Automotive Aerodynamics & Body Engineering

Vehicle Body Engineering
Car Body Construction

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After studying this chapter, we should be able to:

- Explain the current design of motor vehicles

Summarize the various types of frames commonly used on modern cars, trucks, vans, and SUVs

Compare and contrast modern body-over-frame and unibody construction technology

Locate the major parts of a perimeter frame ‘

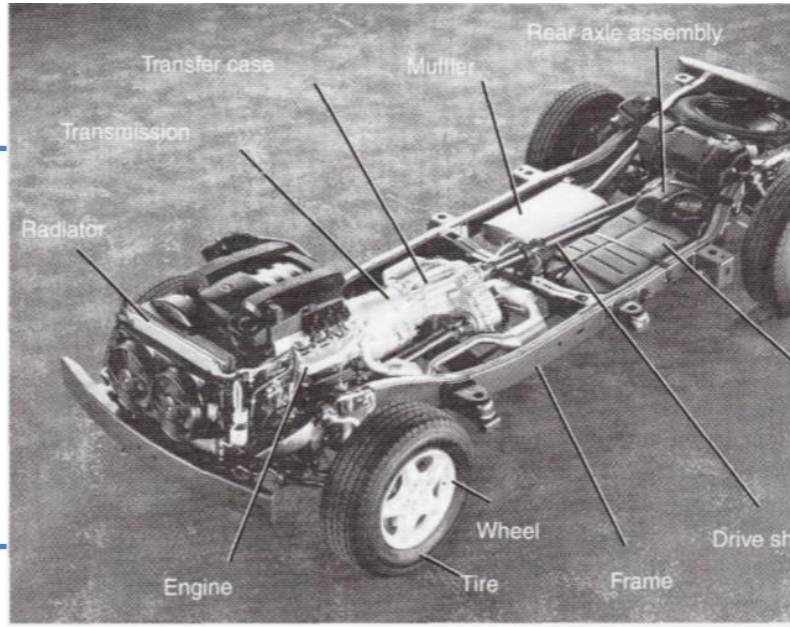
Locate the major parts of a unibody frame ‘i) Compare a conventional full frame with modern hydroformed frames Identify the major structural components, sections, and assemblies of a motor vehicle

Explain how simulated and actual crash tests are used to evaluate the structural integrity of a motor vehicle

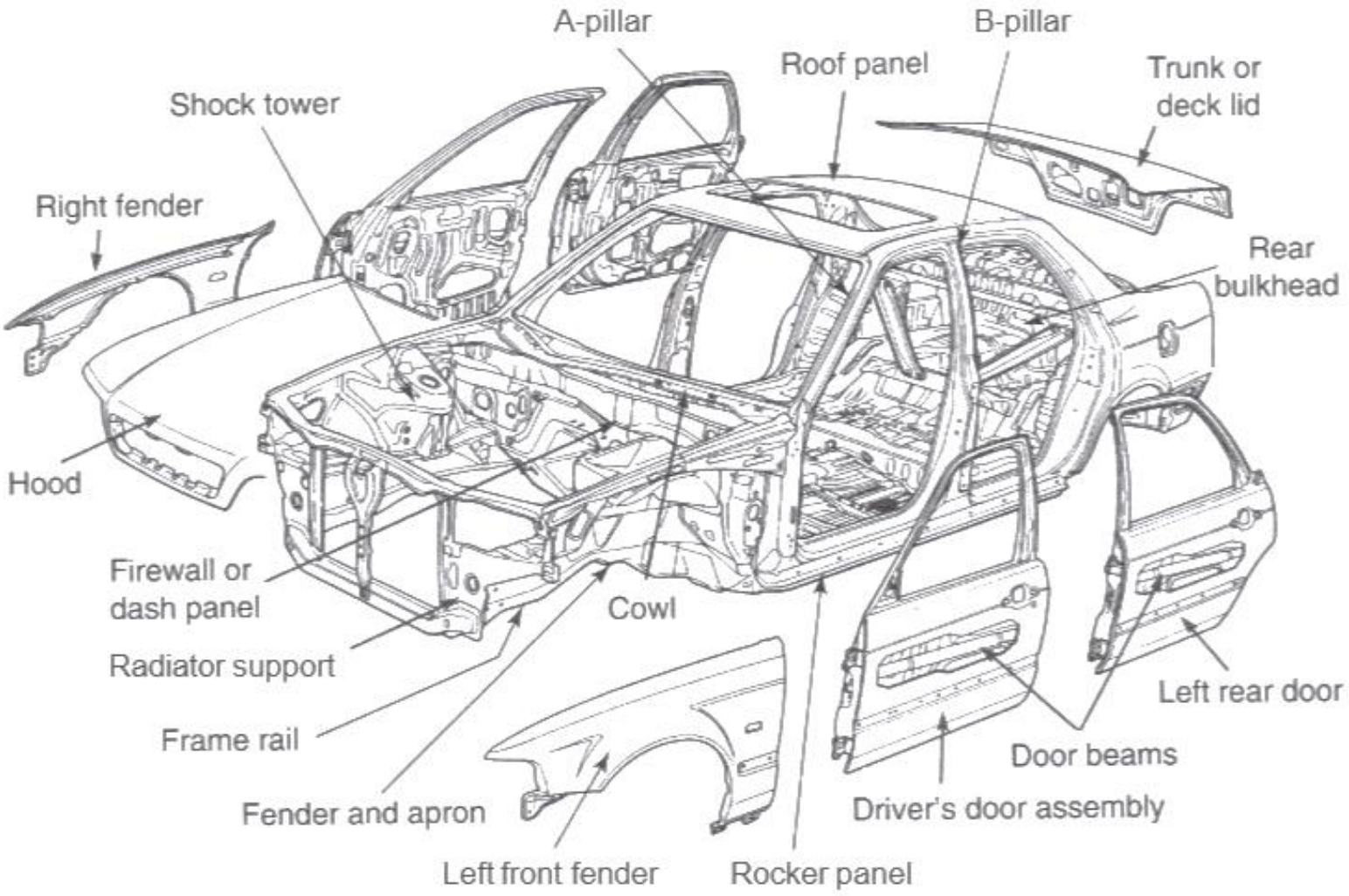
Describe the lay person’s names for body shapes used on passenger vehicles Answer ASE-style review questions relating to vehicle construction

Identification & Functions of Body Pressings

- In a separate body and chassis construction :
  - - Chassis resists bending & twisting loads
  - - Body provides only functional needs
- Separate body & chassis type of construction is being superseded by the integral or mono-construction system
- In integral construction the frame members become an integral part of the body

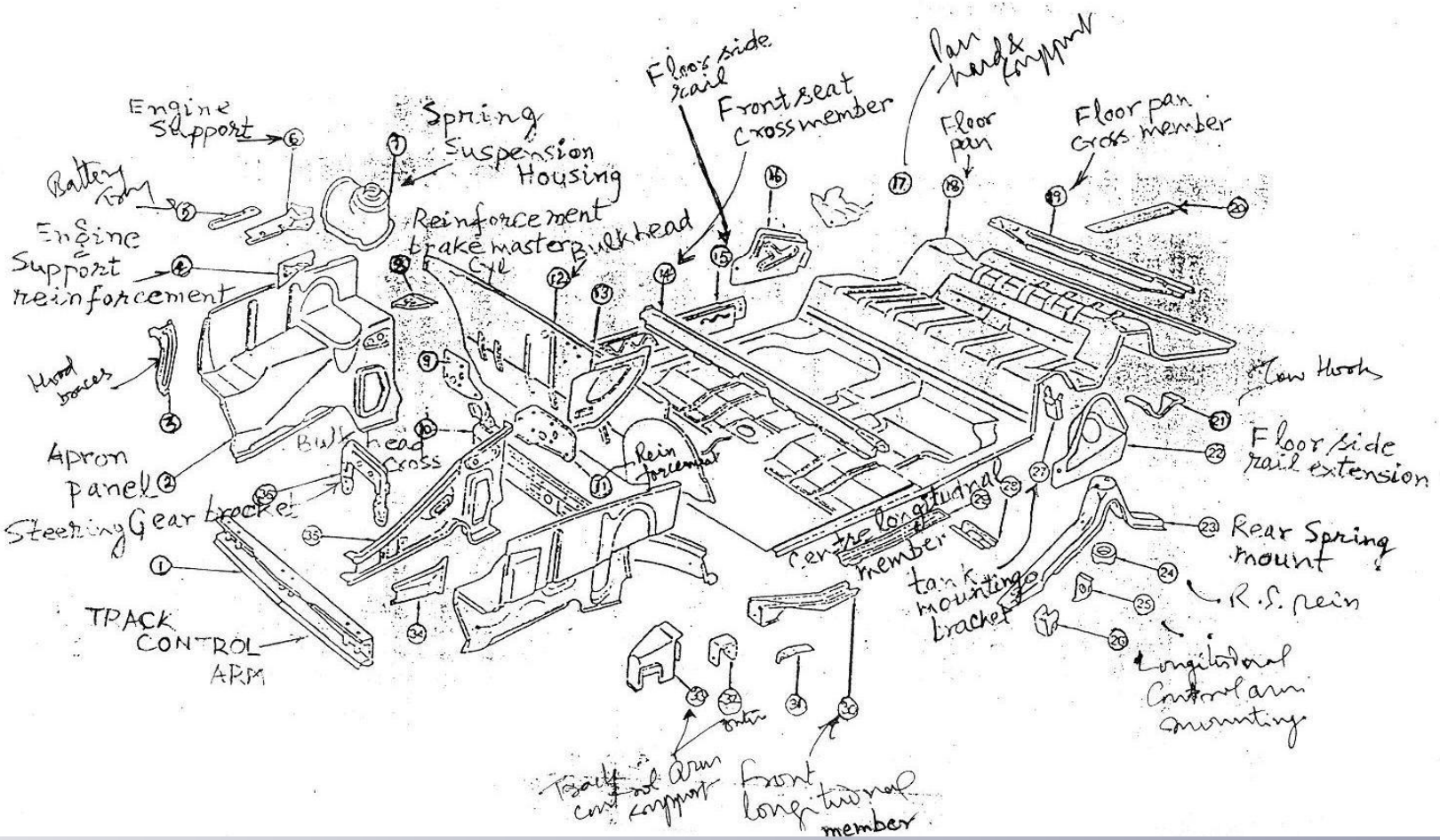


- **Car Body Assemblies**



Identification & Functions of Body Pressings

- **Car Underbody Assemblies**



Identification & Functions of Body Pressings

- Box sectioning of the body sills, door pillars and roof reinforcements form a framed structure in which stresses are distributed to all parts of the body
- In reinforced body shell buckling is prevented by use of curved plates with multiple radii (or crown). A flat plate offer little resistance to buckling.
- For stress carrying parts of body shell greater rigidity can be achieved by using ‘ top of hat ‘ section or channel & angles built into the assembly
- This is also convenient for construction of streamlined shapes for minimum aerodynamic resistance's

Identification & Functions of Body Pressings

- Mass production of car bodies in steel consists of manufacturing of sub-assemblies like floor-pan, two sides, roof cross-member, etc. assembled together and spot-welded to form a complete body shell
- For construction of a typical Car Body Shell various sub-assemblies generally required are described in order to understand a sequence of its construction .

