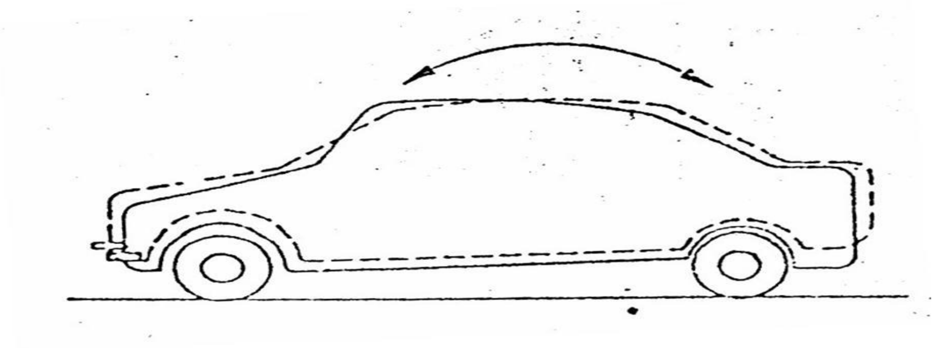


Aerodynamic Forces and Moments :

- - Rolling Moment :
- The rolling moment acts about the longitudinal (horizontal) axis and is produced by the side wind forces. It has only minor influence on vehicle stability depending on the suspension system.
  - RM = 1/2 ρ V^2 A CRM . L , Kgf.m
- where ;
  - CRM = rolling moment coefficient
    - L = wheel base

Aerodynamic Forces and Moments :

- Pitching :
  - The angular oscillation of the vehicle about lateral (horizontal) axis is called pitching as shown
- Pitching Moments
- Pitching moment acts to transfer weight between the front and rear axles. The pitching moment is

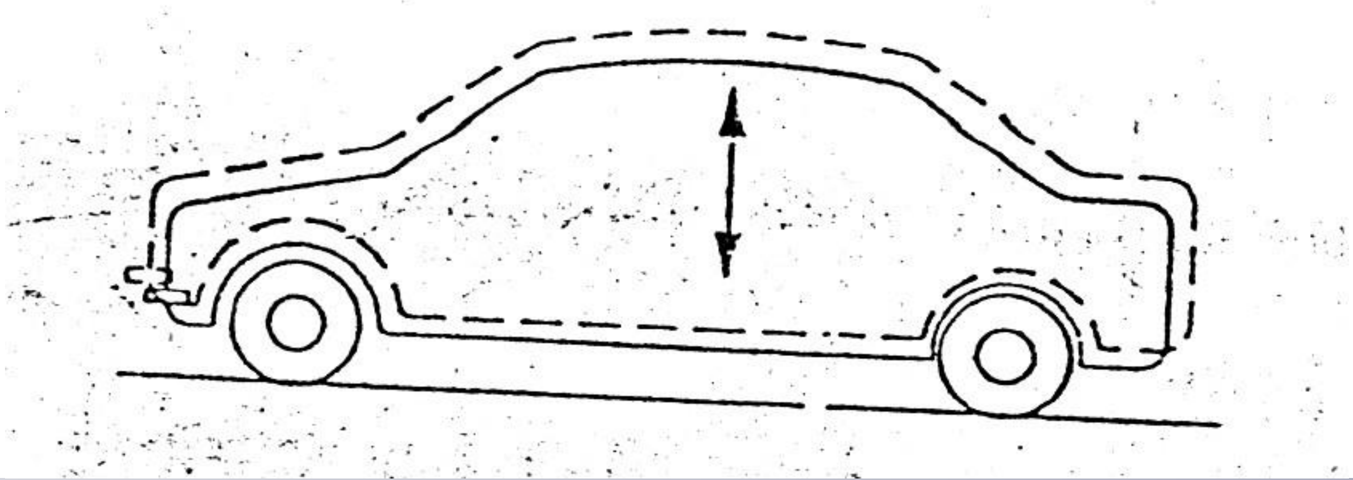


Aerodynamic Forces and Moments :

- usually negative i.e., nose down. This makes the rear axle lift off the ground and further reduce the available traction. The pitching moment arises from the drag but drag itself does not act at the ground plane. The lifting force may not act exactly at the center of the wheel base.
- PM = 1/2 ρ V^2 A Cpm . L , Kgf.m
- where ;
- Cpm = pitching moment coefficient
  - L = wheel base or characteristic length, m

Aerodynamic Forces and Moments :

- - Yawing
- The angular oscillation of the vehicle about the vertical axis is called yawing. It is the vertical movement of the complete vehicle body. So the complete body rises up and down and know as bouncing as shown in the figure below



Aerodynamic Forces and Moments :

- - Yawing Moment
- The lateral force caused by a side wind does not act at the mid- wheel base position. A side wind will produce a Yawing moment tending to turn the vehicle away from the direction of motion. Yawing moment is defined as
- YM = 1/2 ρ V^2 A Cym . L , Kgf.m where ;
- Cym = Yawing moment coefficient
  - L = wheel base or characteristic length, m

Aerodynamic Drag : types & effects

- **The total aerodynamic drag of a vehicle includes many factors which offer overall air resistance to the motion of vehicle. The types of aerodynamic drag components and their approximate relative contributions are ;**
  - **Profile or Form Drag 55 - 60 %**
  - **Induced or Lift Drag ~ 8 %**
  - **Surface or Friction Drag ~ 10 %**
  - **Interference ~ 15 %**
  - **Cooling & Ventilation System Drag ~ 10 %**
  - **Rotating Wheel & other ~ 1 %**

Aerodynamic Drag : types & effects

- Profile or Form Drag
  - The profile drag depends upon the longitudinal section of the vehicle body , and plays the most important part as its contribution is the maximum.
- A careful choice of body profile, essential for low drag, requires streamlines to be continuous and separation of boundary layers with its attendant vortices to be avoided.

Aerodynamic Drag : types & effects

- Induced or Lift Drag
  - A vehicle body produces accelerated air flow and the induced drag is caused by the vortices formed at the sides of the vehicle travelling downwards.
  - The pressure differential from the top to the bottom of the vehicle causes a lift drag.
  - This lift force depends on the upper surfaces especially in areas of the leading edge of the hood, wind shield corners, leading edges of the cowl and underbody such as suspension, exhaust system &other components protruding, and the ground

Aerodynamic Drag : types & effects

- Induced or Lift Drag
  - clearance. Lift is not a serious problem at normal speeds but at very high speeds it can affect stability and braking performance of the vehicle.
  - The lift tends to reduce pressure between ground and wheels. This causes loss of steering control on the front axle and loss of traction on the rear axle.
- Surface Drag
  - The surface or friction drag contribute substantially.
  - It is due to the friction of the layers of air passing

Aerodynamic Drag : types & effects

- over the outside surface of the vehicle body. The friction losses on the boundary layer and the surface roughness has considerable effect on surface drag. If this surface is kept smooth, a laminar boundary layer will be maintained further along the vehicle than with the rough surface.
- Interference Drag
  - This type of drag contribute significantly. This is due to air flow over the many exterior components of the vehicle body and also due to its interactions with the air flow over the basic body shape.
  - Exterior vehicle body projections such as door handles, mirrors,roof luggage, wind shield wipers,
  - etc. and also, projections below the vehicle such as axles, tow-bars,etc. contribute to interference drag

Cooling & ventilation system drag

- **The cooling and ventilation systems also contribute significantly to the total drag. Air flow passing through the radiator impact on the engine and wall which exerts dynamic pressure as drag on the vehicle**

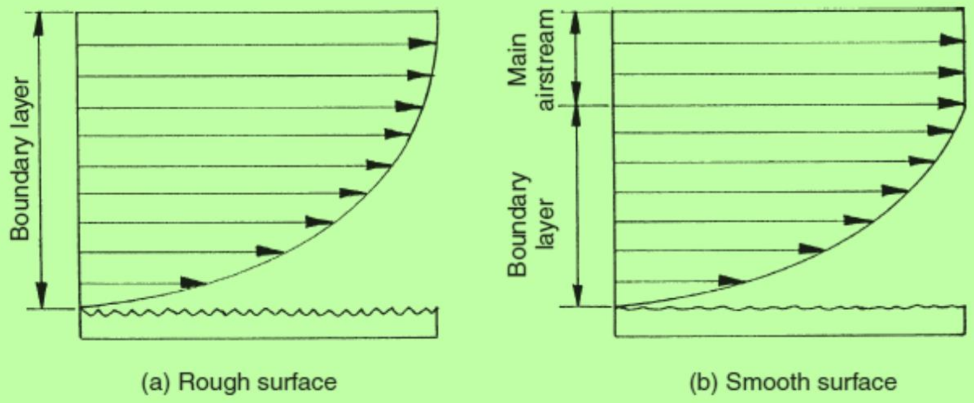


Fig. 14.4 (a and b) Influence of surface roughness on boundary layer velocity profile

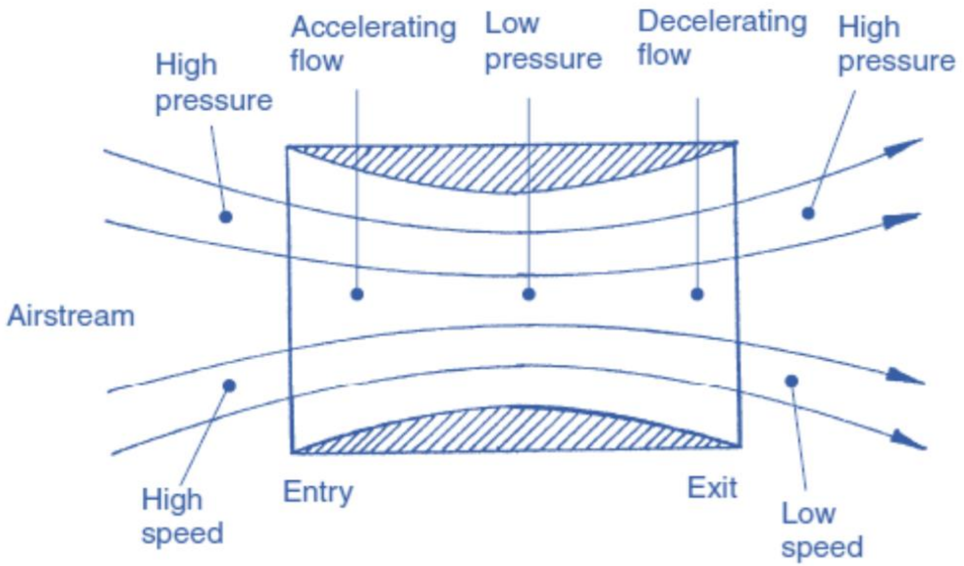


Fig. 14.5 Venturi

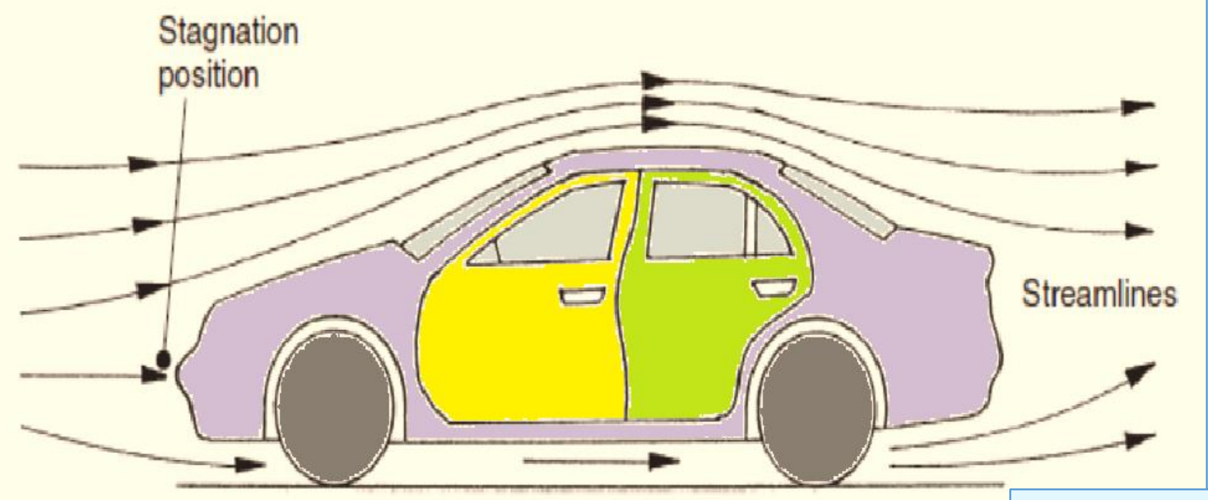


Fig. 14.6 Streamline air flow around car

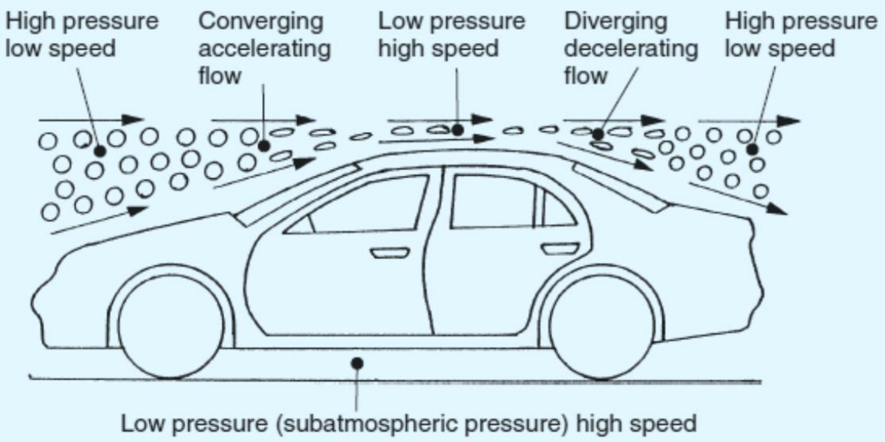


Fig. 14.7 Relative air speed and pressure conditions over the upper profile of a moving car

