Aerodynamics of Road Vehicles – State of the Art and Tasks for the Future

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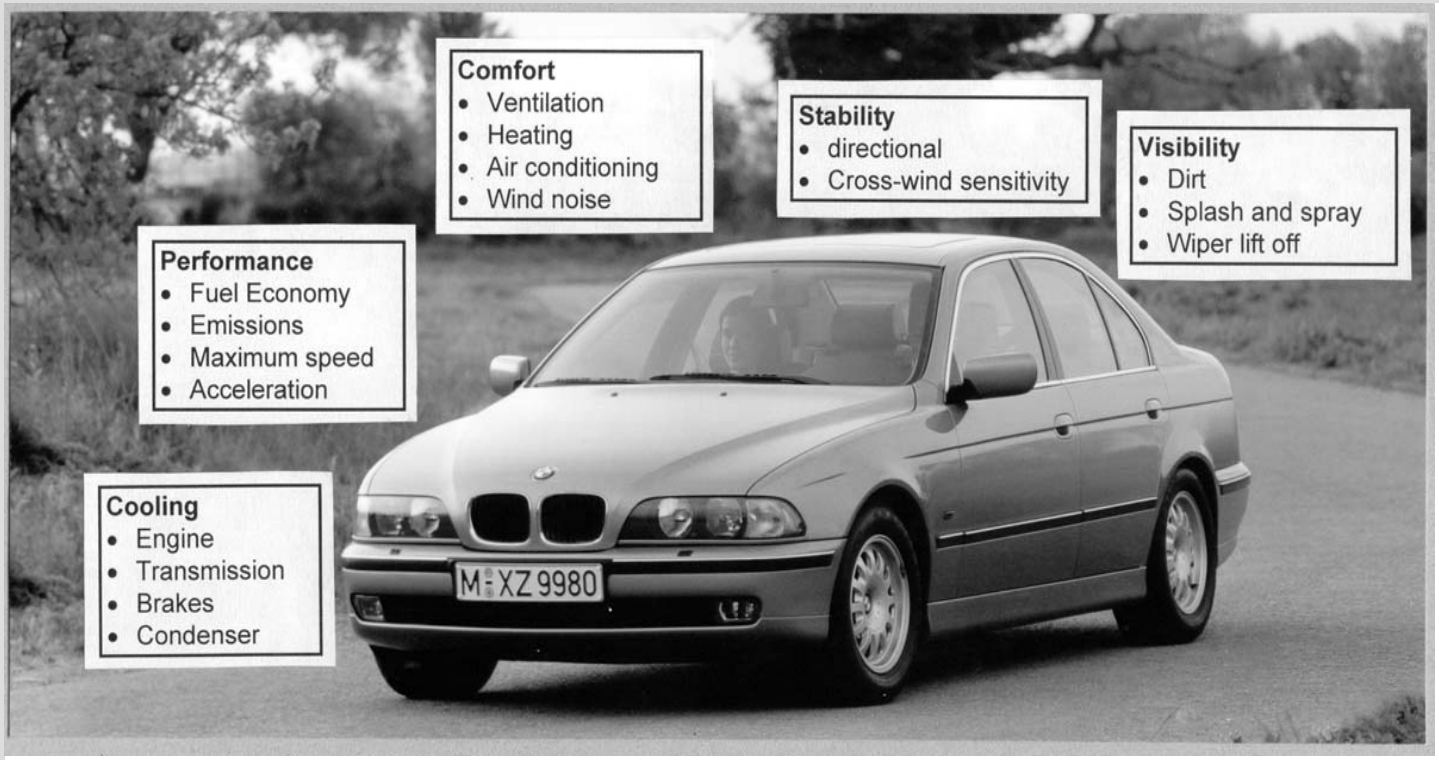
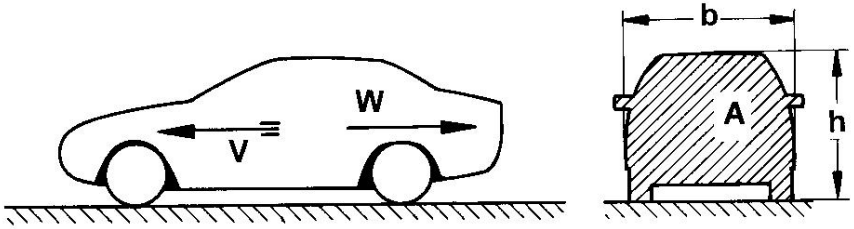
1. Objectives of vehicle aerodynamics
2. State of the art
   - **2.3.2 Cooling-air flow**
3. How to improve the aerodynamics of cars?
4. Trends in styling
5. What is to be expected from aerodynamics in the future?
6. Resume and outlook