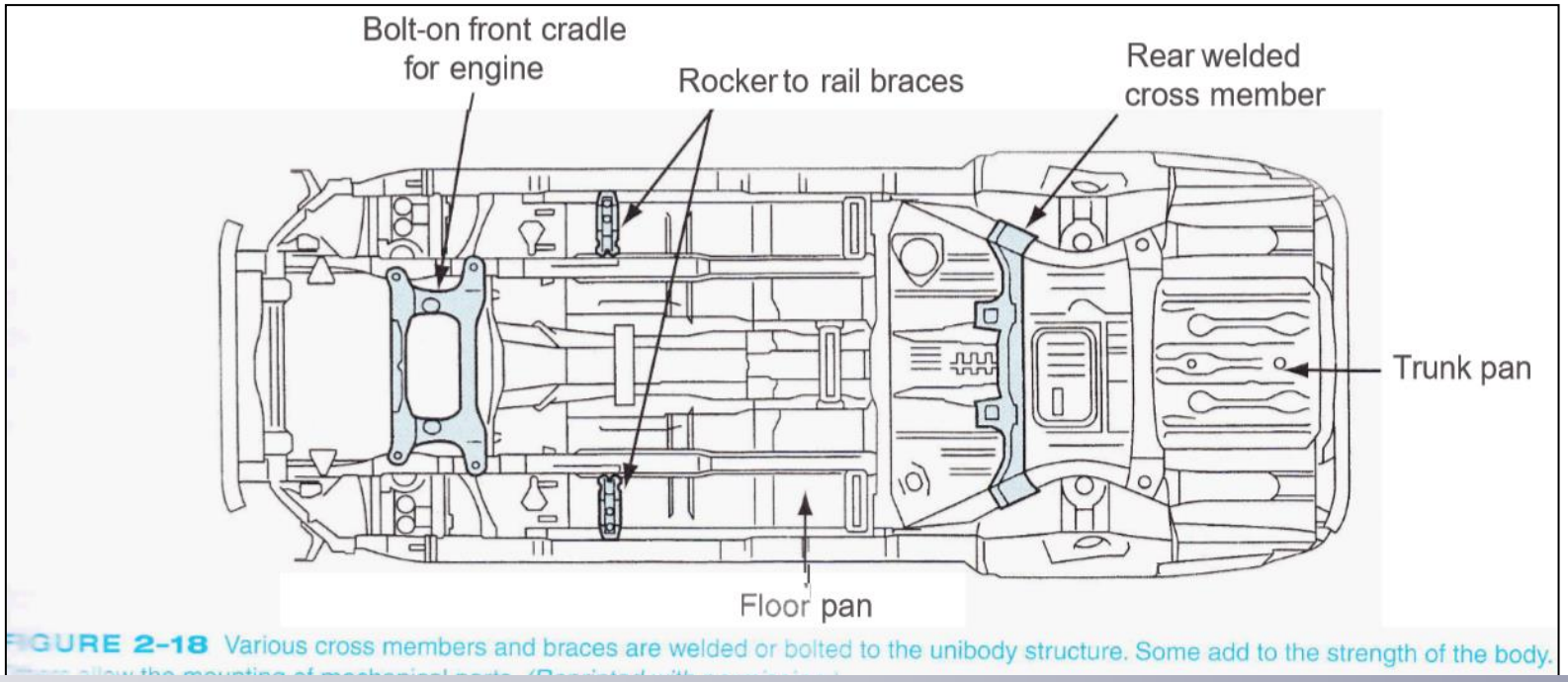
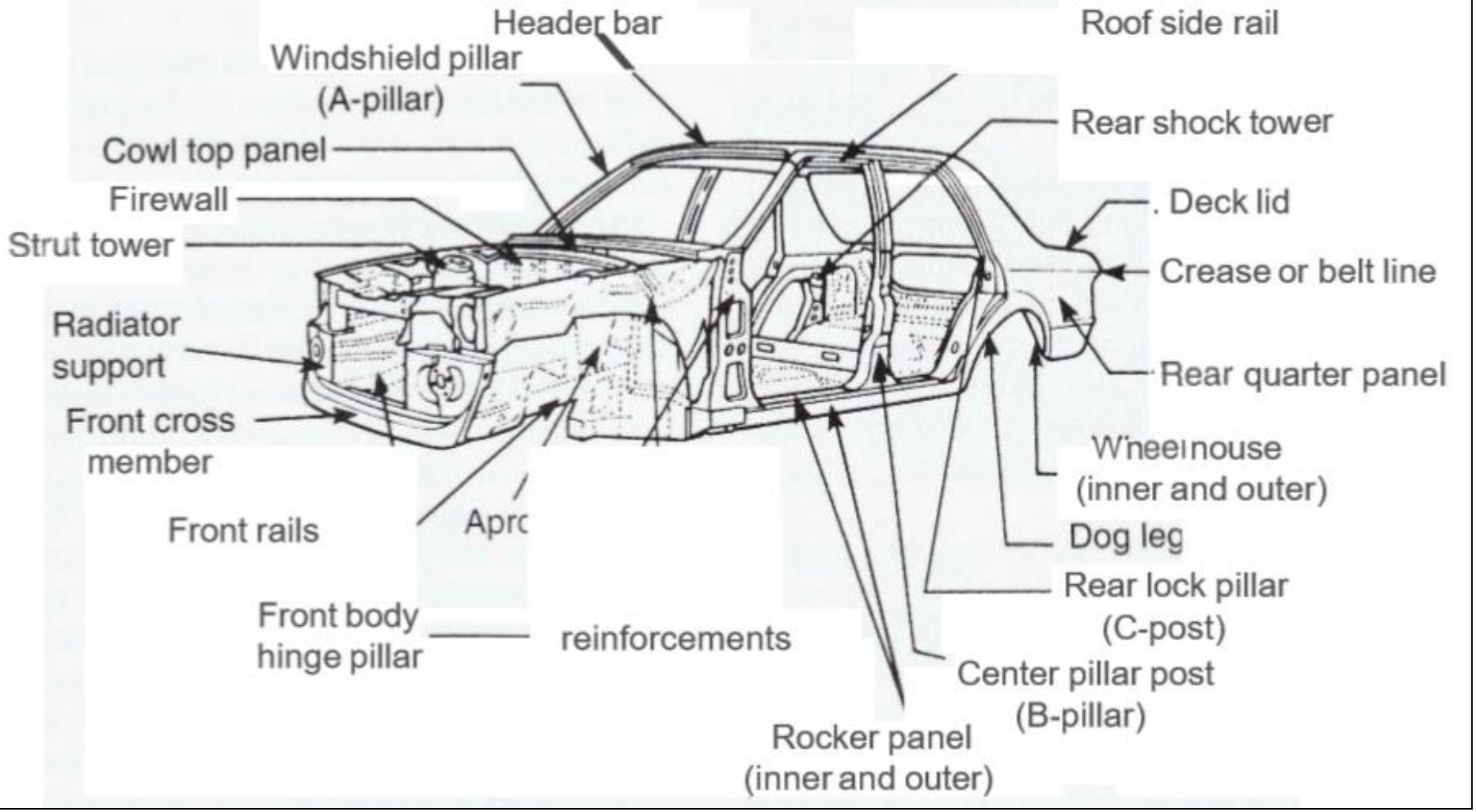


FIGURE 2-18 Various cross members and braces are welded or bolted to the unibody structure. Some add to the strength of the body.

Sub- Assemblies & Construction of Body Shell

- Underbody assembly
- Body side assembly
- Shroud and dash panel assembly
- Roof & back window aperture panels
- The Center pillar (B- C post)
- Rear Bulk-head and parcel shelf
- Front end work
- Front wings
- Door panel assembly


Header bar
Roof side rail
Windshield pillar
(A-pillar)
Rear shock tower
Cowl top panel
Firewall
. Deck lid
Strut tower
Crease or belt line
Radiator
support
Rear quarter panel
Front cross
member
Wheelhouse
(inner and outer)
Front rails
Apr
Dog leg
Rear lock pillar
(C-post)
Front body
hinge pillar
reinforcements
Center pillar post
(B-pillar)
Rocker panel
(inner and outer)

Sub- Assemblies & Construction of Body Shell

- Bonnet panel assembly
- Boot lid assembly
- Under body assembly
  - - This positions the engine, transmission, wheel-arches, seats, etc.
- - Body sills provide longitudinal edge reinforcements
  - - The floor pan strengthened by; box members at right angles to the transmission tunnel; all cross members

Sub- Assemblies & Construction of Body Shell

- Under body assembly
  - at the rear,front of the front seats, front of the rear seats, etc. joined together provide lateral reinforcements
  - - The transmission tunnel, which acts like an inverted channel section provide central strength built into the floor
  - - The remaining area of flat metal is ribbed or dished below the seats and in the foot wells to add stiffness to the sub-assembly

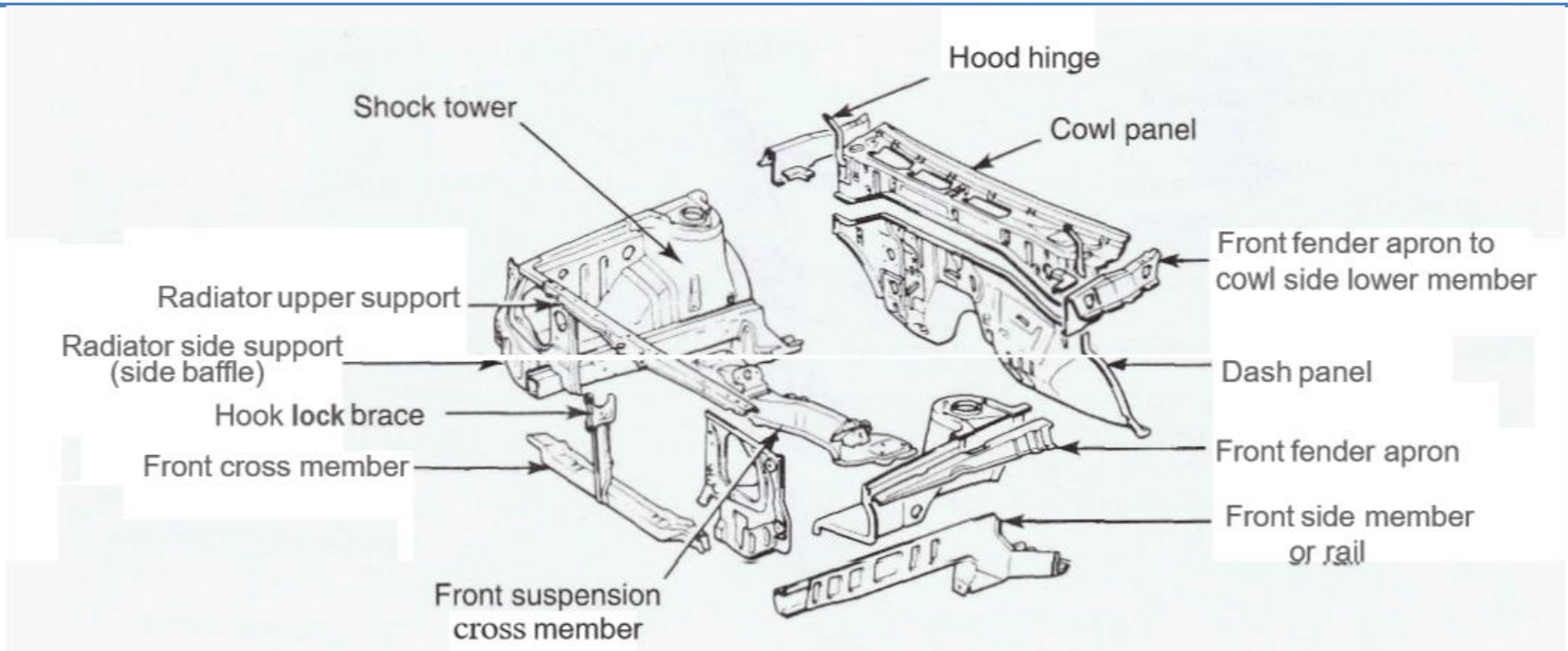


FIGURE 2-14 Study the front body structural components of a typical transverse-mounted engine of a front-engine, front-wheel drive

Sub-Assemblies & Construction of Body Shell

- Body side assembly
  - - The side frames reinforcing the floor pan, body sills also transmit loads between them
  - - The center pillars are welded in between the body sill and the roof / cant rails.
  - - These are usually assembled as a box section using a ‘top-hat’ section and flat plate, with the flanges forming attachments for the door, weather seals, etc.
  - - The front hinge pillars extend forward to join with the dash panel, front bulkhead cross member. This provides strength by ‘boxing’ the front end.

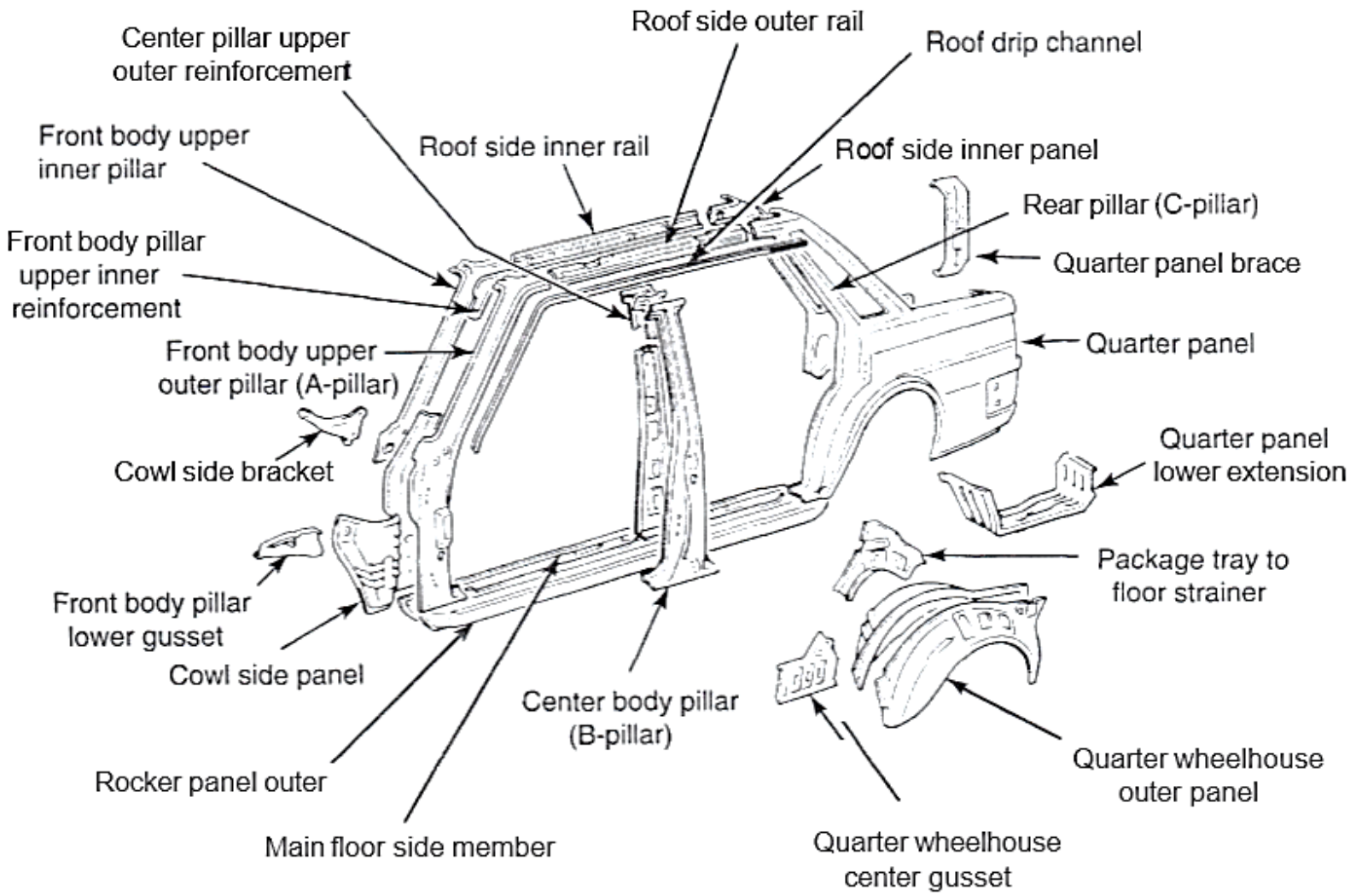


FIGURE 2-16 Note the side body structural components of the typical vehicle. These parts must protect passengers in a side hit or