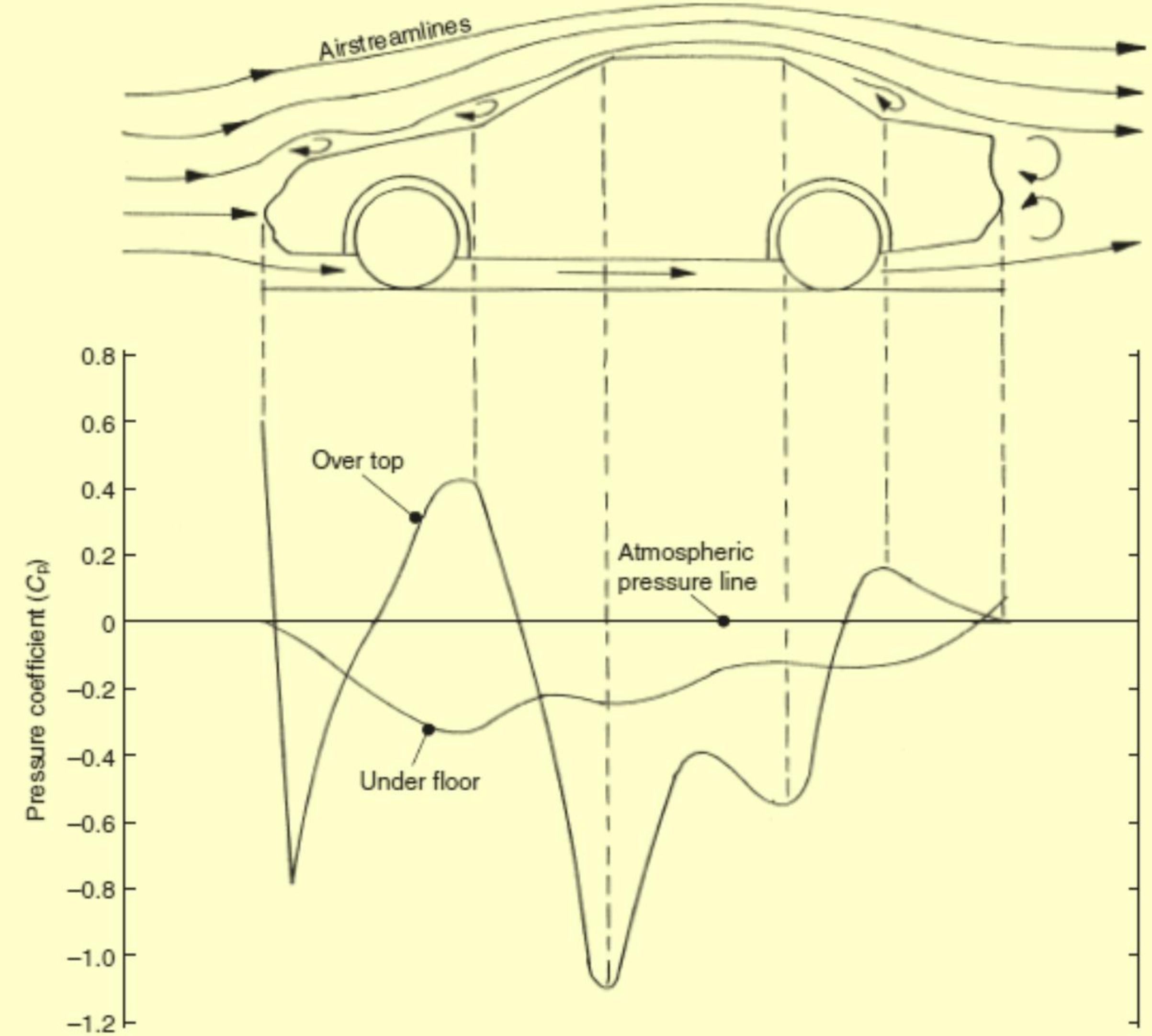


Fig. 14.8 Pressure distribution above and below the body structure

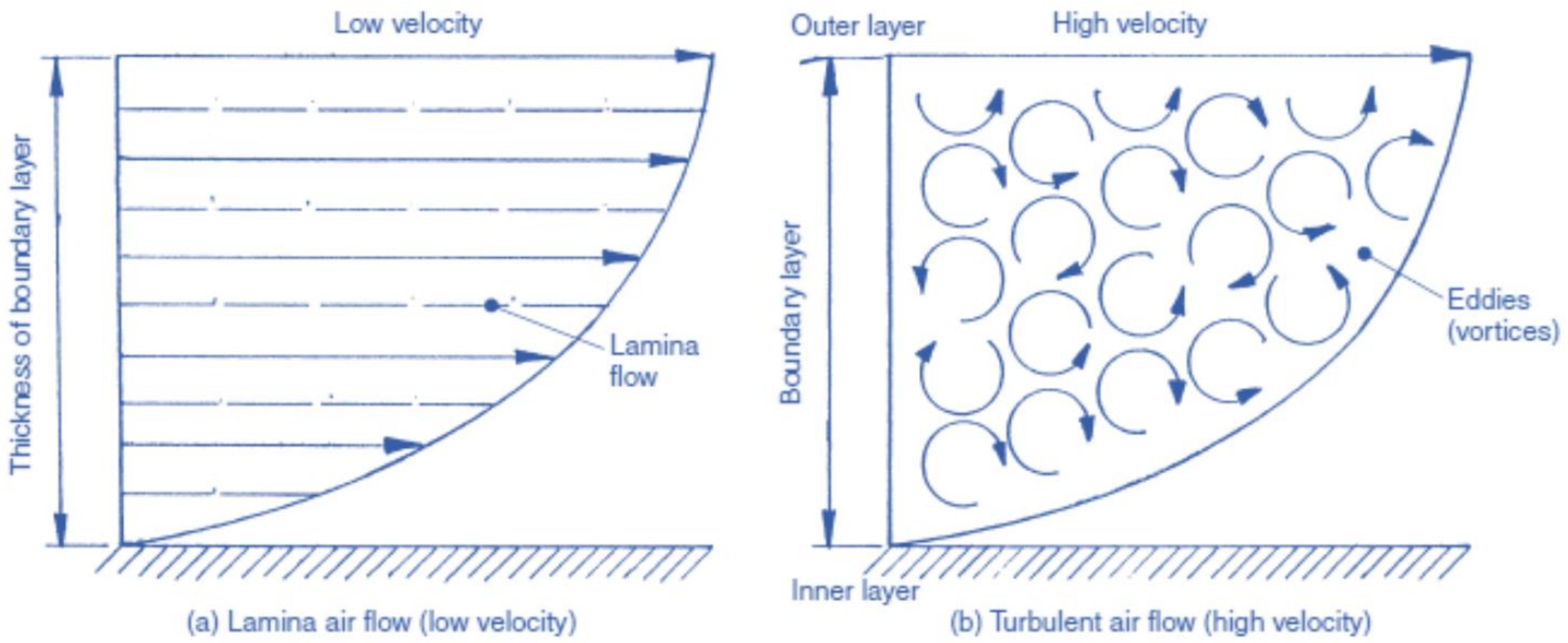


Fig. 14.9(a and b) Lamina and turbulent air flow

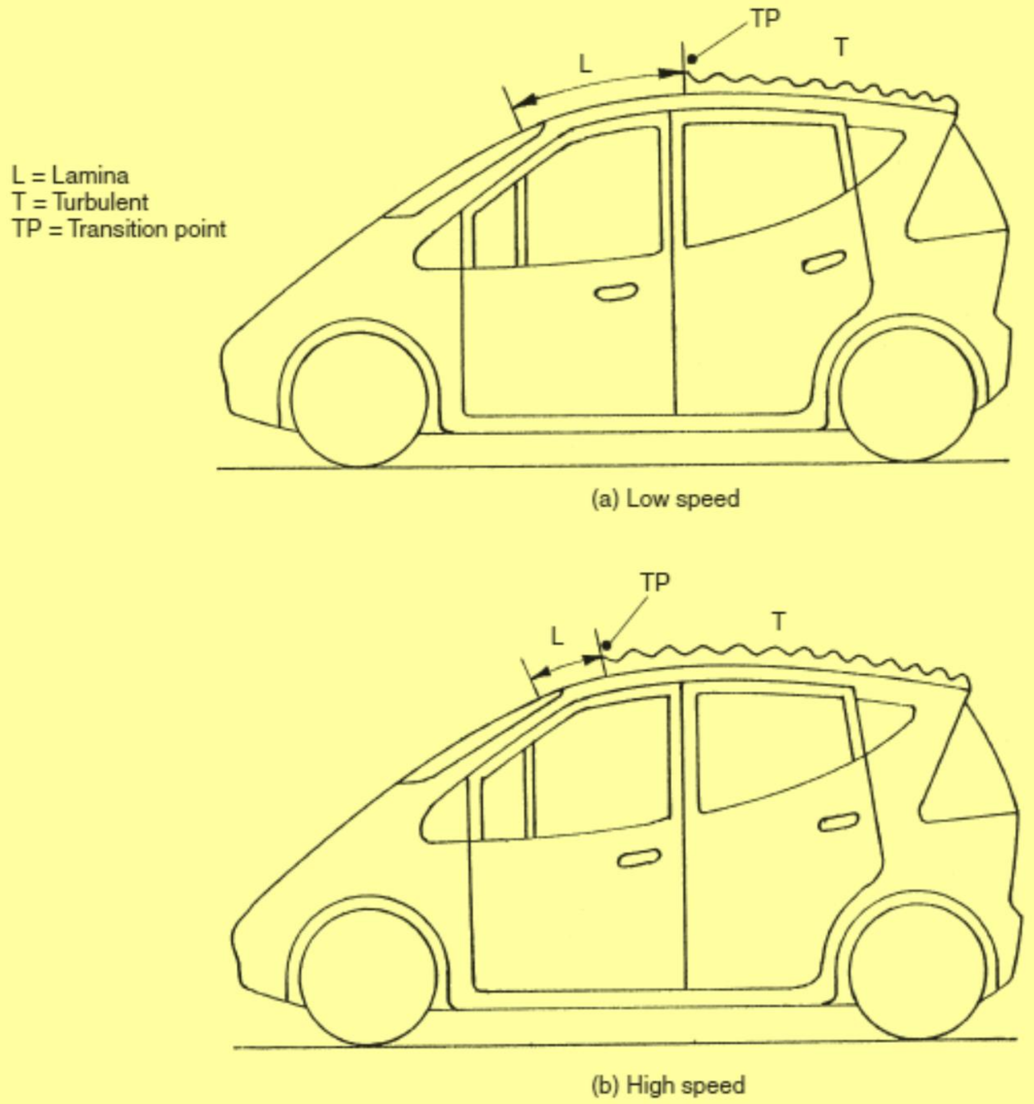


Fig. 14.10(a and b) Lamina/turbulent boundary layer transition point

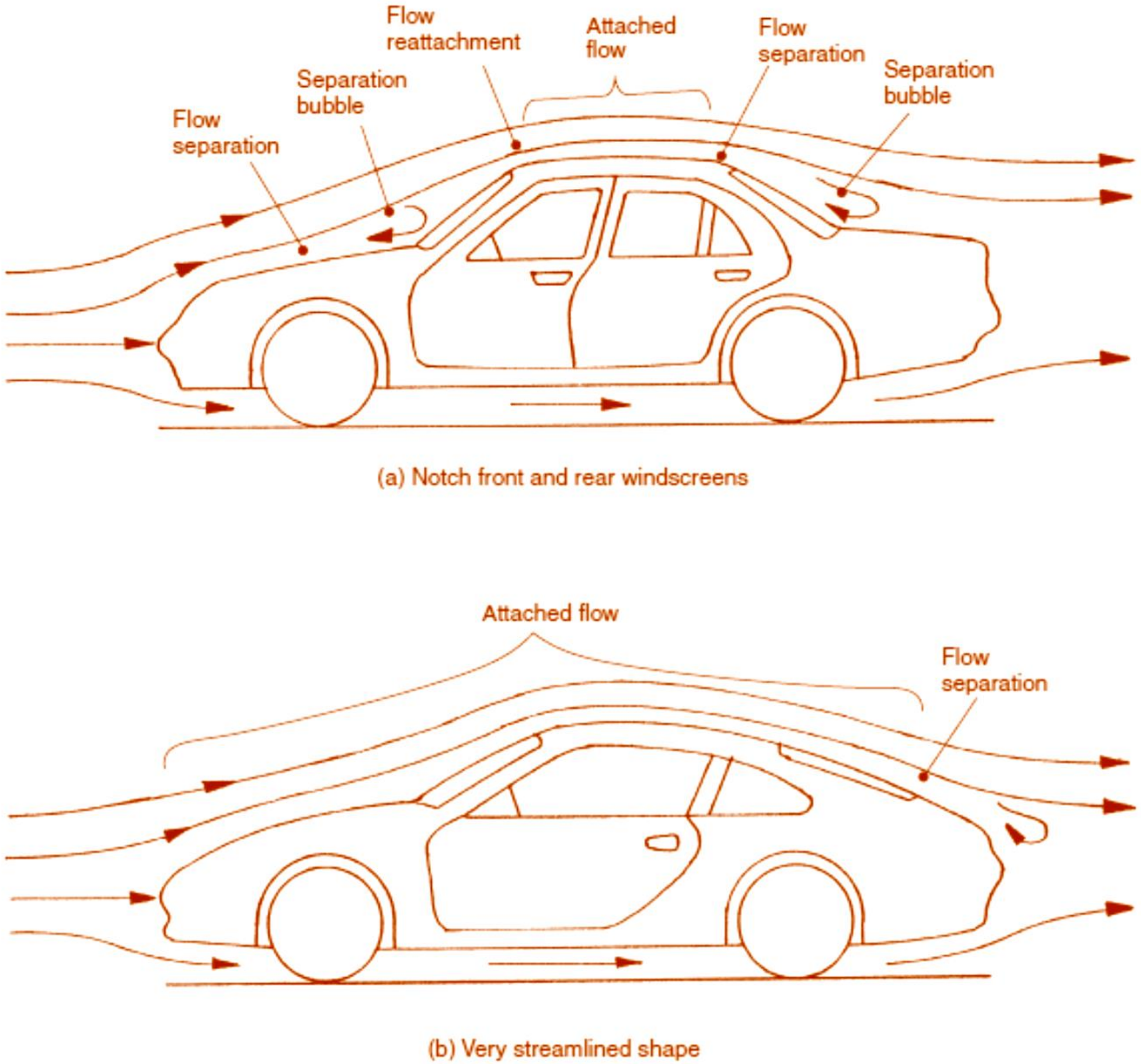


Fig. 14.11 (a and b) Flow separation and reattachment

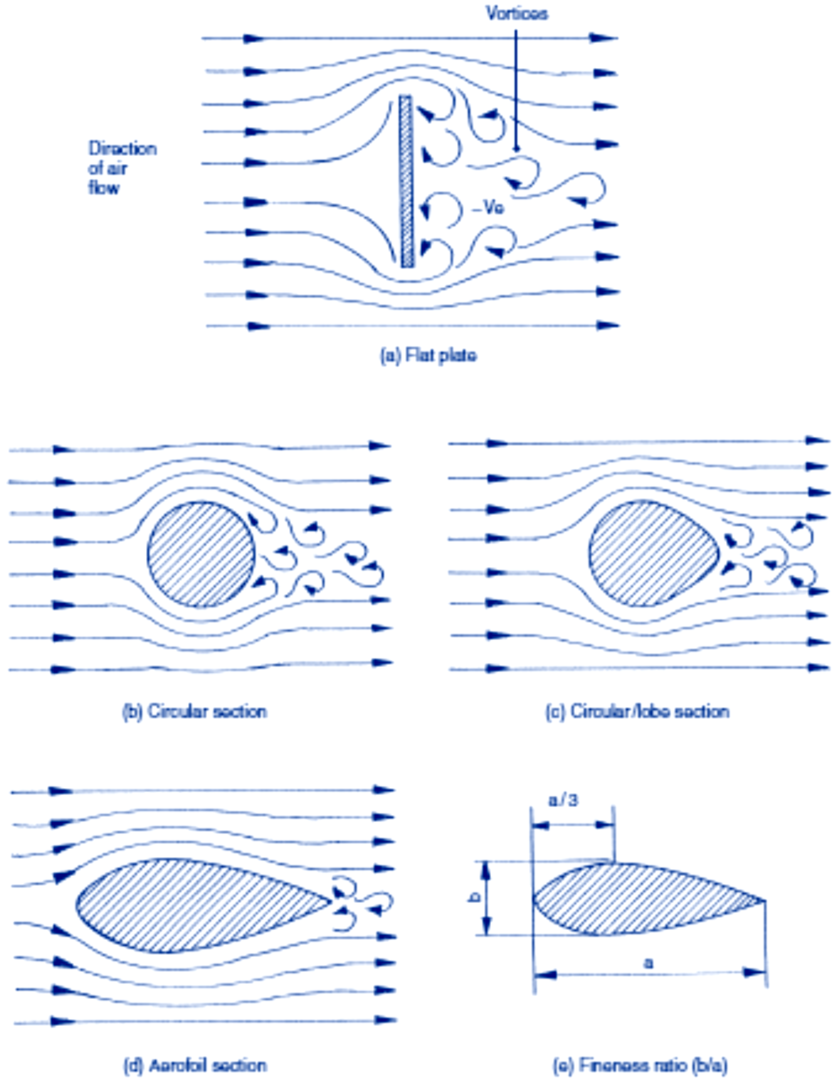


Fig. 14.12 (a–e) Air flow over various shaped sections

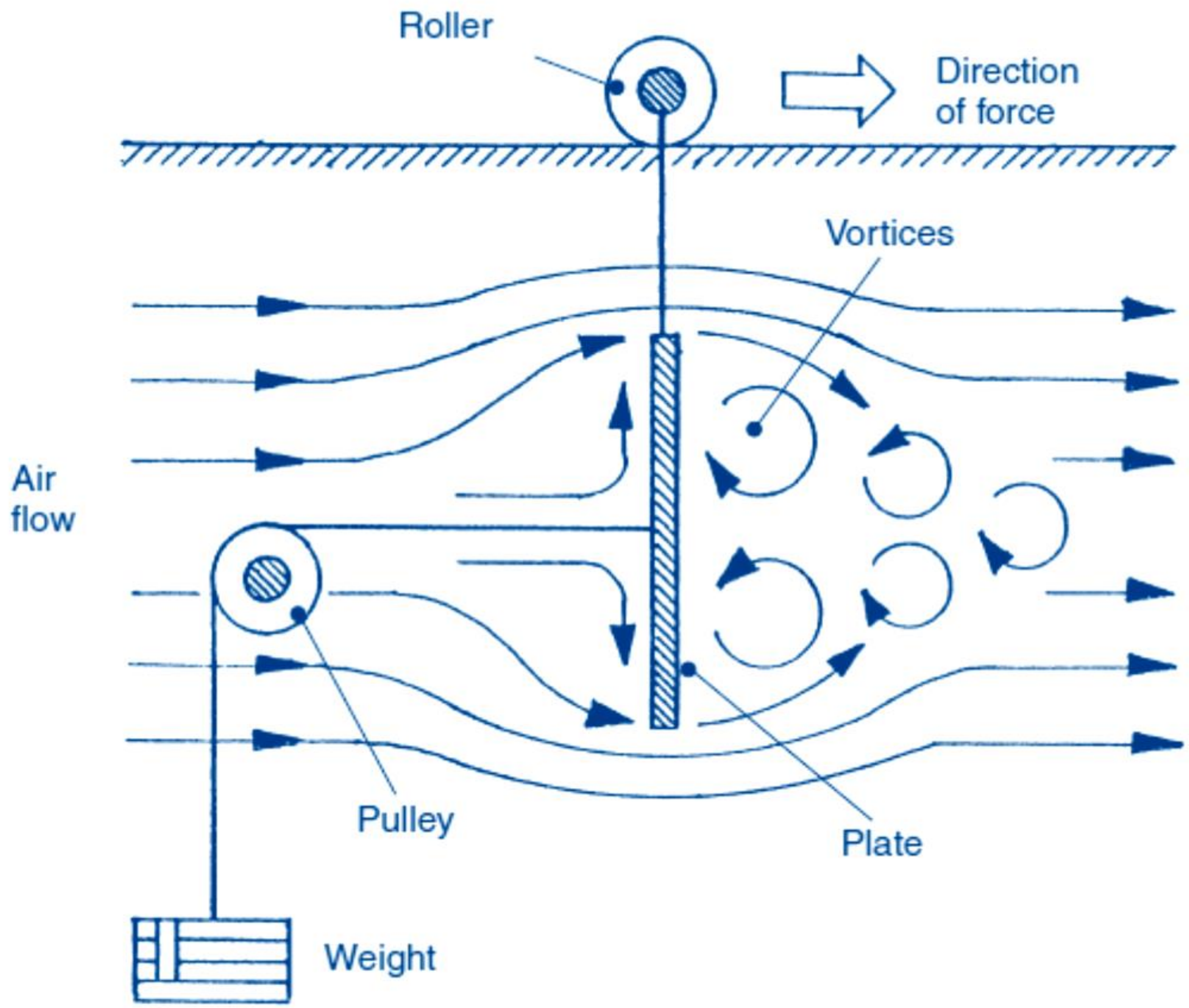


Fig. 14.13 Pressure drag apparatus

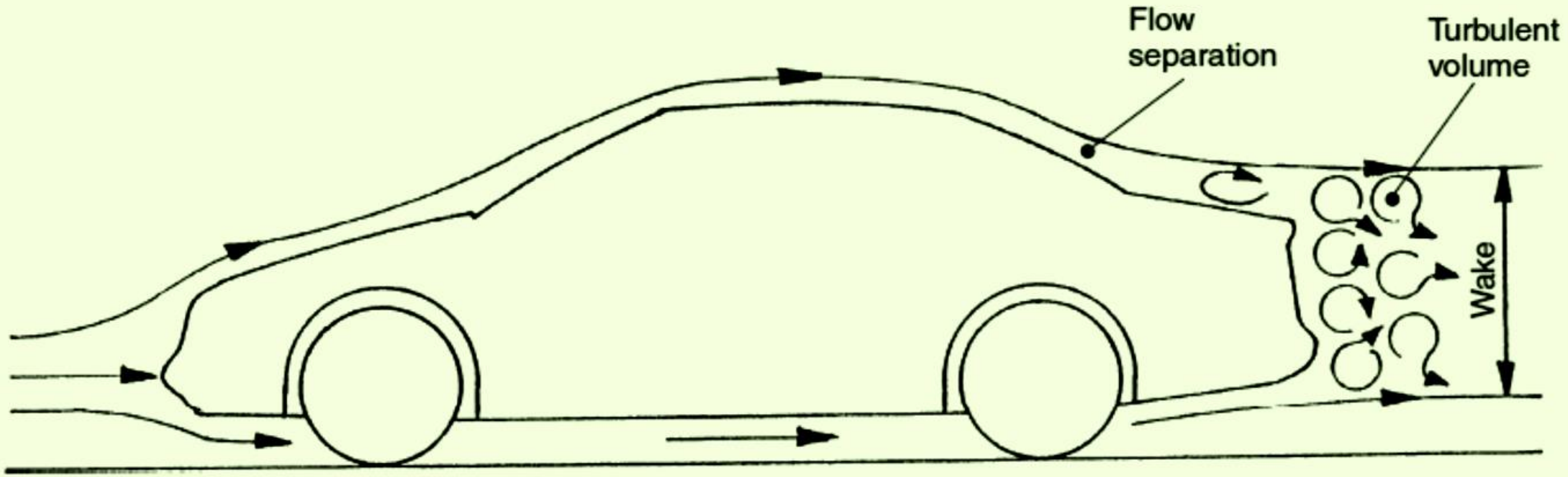


Fig. 14.14 After flow wake

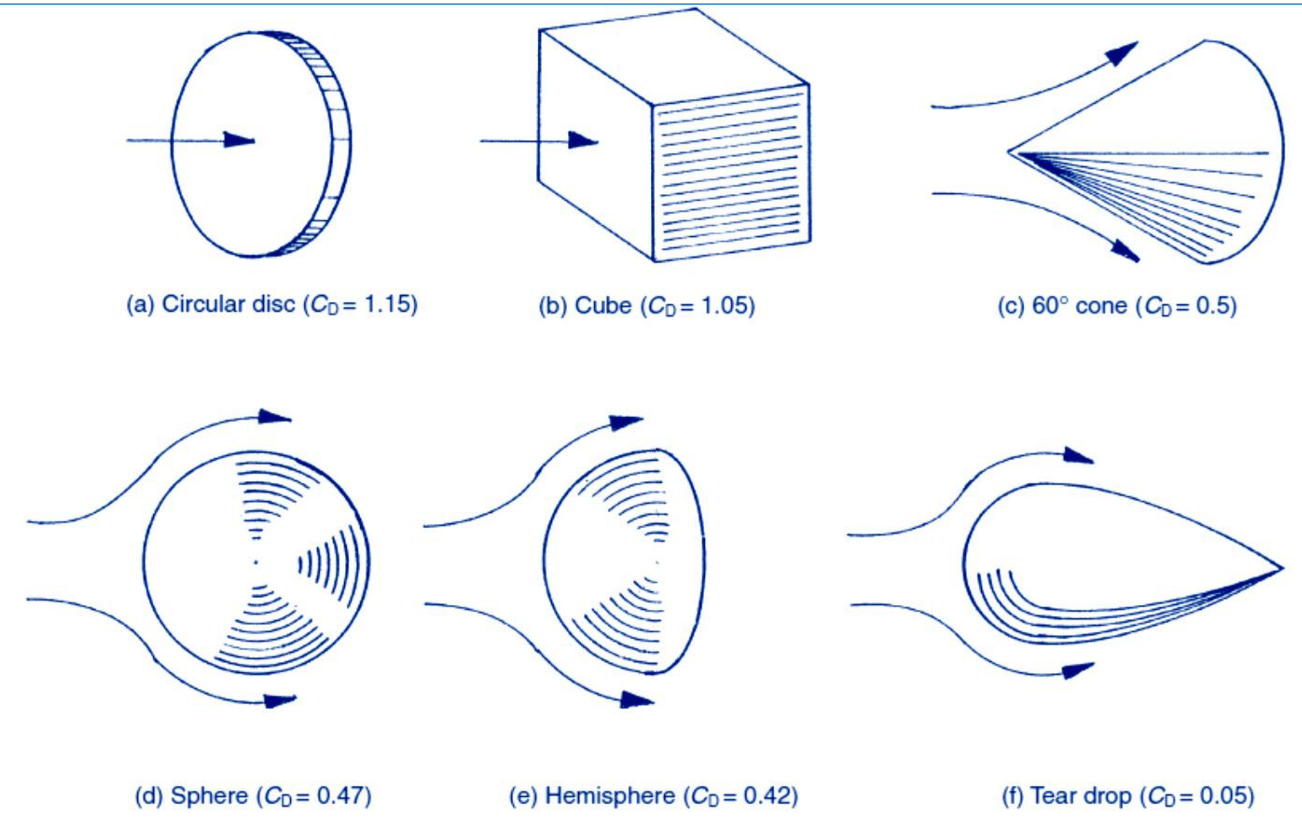


Fig. 14.15 (a–e) Drag coefficient for various shaped solids

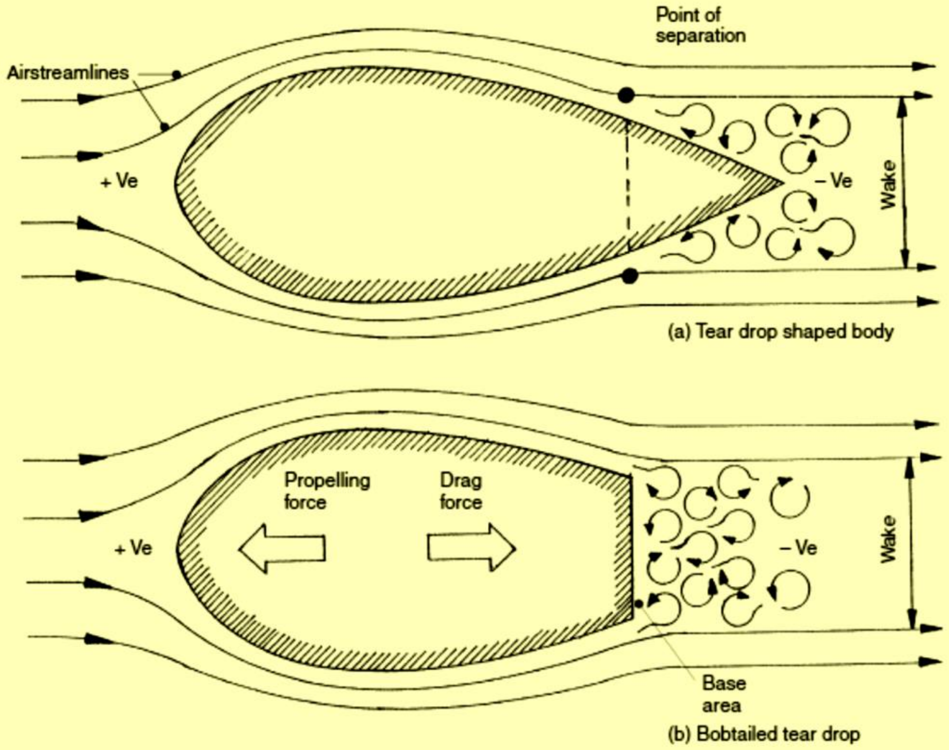


Fig. 14.16 (a and b) Base drag

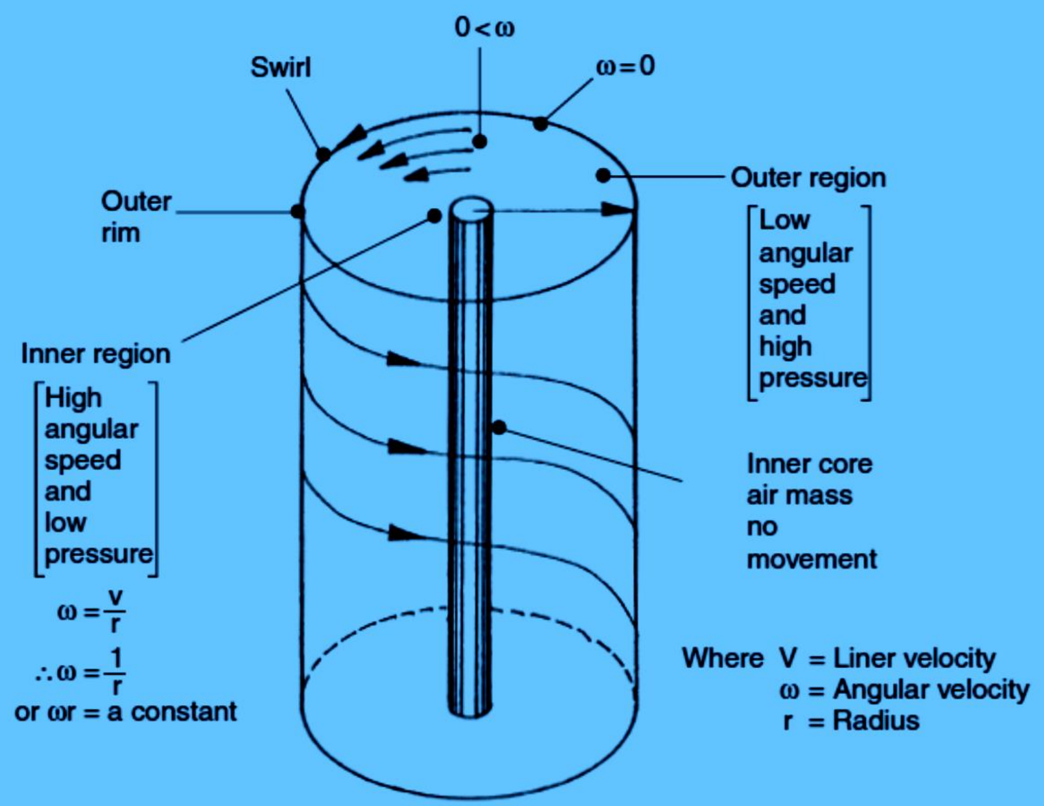
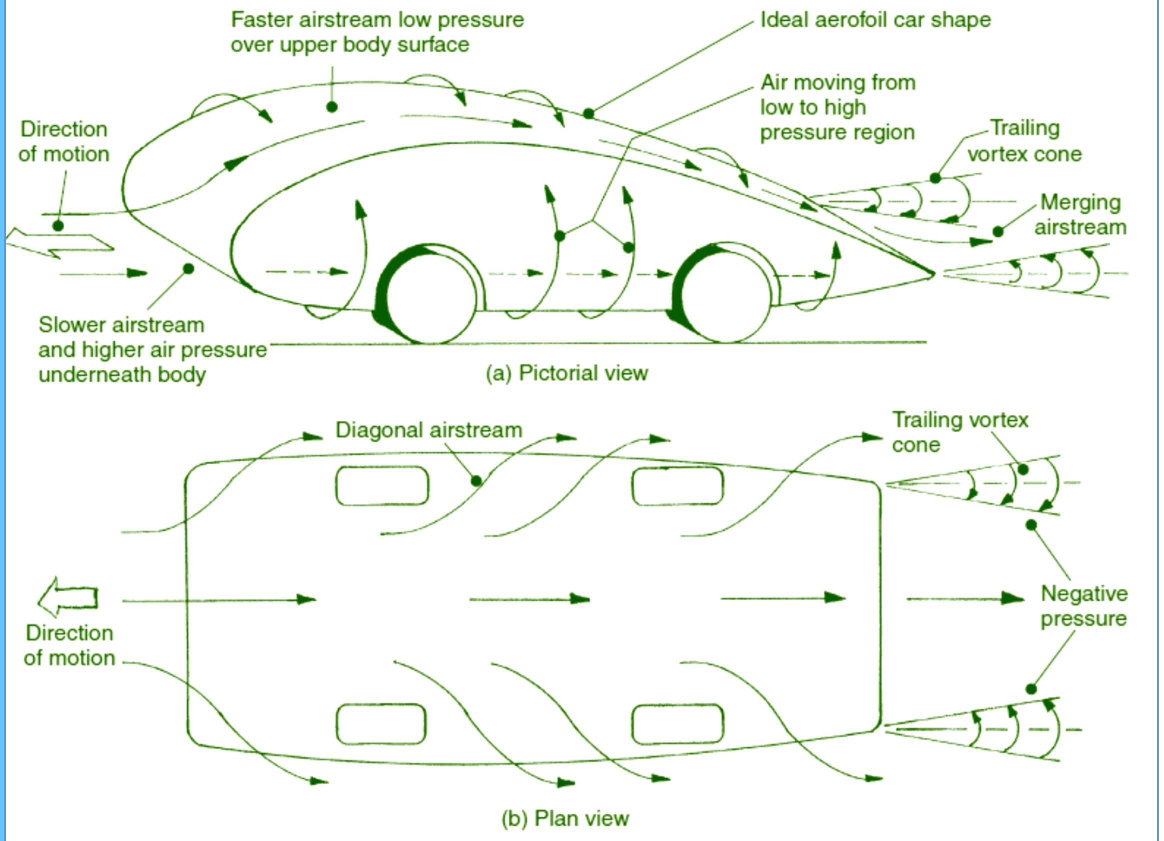


Fig. 14.17 The vortex



.18 (a and b) Establishment of trailing vortices

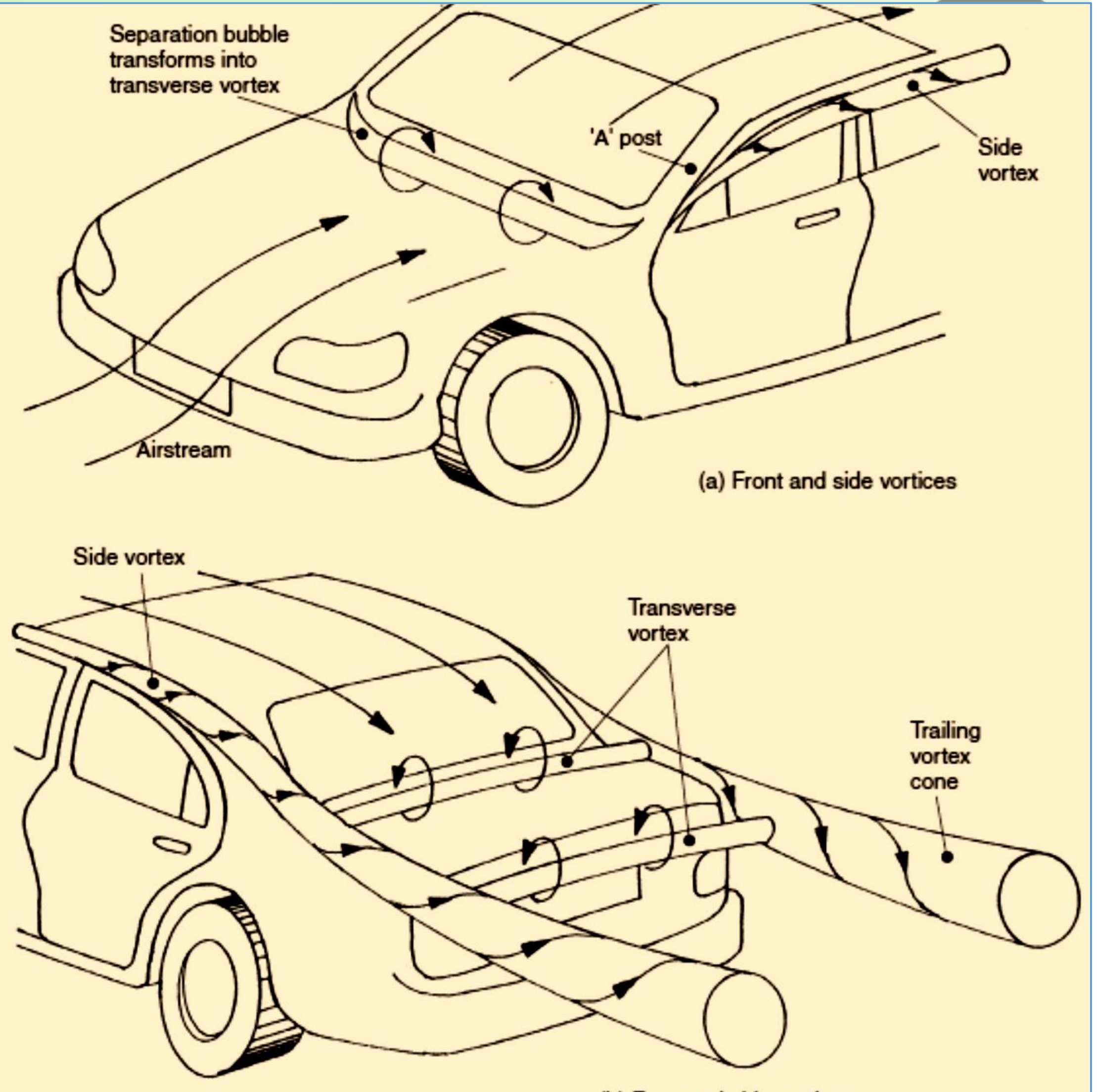


Fig. 14.19(a and b) Notch back transverse and trailing vortices

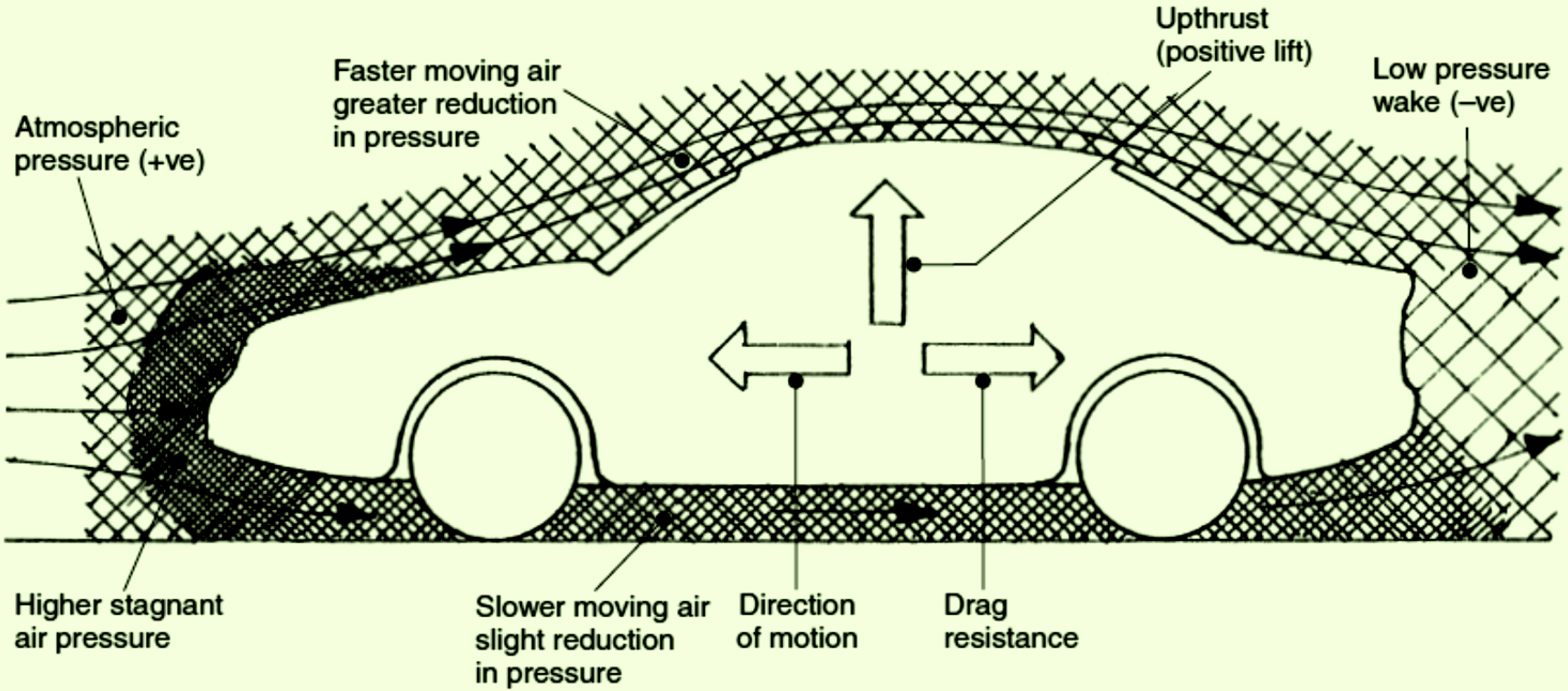


Fig. 14.20 Aerodynamic lift

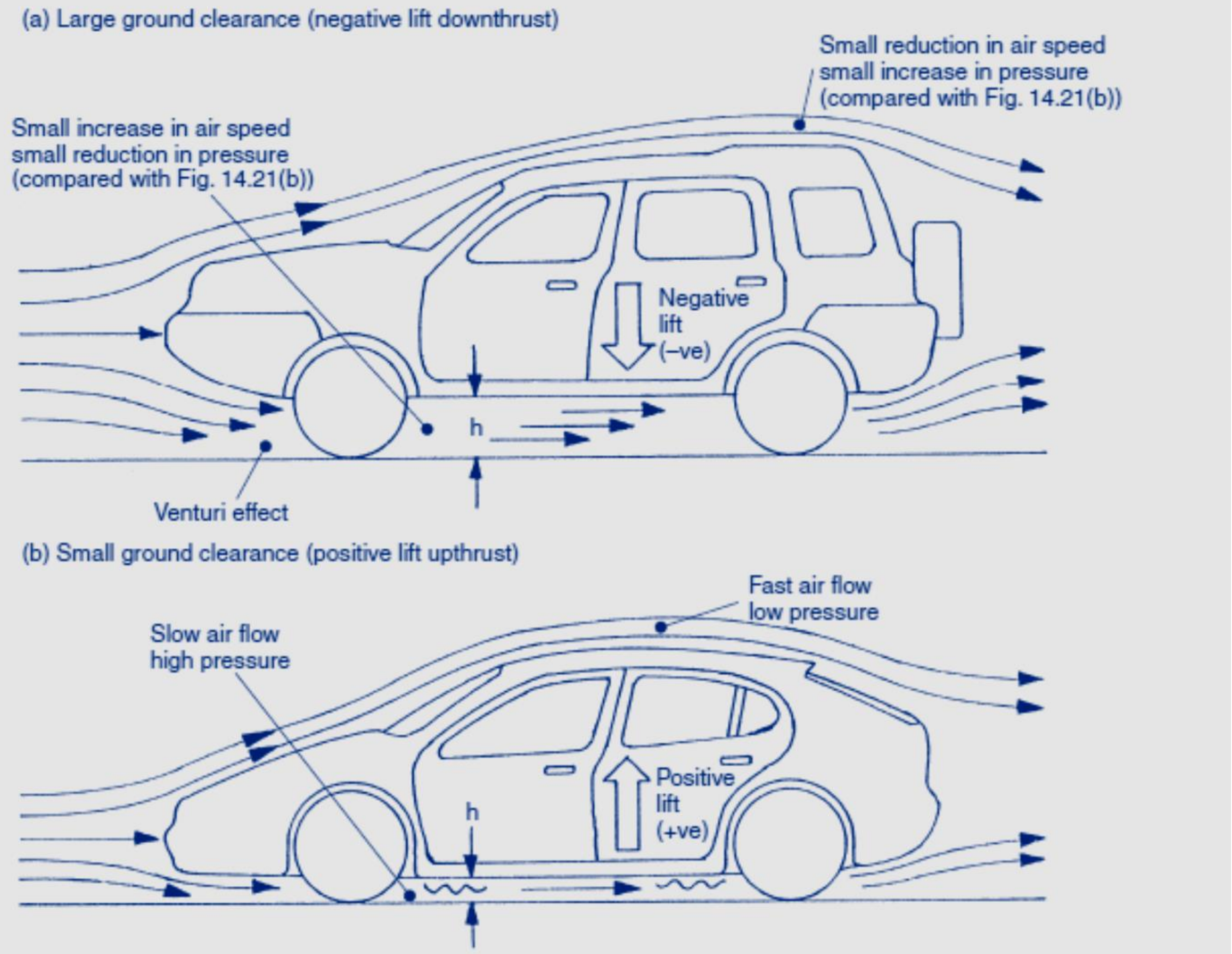


Fig. 14.21 (a and b) Effects of underfloor to ground clearance on the surrounding air speed, pressure and aerodynamic lift