Objectives: Spectrum of tasks for aerodynamics



$$W = c_W A \frac{\rho}{2} V^2$$

$$c_W = \frac{W}{A \frac{\rho}{2} V^2}$$

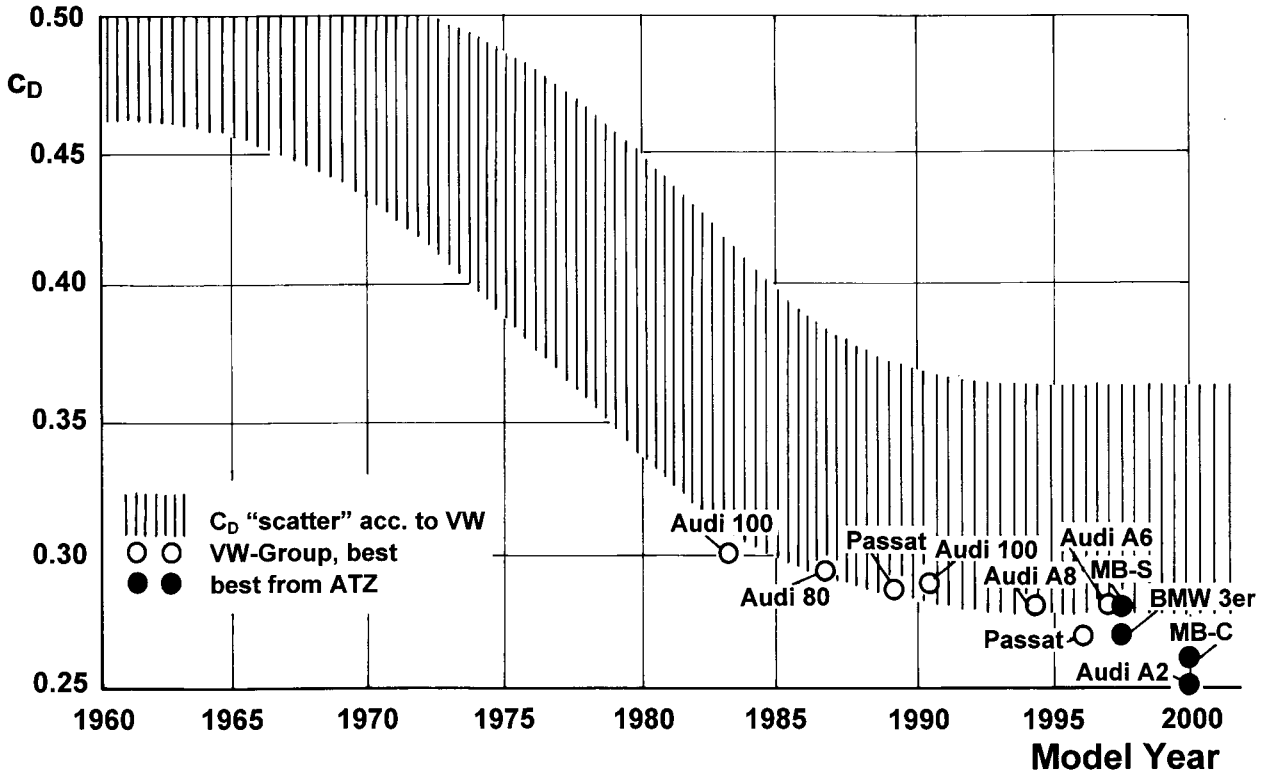
W = Luftwiderstand
c_W = Widerstandsbeiwert
A = Stirnfläche
V = Fahrgeschwindigkeit
ρ = Luftdichte

Stirnfläche $A \approx 0{,}81 \cdot b \cdot h$ *

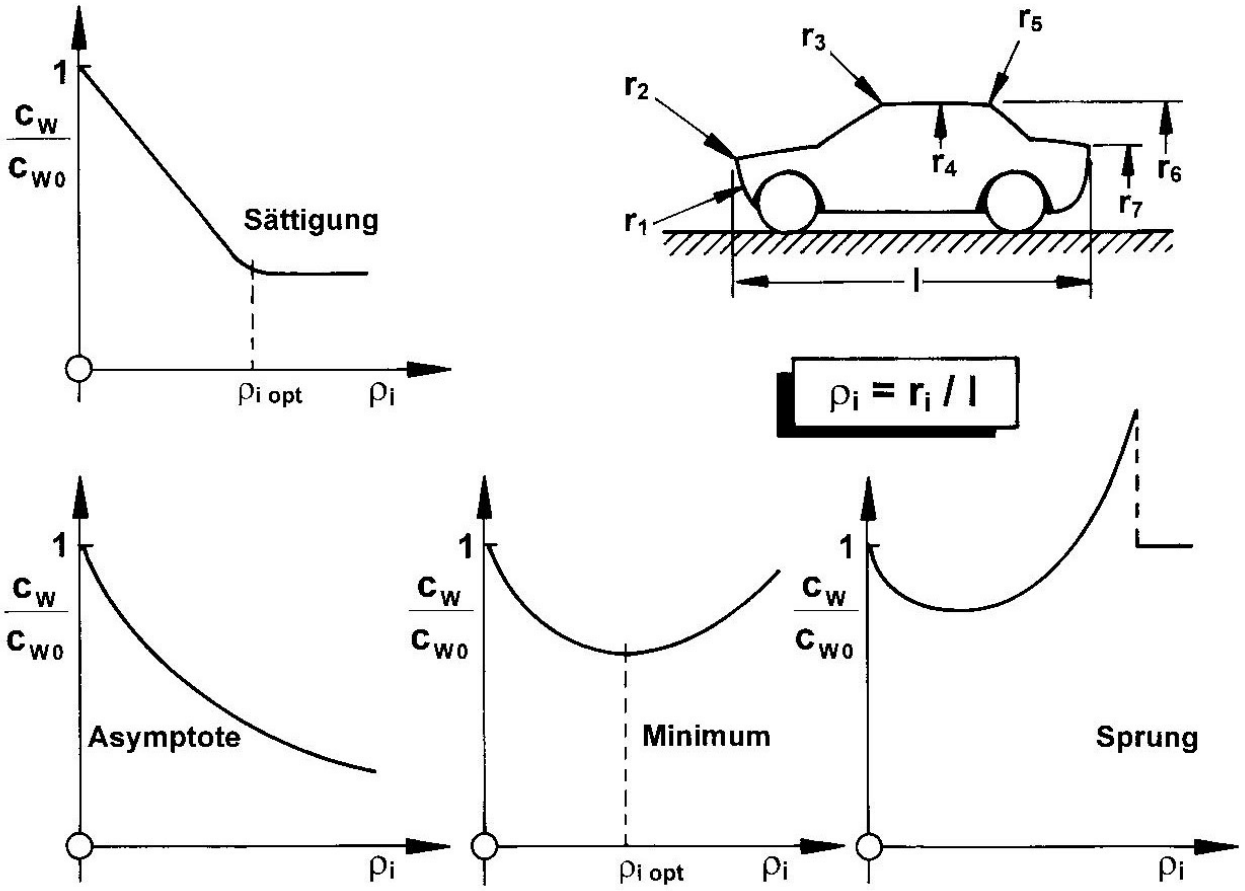
*) nach H. Flegl und U. Bez (1983)