Sub- Assemblies & Construction of Body Shell

- Shroud & Dash panel assembly
  - - These assemblies are complex structures connecting the two body sides across the car
  - - The complete assembly is also called the firewall because it is the partition between the passenger and engine compartment, and carries part of the forces set up by the front suspension, weight of the power unit.
  - - The heating / cooling systems & its distribution chamber, instrument panel & its necessary controls, wiring, tubing, etc., the steering column are all attached to the front bulk head of the body and is

Sub- Assemblies & Construction of Body Shell

- Shroud & Dash panel assembly
  - usually formed by assembling together several smaller panels (dash & shroud) which are joined by welds to form an integral unit.
  - - The instrument panel connected to the cowl panel provides mountings for instruments.
  - - In some cases the wind screen opening is connected to the cowl panel. In this case the windscreen pillars, the narrow sloping construction at either side of the windscreen opening are part of the cowl. Upper edge of the cowl panel forms the front edge of the roof panel
  - **Shroud & Dash panel assembly**
    - **- On many passenger cars the front door hinge pillar is also an integral part of the cowl**
  - **Roof & back window aperture panels**
    - **- Roof panel is one of the largest of all major body panels and it is one of the simplest in construction.**
    - **- Usually it is all-steel, one piece construction.**
    - **- On some cars it ends at the windscreen on front side & rear window on the rear side. It may extend down**
  -

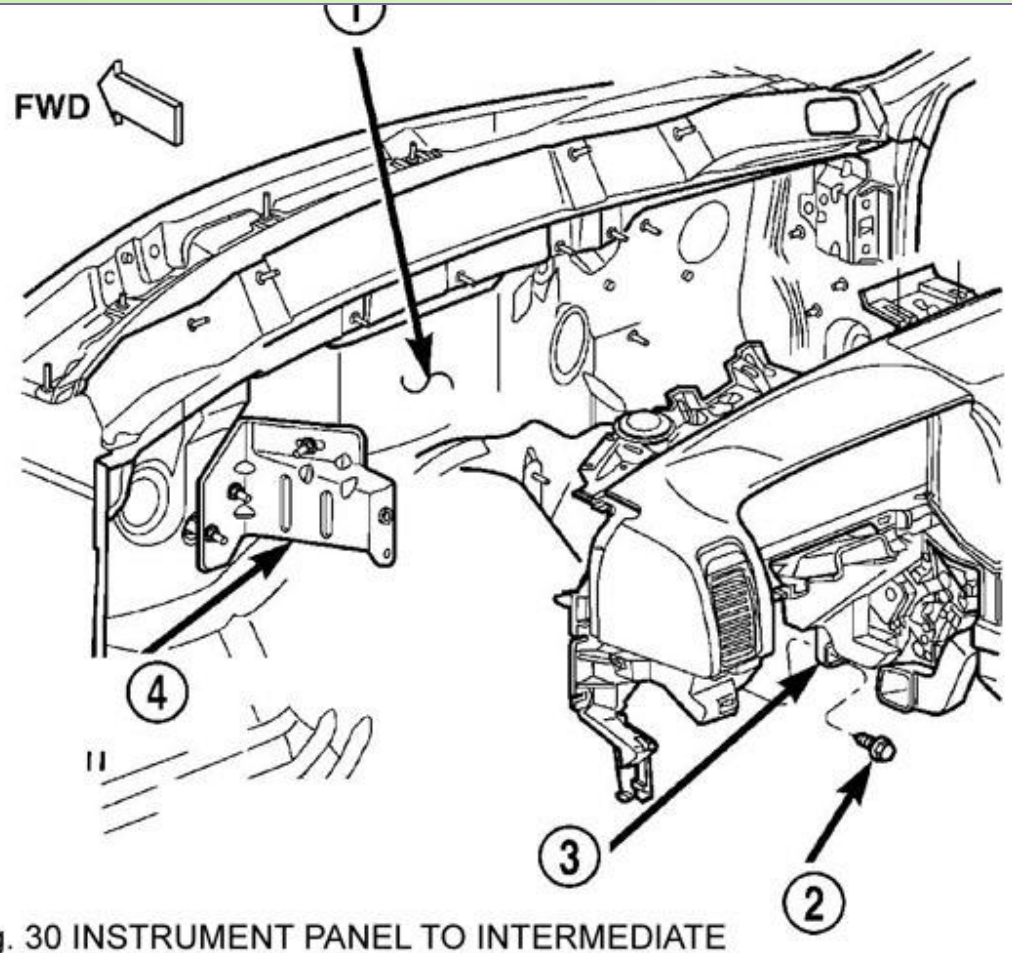


Fig. 30 INSTRUMENT PANEL TO INTERMEDIATE BRACKET MOUNTING
1 - DASH PANEL
2 - SCREW
3 - INSTRUMENT PANEL STEERING COLUMN SUPPORT BRACKET
4 - INTERMEDIATE BRACKET

Sub- Assemblies & Construction of Body Shell

- Roof & back window aperture panels
- wards around windscreen on front side and on rear side the rear window opening is in the lower rear roof and forming the top panel around the rear boot opening
- - The roof and its reinforcing members form lid of the box structure.
- - The stiffness is built by the curvature given to it, the reinforcement consisting of small metal strips placed crosswise to the roof at intervals along the inside surface. These also provide tacking strips for securing
- the heal lining & inside trims in place . In some cases the roof panel is also ribbed or dished longitudinally.
- The Center Pillar (B - C post)
- - It acts as central roof and side support between the front and rear of the car body side structure.
- - Its construction must be exceptionally strong as it is the shut (lock) pillar and the hinge pillar for the doors.
- - The center pillar is irregular in shape since it must conform to outside contours of the door as well as

Sub- Assemblies & Construction of Body Shell

- Roof & back window aperture panels

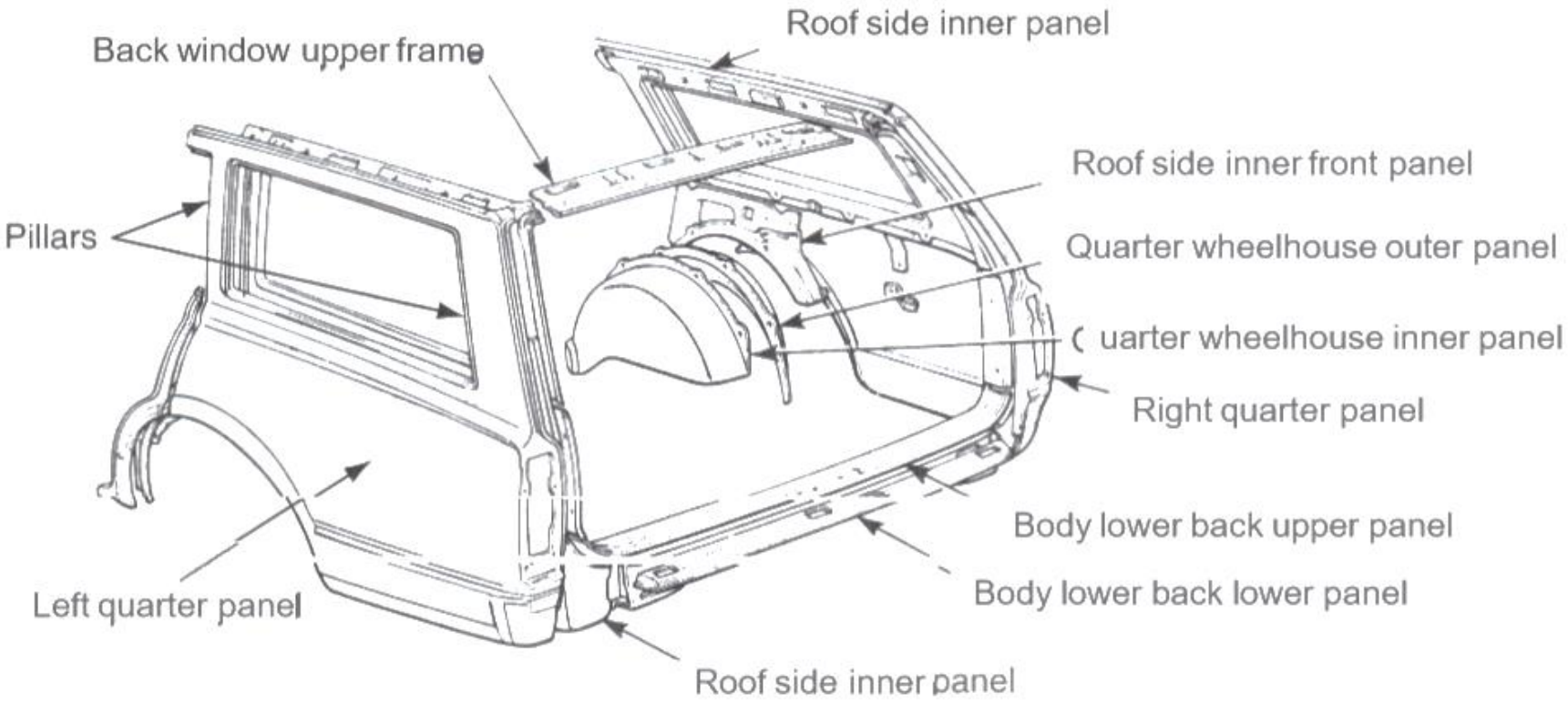
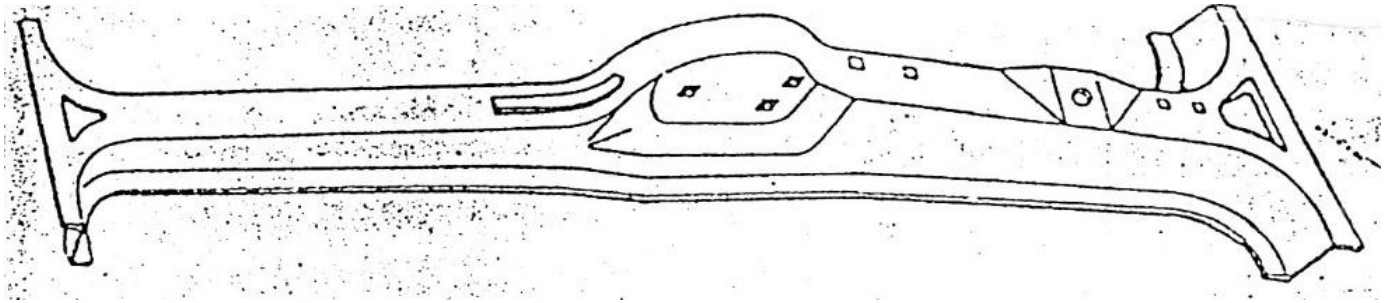


FIGURE 2–28 Study the rear body structural components for a typical FR station wagon. *(Reprinted with permission.)*

Sub- Assemblies & Construction of Body Shell

- The Center Pillar (B - C post)
  - accommodate door lock, striker plate, hinges,etc. depending on the body style.



Sub- Assemblies & Construction of Body Shell

- Rear Bulk - Head and Parcel Shelf
- - This provides transverse stiffness and is welded between the body side frames and rear seat frame. In construction they are often pierced and flanged to increase rigidity.
- - The rear panel is curved to form part of the external shape of the body with its upper edge providing support to the boot lid seal.