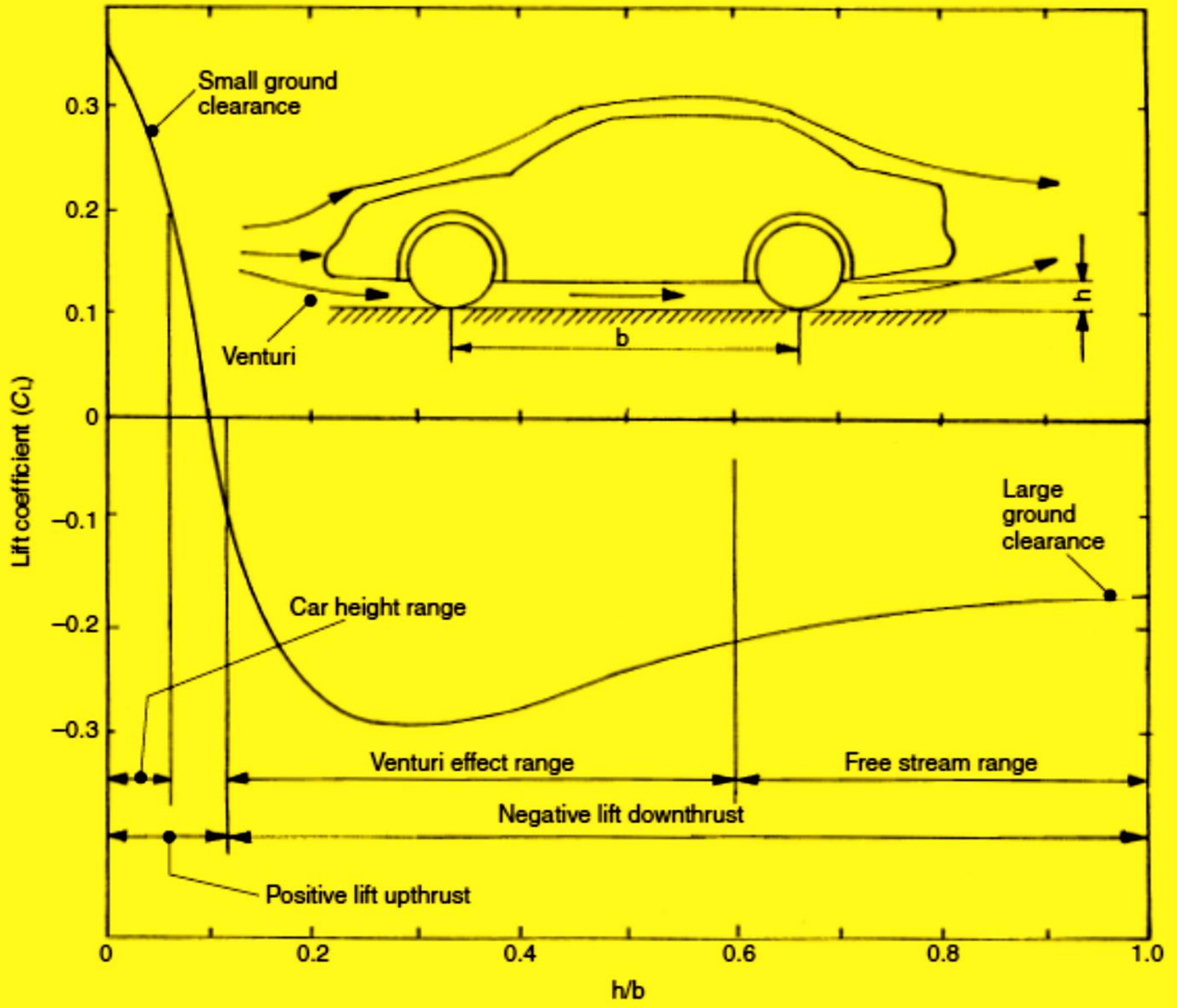
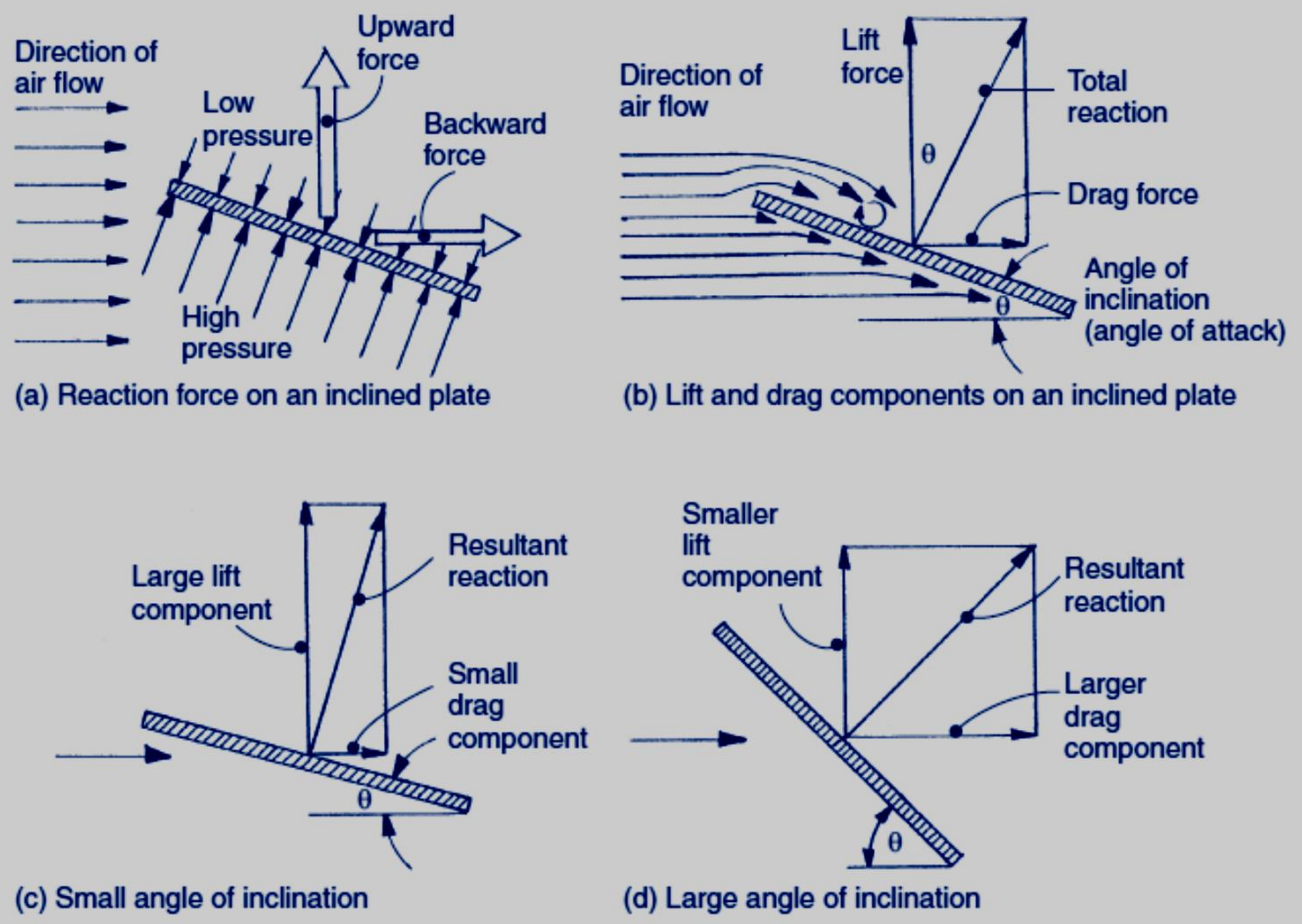


Fig. 14.22 Aerodynamic lift versus ground, floor height



d) Lift and drag on a plate inclined at a small angle to the direction of air flow

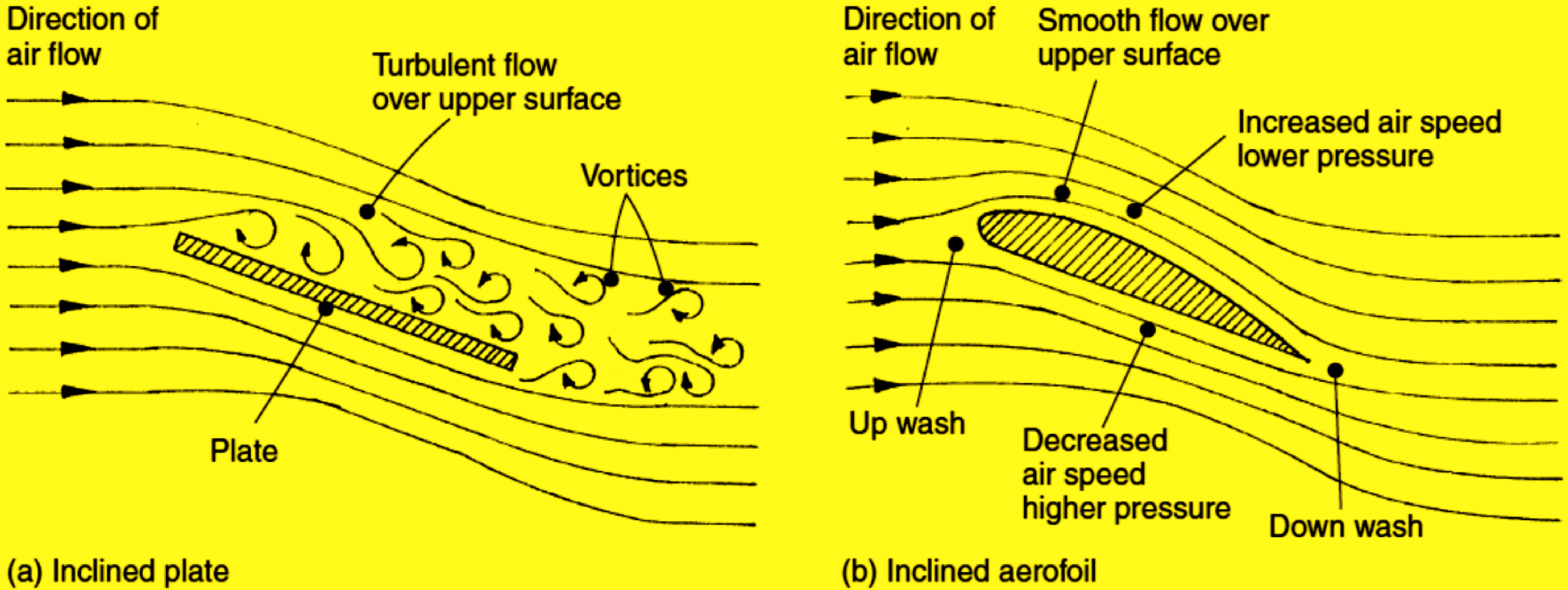


Fig. 14.24 (a and b) Air flow over a flat plate and aerofoil inclined at a small angle

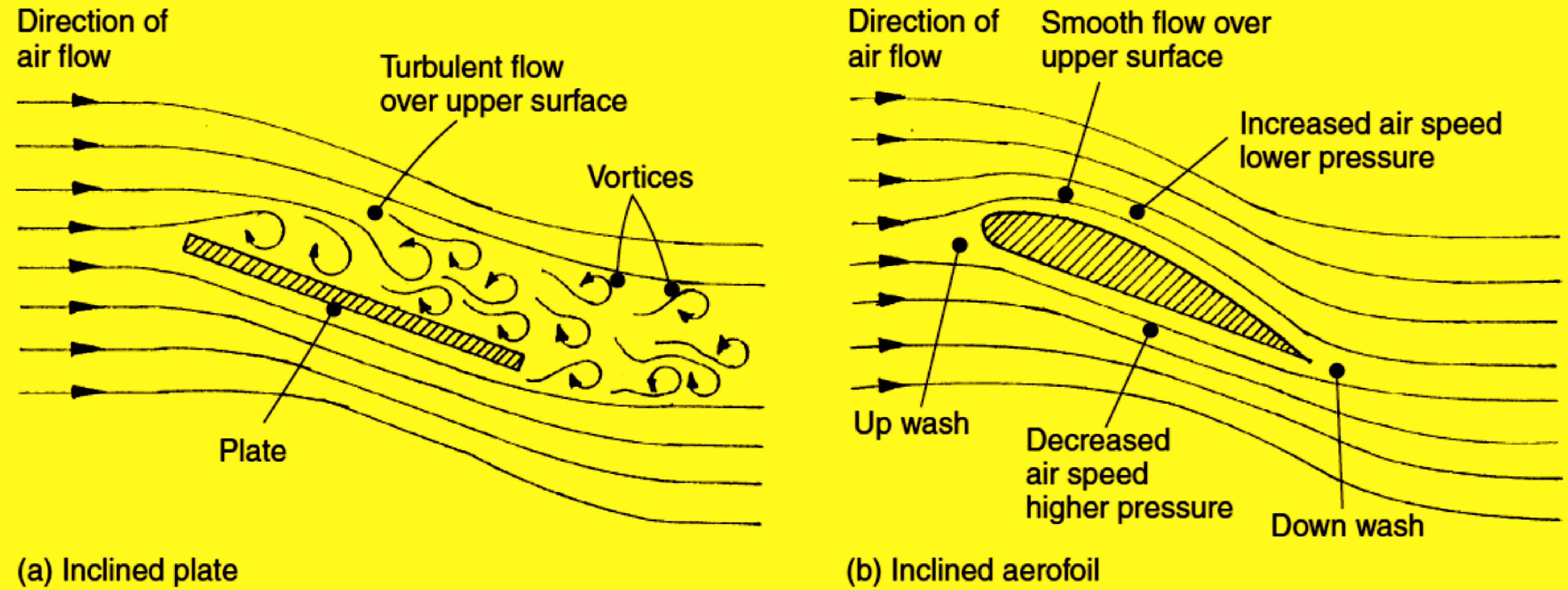
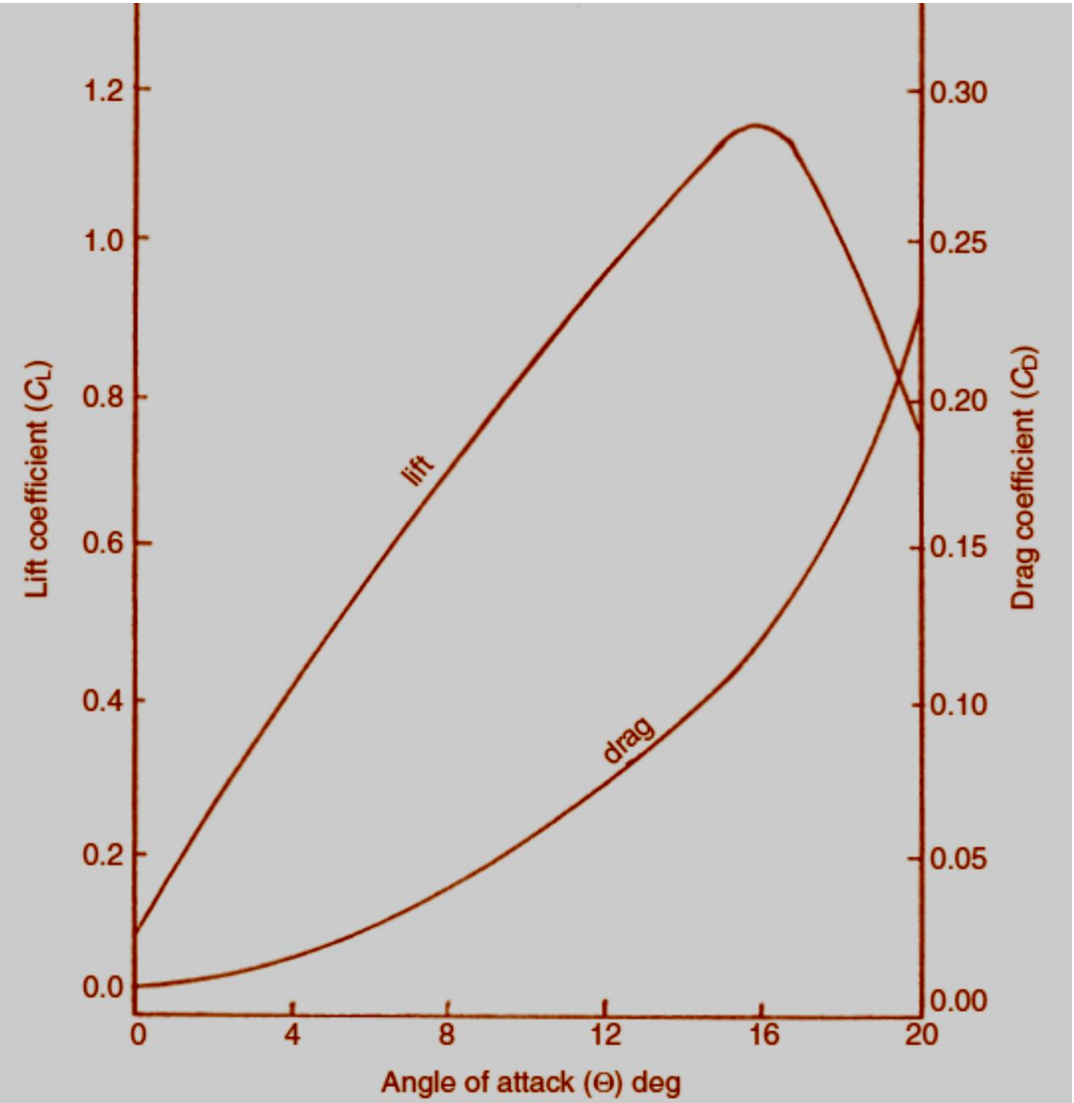
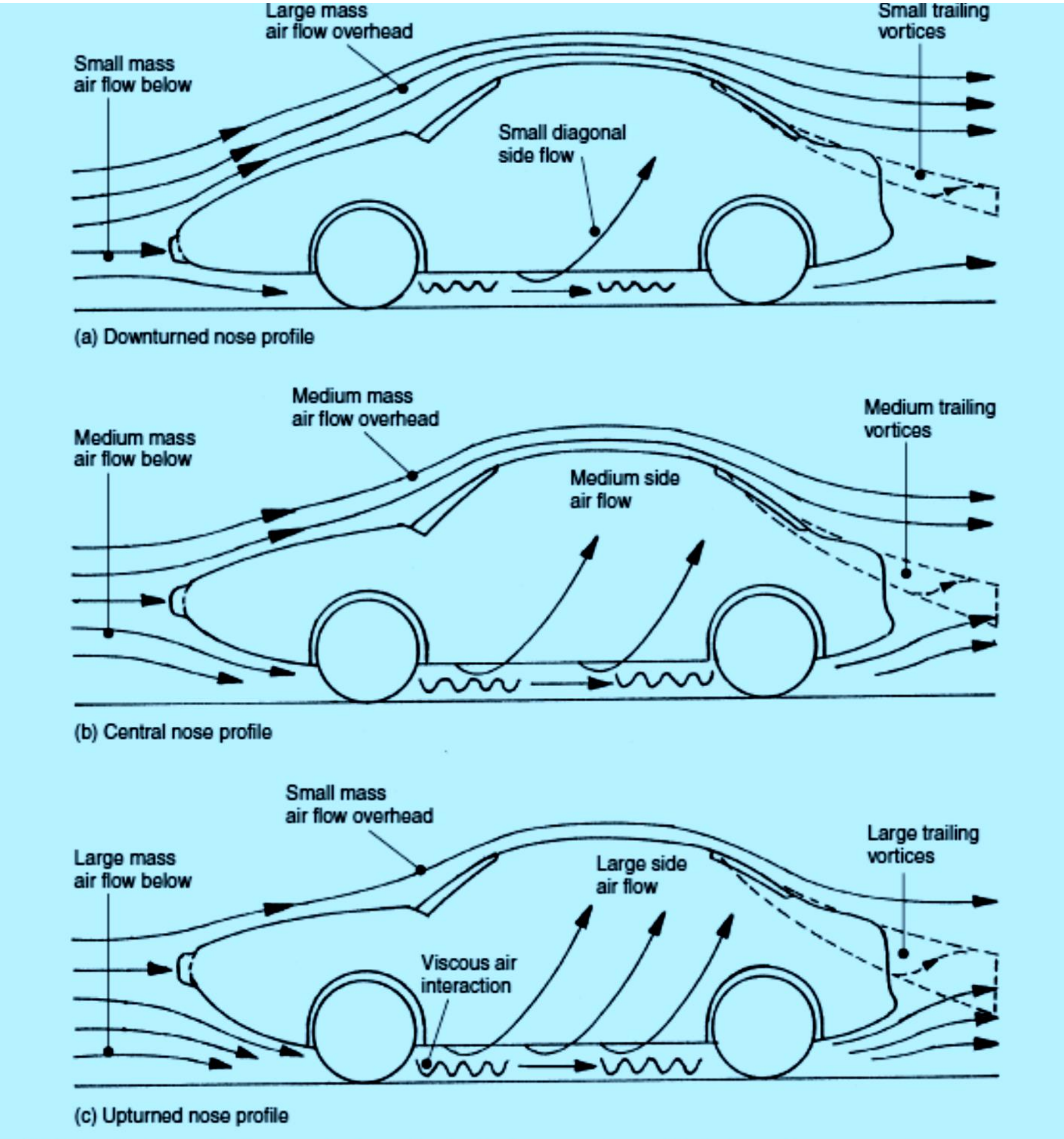


Fig. 14.24 (a and b) Air flow over a flat plate and aerofoil inclined at a small angle



Lift and drag coefficient versus angle of inclination (attack)



g. 14.26(a–c) A greatly exaggerated air mass distribution around a car body for various nose profiles

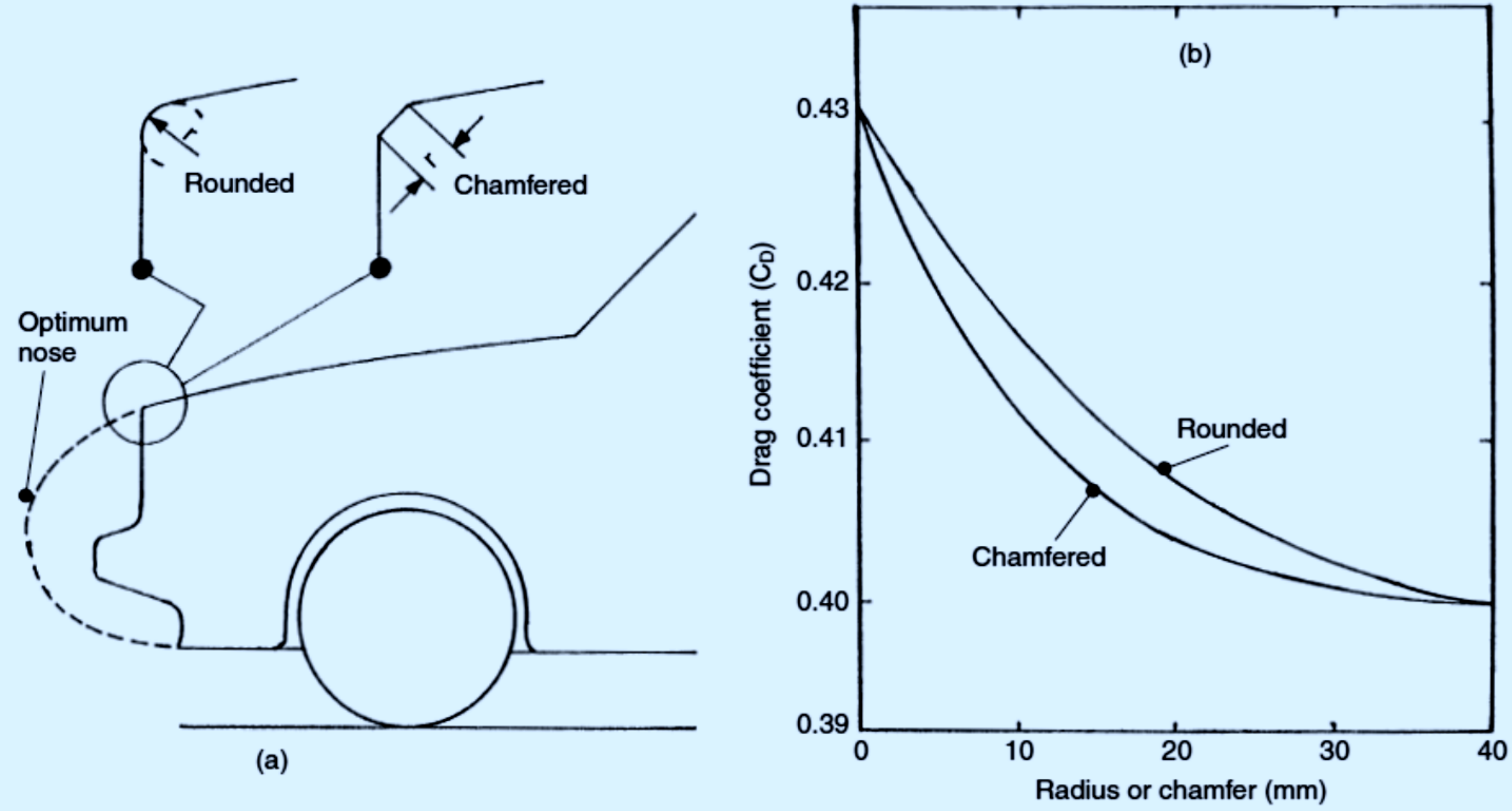


Fig. 14.27 (a and b) Influence of forebody bonnet (hood) edge shape on drag coefficient