Wagenklasse	Strinfläche A m^2
Kleinwagen	1,8
Untere Mittelklasse	1,9
Obere Mittelklasse	2,0
Oberklasse	2,1

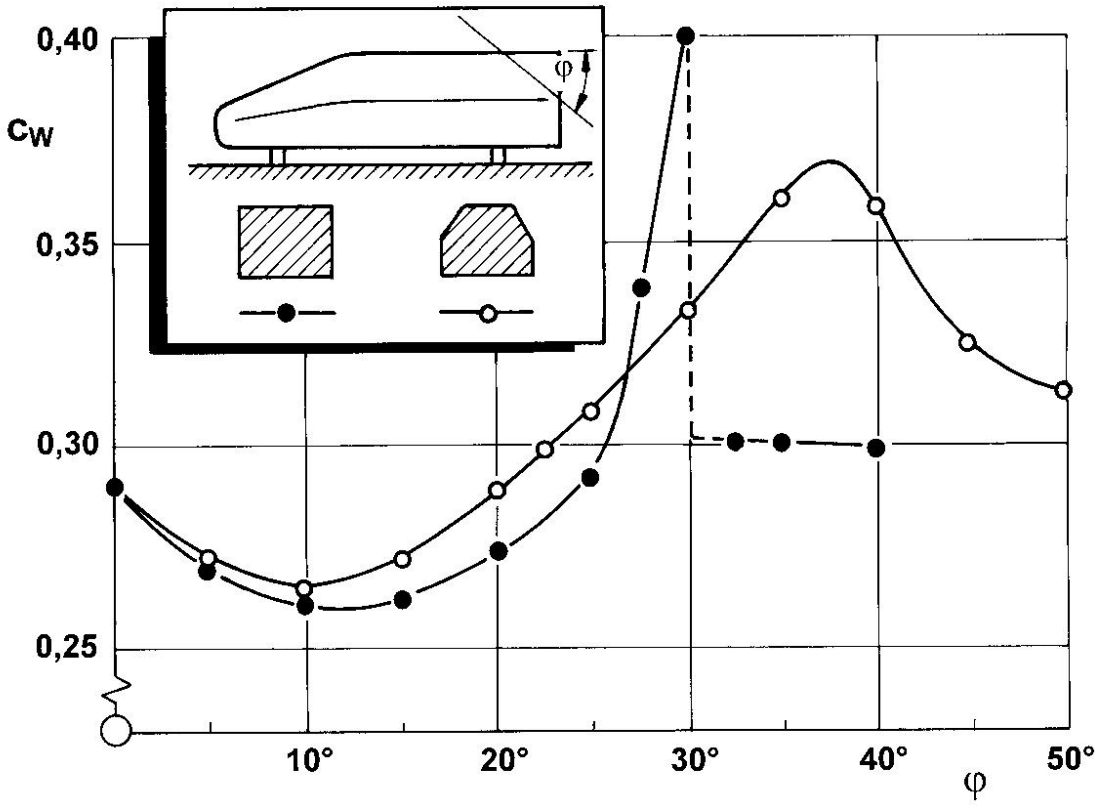
Definition of drag coefficient c_W (c_D)



State of the art: Has drag reduction come to an end?