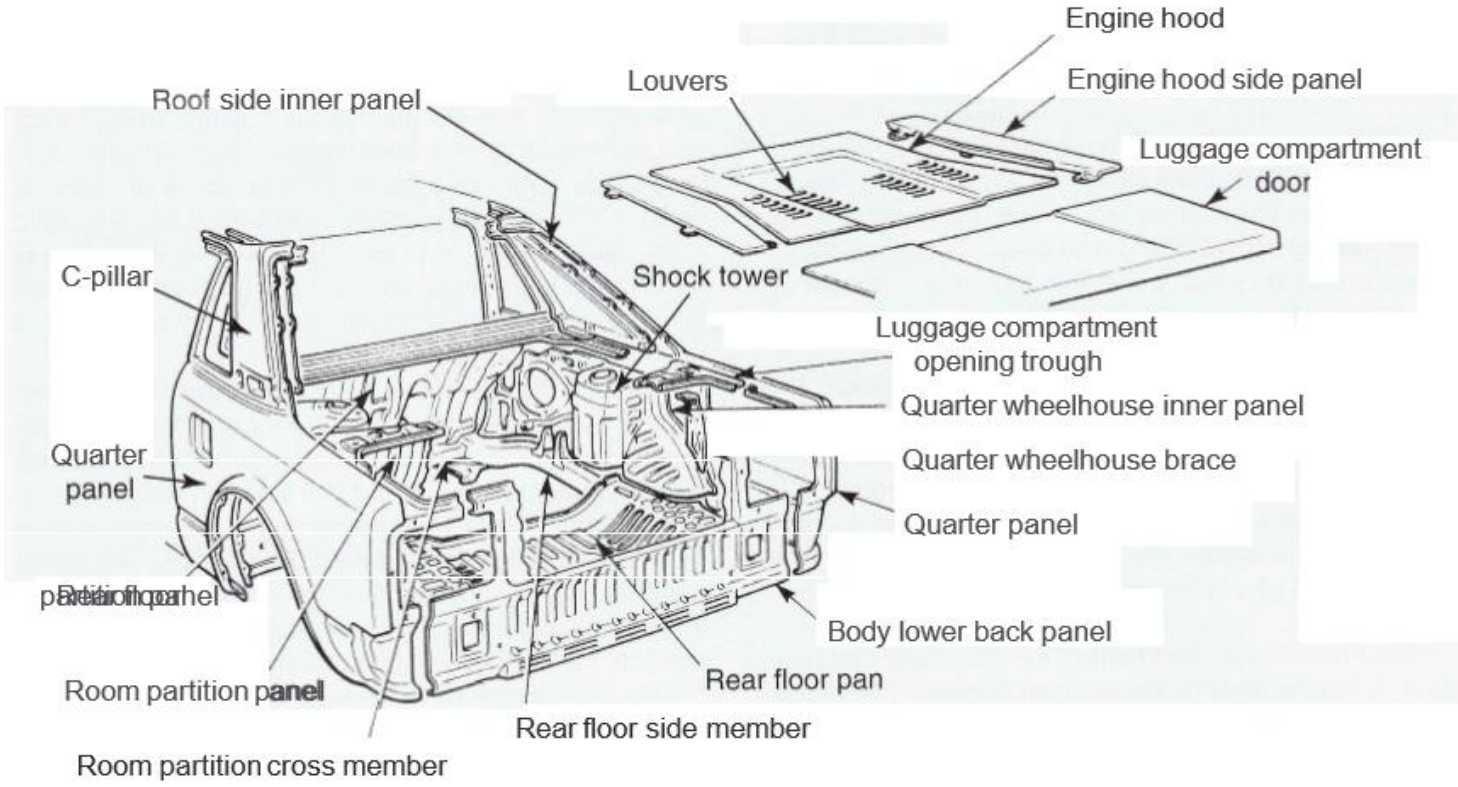
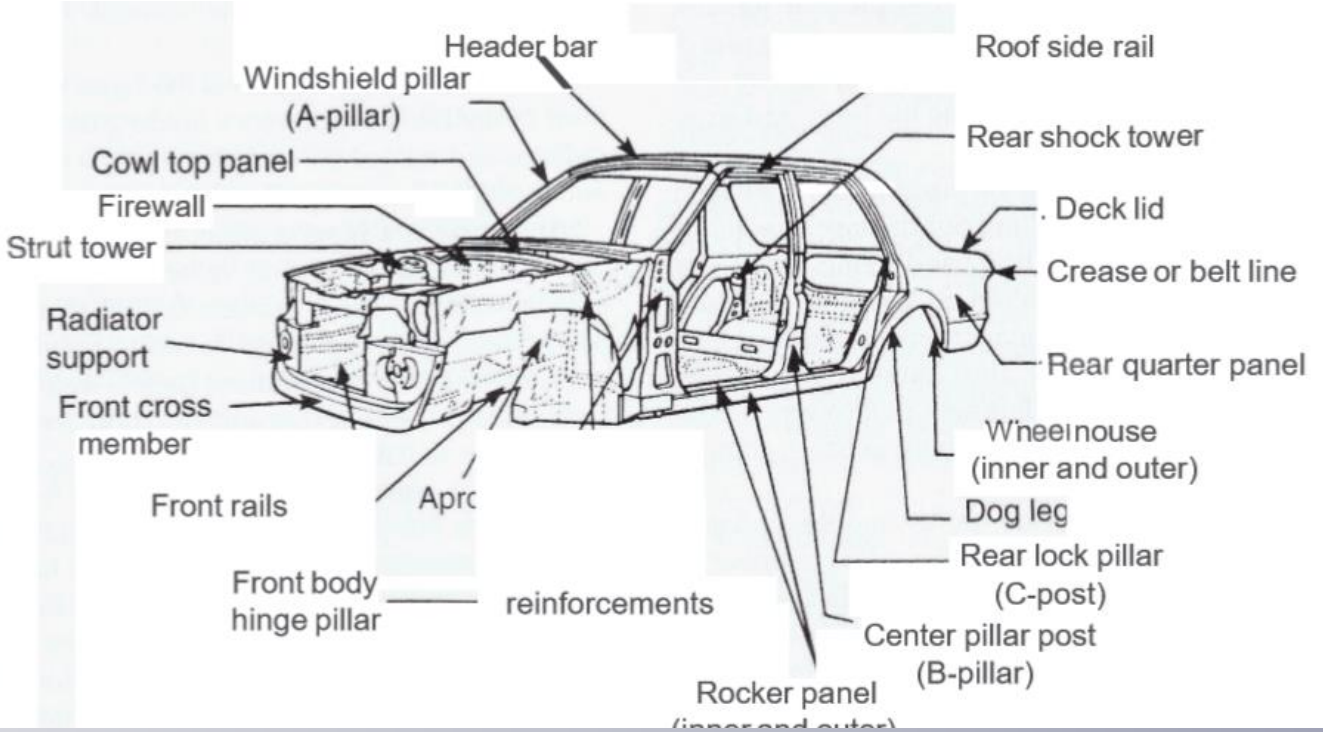


FIGURE 2-31 Note the rear body structural components of a typical MR vehicle. Because the engine mounts in back, body structure must

Sub- Assemblies & Construction of Body Shell

- Front End Work
  - -The front end carries the engine and front suspension, steering gear and radiator.
  - - The suspension system may affect detail design of the panels but the loads must be transmitted to the wings and/or wheel arches and on into the body panels
  - - The front cross- member assembly braces the front of the car and carries the radiator, headlamps, etc. The side assemblies and front wheelhouse panel assembly form a housing for the wheel, a mating edge for the bonnet and a strong box section for attachment to the side frames and front bulkhead.

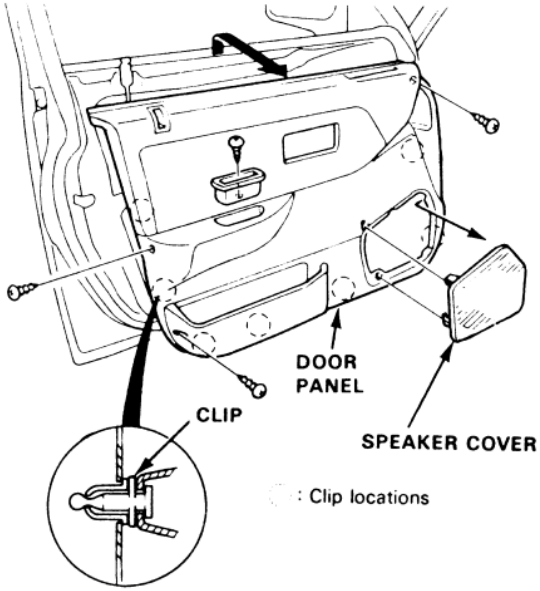


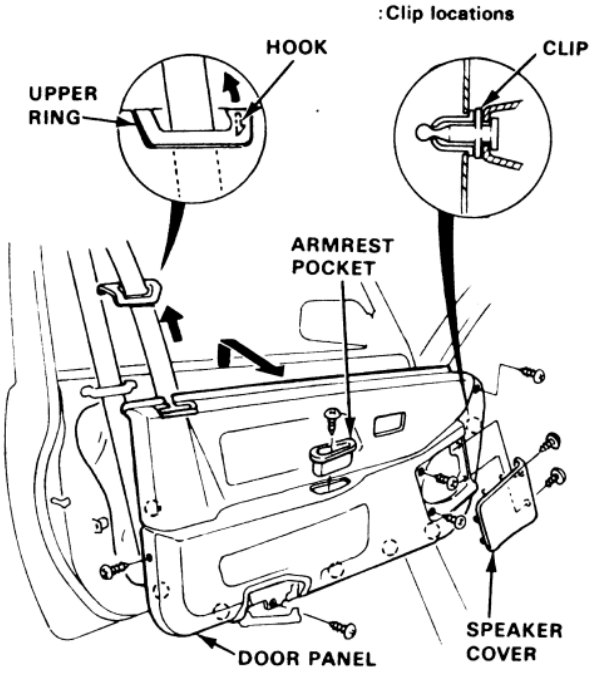
Sub- Assemblies & Construction of Body Shell

- Front Wings
  - - The front wings are each attached to the inner construction of the car body by means of a flange along the length of the wing, which is turned inwards from the outside surface and through which securing bolts can pass.
  - - To add strength and to prevent vibration the wing brackets are sometimes fitted.
  - - The unsupported edges are swaged and turned inwards to give strength& cracks developing in the edges of the wings due to vibrations. This provides a smooth finished appearance to the edges of the wings.
  - - Apart from covering the suspension & wheel the wings prevent water and mud, etc. being thrown up onto the body by the wheels.
  - Door Panel Assembly
    - - The door is composed of two main panels; outer and inner panel, constructed to act as a frame for the door.
    - - The outer panel flanges over the inner panel around the edges to form a single unit.

Sub- Assemblies & Construction of Body Shell

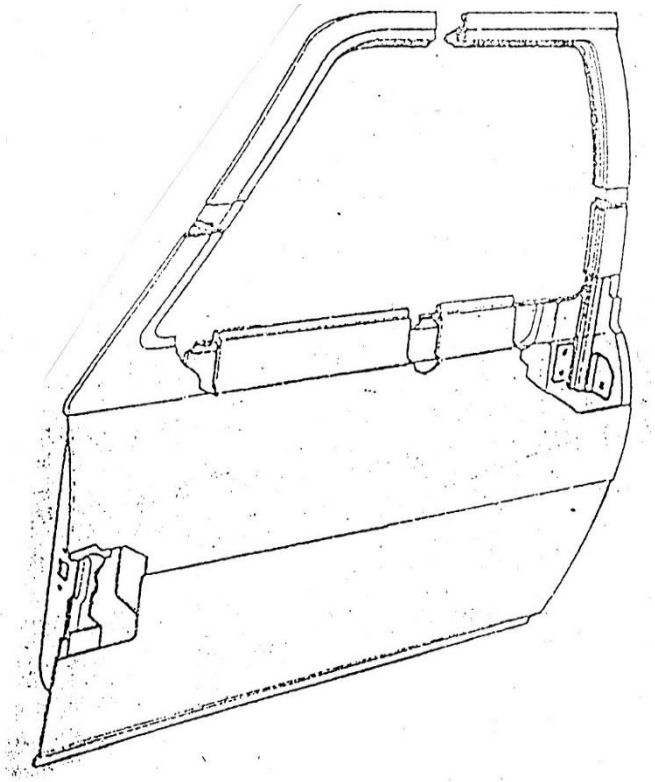
- Door Panel Assembly
  - - The window channel may be welded or bolted to inner door panel to provide support & direction to the window glass.
  - - The inner panel has holes or apertures drilled, punched or formed for attachment of door trims.
  - - The thickness of the door is due to the depth of the inner panel which accommodate door catch,window mechanism,etc.
  - - The inner panel forms the lock pillar and the hinge pillar sections of the door.





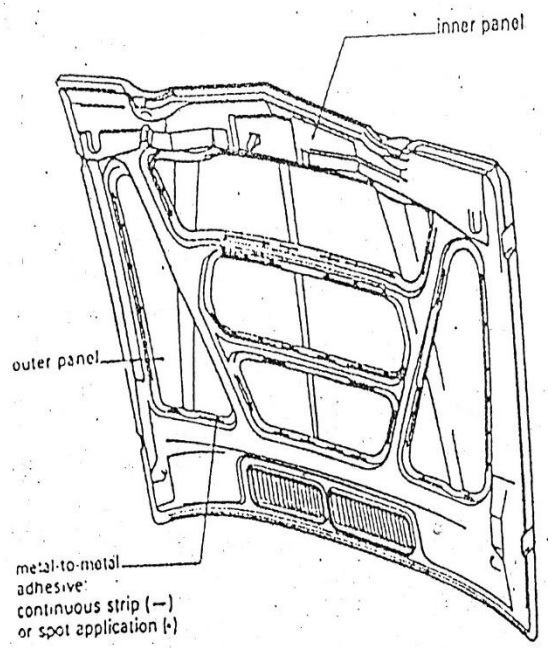
Sub- Assemblies & Construction of Body Shell

- Door Panel Assembly
  - - Small reinforcement angles are
  - usually used between the outer
- and inner panels where lock is
- inserted through the door and the
- hinges are attached.
  - - The outer panel is provided with
  - an opening through which outside
  - door handle protrudes.



Sub- Assemblies & Construction of Body Shell

- Bonnet Assembly
  - - The bonnet is the panel covering
  - the engine compartment.
  - - Most one-piece bonnets are
- hinged at the rear so that the front
- end swings up when opened. The
  - catches are at front and in most
  - cases controlled from inside the car.