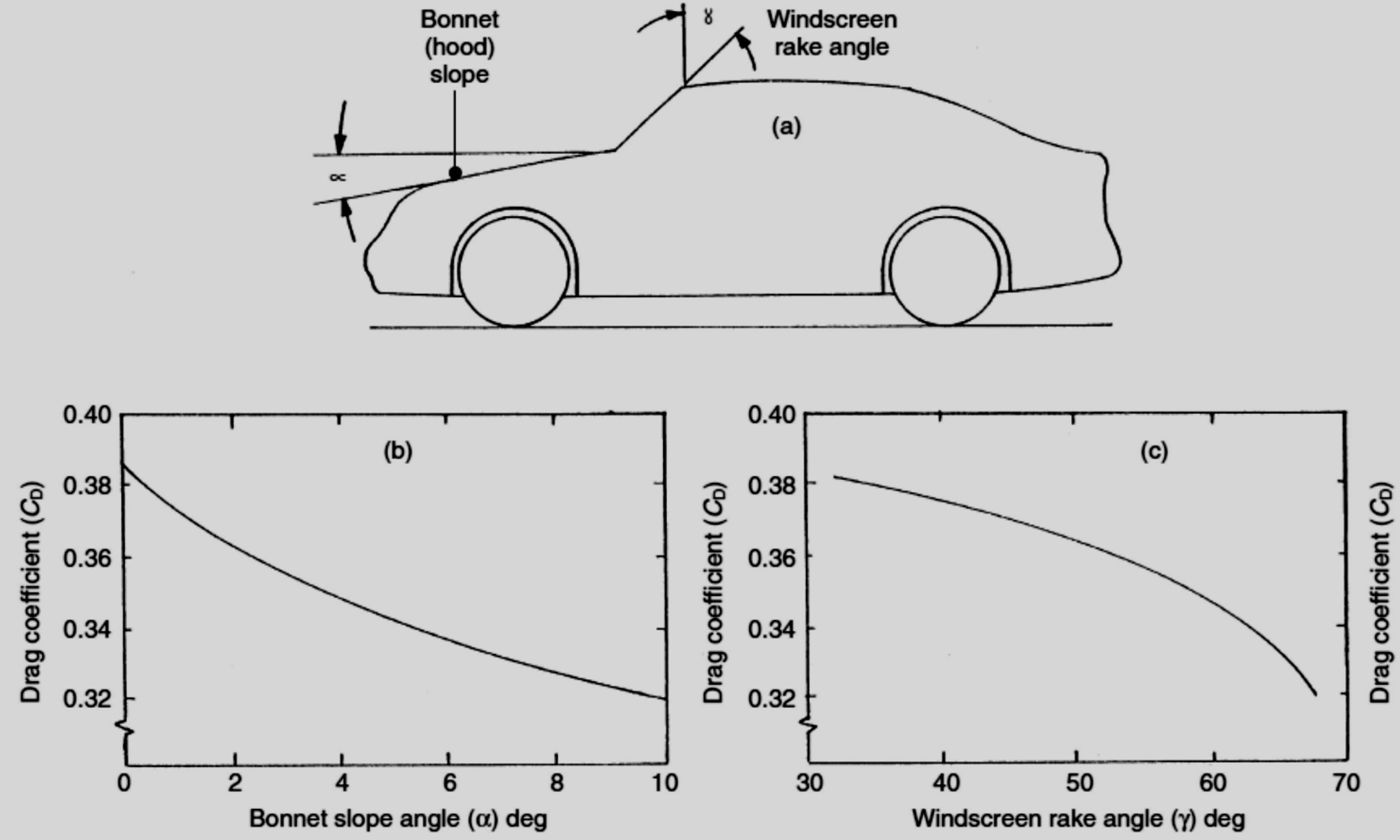


Fig. 14.28 (a–c) Bonnet slope and windscreen rake angle versus drag coefficient

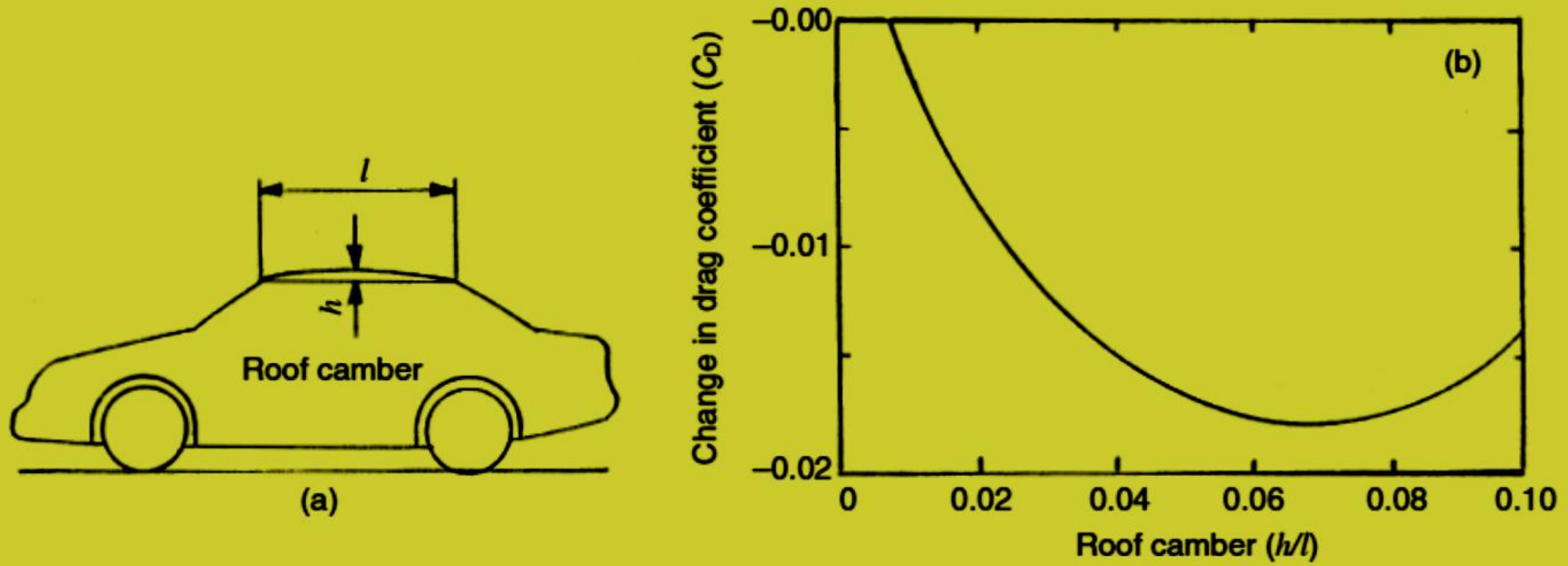


Fig. 14.29 (a and b) Effect of roof camber on drag coefficient

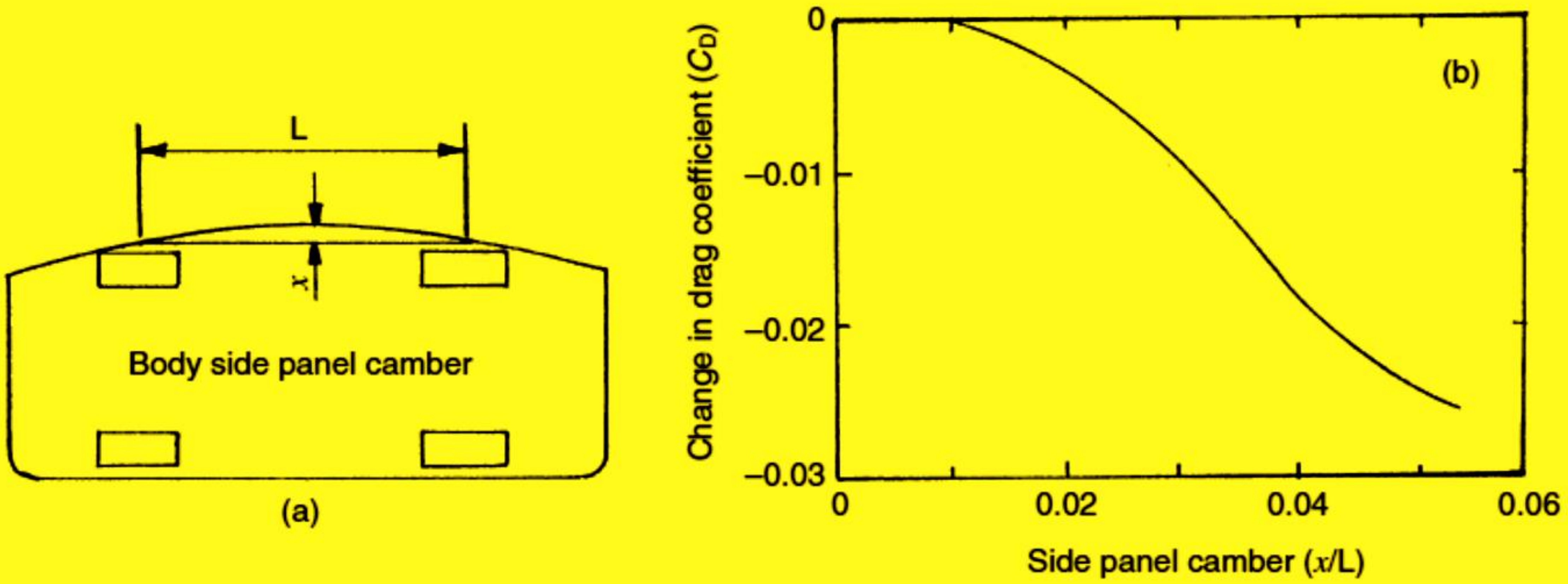


Fig. 14.30 (a and b) Effect of side panel camber on drag coefficient

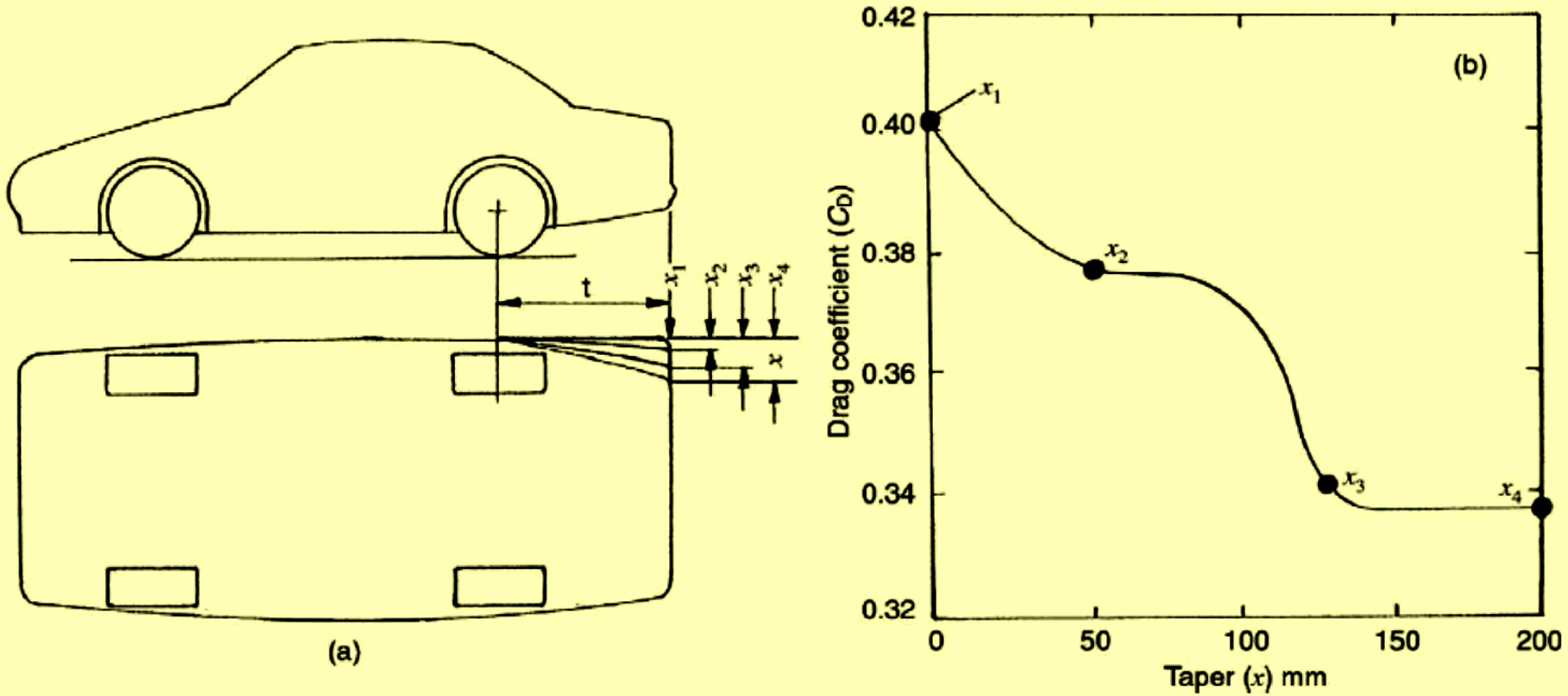


Fig. 14.31 (a and b) Effect of rear side panel taper on drag coefficient

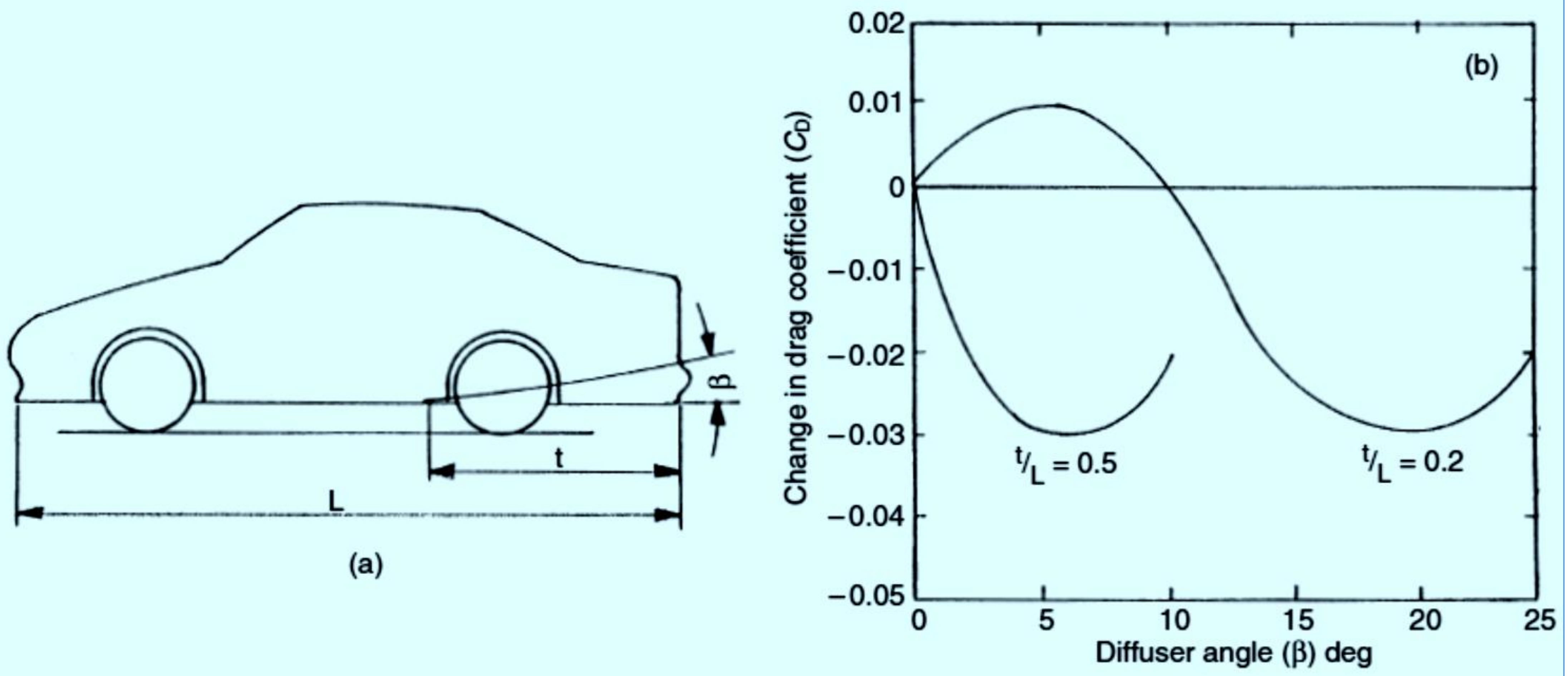


Fig. 14.32 (a and b) Effect of rear end upward taper on drag coefficient

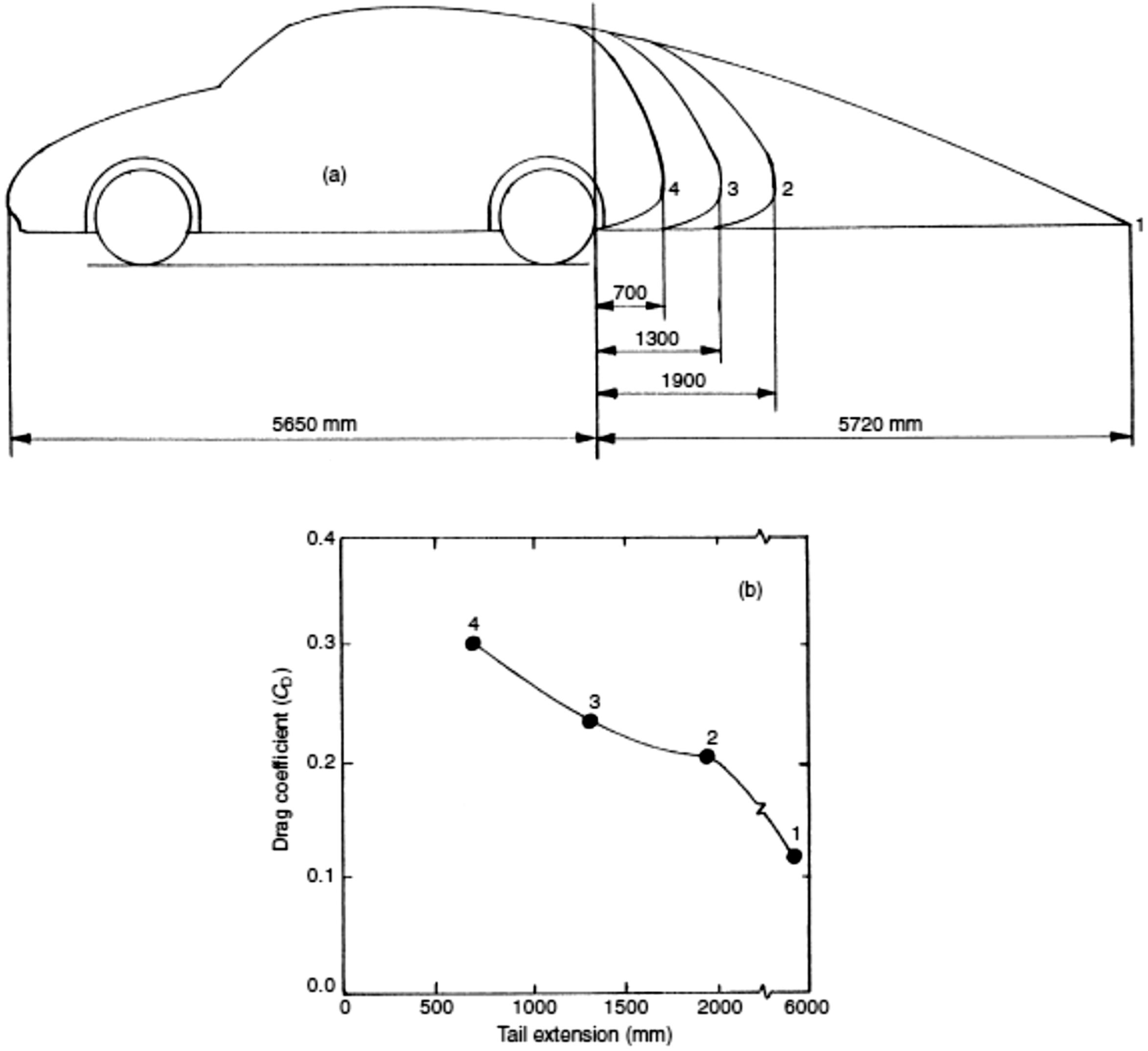


Fig. 14.33(a and b) Effect of rear end tail extension on drag coefficient

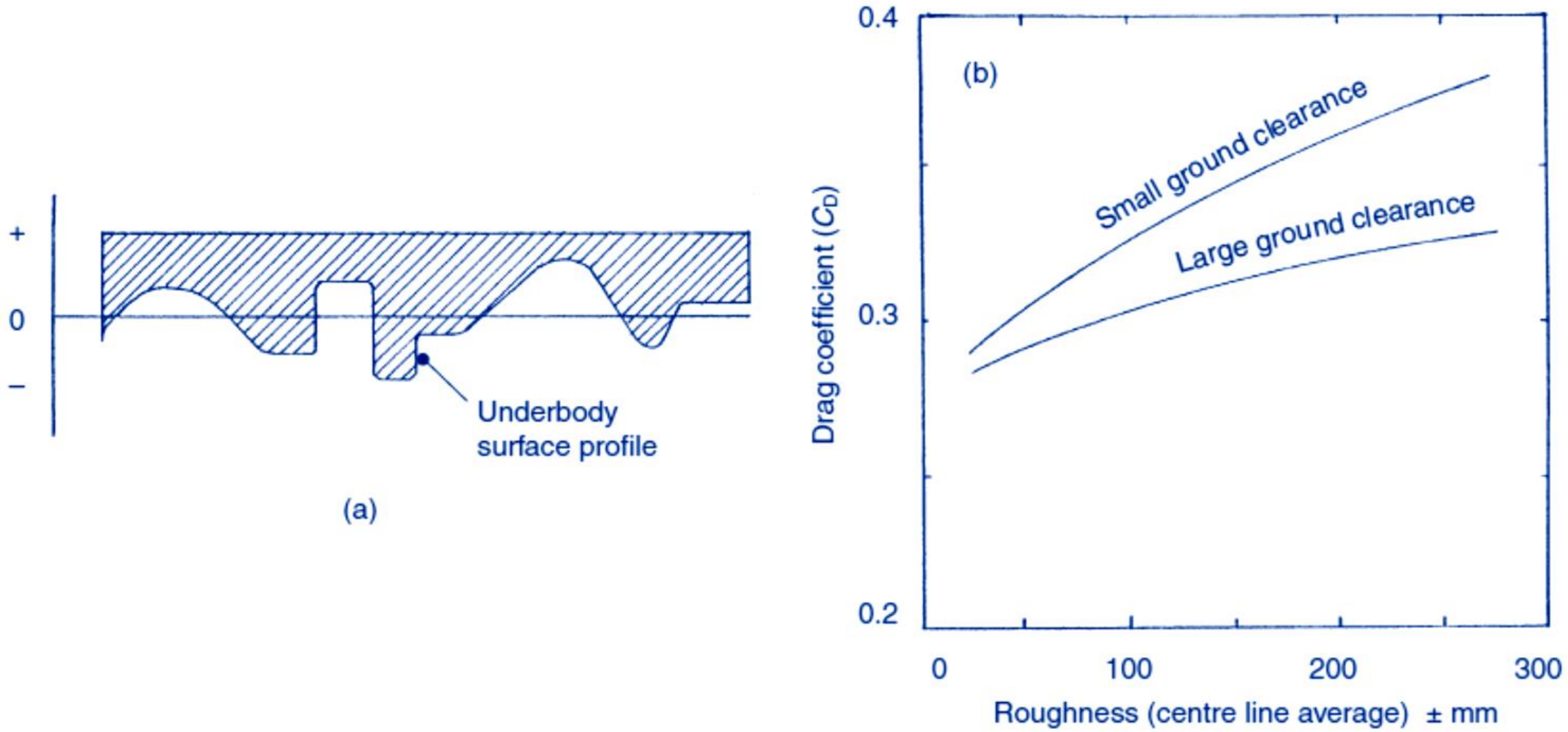


Fig. 14.34 (a and b) Effect of underbody roughness on drag coefficient

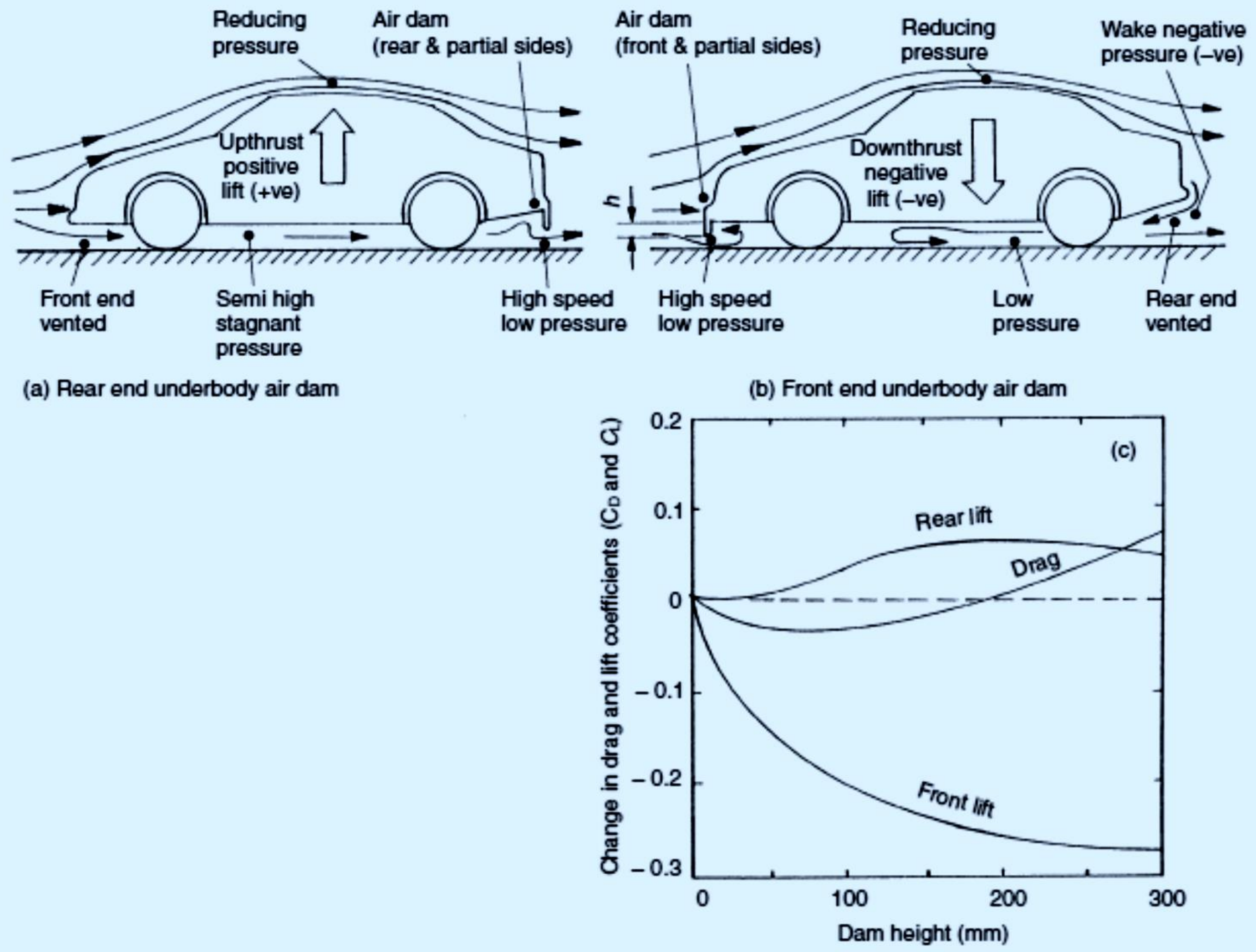


Fig. 14.35(a–c) Effects of underbody front and rear end air dams relative to the lift and drag coefficient

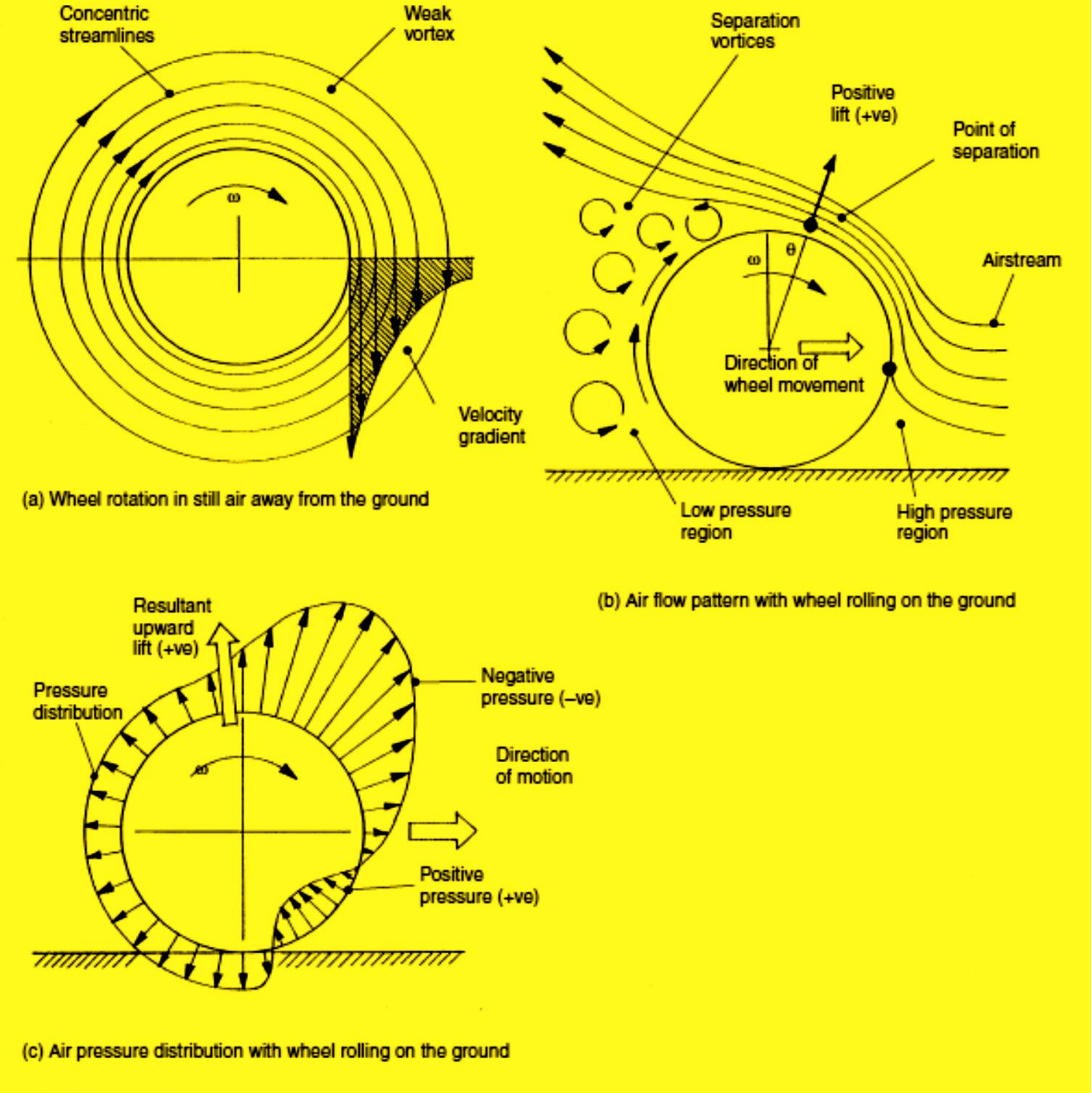
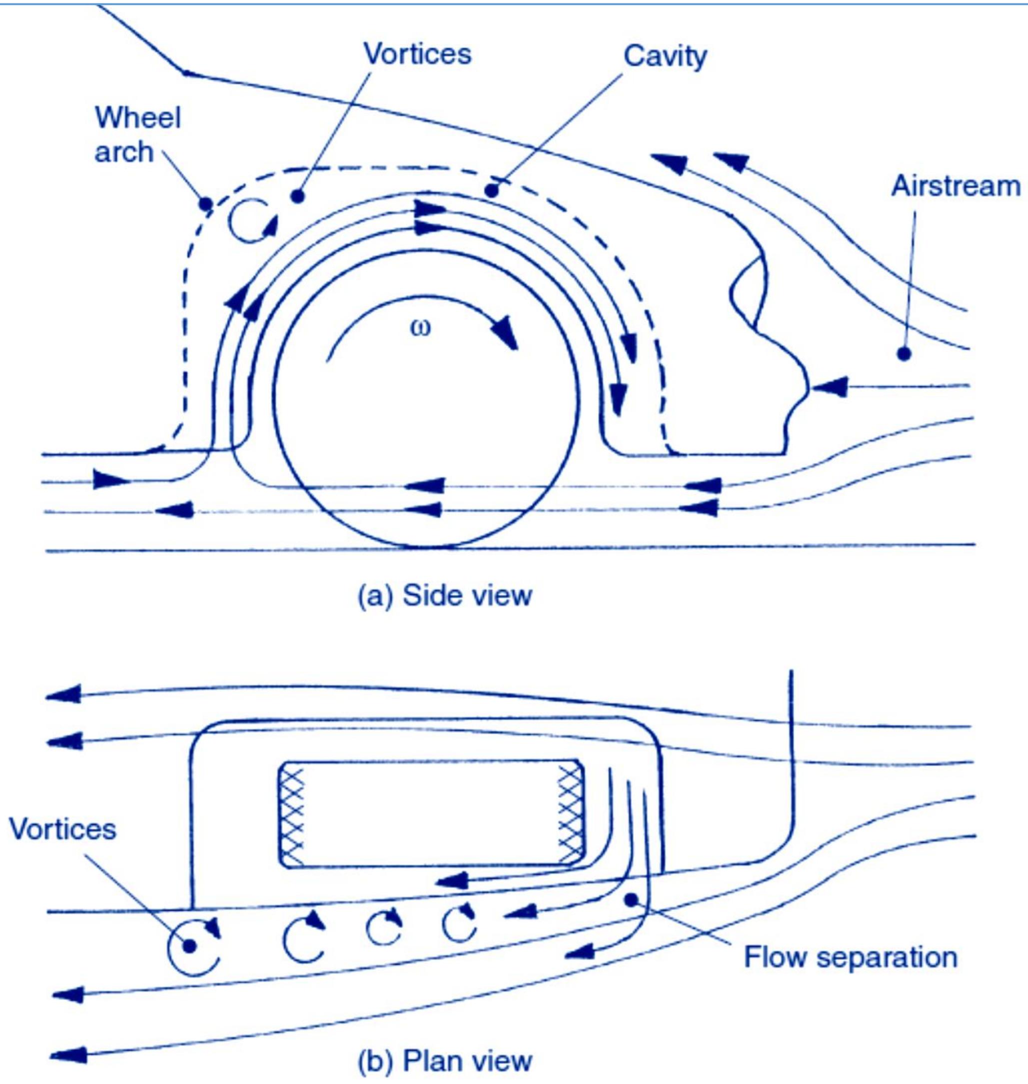


Fig. 14.36(a–c) Exposed wheel air flow pattern and pressure distribution



(a and b) Wheel arch air flow pattern

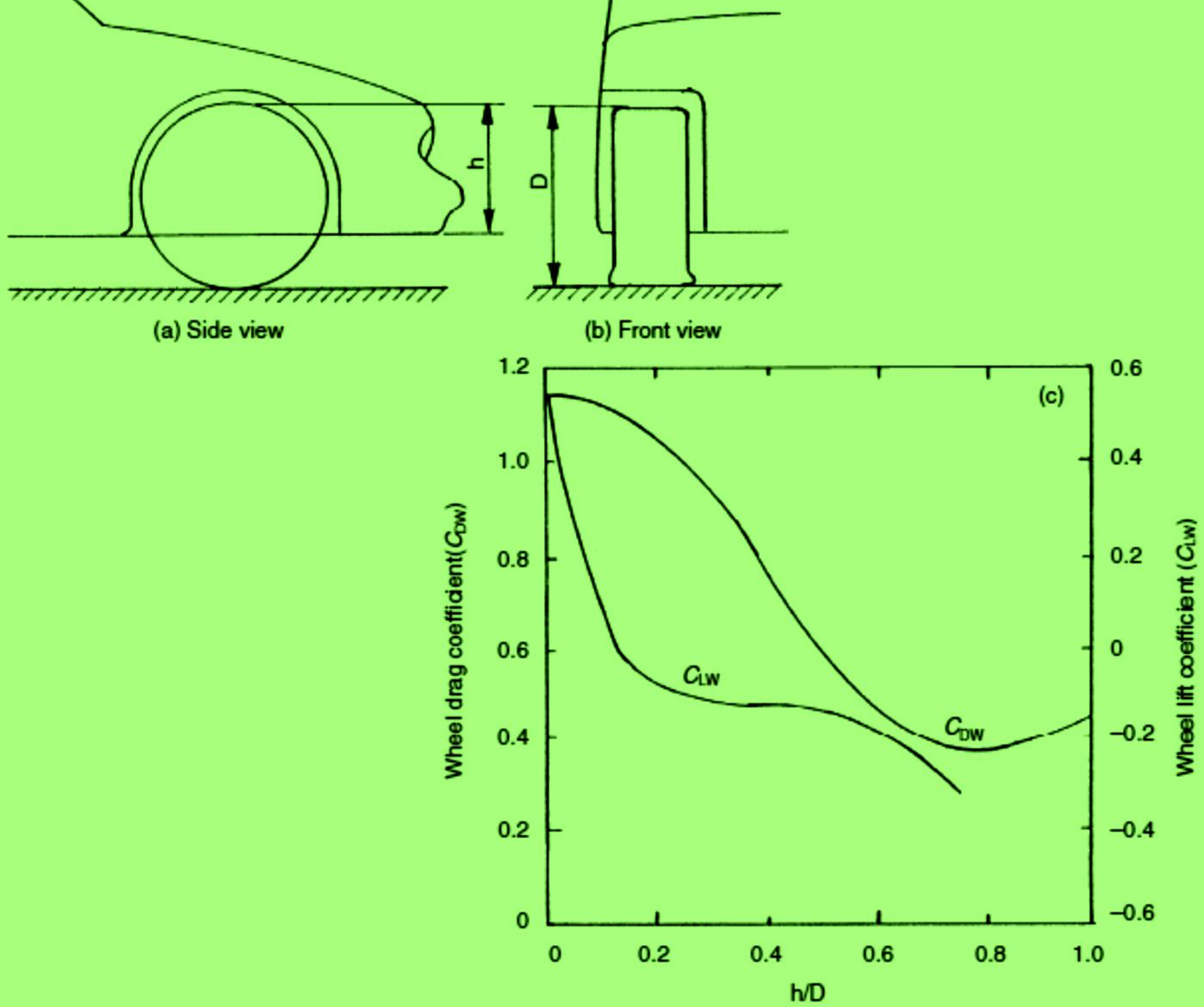


Fig. 14.38(a–c) Effect of underside ground clearance on both lift and drag coefficients