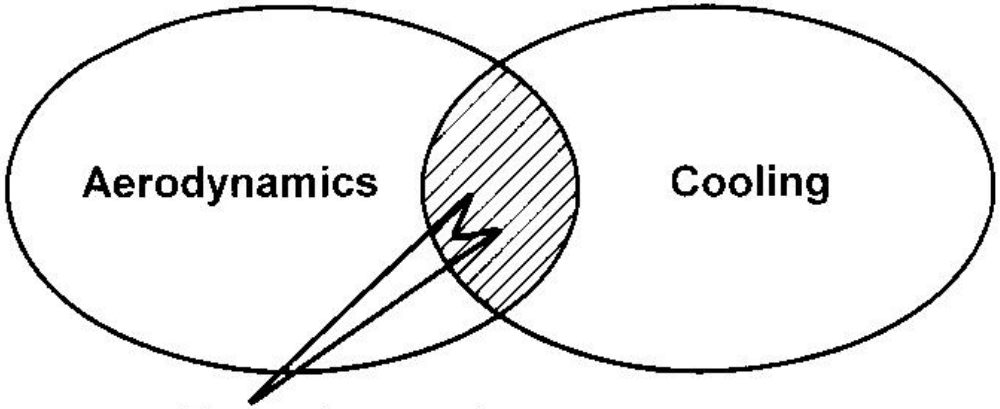


Drag versus geometry: only four types of function

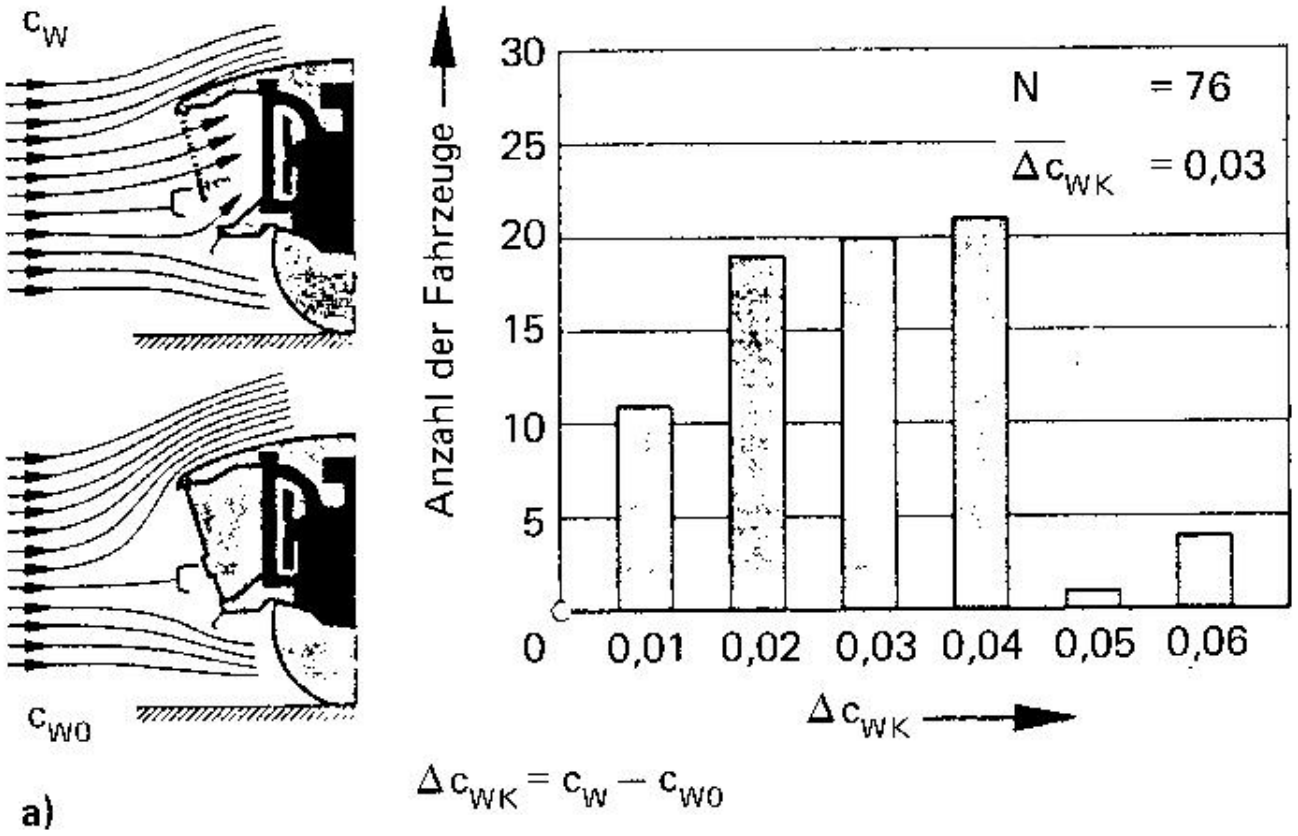


The surprise: big effect from „minor“ shape modifications

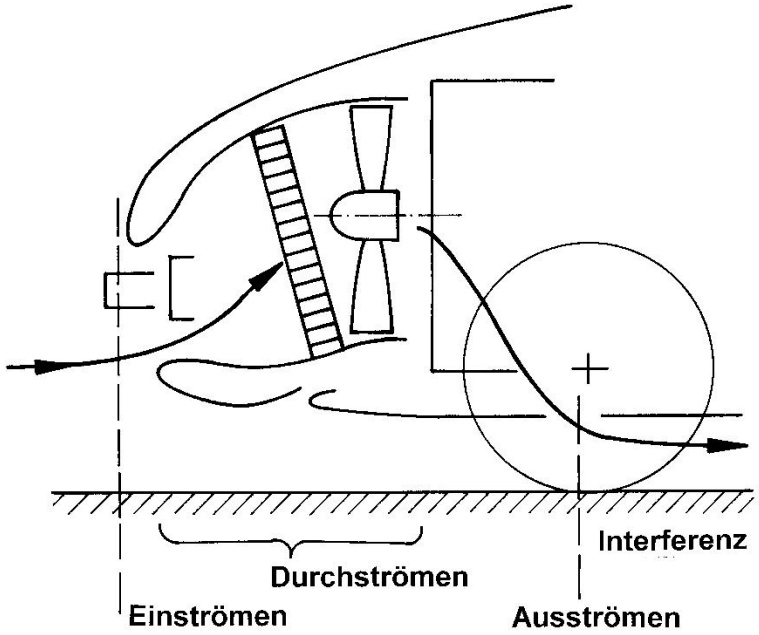
Result: smooth flow around a car,
foto Audi AG



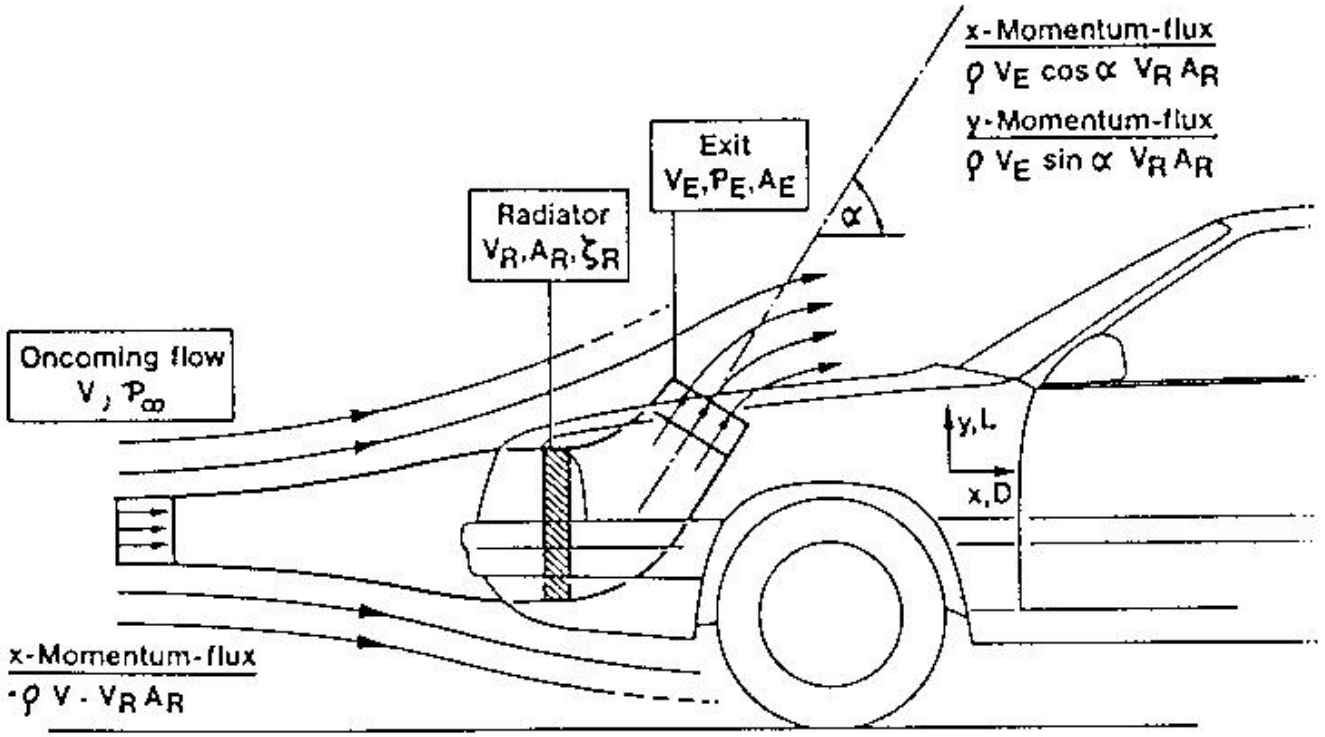
Intersection of the sets “aerodynamics“ and “cooling“