Sub- Assemblies & Construction of Body Shell

- Bonnet Panel Assembly
  - - One-piece bonnets are quite large and, to make opening easier, the hinges are usually counter - balanced by means of tension or torsion springs.
  - - Smaller bonnets are held in place by a stay
  - - The bonnet consists of the outer panel and inner reinforcement constructed in the 'H' or cruciform pattern. The reinforcement is basically a top-hat section to give rigidity to the component.
  - - The main strength of the bonnet lies in the fact that the inner construction acts like a frame and the outer panel is formed round its edges, acting as flanges

Sub- Assemblies & Construction of Body Shell

- Boot Lid Assembly
- - The boot lid is composed of an inner and an outer panel spot-welded together along their flanged edges to form a single unit .
- - Both type of hinges ; external & concealed are used.
- - A catch is provided at the bottom rear of the boot lid and controlled by an external handle. In some models handles are not provided. The hinges are spring loaded so that lid rises automatically by the hinge mechanism for opening & holding it in place.

Body Build, Paint and Sealing

- Body build
- - A car body is made up of six major units ; Floor, Two sides, Front end, Rear end, Roof
- - These major units themselves made up from numerous smaller pressings reach main body-build conveyors as sub-assemblies
- - Special jigs carry the body floor assembly, pairs of side frames, front & rear sections mate up with the trucks so that all the units are clamped securely together while the welding is done. The roof is the last major section to go on.

Body Build, Paint and Sealing

- Body build
- - Various forms of welding are used in building up a car body shell like spot- welding, seam welding, etc.
- - After welding, every joint is sealed with special compounds to make it a watertight car body.
- - After the body shells have assembled their doors, bonnet panels, boot lids, etc. they are prepared for the paint shop.
- - Panel surfaces are inspected and blemishes in the sheet metal are removed with portable sanding machines

Body Build, Paint and Sealing

- Painting
- - The painting of a car body means protection of sheet metal, inside and out, underneath as well as on top besides giving them a coat of bright shiny colour.
- - The first stage is a multi-part rust-proofing treatment by complete immersion of the body shell in a huge bath of anti-rust alkyd primer.
- - This is followed by surface priming. The entire under body,wheel arches, insides of the body sills,etc. are treated with multi-coats of epoxy primer followed by baking in huge high- temperature ovens.

Body Build, Paint and Sealing

- Painting
- - The under body areas are coated with thick layers of bituminous or polymer compounds for anti-corrosion protection. This also helps reduce road noise.
- - In final stage the complete body is given a base coat of acrylic paint with special adhesion qualities. This is followed by multi-coats of the finish colour paint which is basked in hot oven to create a hard, deep-gloss finish.
- - In between these operations rubbing, washing, cleaning, etc are carried out .

Body Build, Paint and Sealing

- Sealing
- - The entire car body is vulnerable to the entry of water, fumes, and dust.
- - The various locations on the vehicle body that require some form of seal are ;
  - 1. Areas where a permanently flexible seal is required, e.g. windscreen, rear screen
  - 2. External panel seams.
  - 3. Areas where a seal is required to withstand stone pecking, e.g. wheel arches, floor pan
  - 4. Protected areas where a bulk sealer is required

Body Build, Paint and Sealing

- Sealing
- - It is essential for the various sealing materials (caulking cmpound, multi-purpose adhesive, metal joint sealer, windshield sealer, double-sided adhesive tape, PVC foil, etc.) to be applied to clean dry surface if they are to adhere and form an effective seal.
- Fixtures and fittings
- - From paint shop the car body pass into the trim shop for ‘furnishing’ where various items like carpets, seats, door handles, window glass, chrome moldings, electric wiring, steering wheel,fascia panels,instrument

Body Build, Paint and Sealing

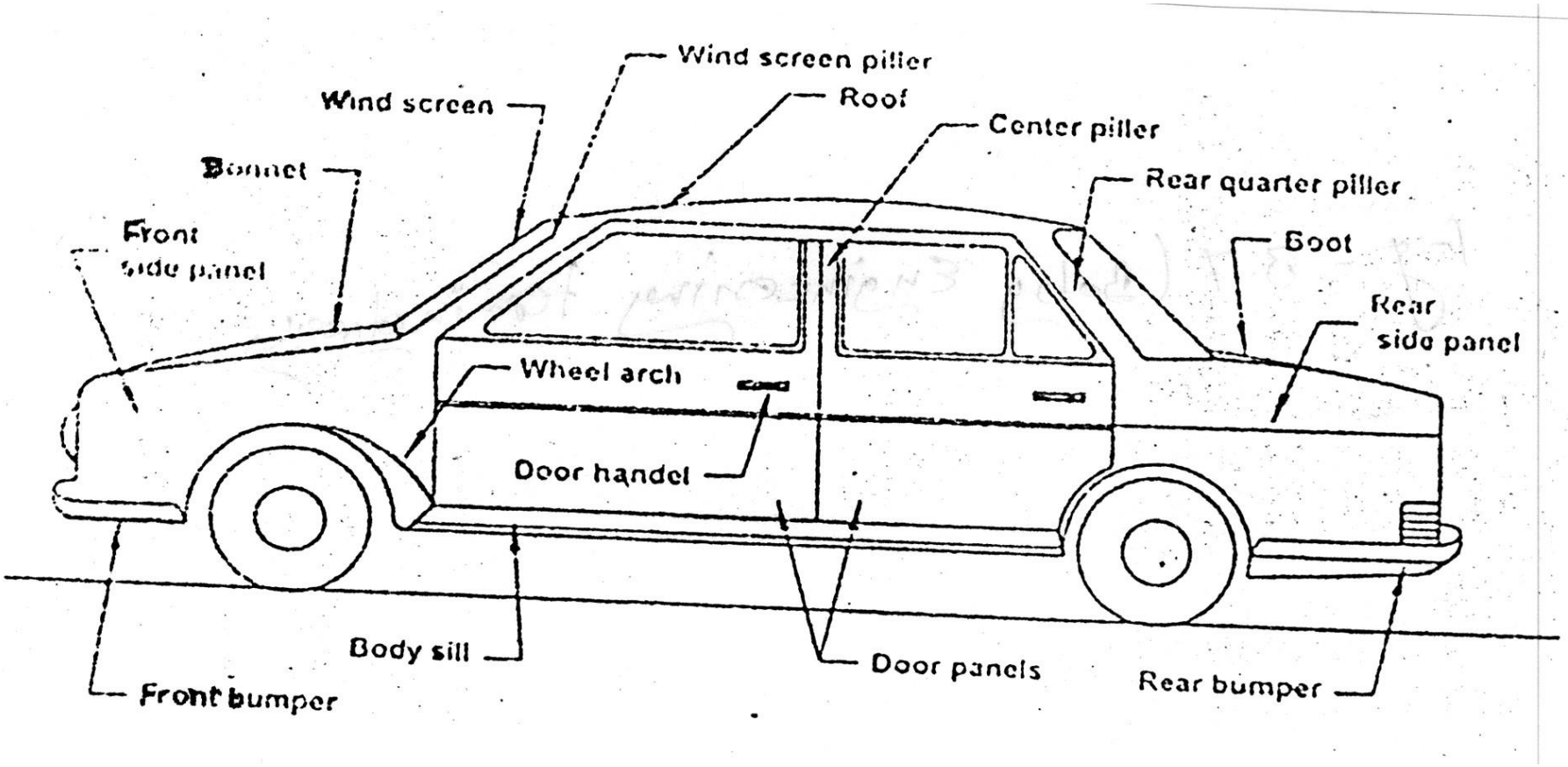
- Fixtures and fittings clusters, etc. are fitted
- - Midway through this long furnishing the body pass through a long water tunnel where it is drenched by powerful jets of water. This water contains a fluorescent dye and any drop of water that may have found its way into the body can be detected.
- - Before the bodies leave the trim-shop some minor mechanical units are added and transferred to the ‘body drop’.

Automotive Aerodynamics & Body Engineering

Unit IV

Body Terminology, Visibility & Space

Body Engineering Terminology



Tailfin

- The tailfin era of automobile styling encompassed the 1950s and 1960s, peaking between 1957 and 1960. It was a style that spread worldwide, as car designers picked up styling trends from the US automobile industry where it was the *golden epoch* of American auto design

The center console in an automobile refers to the control-bearing surfaces in the center of the front of the vehicle interior. The term is applied to the area beginning in the dashboard and continuing beneath it, and often merging with the transmission tunnel which runs between the front driver's and passenger's seats of many vehicles

Fascia

Fascia often refers to the decorative panels of a car's dashboard or the entire dashboard assembly

Fender skirts

Fender skirts, known in Australia and the United Kingdom as spats, are pieces of bodywork on the fender that cover the upper portions of the rear tires of an automobile

Glove compartment

A glove compartment or glovebox or glovie is a compartment built into the dashboard, located over the front-seat passenger's footwell in an automobile often used for miscellaneous storage

Greenhouse

The greenhouse (or glasshouse) of a car comprises the windshield rear and side windows, the pillars separating them (designated A-pillar, B-pillar and so on, starting from the car's front), and the car's roof

Hood scoop

A bonnet/hood scoop, sometimes called bonnet airdam /air dam, or colloquially speed hole, is an upraised component on the hood of an automobile that either allows a flow of air to directly enter the engine compartment, or appears to do so

Nerf bar

A nerf bar is a tubular device fitted to the side of a racecar, typically single-seat race cars that compete on asphalt or dirt oval tracks. A "nerf" is a small, sometimes intentional, collision between two cars in which one driver bumps the other to facilitate a successful pass. The nerf bar protects the sides of the vehicles and also keeps their tires from becoming entangled

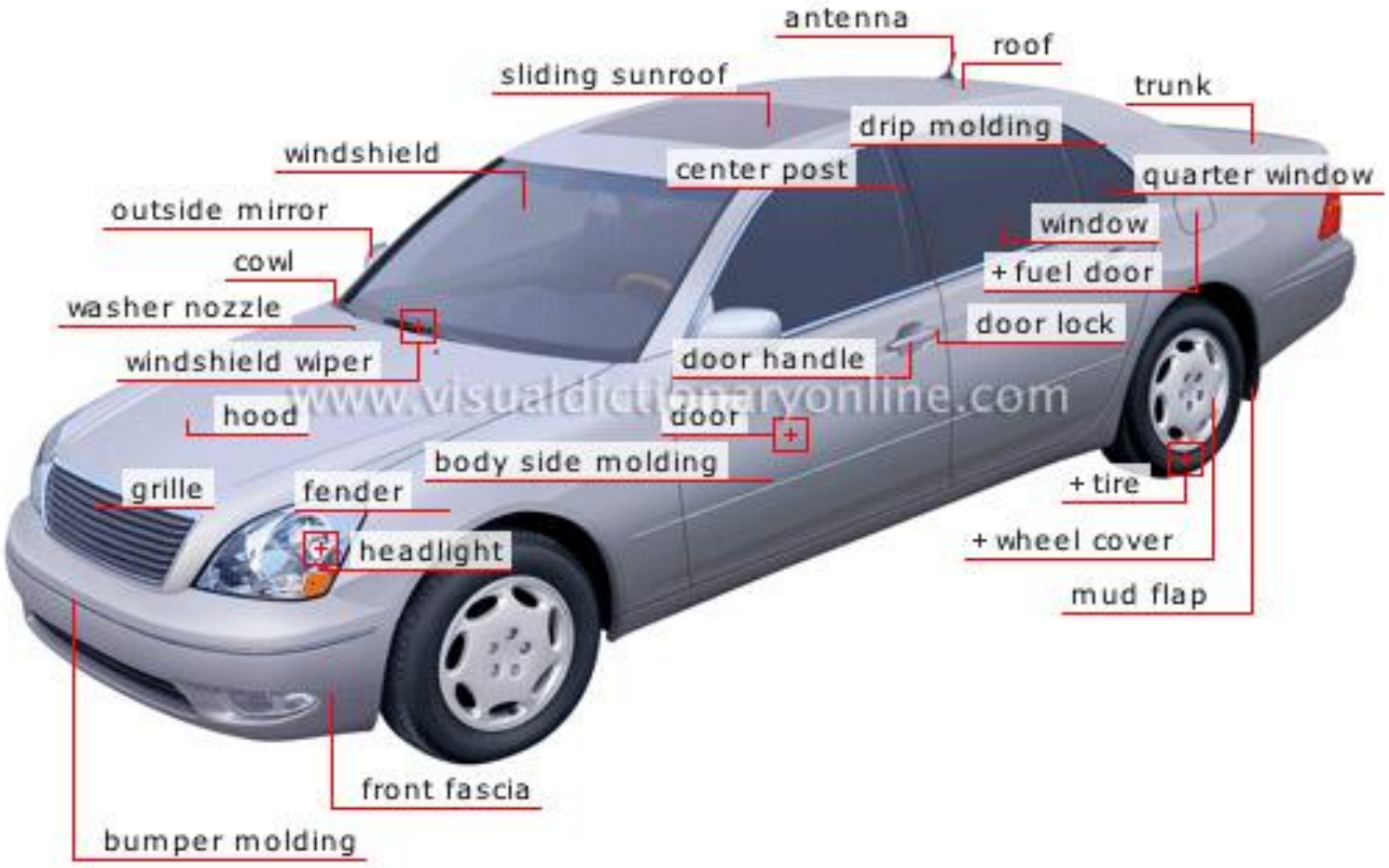
Power bulge

A power bulge is a raised part (a bulge) of the hood of a car. The reason for a power bulge is to fit for instance a large engine or air filters that otherwise would not fit. Sometimes a power bulge is used to be able to fit a larger engine into a car that originally was not designed for it or it may be a design choice to be able to get a lower profile. As a power bulge is associated with performance cars it may also be used as a design element to give the impression of a fast car