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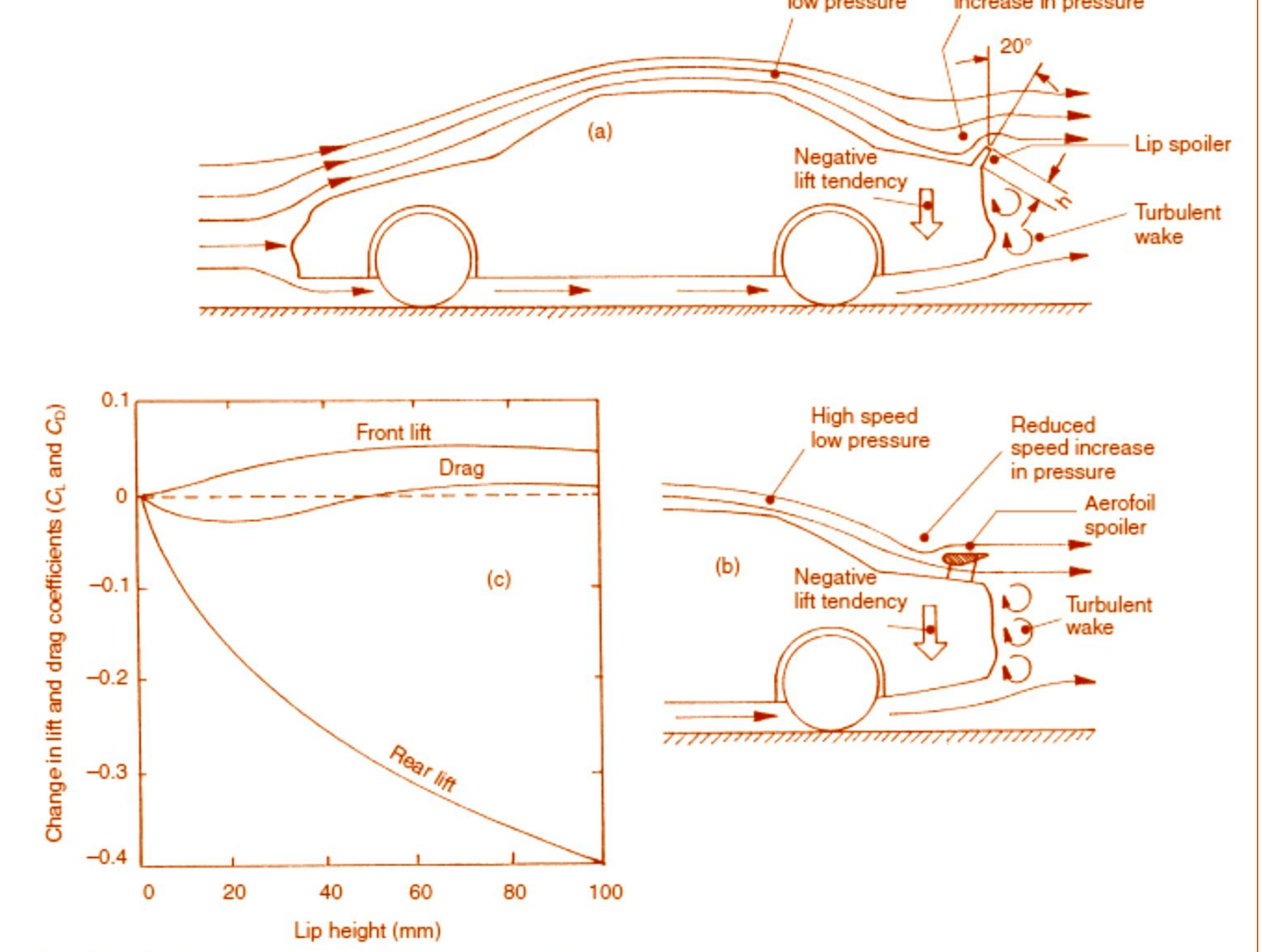


Fig. 14.39(a–c) Effect of rear end spoiler on both lift and drag coefficients

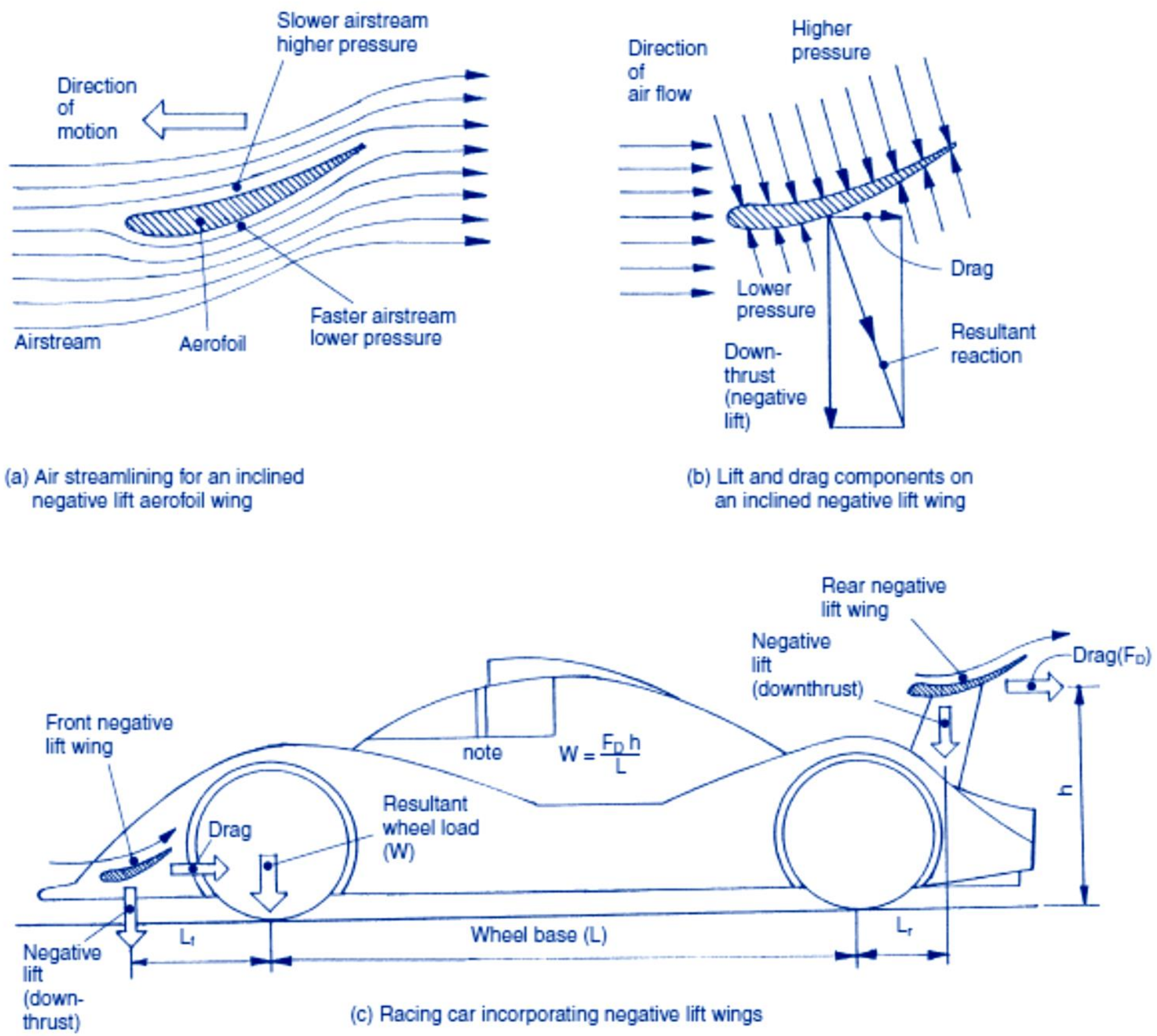
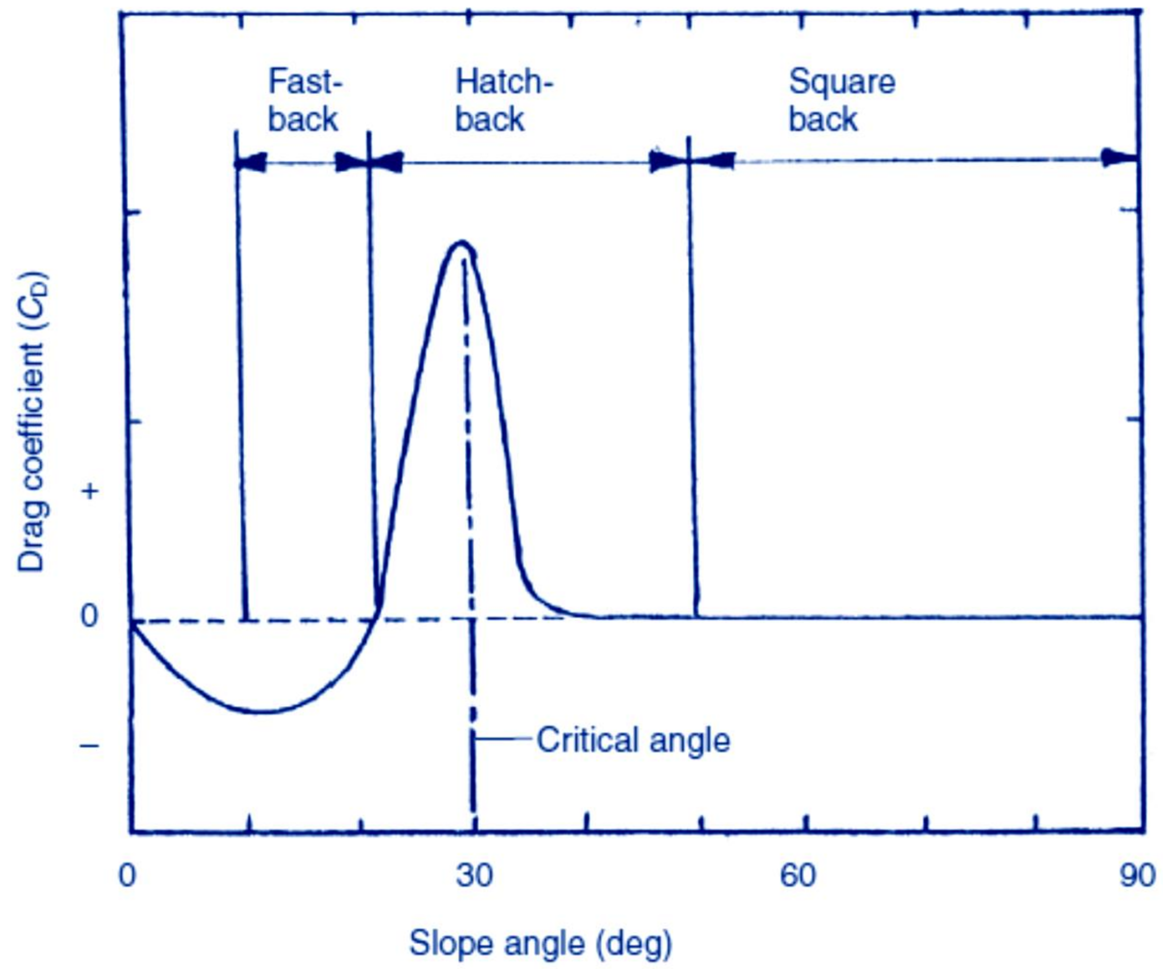


Fig. 14.40(a–c) Negative lift aerofoil wing considerations



Effect of rear panel slope angle on the afterbody drag

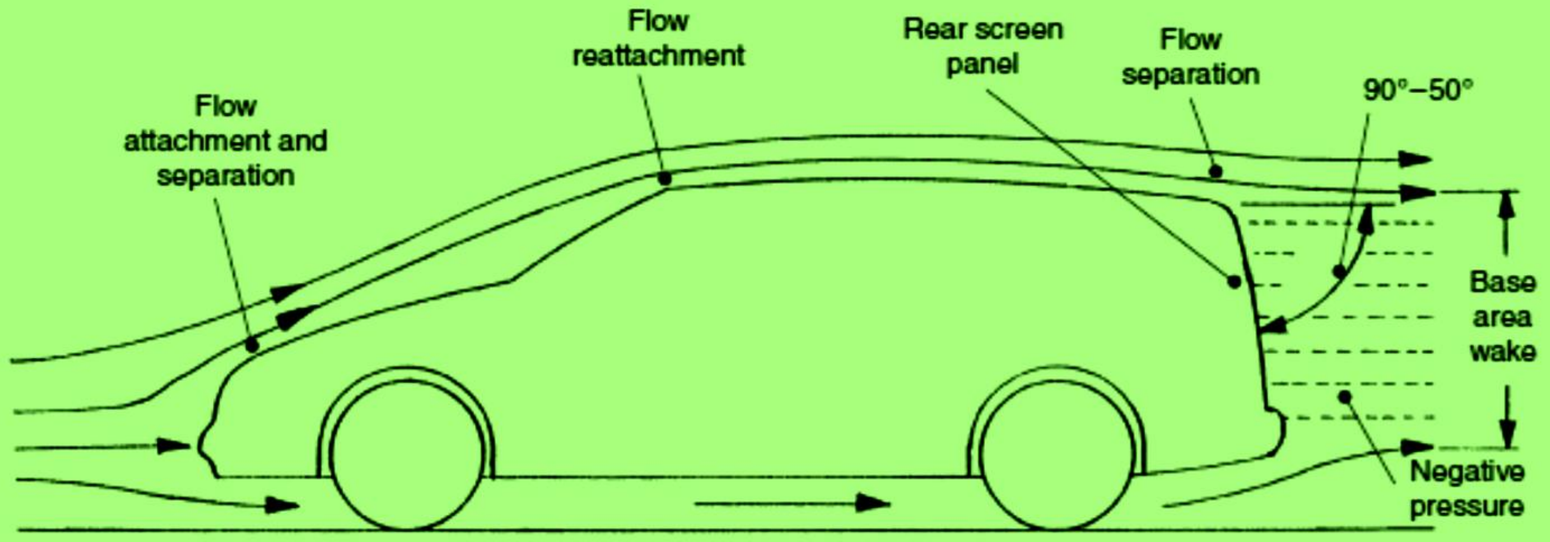


Fig. 14.42 Squareback configuration

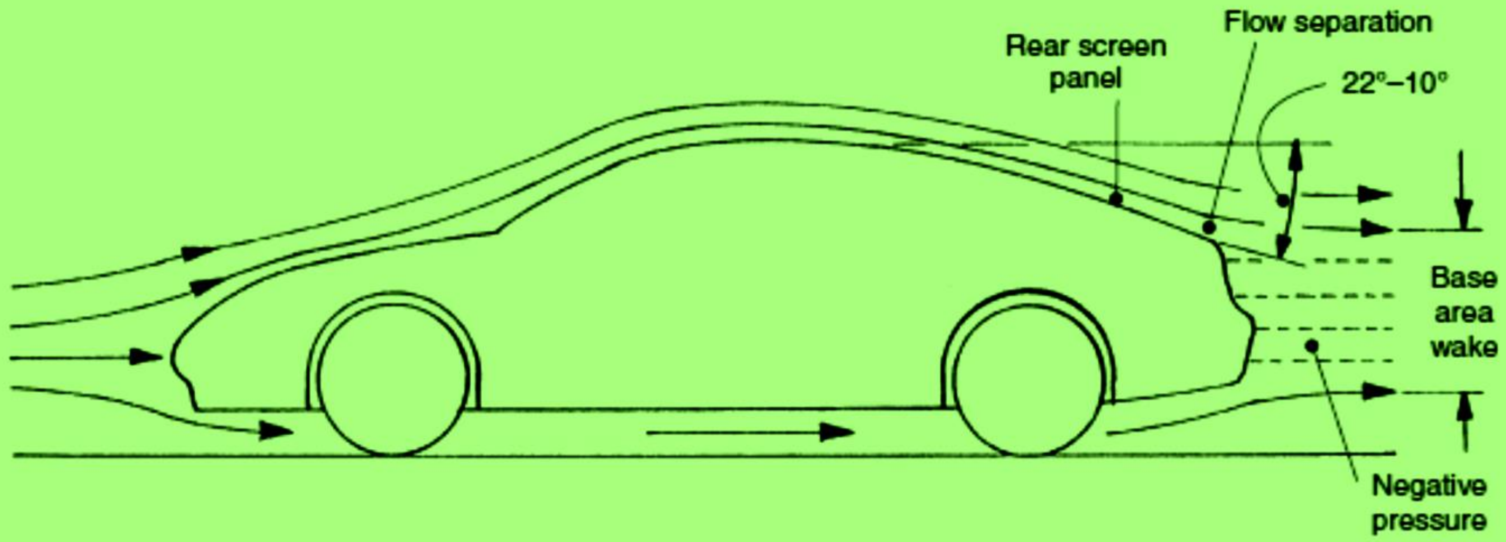
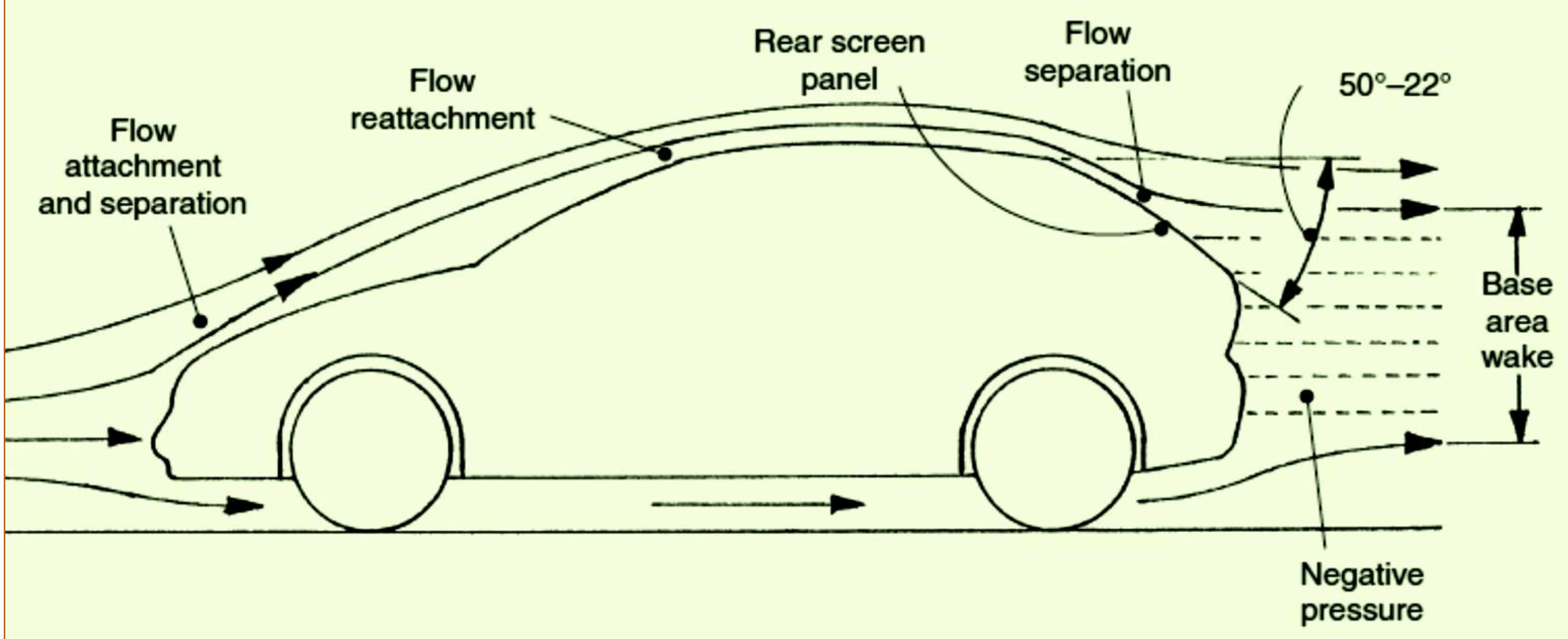


Fig. 14.43 Fastback configuration



Hatchback configuration

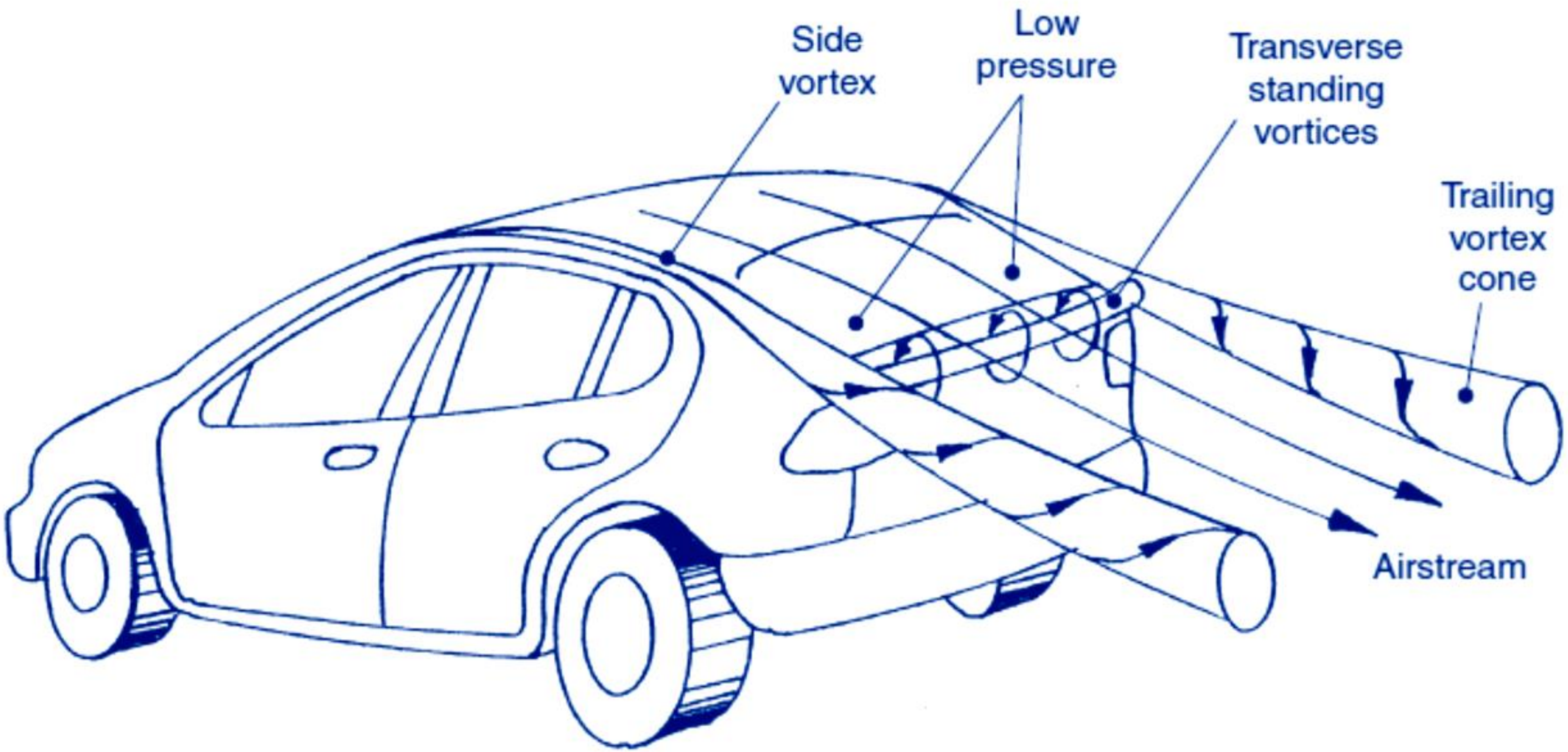


Fig. 14.45 Hatchback transverse and trailing vortices

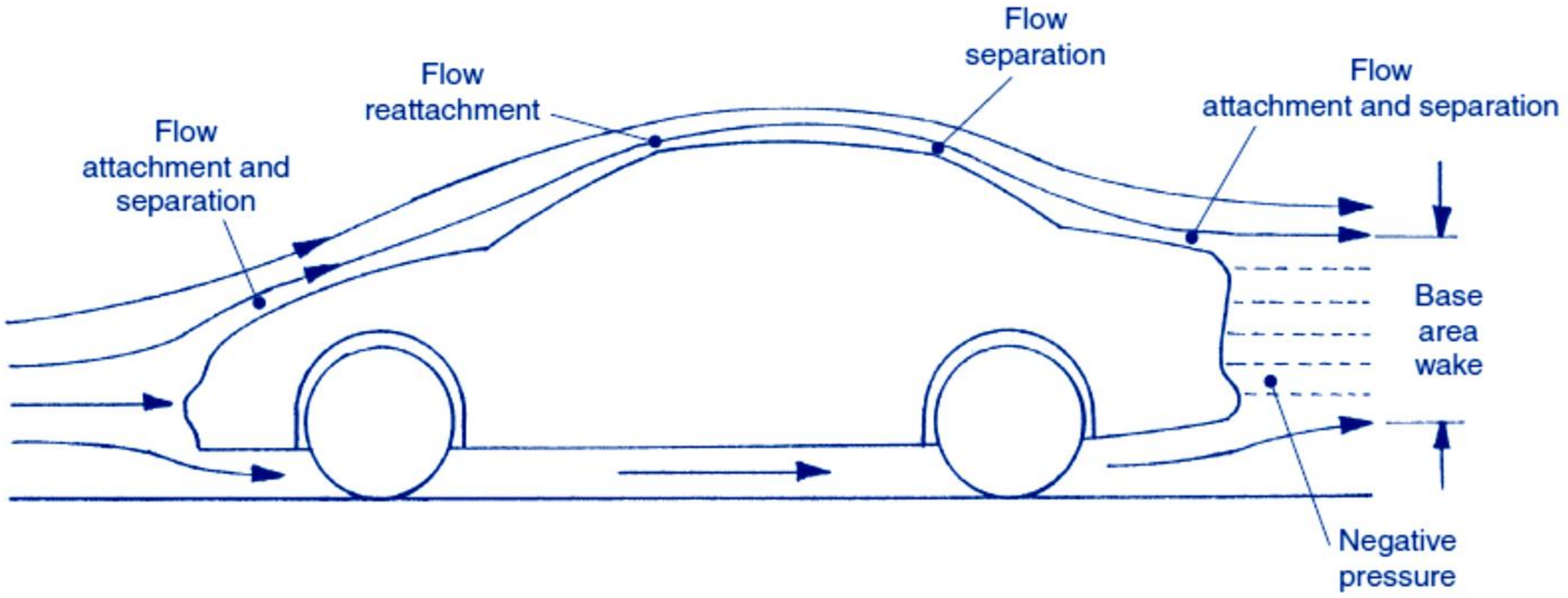


Fig. 14.46 Notchback configuration

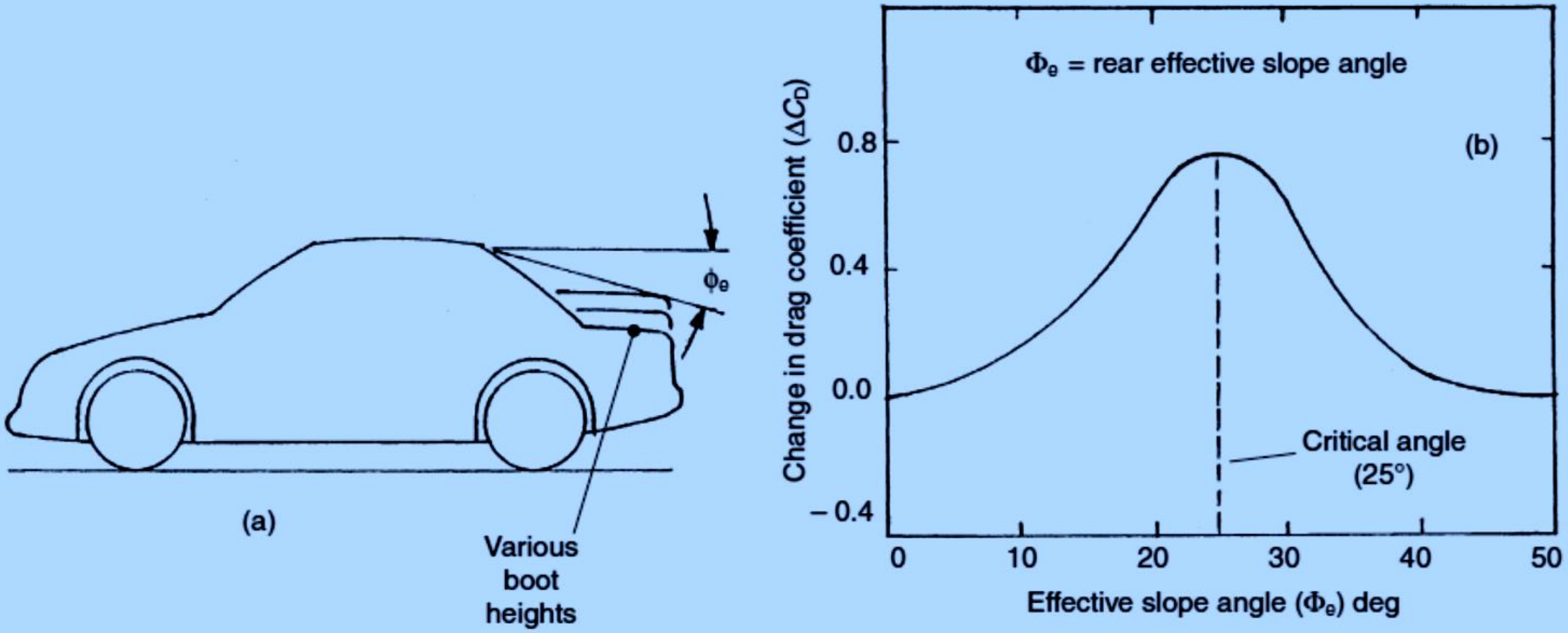


Fig. 14.47 (a and b) Influence of the effective slope angle on the drag coefficient