Internal flow: drag increase due to cooling air flow



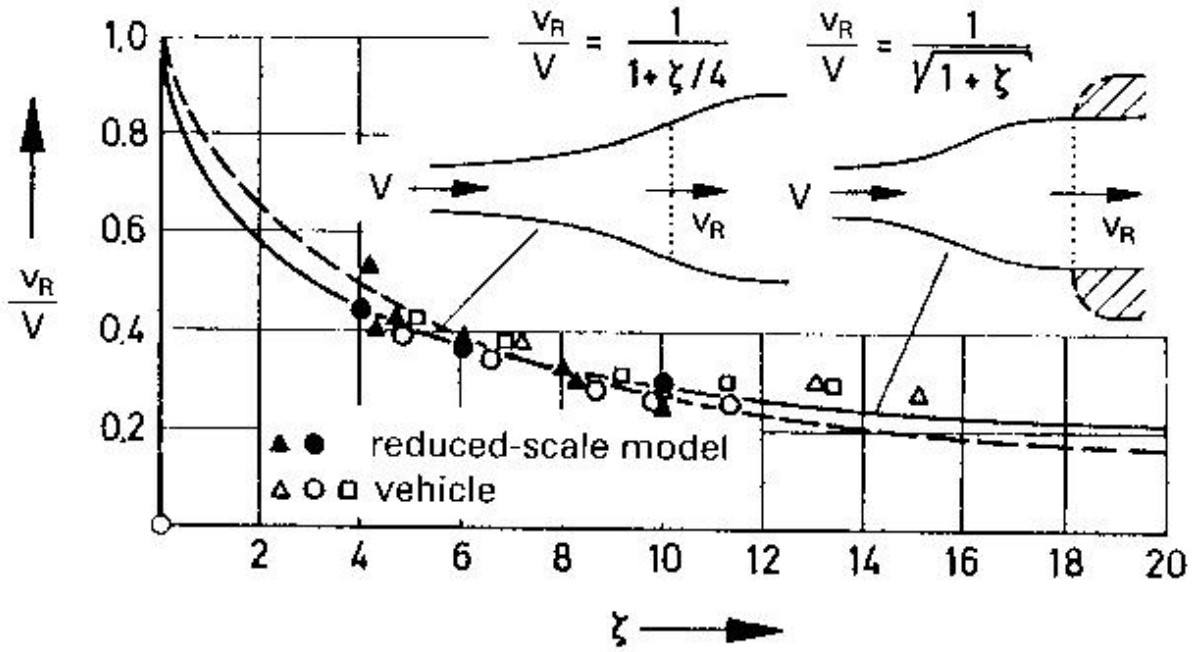
The four sections of the cooling-airflow duct



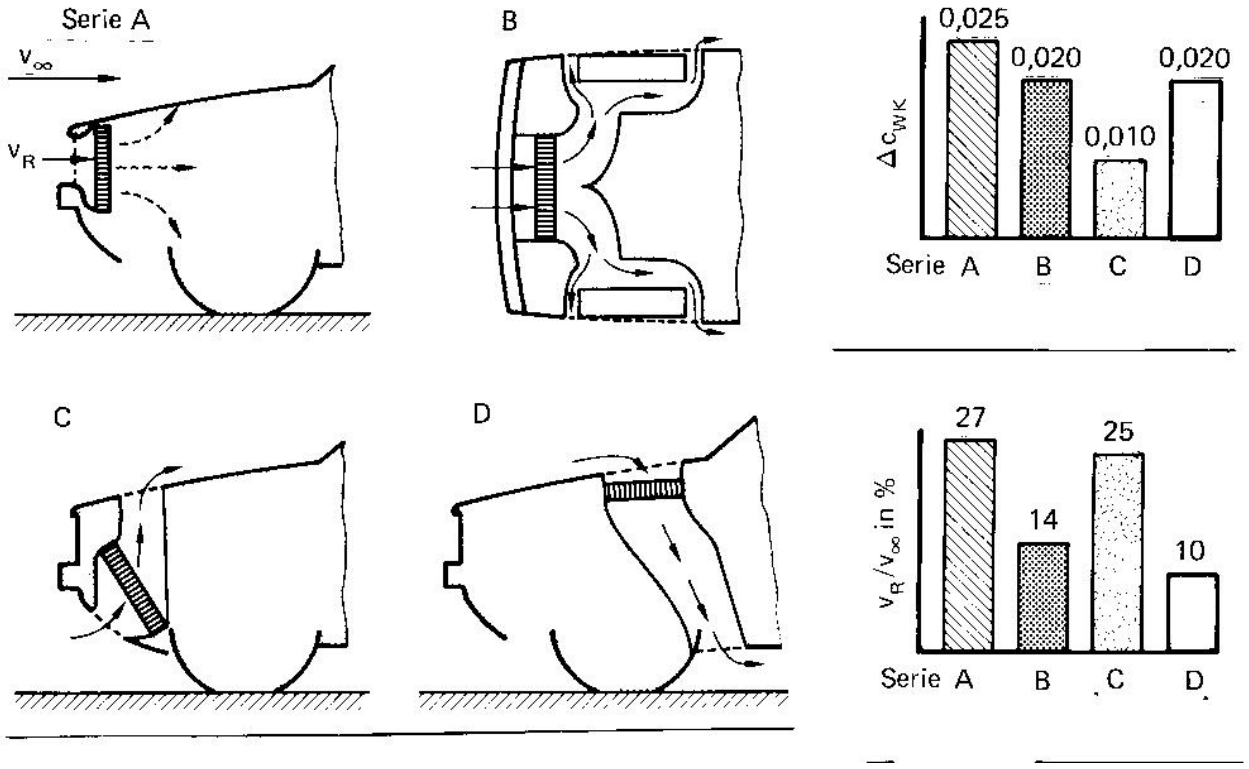
Drag-force: $D_C = \rho V_R A_R (V - V_E \cos\alpha) - (P_E - P_\infty) A_E \cos\alpha$