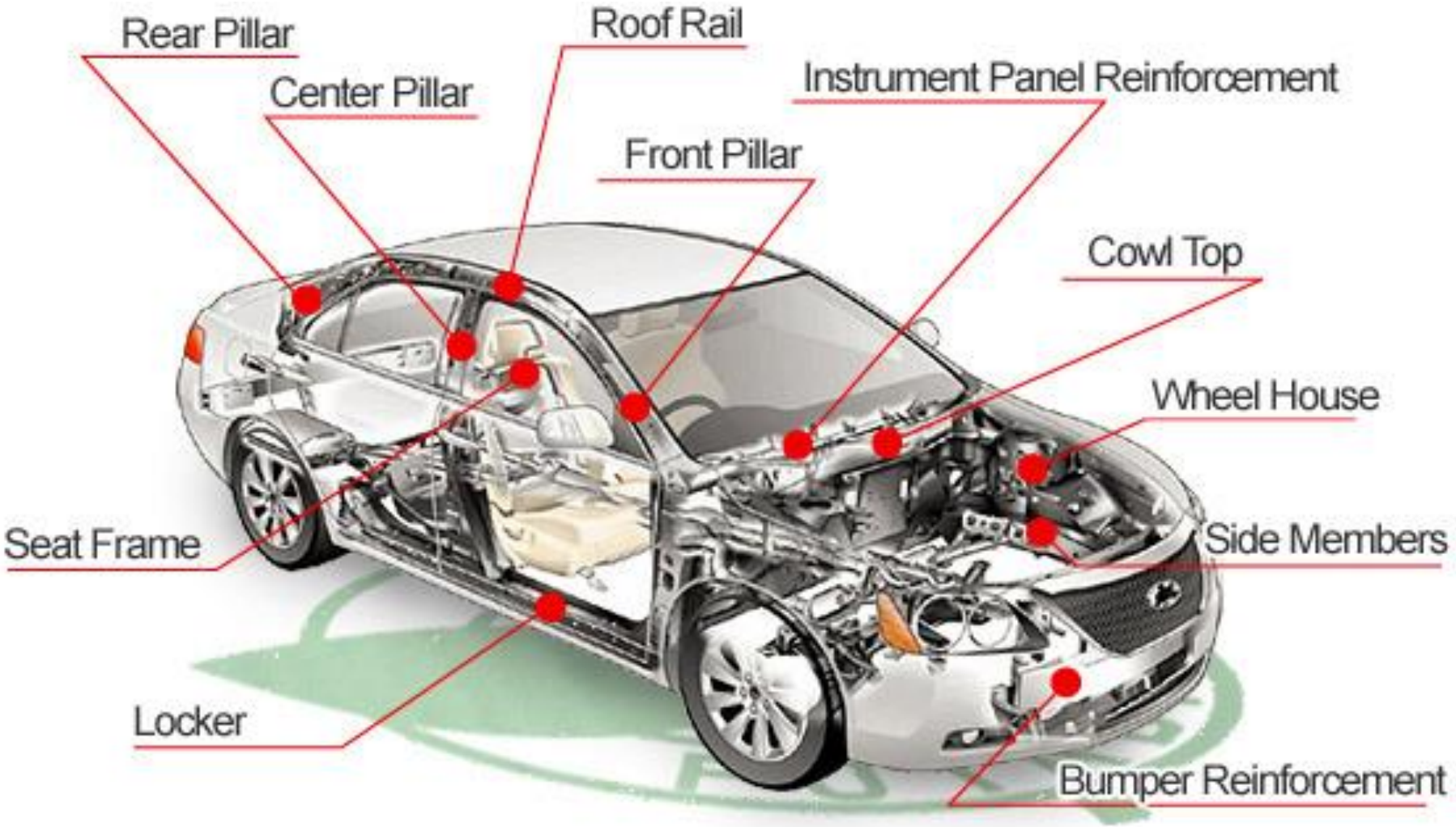
Quarter panel

A quarter panel is the body panel (exterior surface) of an automobile between a rear door (or only door on each side for two-door models and the trunk (boot) and typically wraps around the wheel well. The similar front section between the door and the hood (bonnet) , is called a fender but is sometimes incorrectly also referred to as a quarter panel. Quarter panels are typically made of sheet metal, but are sometimes made of fiberglass or fiber-reinforced plastic

Body Engineering Terminology

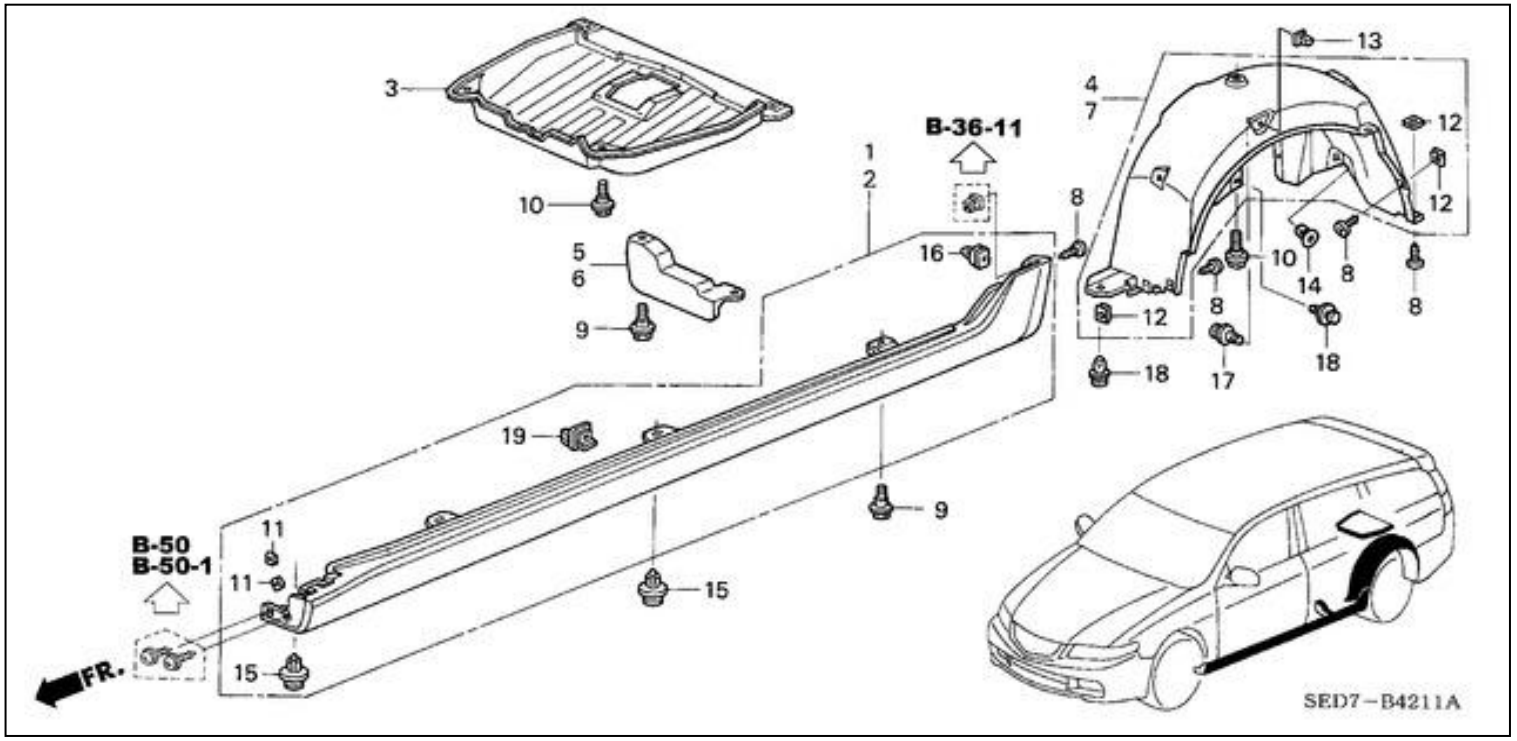


Body Engineering Terminology



Body Engineering Terminology

Body Sill : The panel (metal plate) directly below the bottom of doors supporting the floor and may be used to combine floor & body.



- Bonnet : The metal cover over the engine compartment

- Bulk Head : A transverse support or assembly in a body structure.

- Boot : A compartment which takes luggage and often the spare wheel & fuel tank

- Center Pillar : The central vertical support of a four door saloon, sometimes referred to as B-C post

Body Engineering Terminology

- Cant Rail : The longitudinal framing of the roof at the joint

- Cant Panel : The curved section of the roof top running between the comparatively flat top and the rain channel

- Door Skins : Door exterior panels/outside door panels

- Door Trim : The interior lining of a door

- Drip Moulding : A roof gutter to direct water from door openings

- Fire wall : Panel dividing engine compartment from passenger compartment

Body Engineering Terminology

- Head Lining : The material, cloth, PVS, etc.
- Heel Board : A vertical board or panel rear seat which forms the support for the seat cushion
- Hinge Pillar : A pillar on which the door swing open or close
- Pillar : A vertical support of a body frame
- Quarter Panel : The curved side panels extending from the door to the rear end of the body including the wing or the curved panels which connect the side panels, including the rear wing

Body Engineering Terminology

Body Engineering Terminology

- - Quarter light : The window directly above quarter panel
- - Scuttle Panel: The panel between bonnet & windscreen
- Sub- frame : Members to which the engine & front-end assembly are attached
- - Tunnel : A raised floor panel section for drive shaft clearance
- - Wheel arch : A break in the rear panels to accommodate the rear mudguards and wheels
- - BBC : Abbreviation for the distance from the bumper to the back of cab

Body Engineering Terminology

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Body Engineering Terminology

- - Bearers : The cross- members that support the body floor. They are located on either chassis member or longitudes
- - Bulker : A general term for vehicles carrying liquid and powder
- - Cab : The part of a vehicle enclosing the driver
- - Cant rail : The member which connects the side panels of vans to the roof structure

Body Engineering Terminology

- - Cleat : Bracket used for joining longitudinal transverse body members
- - COE : Abbreviation for “cab over engine”
- - CV : Abbreviation for “commercial vehicle”
- - Drop side panels : Hinged panels which are fitted to the sides of platform bodies
- - GRP : Abbreviation of glass reinforced plastic used for vehicle roofs and vehicle cab
- - GVW : Gross Vehicle Weight is total weight of vehicle
- - Longitudes : The main longitudinal members of a body which normally rest upon the chassis

Body Engineering Terminology

- Overhang : The dimension from the center-line of the rear axle to the rear of the body
- Pay load : The difference between gross vehicle weight and unladen weight , that is carrying weight of vehicle
- Rave : Often referred to as bottom rail, this is the longitudinal section which mates with the outer extremities of the floor & bearers and in case of vans, connects with the side panel
- Rub rail : A longitudinal section fitted to van sides in order to minimize damage to side sheets

Requirements of Automobile Body

- A frameless type body of an Automobile must satisfy requirements in terms of :
  - Strength
  - Stiffness
  - Space
  - Air Drag
  - Protection against weather
  - Resistance to Corrosion
  - Protection in accident

Body Engineering Terminology

Strength : Body must withstand all types of forces to which vehicle is subjected to ;

- - weight of the vehicle, passenger, luggage
- - inertia, braking, & side forces
- - impact loads of reasonable magnitude

Stiffness : Body may be considered as a beam supported on wheels at each end. It must possess sufficient stiffness to prevent sagging in the middle.

Torsional Stiffness : Body should be sufficiently rigid to resist twisting on bad roads.

Space : Adequate space to be provided in the body for passenger and luggage.

Body Engineering Terminology

Air drag : Resistance of air during vehicle movement depends upon body shape. The shape of the body should be such that the air drag is minimum

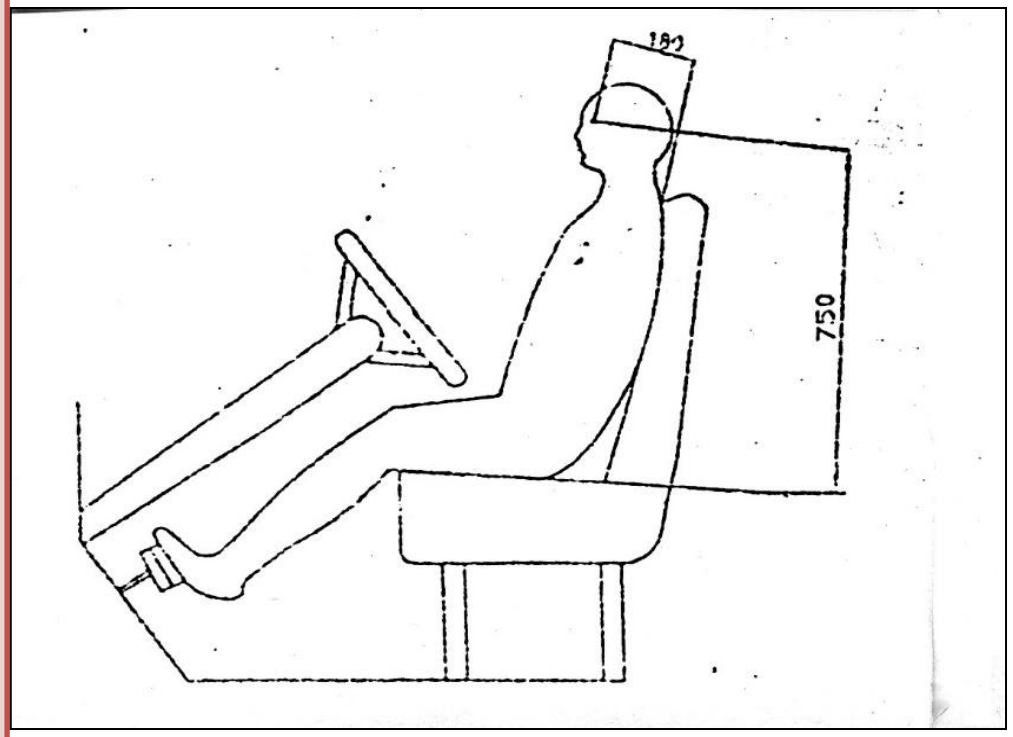
Protection against weather : Body should be such that the occupants and luggage not affected from weather.