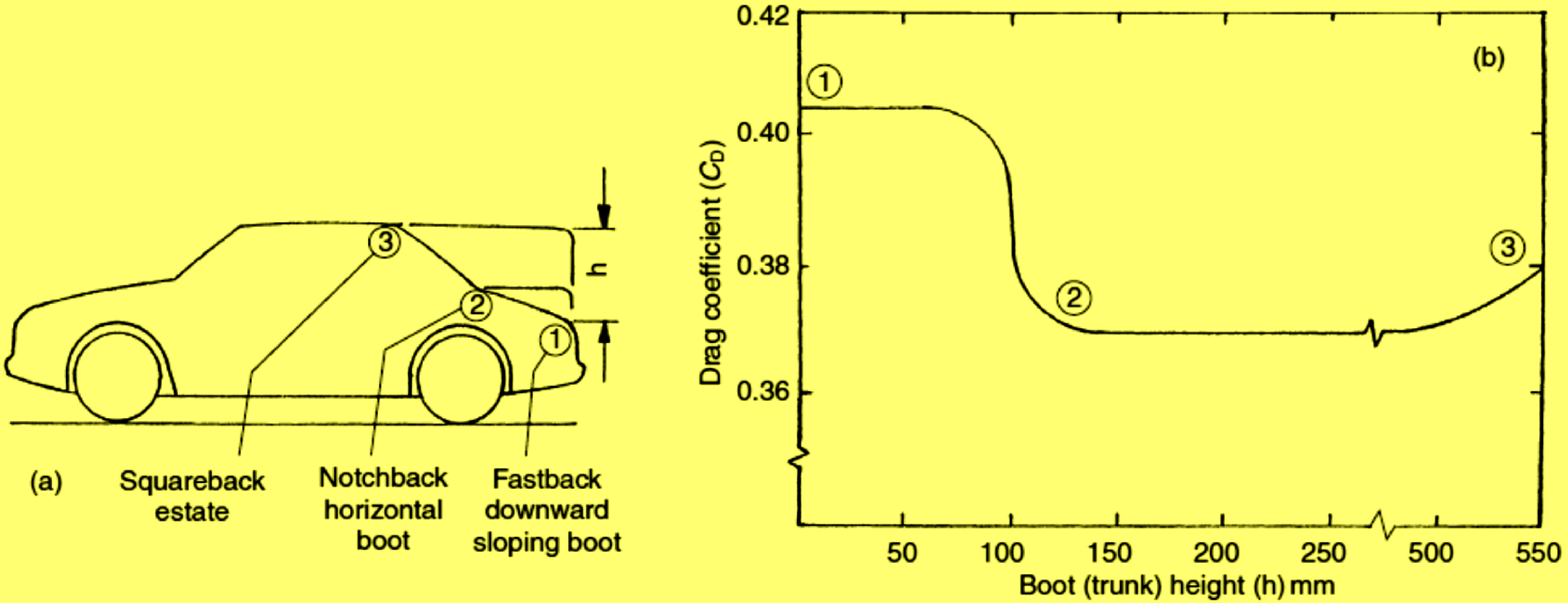


Fig. 14.48 (a and b) Effect of elevating the boot (trunk) height on the drag coefficient

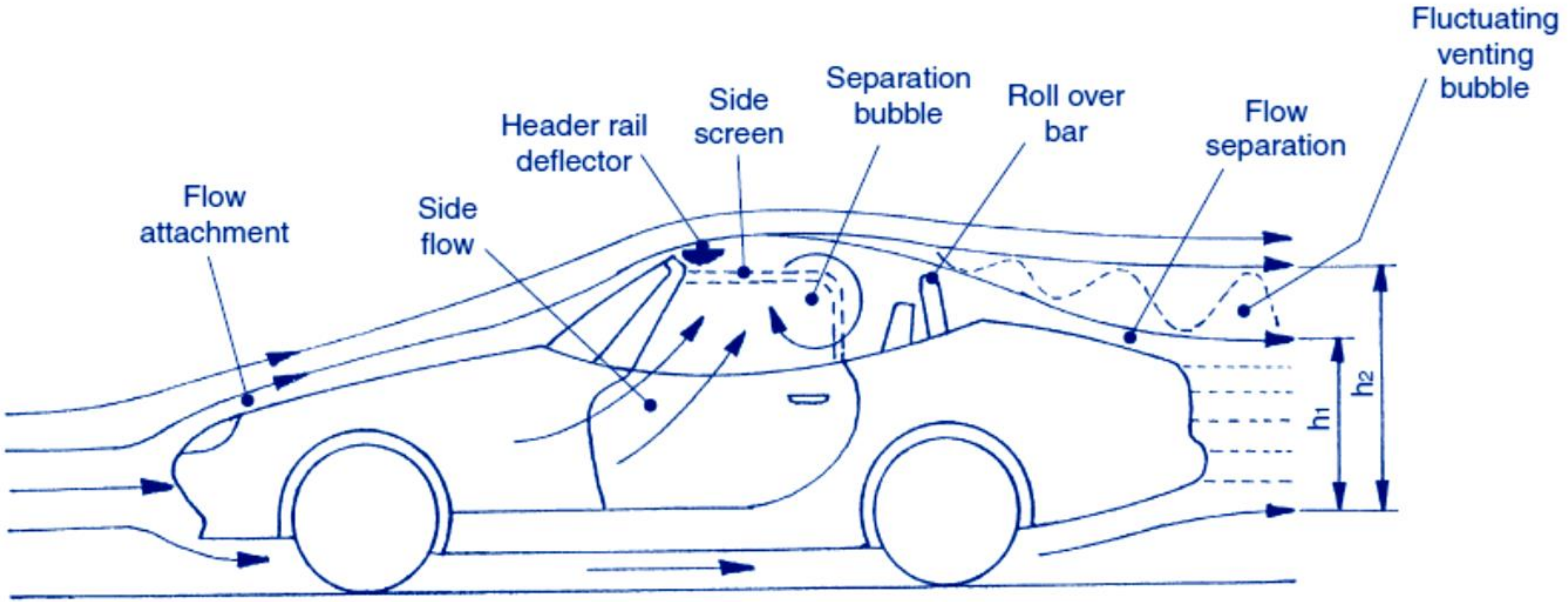
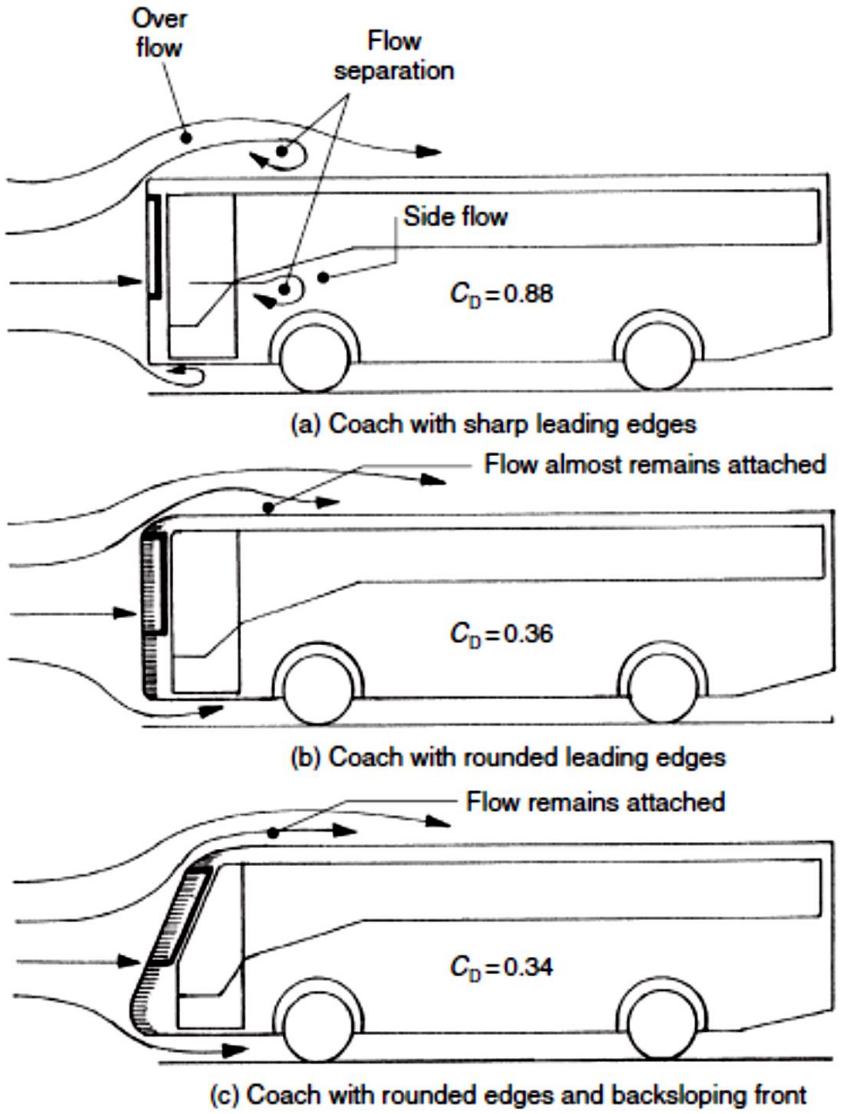


Fig. 14.49 Open cabriolet



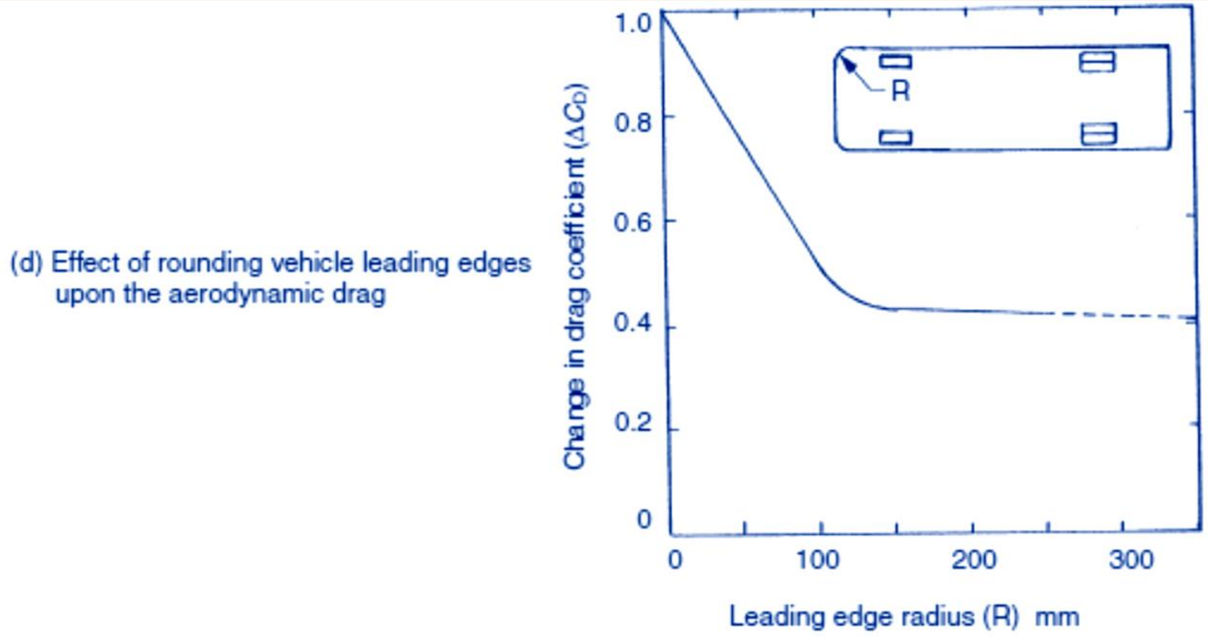
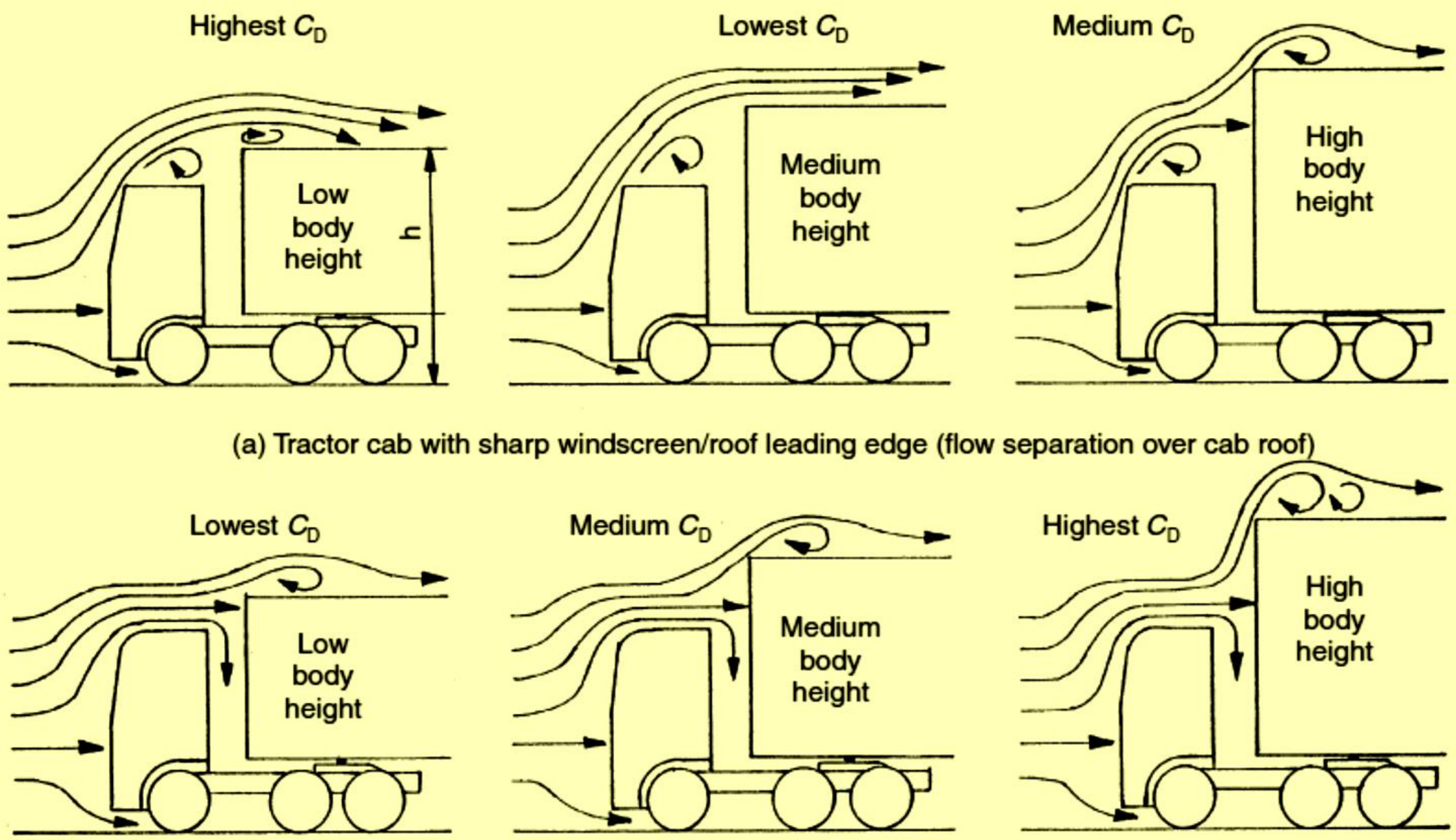
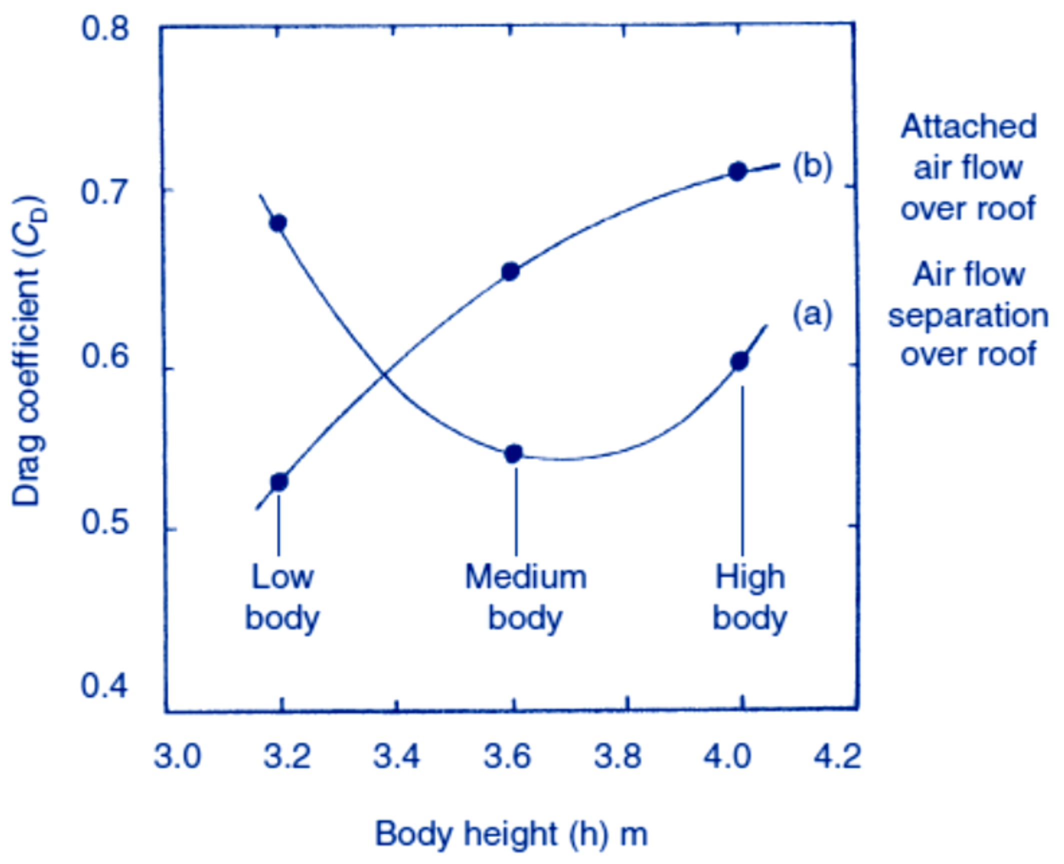


Fig. 14.50(a–d) Forebody coach streamlining



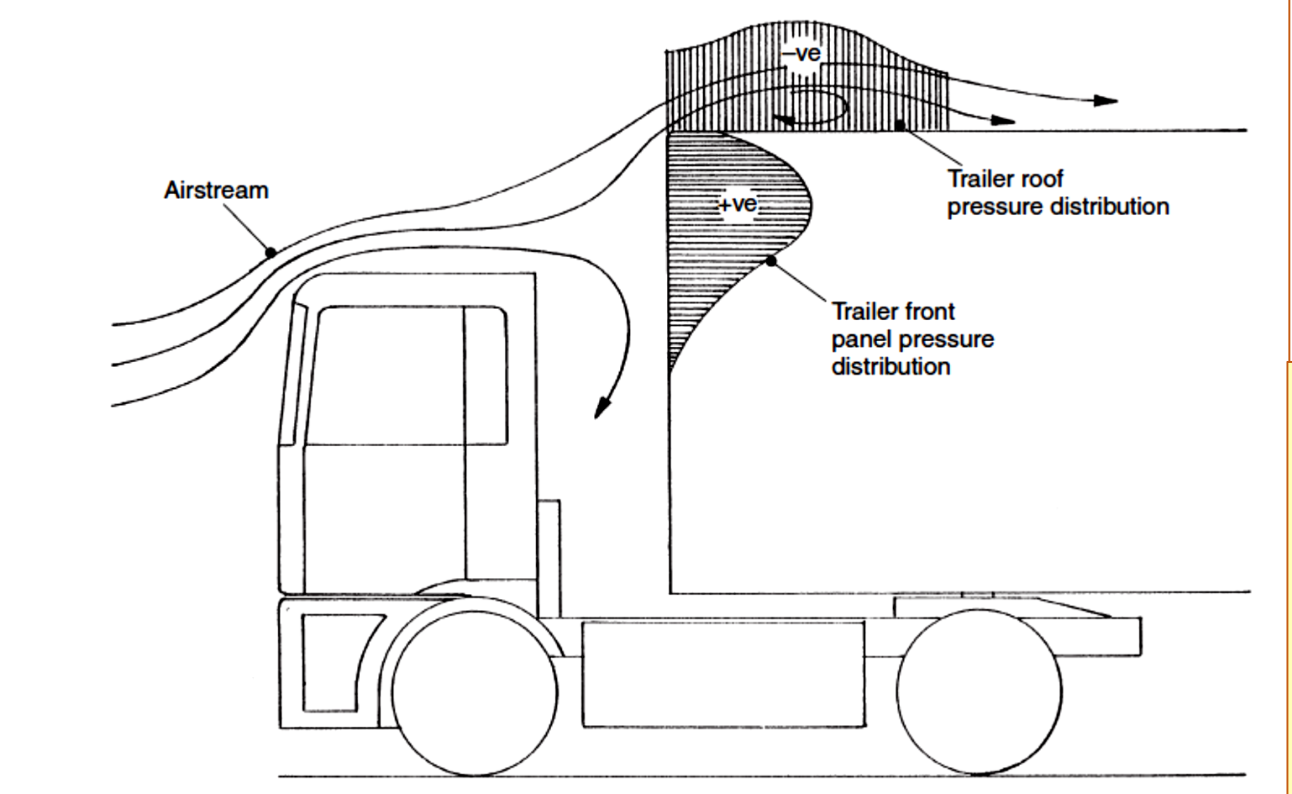
(a) Tractor cab with sharp windscreen/roof leading edge (flow separation over cab roof)

(b) Tractor cab with rounded windscreen/roof leading edge (attached air flow over cab roof)

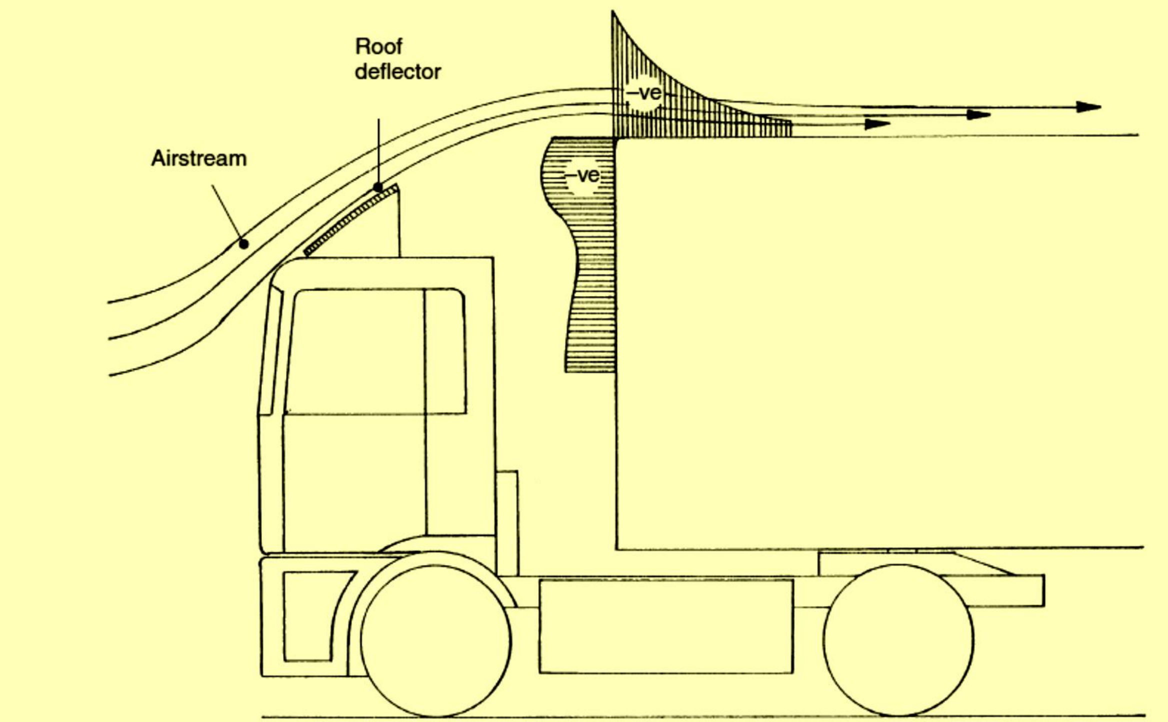


(c) Influence of cab to body height and cab shape upon the drag coefficient

Fig. 14.51 (a–c) Comparison of air flow conditions with both sharp and rounded roof leading edge cab with various trailer body heights



(a) Cab without roof deflector



(b) Cab with roof deflector

Fig. 14.52 (a and b) Trailer flow body pressure distribution with and without cab roof deflector

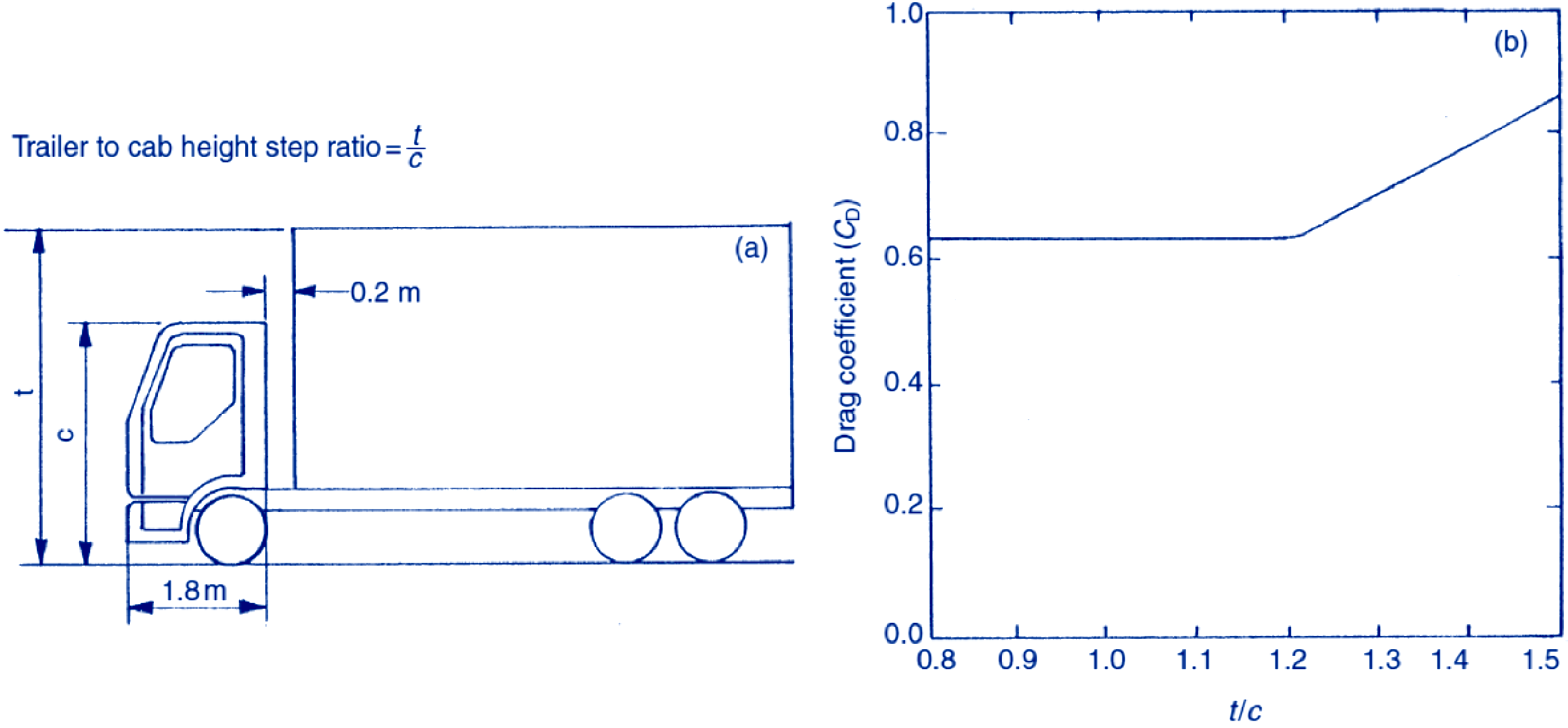


Fig. 14.53 Influence of cab to trailer body height upon the drag coefficient

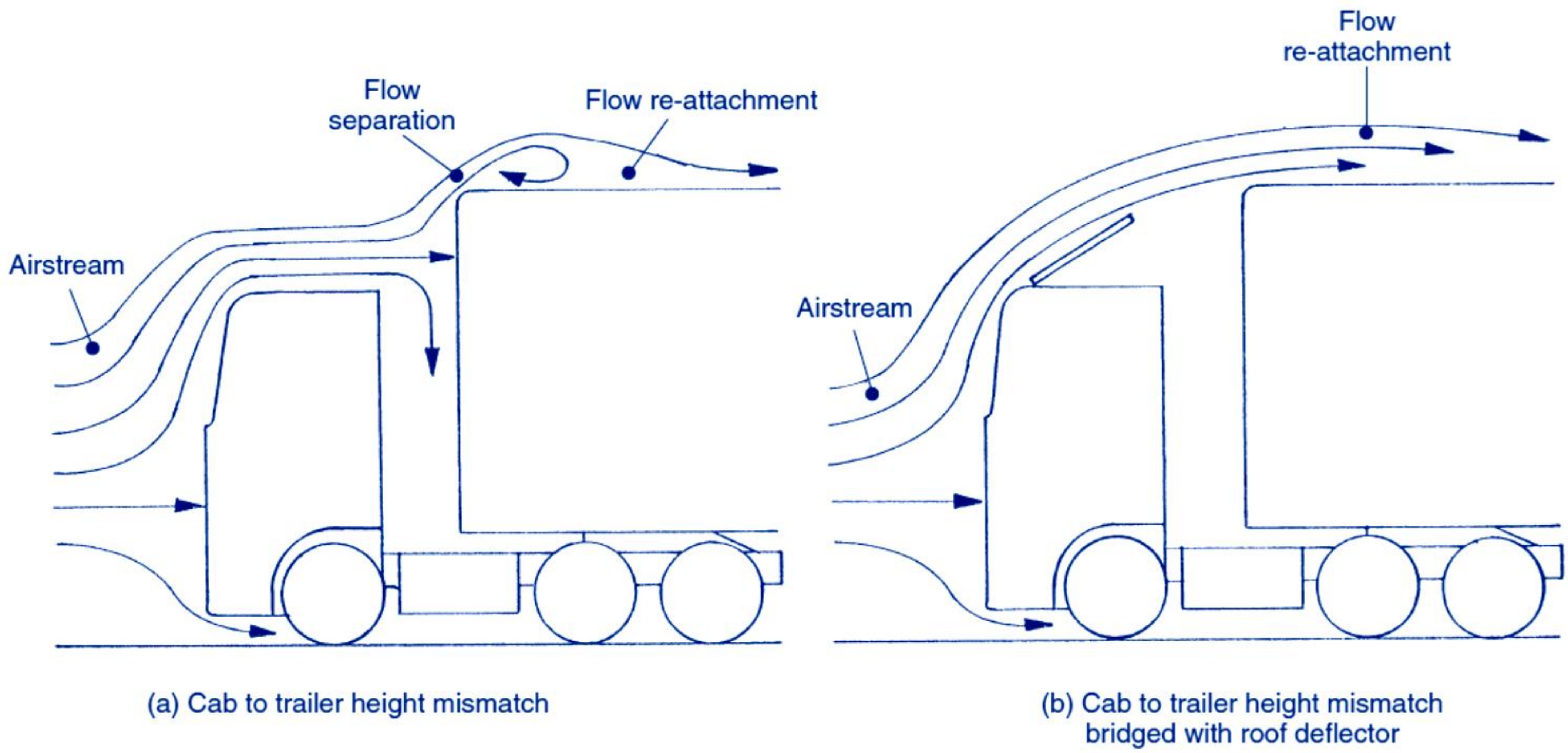


Fig. 14.54 (a and b) Air flow between cab and trailer body with and without cab roof deflector