Lift-force: $L_C = -\rho V_R A_R V_E \sin\alpha - (P_E - P_\infty) A_E \sin\alpha$

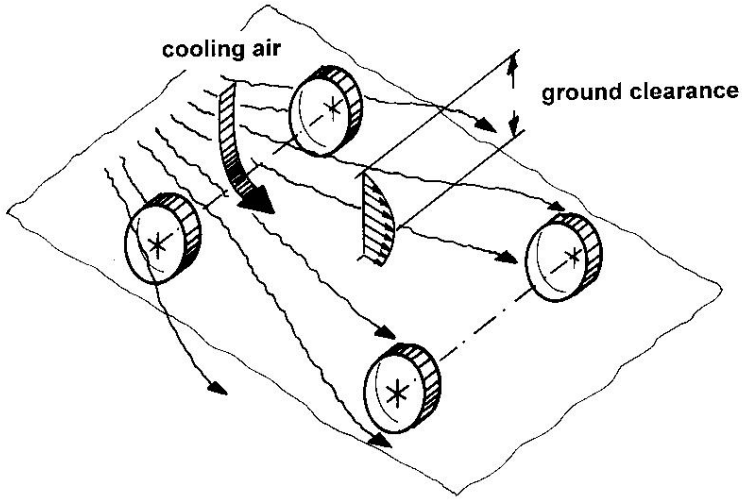
Lift and drag as functions of cooling-air duct layout,
after Wiedemann



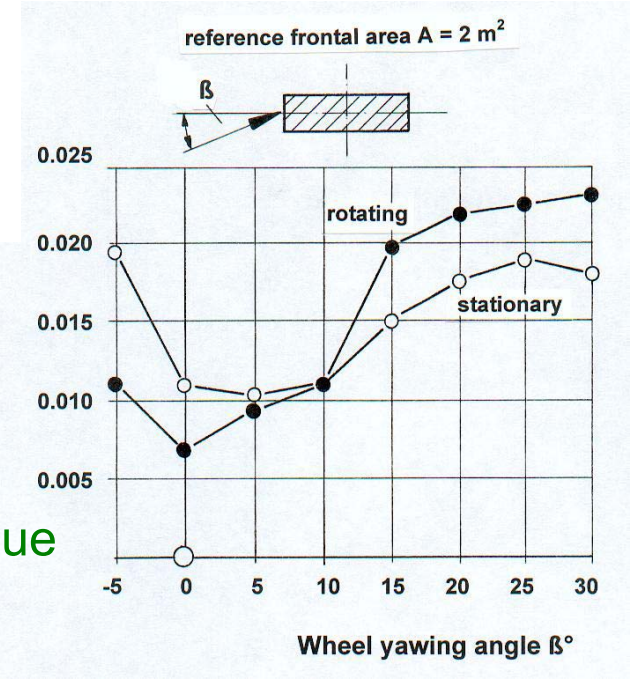
Internal flow: face velocity versus loss coefficient



Cooling-air flow: lowest drag and large volume with version C,
after Buchheim et al.



Interaction of inner and outer flow



Drag increase of wheels due to oblique air flow,
after Wiedemann et al.