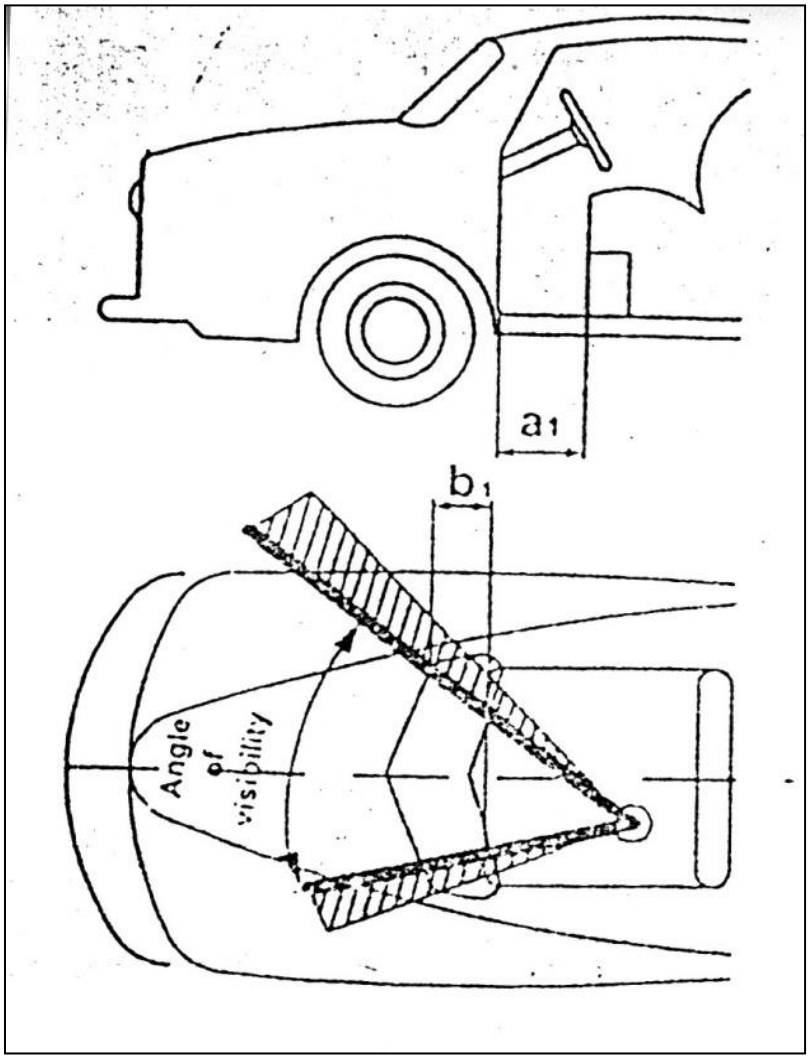
Resistance to Corrosion : Body should be designed such that no moisture is accumulated and material should be such that rust & corrosion does not take place.

Protection in accident : It is an important consideration of vehicle body design. Driver must be at maximum ease to avoid accident due to fatigue. However, body should be designed such that the occupants are best protected even in case of accident

Visibility

- Good all round visibility is one of the main requirements of body design
- Visibility depends upon the window opening and their relative position to the occupants
- Figures below show eye position of driver, angle of visibility & space between the pillar and seat





1x2z

Improvement in Frontal visibility

Visibility

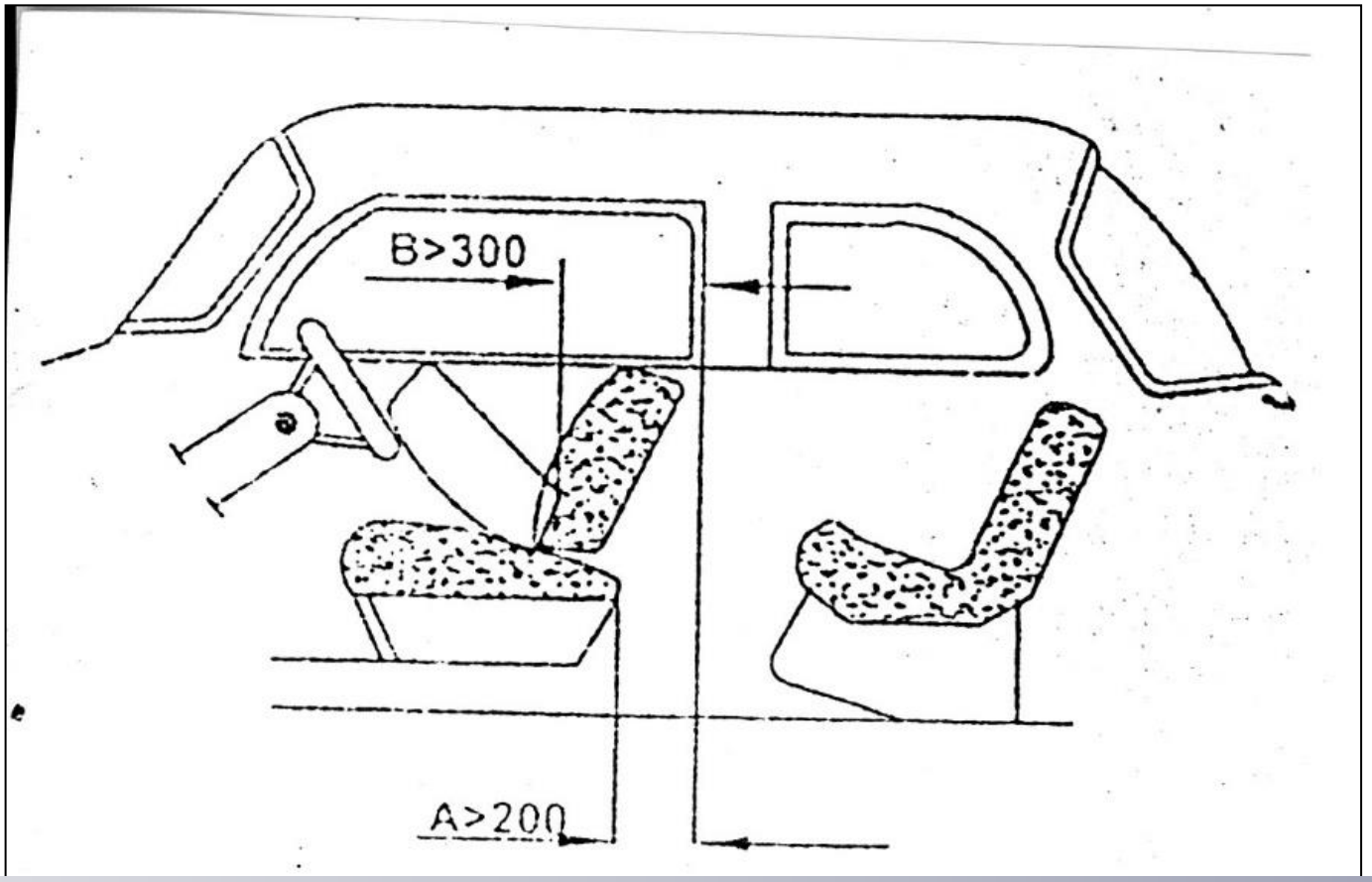
- Types of Visibility
- - If occupant is placed close to windscreen the forward visibility is considerably improved but comfortable entry is adversely affected as dimension between pillar & seat is decreased requiring suitable shaping of the door, if possible.
- - Downward visibility can be improved by positioning the driver as high as possible in relation to the lower edge of windscreen.
- - Rearward visibility is achieved by increase in glass area required to maintain rear view vertical angle with back window

Space Requirements & Methods of its Improvements

- Amount of space has to be allocated to passenger needs according to dimension & type of body
- Space for access to fuel tank, spare wheel, batteries, tools, boot, and spare wheel placing, etc. depend upon dimension & type of body and the inventiveness of the designer.
- Window opening should ensure good visibility without affecting stiffness of the body shell.
- Main requirement of door opening is the comfort of entry
- In two door design passage way to back seat should be ensured

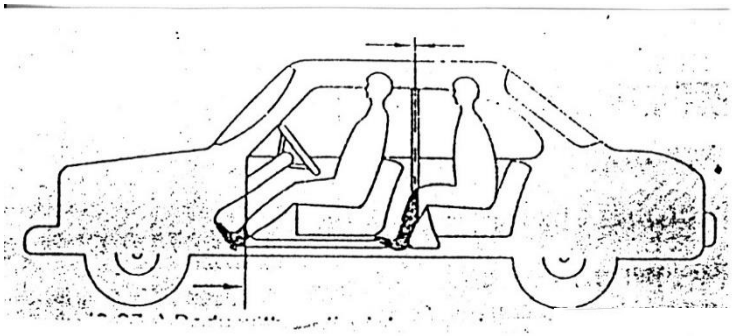
Space Requirements & Methods of its Improvements

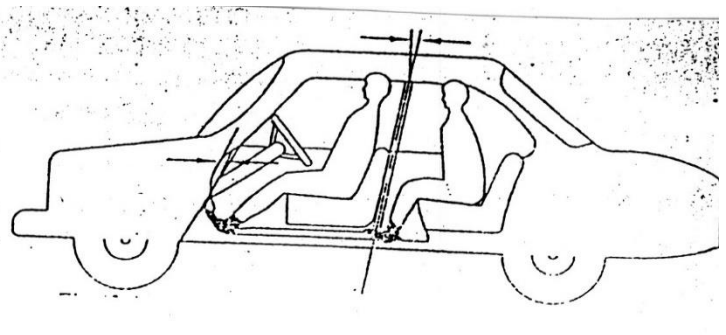
Measurement of comfortable passage way is shown in figure.

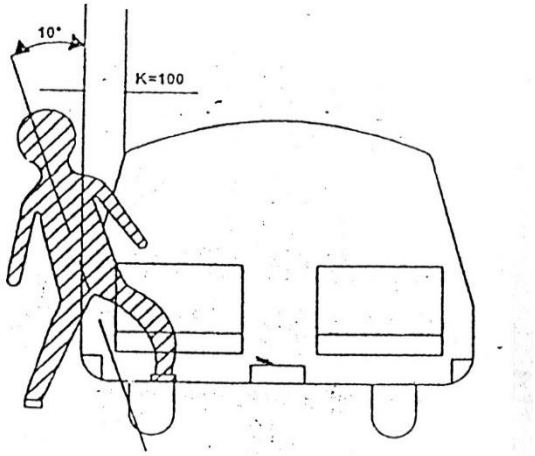


Space Requirements & Methods of its Improvements

- **Avoid pockets for the feet by sloping the door post & side walls as shown.**







Space Requirements & Methods of its Improvements

- **Considerable experience in design is needed to position the compartments in a planned outline of the body.**
- **Good utilization of space is particularly significant for small vehicles and in general makes the vehicle lighter resulting in improved power-to-weight ratio. This reduces cost of vehicle also.**

Automotive Aerodynamics & Body Engineering

Unit IV

Design Considerations & Body Construction

Morphology of Vehicle Body (Structural) Design

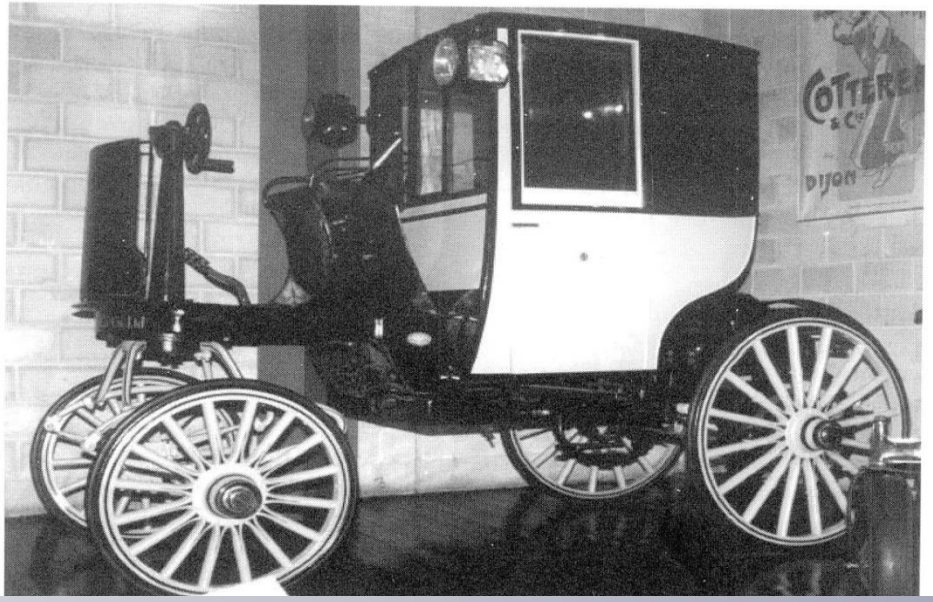
- Emancipation of the Body Designer
  - - A wide range of skills required for vehicle design and manufacture
  - - Development of motor vehicle may require following group of activities;
    - Technical innovation and refinement
    - Construction and configuration by Designing & Styling
    - Methods of production, and manufacturing systems

Morphology of Vehicle Body (Structural) Design

- Technical innovation and refinement
  - - Innovative developments have often been the work of several different engineers working in parallel but independently
- - Many apparently new inventions are adaptations from different technologies, e.g.,
- *differential mechanism used by watchmakers, aerospace, electronics, materials,etc.*

Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
  - Methods of production and manufacturing systems in early times were adaptations from horse-drawn carriage construction methods for upper body works.