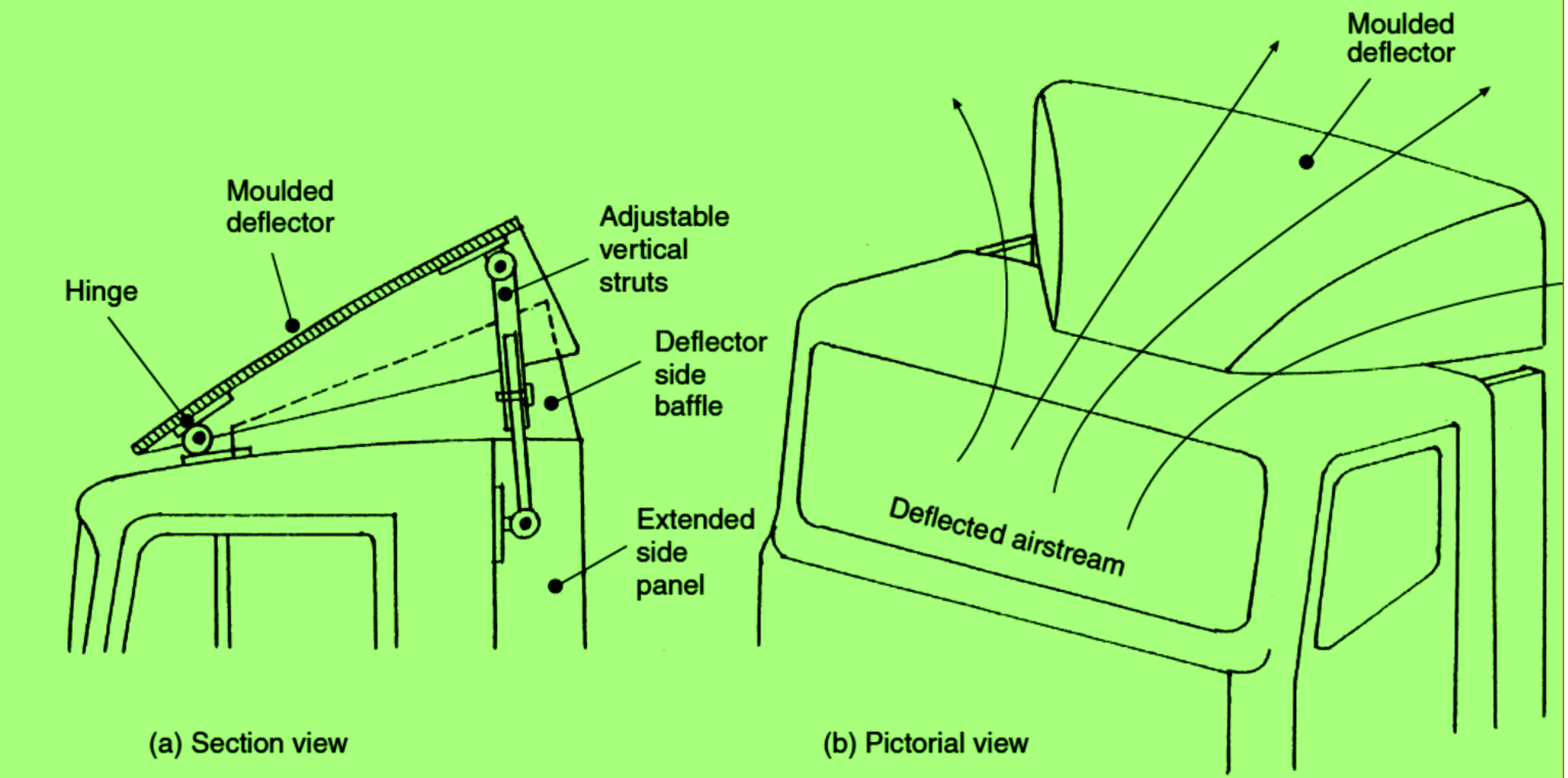


Fig. 14.55 (a and b) Moulded adjustable cab roof deflector

Un

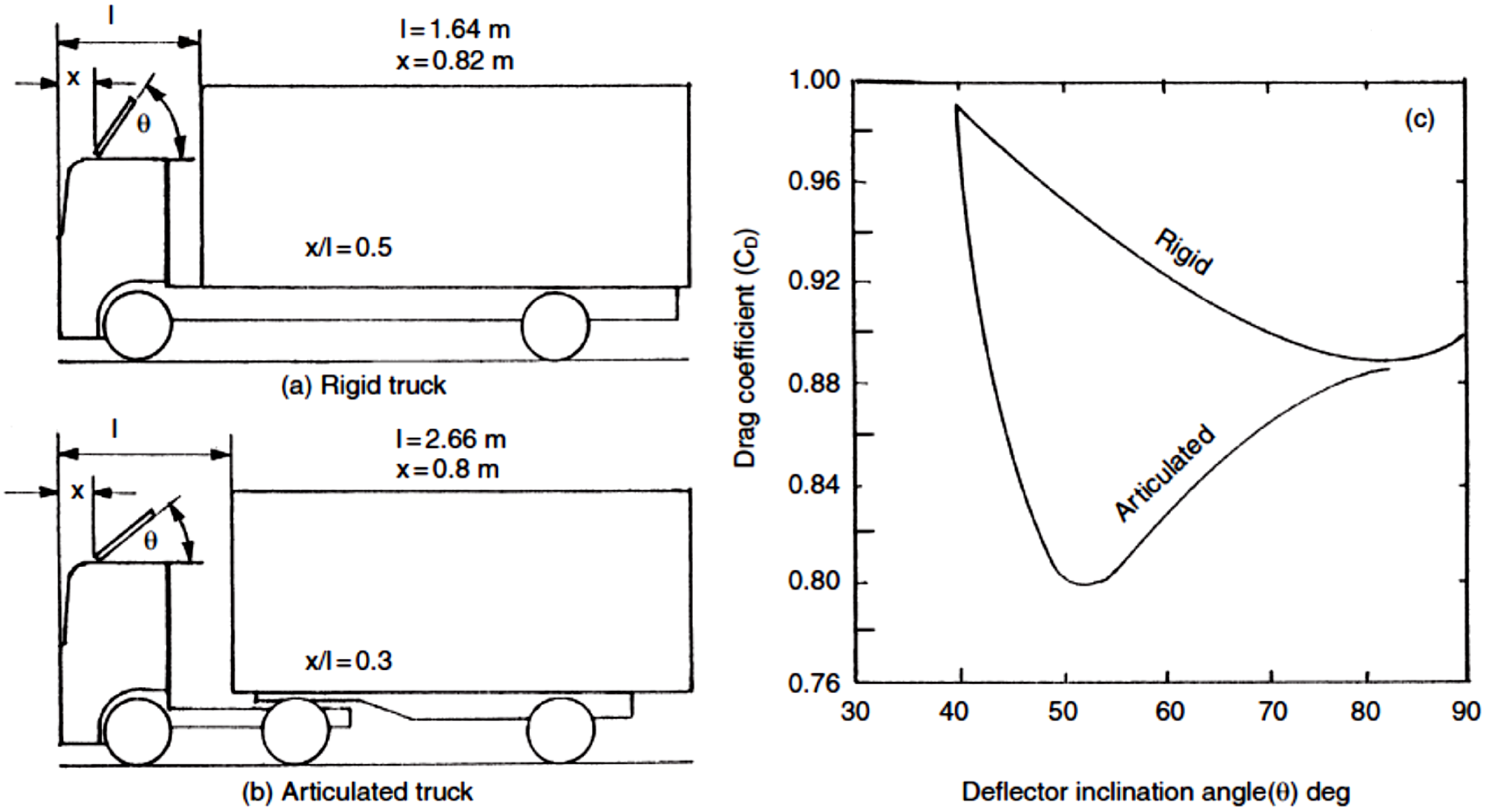


Fig. 14.56 (a–c) Optimizing roof deflector effectiveness for both rigid and articulated trucks

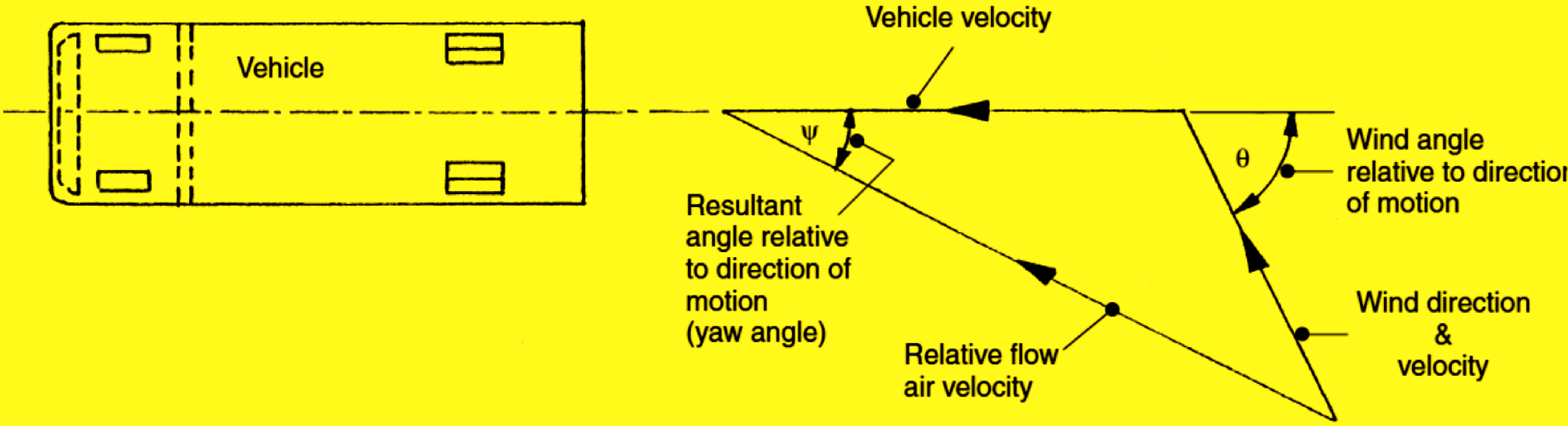


Fig. 14.57 The yaw angle

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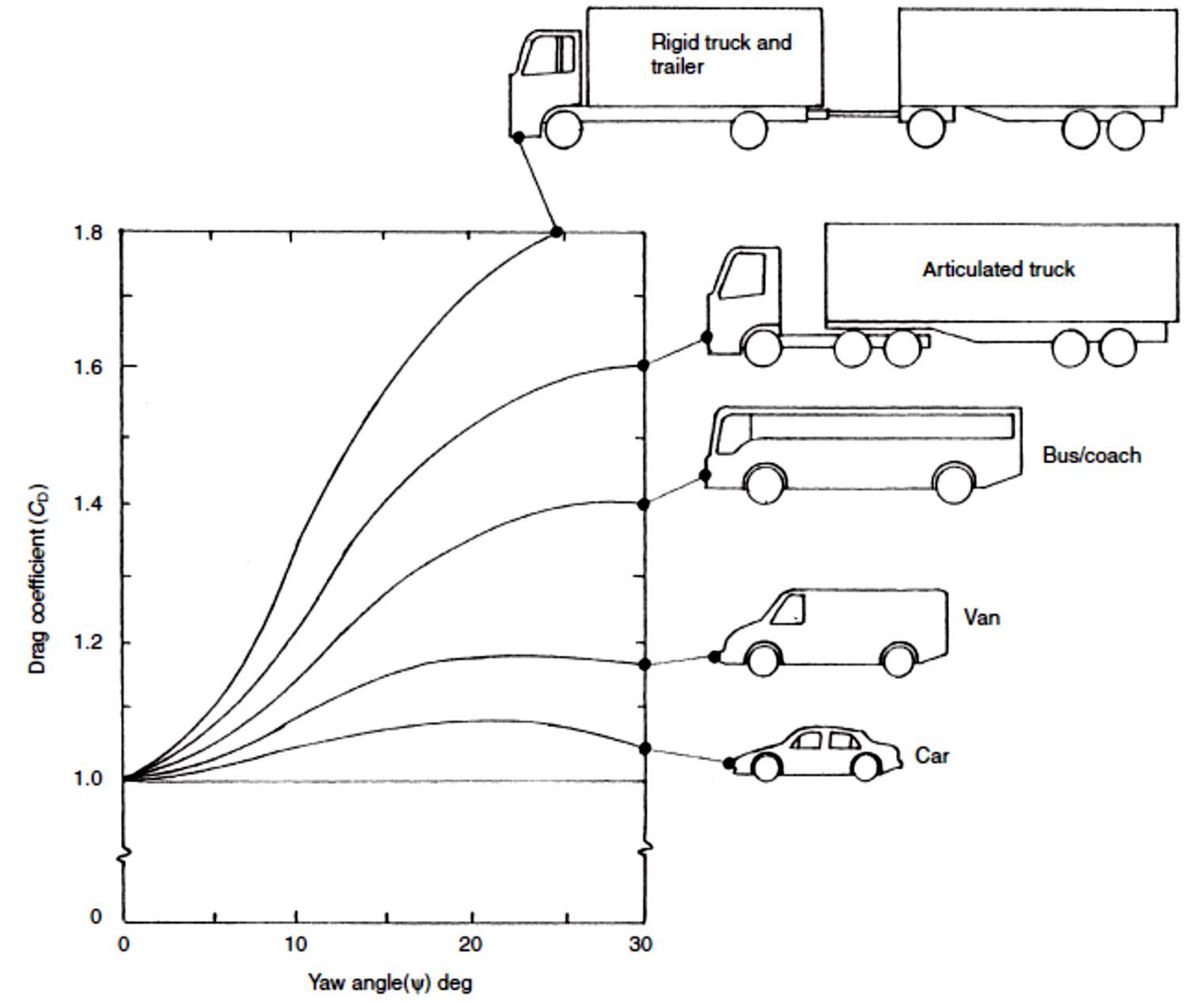


Fig. 14.58 Influence of yaw angle upon aerodynamic drag

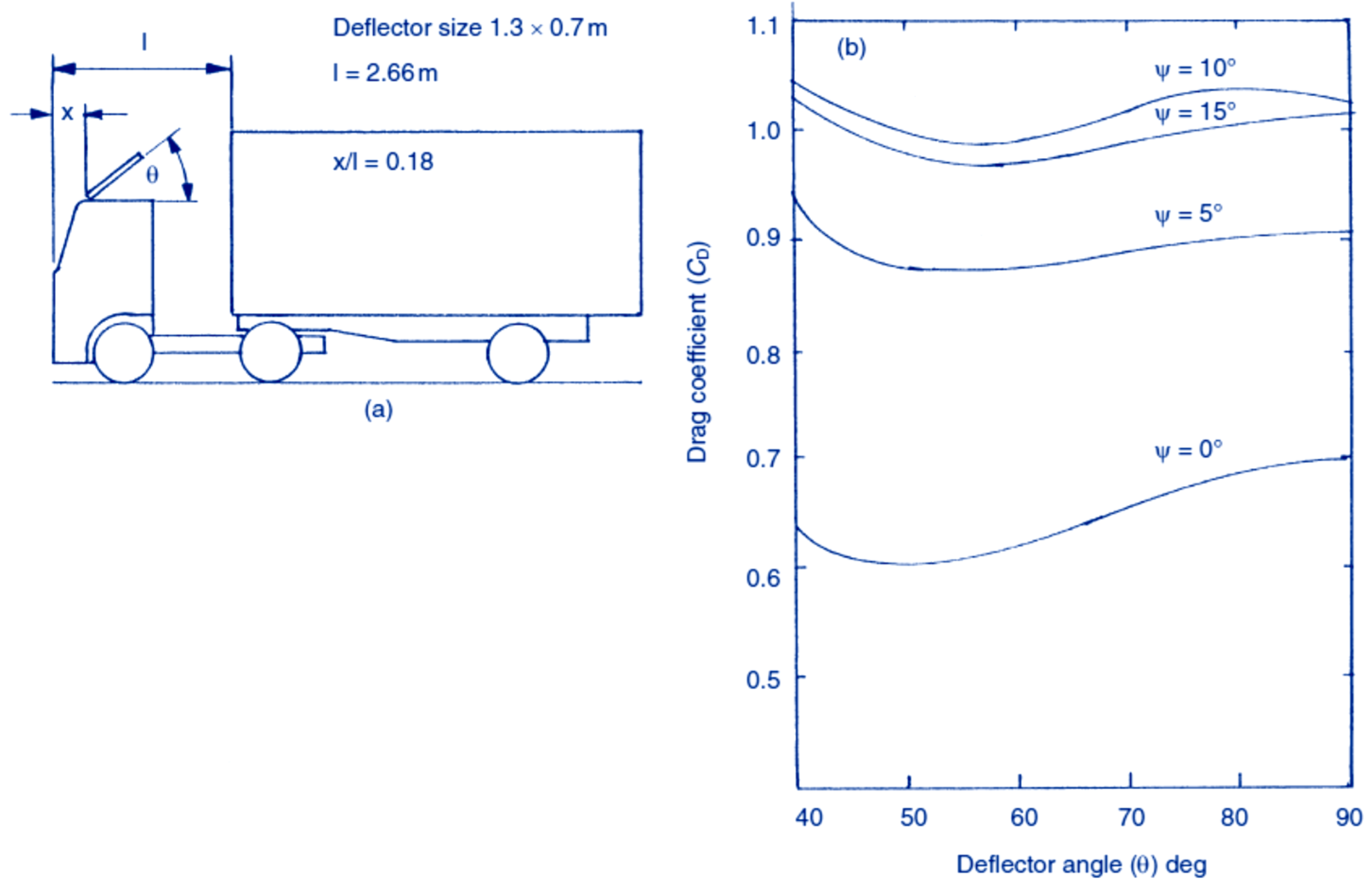
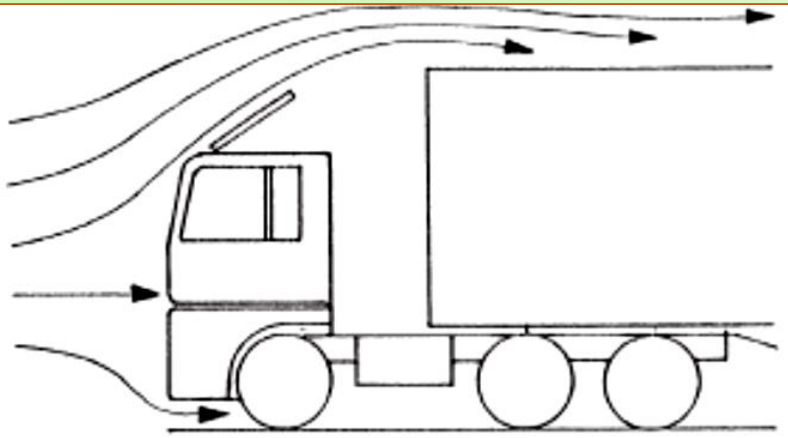
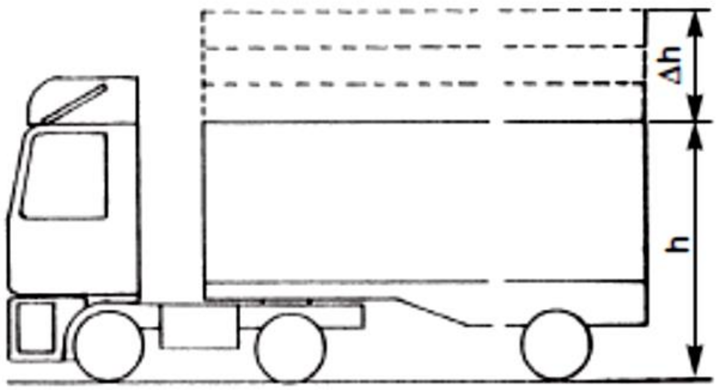


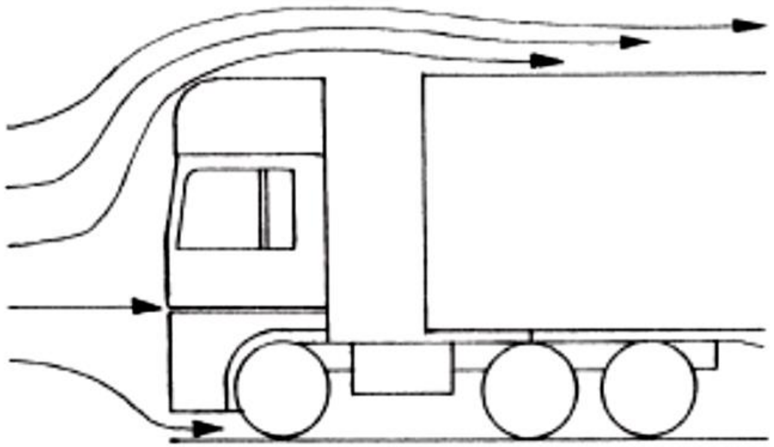
Fig. 14.59 (a and b) Effect of yaw angle upon drag reducing effectiveness of a cab roof deflector



(b) Low cab with deflector and high trailer body



(e) Articulated truck with different trailer body heights



(c) High cab and trailer body

Fig. 14.60(a–e) Methods of optimizing air flow conditions with different trailer body heights

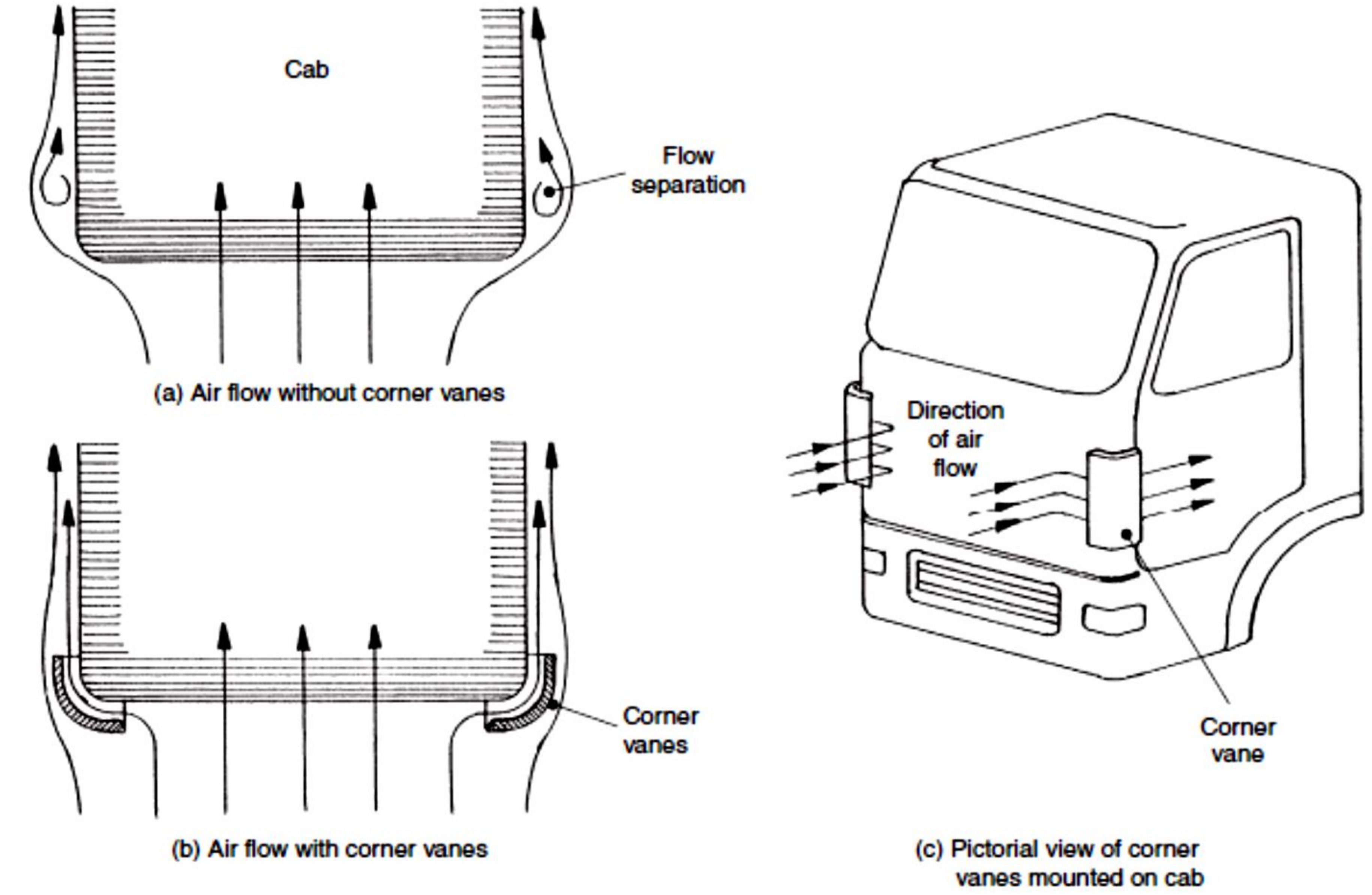


Fig. 14.61 (a–c) Influence of corner vanes in reducing cab side panel flow separation

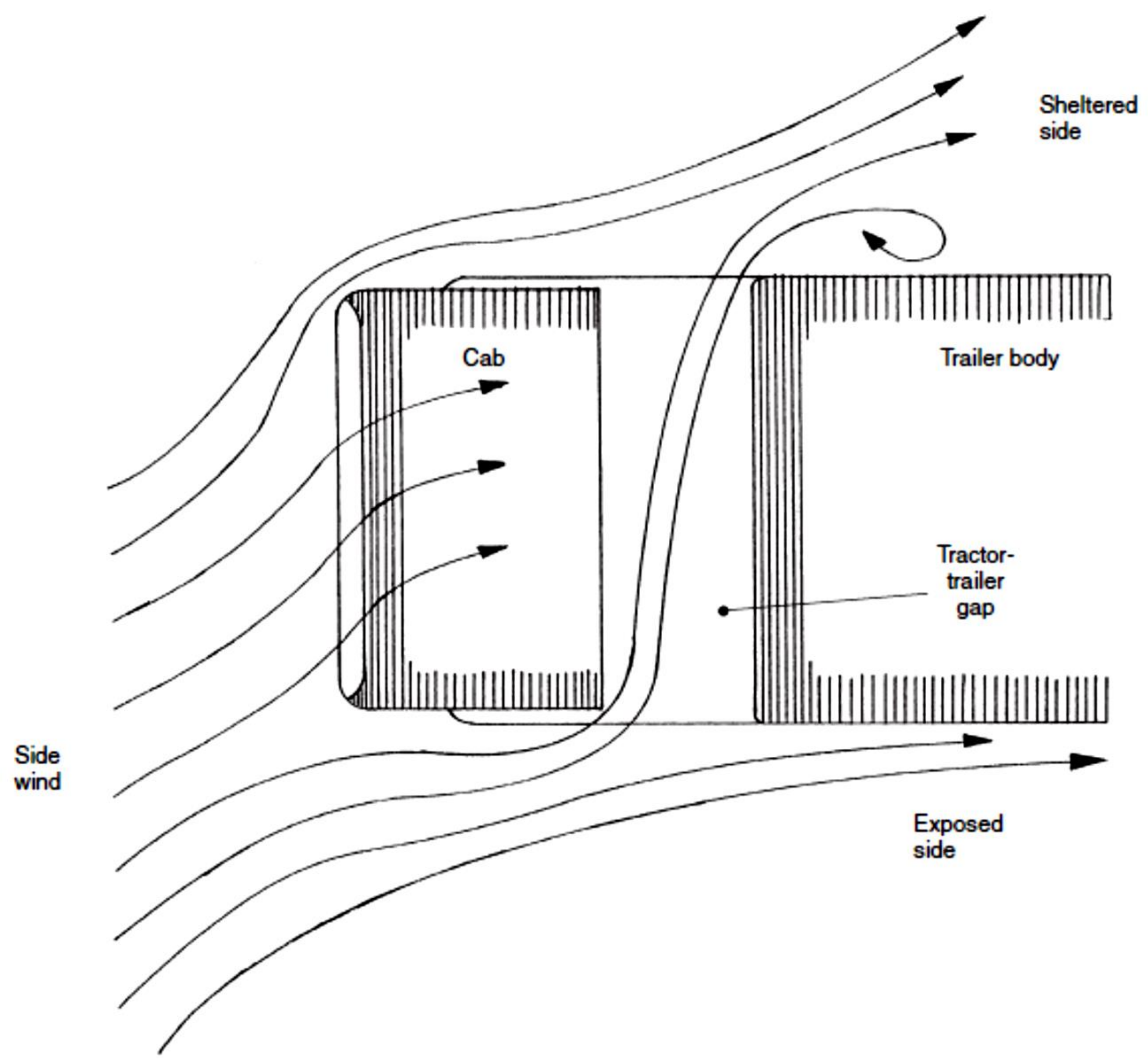


Fig. 14.62 Air flow through tractor-trailer gap with crosswind

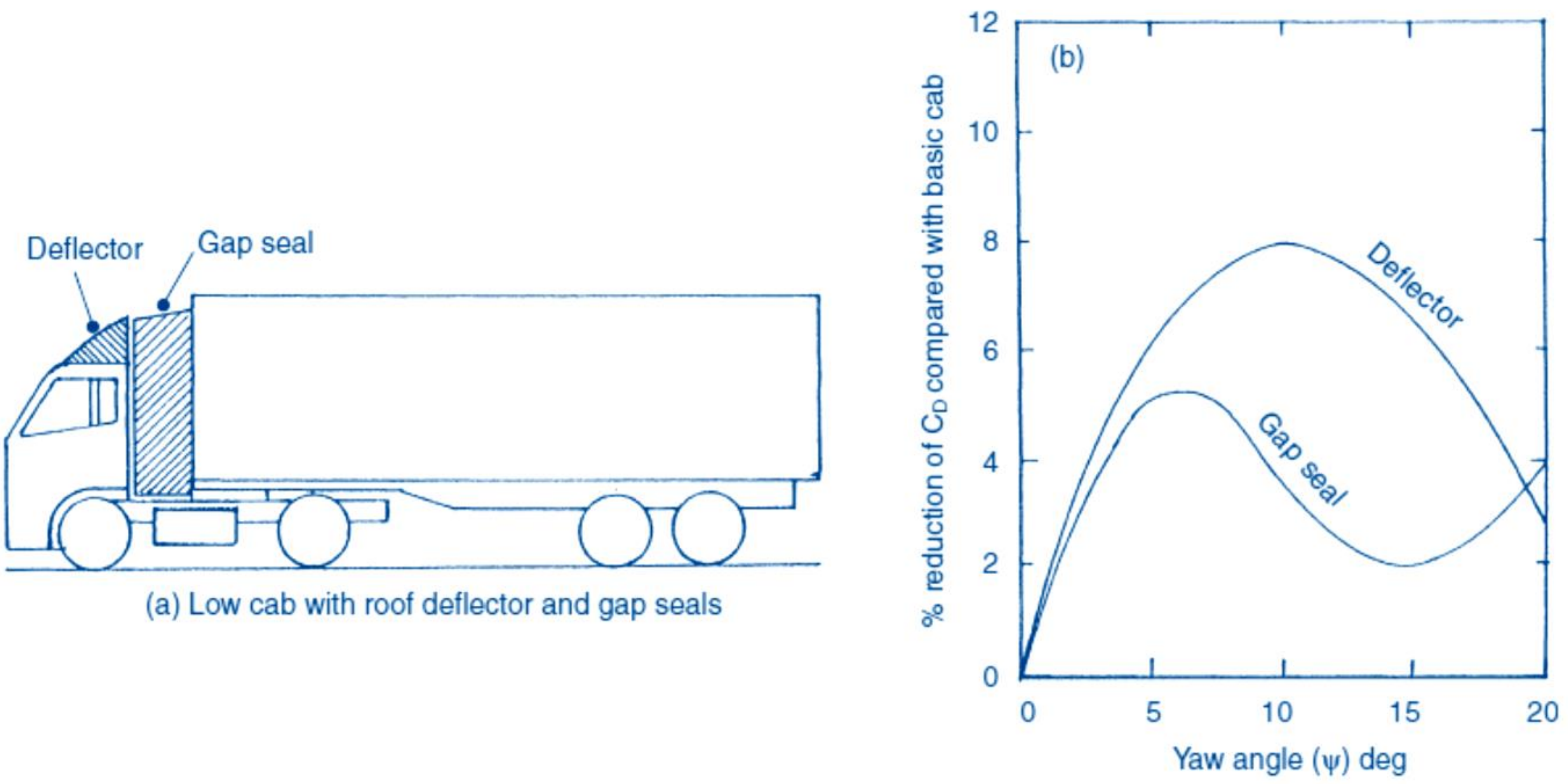


Fig. 14.63 (a and b) Drag reductions with crosswinds when incorporating a roof deflector and gap seal