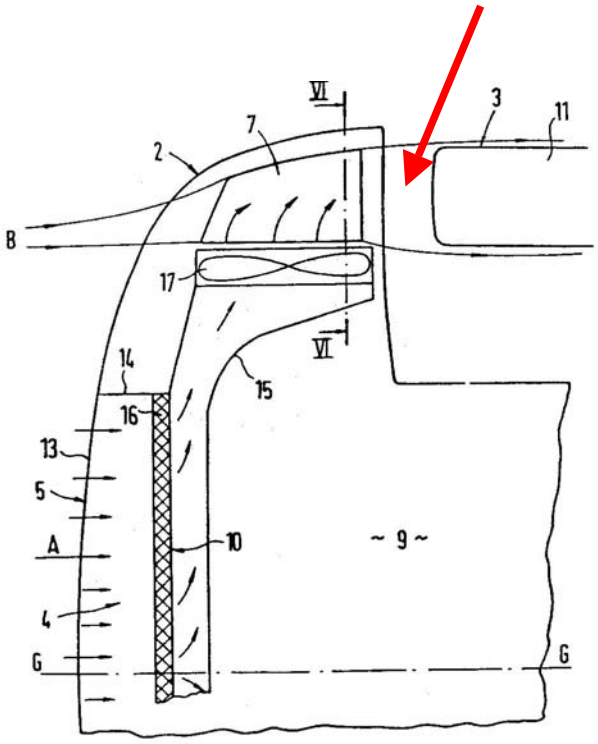


FIG.3

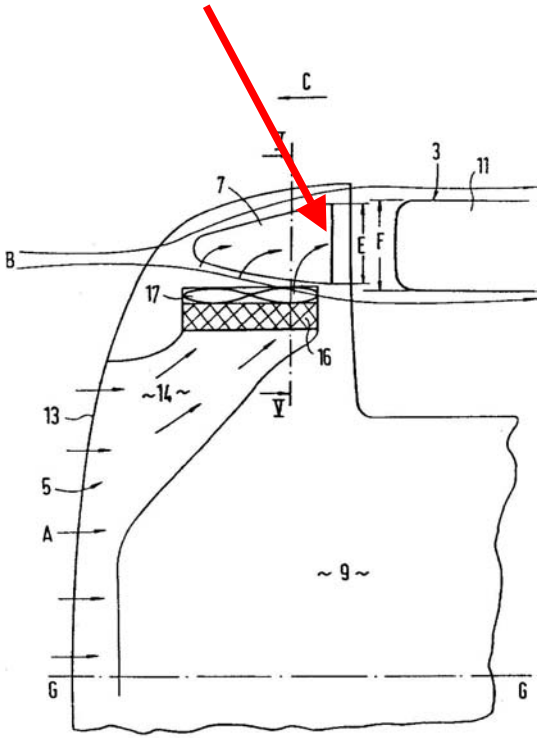
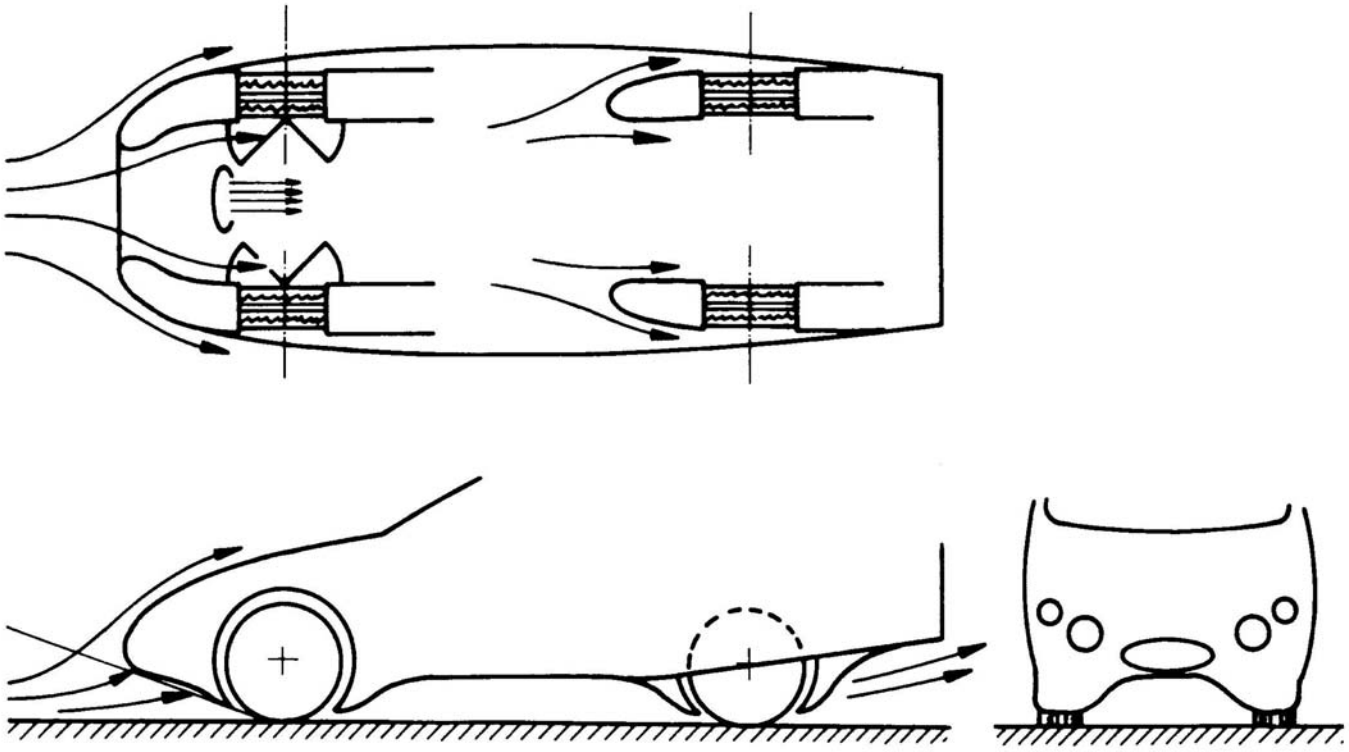