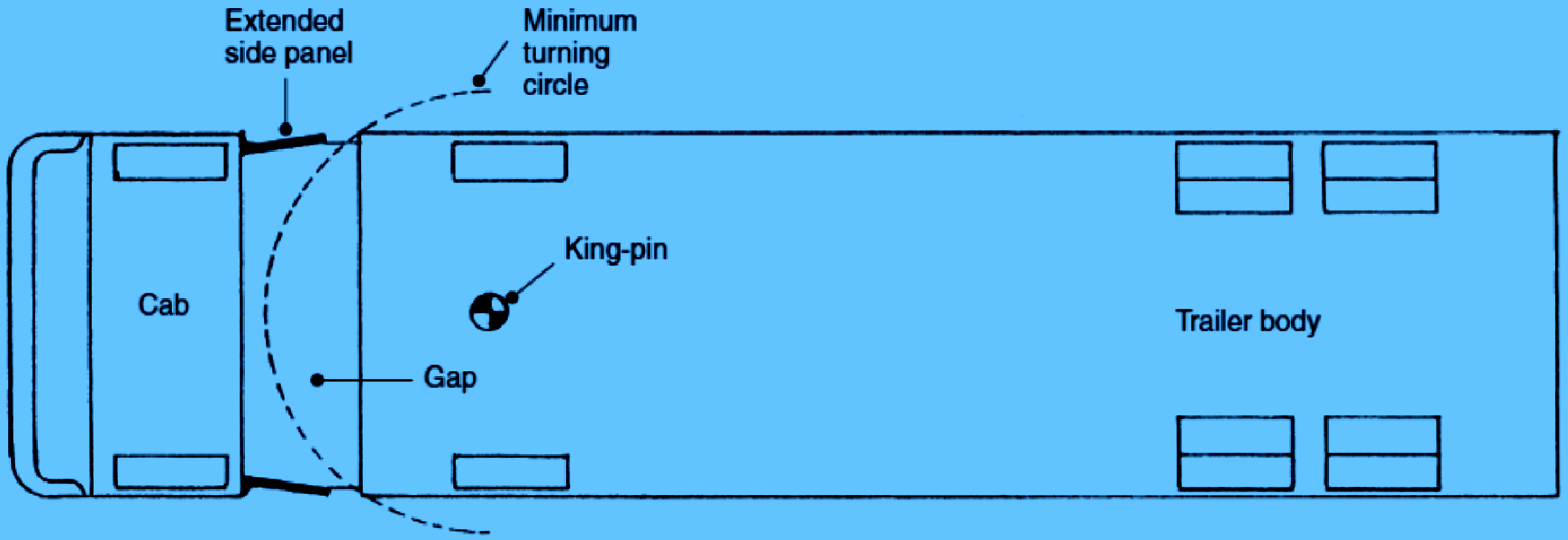


Fig. 14.64 Cab extended side panels

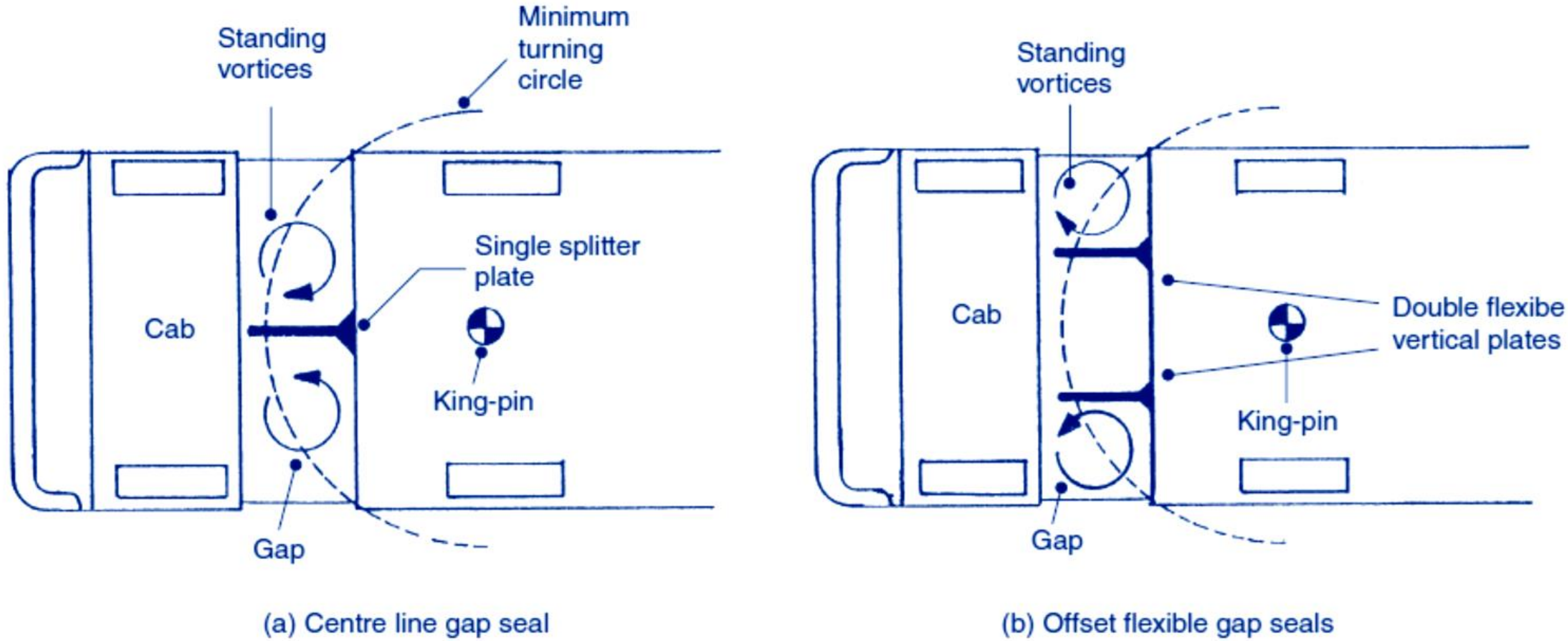
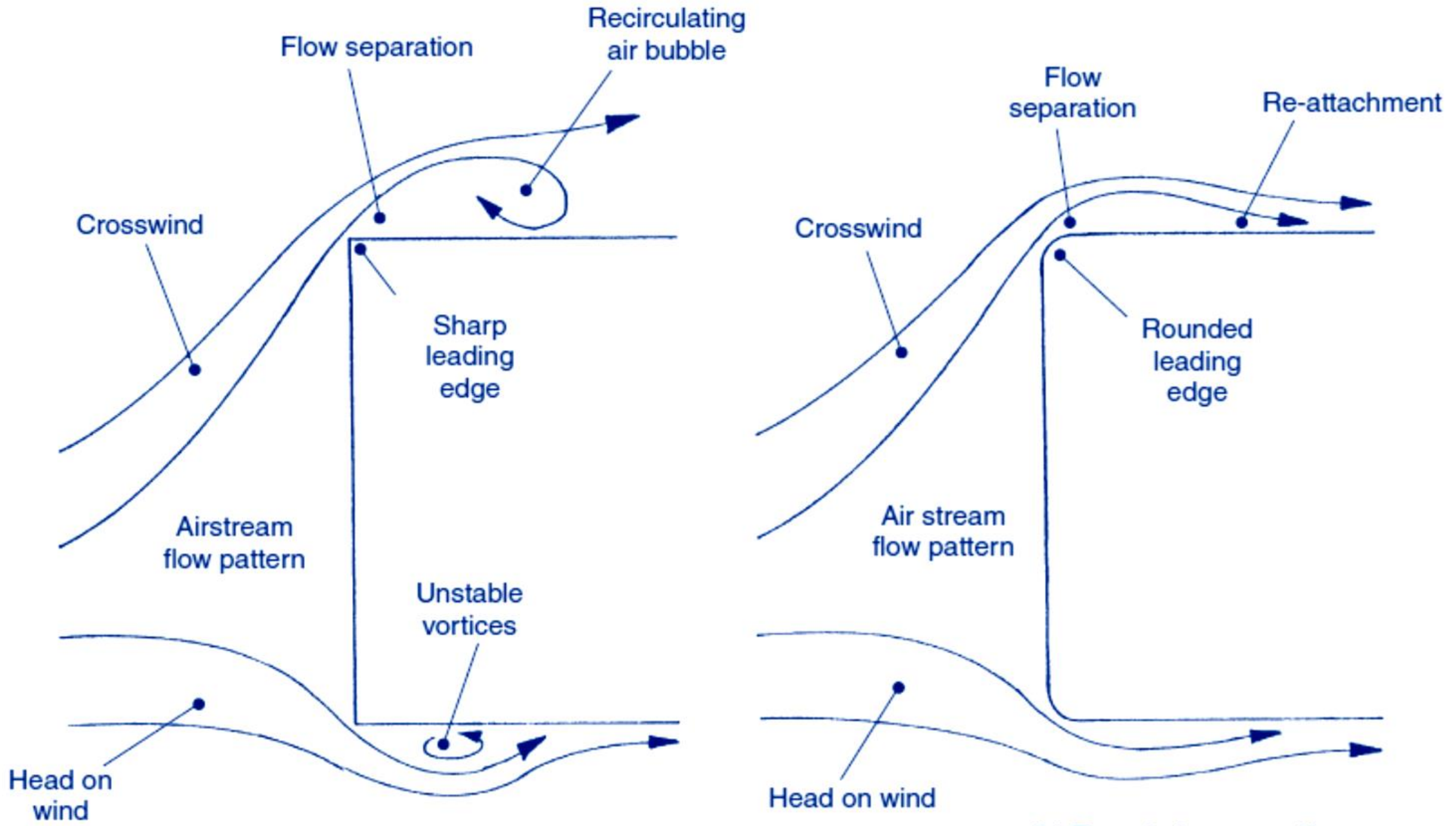


Fig. 14.65 (a and b) Cab to trailer body gap seals



(a) Sharp corner with and without crosswind

(b) Rounded corner with and without crosswind

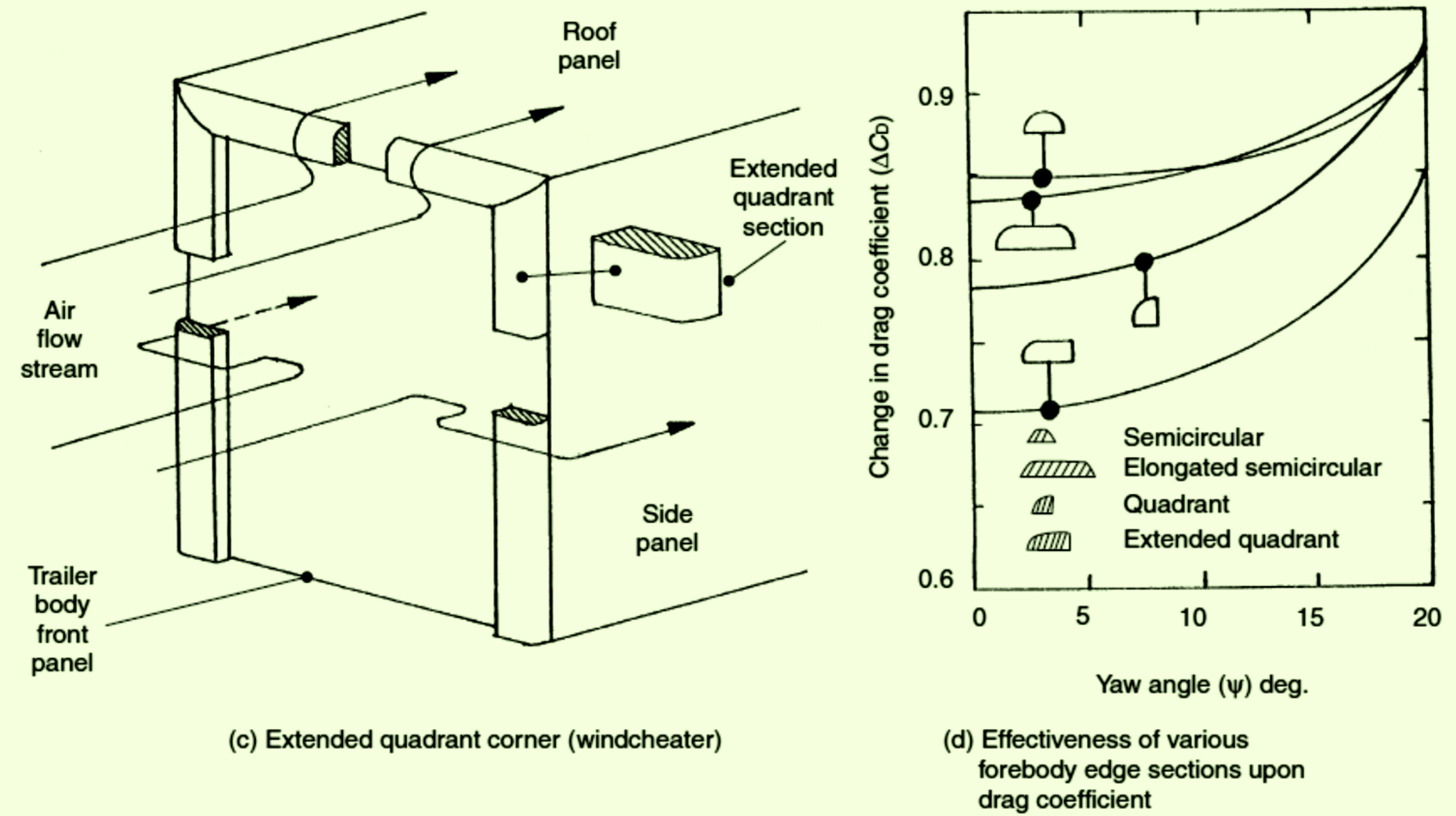


Fig. 14.66 (a–d) Trailer forebody edging fairings

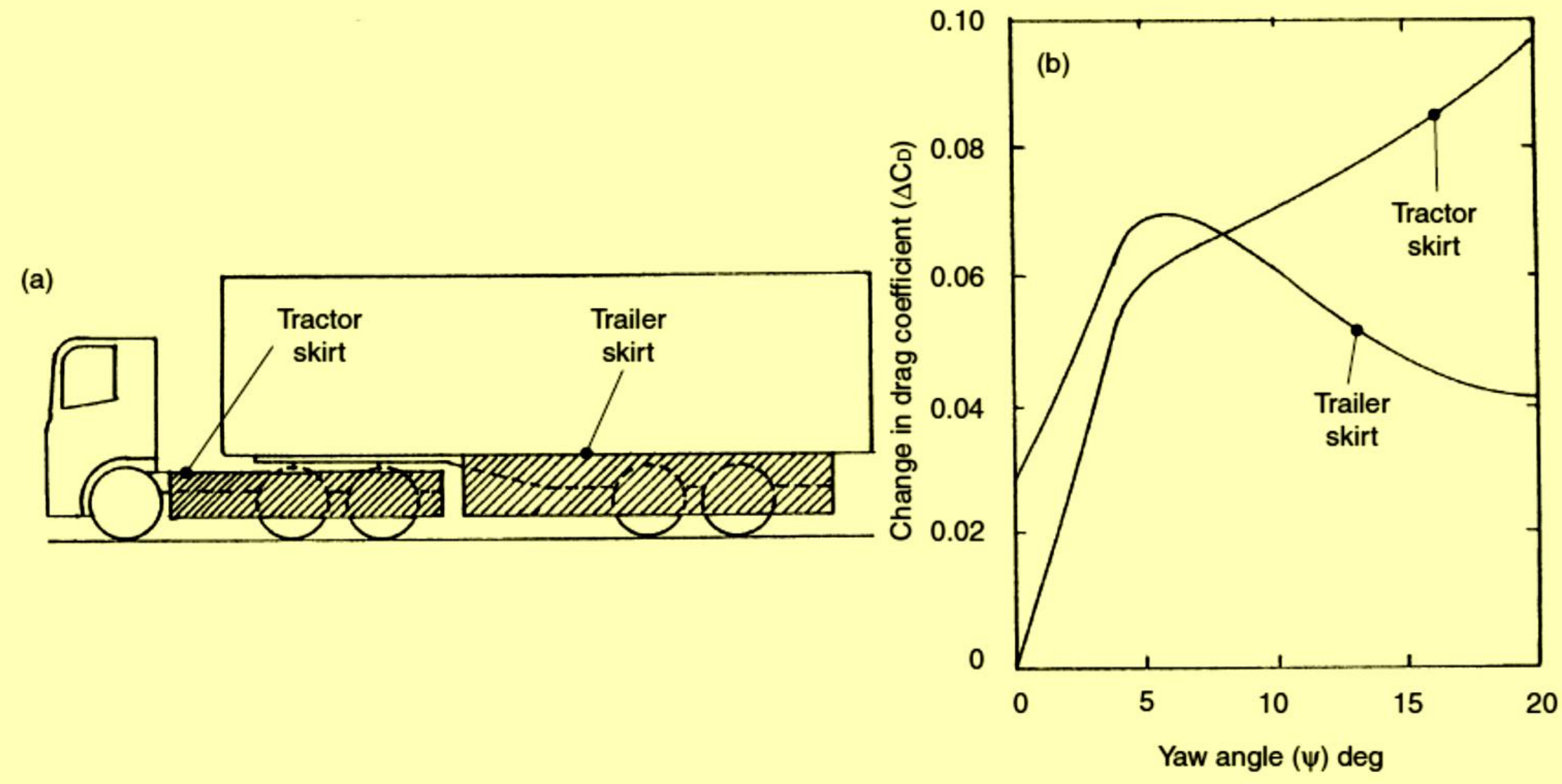
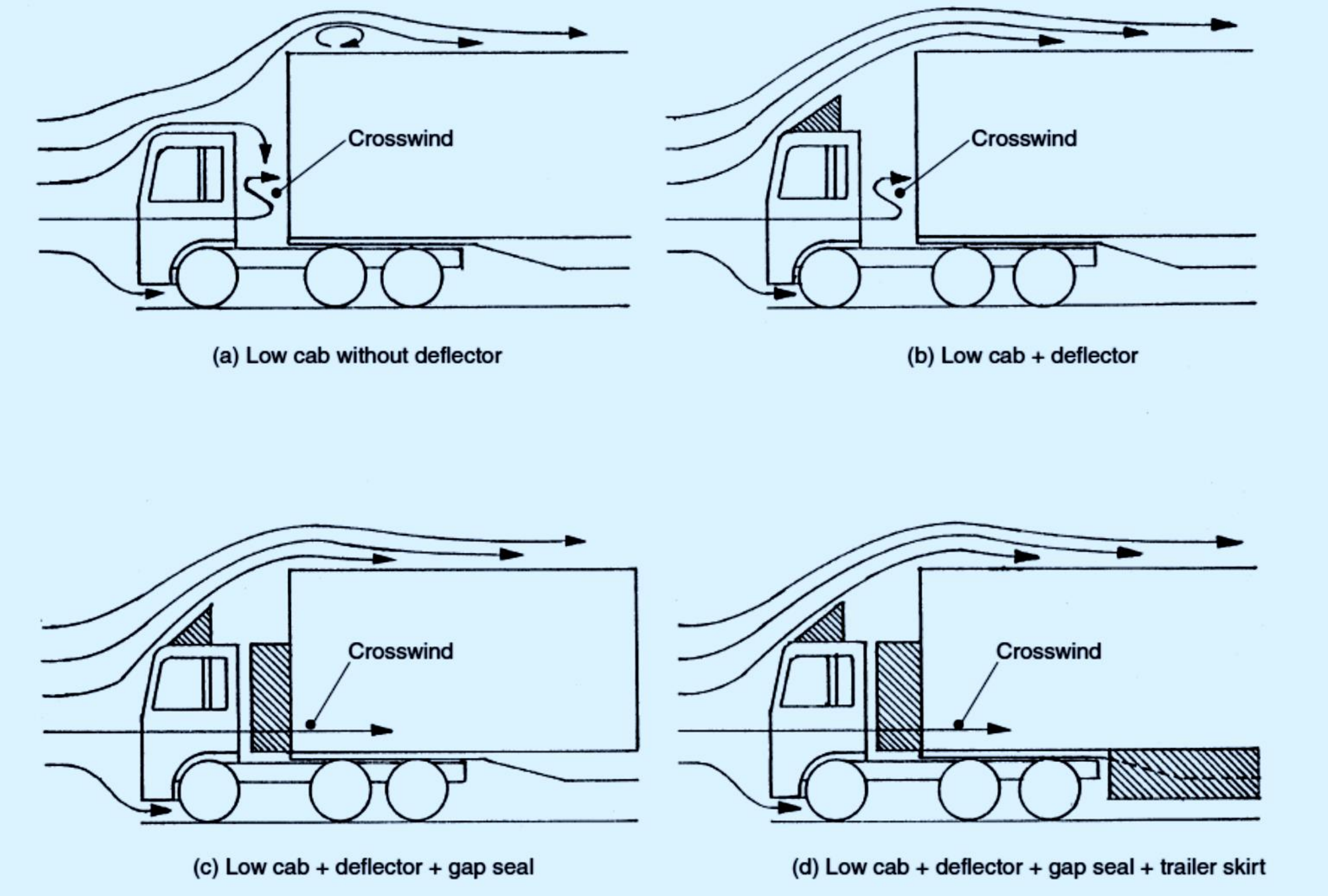


Fig. 14.67 (a and b) Effectiveness of tractor and trailer skirting upon drag coefficient



(a) Low cab without deflector
(b) Low cab + deflector
(c) Low cab + deflector + gap seal
(d) Low cab + deflector + gap seal + trailer skirt

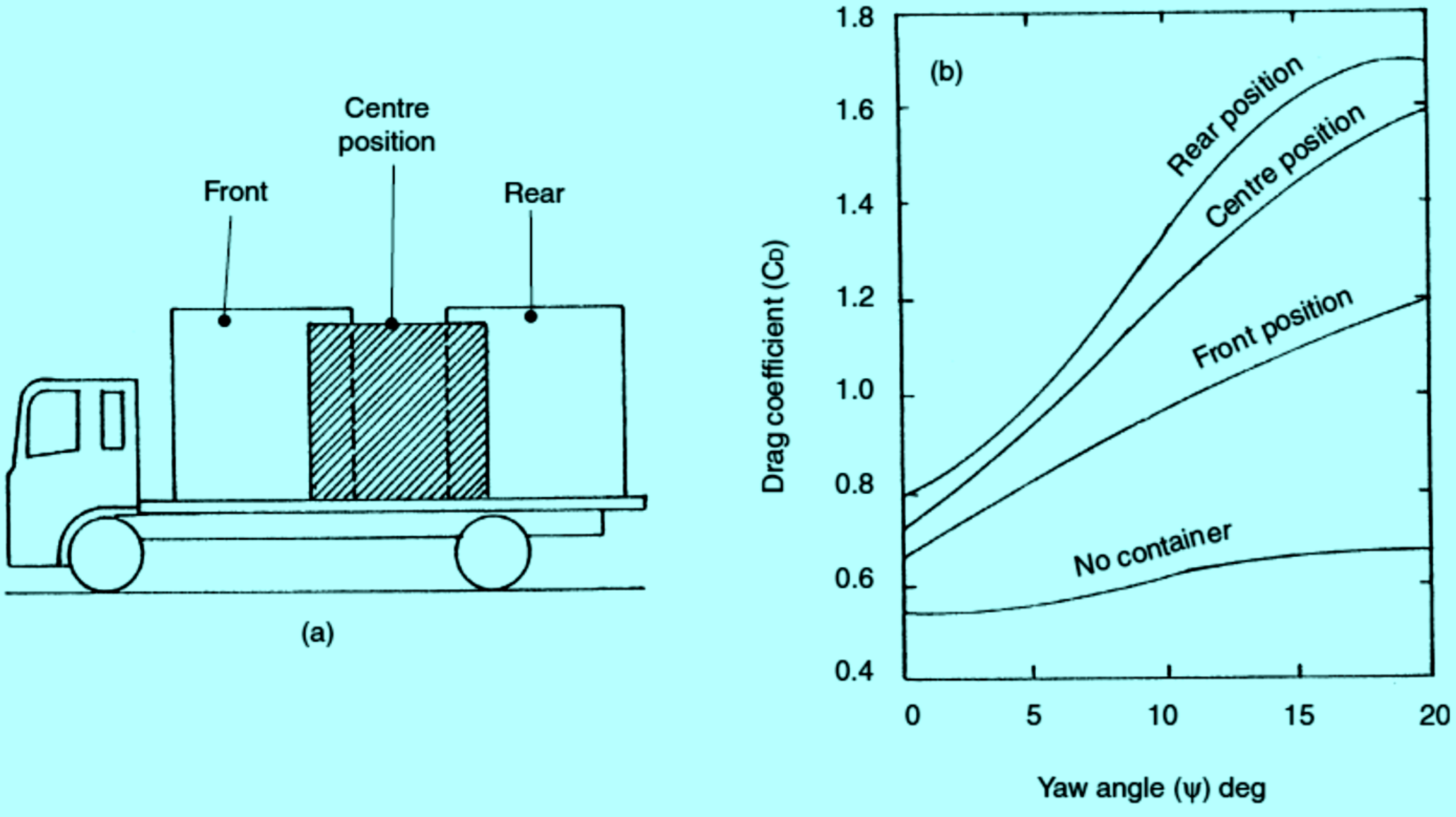


Fig. 14.69 (a and b) Effects of trailer load position upon drag coefficient

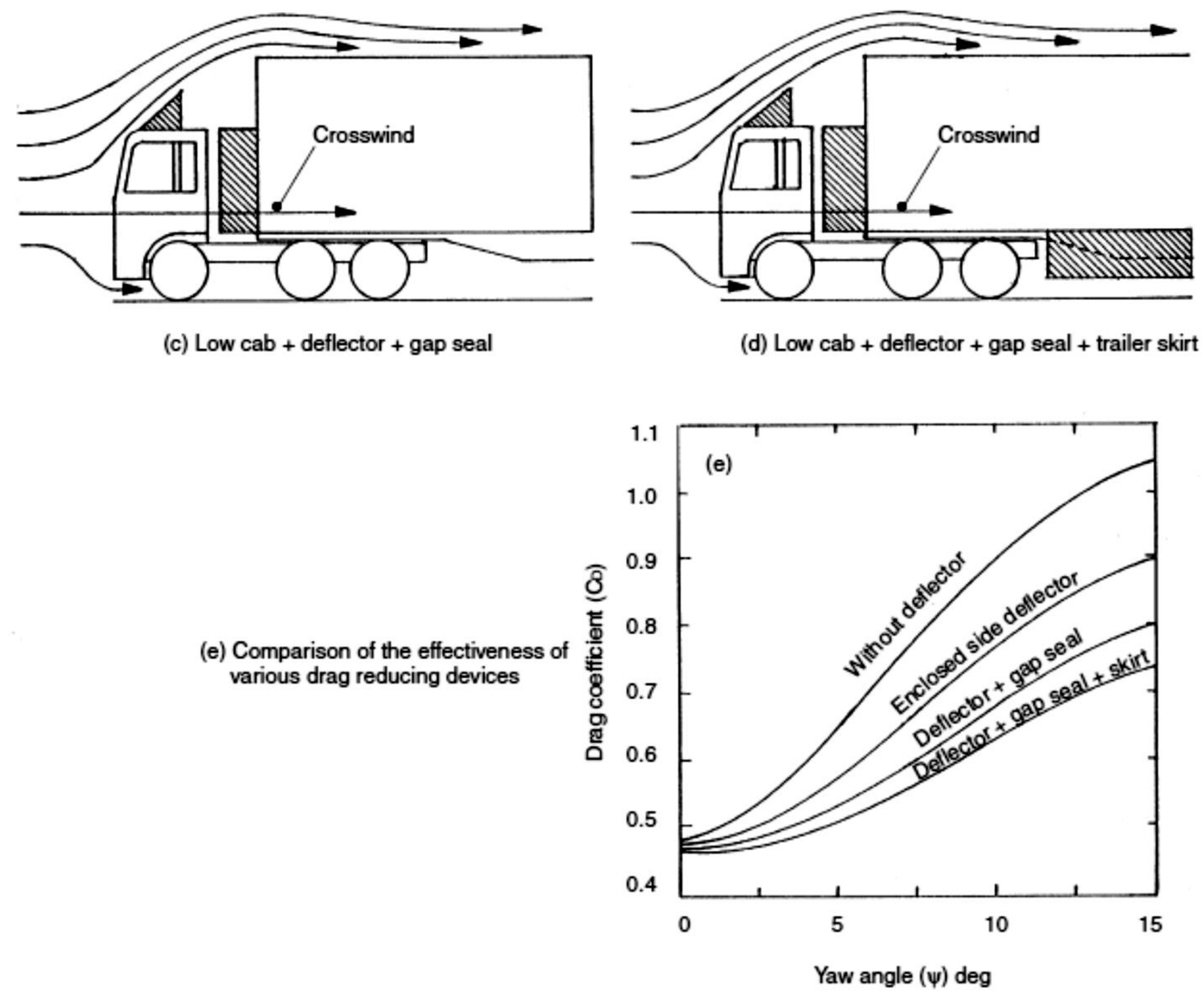


Fig. 14.68(a–e) Influence of various devices used to reduce drag when vehicle is subjected to crosswinds