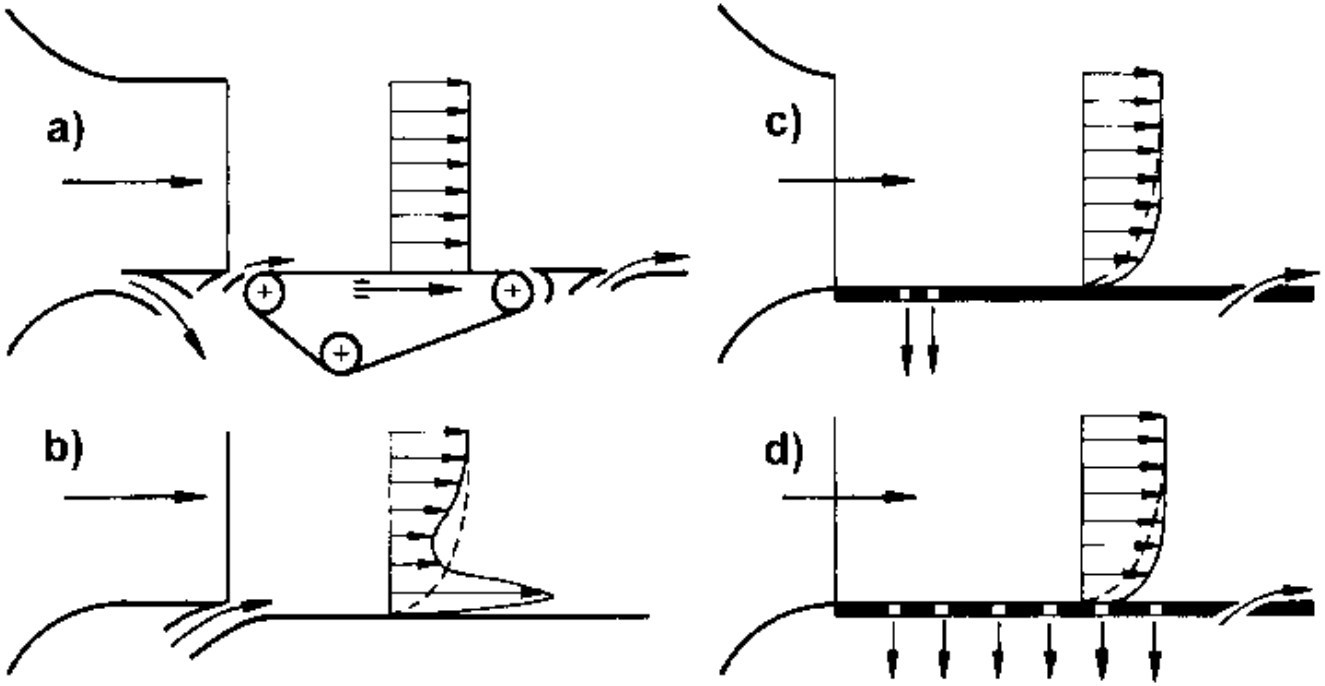
FIG.4

Reduction of drag by guided cooling-air outlet flow

Patent Porsche AG



Design of underbody to minimize air drag



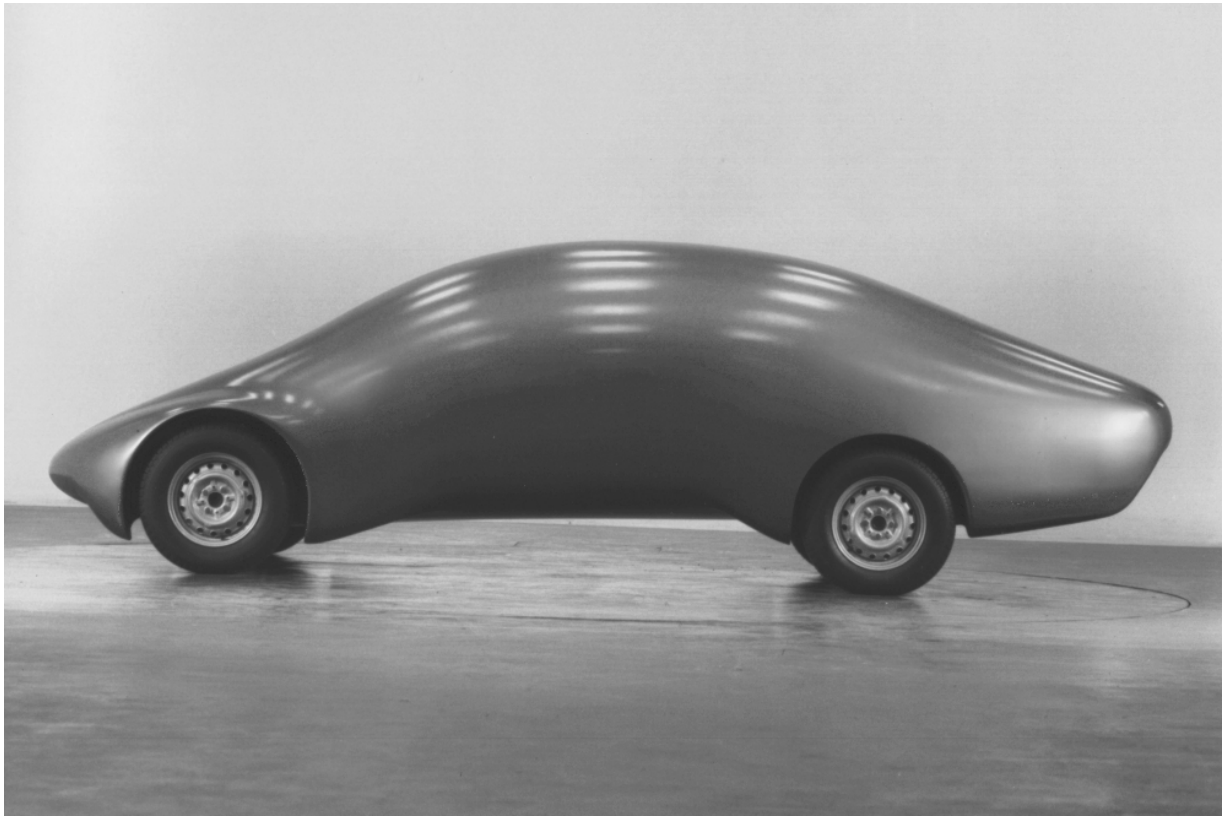
How to simulate in a wind tunnel relative motion between vehicle and road

Cooling-air inlet: recent examples for limousines and sports cars, IAA 2001

Renault, IAA 2001

Cadillac CTS, MY 2003

New faces: brand versus function



The ultimate shape? CNR-PF, 1976,
courtesy Pinifarina

Thank you for your attention