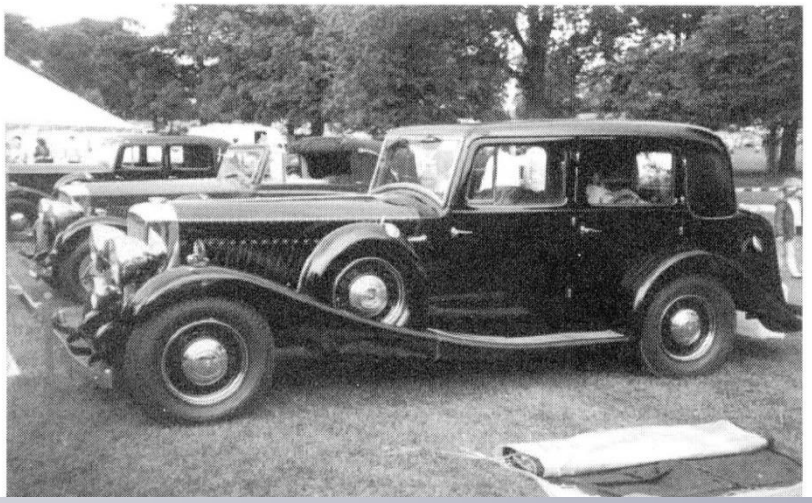


Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
  - Above a wooden chassis, sat a light wooden framework covered with a skin of sheet metal, wood or fabric.
  - As motor vehicles had to sustain loads and vibrations of engine, transmission and of vehicle dynamics at higher speeds (higher shock loads) the metal chassis frame were quickly adopted

Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
  - A combination of steel chassis, wooden framework and sheet metal skinning were used for most vehicle with aluminum often used in more expensive and higher performance vehicles



Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
  - A few fabric and wooden bodied vehicles were still produced as late as 1930s by specialist coach builders mainly because the antiquated style conveyed an air of past elegance.
  - Subsequently increasing use of pressed – steel skin panels in place of flat sheets or hand beaten or wheeled panels followed.

Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
- Sheets of steel were pressed in moulds to produce complex shapes with multiple curvature and the process enabling economic production bulbous styling forms, that became popular, took over

Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
  - Multiple curvature also made panels much stiffer and the skin could take a significant part of load.
  - Some manufacturers began to dispense with wooden frames and use metal frame or even no frame work at all, relying on panels & formed sheet metal stiffening elements to provide all rigidity necessary for upper body

Morphology of Vehicle Body (Structural) Design

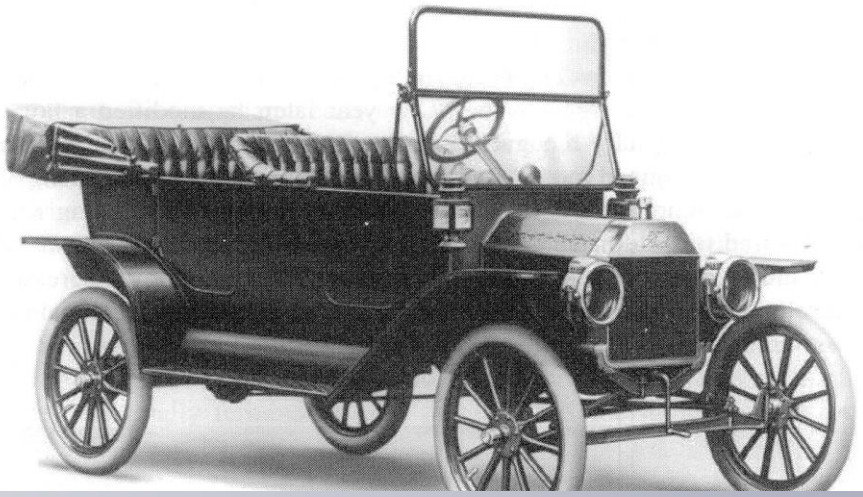
- Construction and configuration by Designing & Styling
- Lower chassis frames initially retained but separate chassis began to disappear, being replaced by a stiff floor 'pan' that was fabricated from welded shaped sheet elements.
- By 1950s 'unitary' type of construction was almost universally adopted for mass-produced cars.
- Recently, the shell construction has been refined to produce smooth aerodynamically shape with minimum protrusions or gaps.

Morphology of Vehicle Body (Structural) Design

- Construction and configuration by Designing & Styling
- Composite construction in fiberglass and resin was developed soon after the war

Mass Production - Designing & Styling

- Two giants of vehicle manufacture following World War I were Ford and General Motors
- Initially Ford were predominant with standardized Model-T car & van



Mass Production - Designing & Styling

- Ford fathered mass production and design standardization.
- GM in addition recognized another strong force in the market place: customers personal preference
  - - sectorized market & designed accordingly
  - - offer proliferation of body shapes & colours
  - - in mid 20s GM gave birth to ' Stylist'
- GM was outselling Ford. Serious business of body design took its place amongst industry professionals.
- A stylist would 'package' occupants and luggage around a fairly standardized layout of engine and drive train.

Design Considerations

- Task Assignment
- General layout
- Artistic utilitarian design
- Dummies & models
- Preliminary design
- Body weight, stress, geometric analysis, etc.
- Master model and mathematical models
- Scanning of master model with electronic sensors and compilation of data
- Scanned data integration and analysis with the help of

Design Considerations

- computers to generate geometrically perfect surfaces & reproduction of tapes
- Tapes are used by numerically controlled machines (e.g. milling) to prepare high precision dies
- These dies are used by Power Presses to produce the Pressed Metal Panels which are welded together to construct the structures and body of the vehicle

Design Considerations

- **Task assignment :**
- **- The task of designing of vehicle is broken down into various components ;**
- ***Body / Chassis / Engine / Transmission***
- **- Consider components need to be designed and the components to be used as standard items, e.g, transmission system.**
- **- Consider ergonomics of seating &controls, legal requirements of body, engine, etc. field of vision, aerodynamics, etc.**

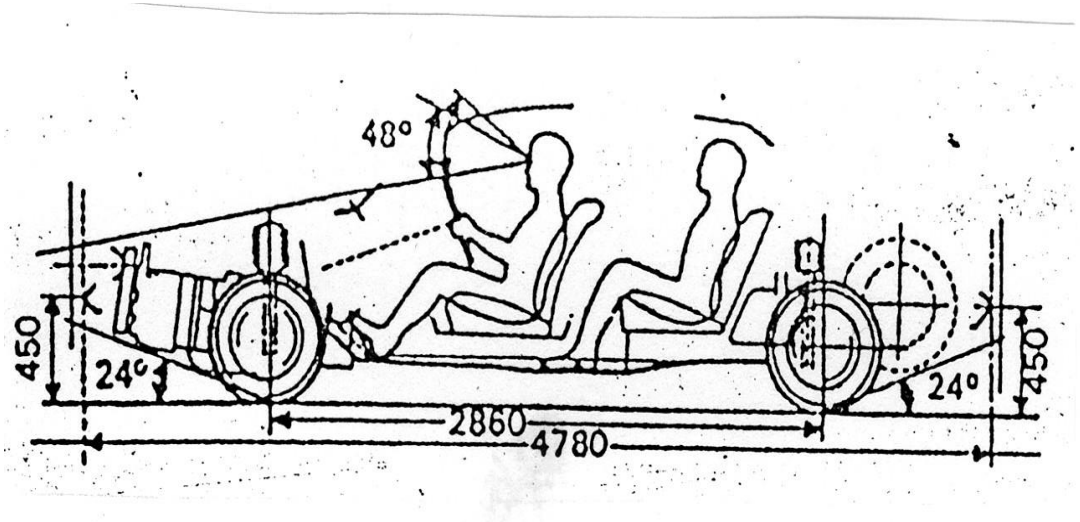
Design Considerations

- General layout :
  - - Designer in consultation with Stylist prepares perspective drawings & sketches
  - - Construct suitable models or mock-ups and initial design drawings
  - - Carryout structural analysis on body design and compare new design with existing designs to ensure
  - some advances made
  - - Finalize basic dimensions, often called ‘ package of the vehicle ‘ and include overall dimensions as per legal requirements

Design Considerations

General layout :

- As per above the external dimensions, wheel-base, etc. are decided and a general layout is prepared as shown :



Design Considerations

- Artistic Utilitarian Design :
- - Aesthetically pleasing body shape is set out considering aerodynamics and other design requirements
- - The design of a shape based on the elements of functions and logic together with an artistic appreciation of forms is called “ artistic utilitarian design “. Such designs have advantage over irrational styling and is a necessary part of good design.

Design Considerations

- **Dummies & Models :**
  - **- The dimensionally complicated form of vehicle bodies require practical checking at all stages of design. These are carried out by means of dummies and models**
- **Dummies :**
  - **- Dummies are built to ensure that the principal dimensions are compatible. This includes dimensions of driver's position, passenger's seat, size of door & window openings, etc.**

Design Considerations

- **Dummies & Models :**
  - **- A full scale dummy allows for complete reproduction of the drawing dimensions and thus check for comfort, visibility, ease of exit & entry, position of steering wheels, chassis - engine mechanisms, layout of dashboard, etc.**
  - **- Dummies are usually constructed in timber and / or other synthetic materials which are easy for manual working.**
  - **- Apart from checking dimensions of the body the position of components can be determined using**

Design Considerations

- Dummies & Models :
  - chassis & engine either real or their dummies
  - Models :
  - - Inside dimensions of a vehicle body, having being checked & finalized with dummies, form the basis for developing models of the outside surfaces of the body.
  - - Scale models (say 1 in 20) are constructed using materials like plasticine or plaster of paris laid on a wooden base with tools such as knives & spatulas, etc. Some scribing devices are used as measuring

Design Considerations

- Models :
  - the principal sections (called outlines) are transferred onto the model using templates.
  - - A few variants of a model with corrected basic sections of the design are considered for finally choosing the model for obtaining templates for larger scale models (say 1 in 5) such that it represents vehicle in details as far as possible. Such a model is called a “ reduced model “
  - - the principal dimensions of the vehicle are determined by the development of such models and

Design Considerations

- **Models :**
  - **and dummies, and the first outlines of the drawings can be made without details.**

Material Requirements and Body Parts

- Steel Sheets used for making Car Bodies :
  - - Low tensile strength and high ductility for ease of forming
  - - Easily assembled to form a body unit
  - - Light in weight
  - - Low cost
- A Typical Low-Carbon Steel Composition
  - Carbon - 0.080 % Phosphorus - 0.020 %
  - Silicon - 0.002 % Manganese - 0.350 %
  - Sulfur - 0.020 %

Material Requirements and Body Parts

- The liquid steel is cast into large ingots for subsequent hot - rolling to sheets of different thickness. Typical sheet thickness & their use are :
  - 10g 3.25mm brackets & supports and heavy
- 12g 2.65mm internal construction
  - 14g 2.03mm panel assemblies which take
- 16g 1.63mm stresses & loads (floor bulk head,
- 18g 1.22mm sills, sub-frames, cross-members
- and inner stress panels)

Material Requirements and Body Parts

- 20g 0.95mm outer panel construction (skin
- 22g 0.71mm panels, doors, bonnet, boot, lid,wing panels)

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
  - - The requirements of Fuel Economy & Environment has demanded Vehicle Body weight reductions.
  - - Aluminum has been considered strong alter native to steel in order to achieve weight reduction. However, the magnitude of weight reduction has to be attractive despite its higher cost.
  - - Generally, Aluminum has been found better in castings for housing, engine blocks, etc resulted in savings in weight & costs

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
  - - The compelling demand for change in material
- properties has been the need for reduced weight
  - - To meet such demand a new generation improved
- high-strength steels has been developed that offer :
- I) sufficient ductility to meet fabrication requirements
- ii) meets the minimum yield strength requirements
  - iii) improved conductivity & weldability

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
  - - Comparison of Relative Material Properties of Aluminum (Base Steel = 1)
  - I) Tensile Strength 1/3
  - ii) ductility 1/2
- iii) density 1/3
  - iv) elastic modulus 3

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
  - - Considerations for Competitiveness
- For tensile strength limited applications replacement of steel by aluminum requires a cross-section that is
- three times greater which makes it approximately equal in weight for equivalent modulus of elasticity. Overall it means three times the cost.

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
- Factors for material selection for Car Body Pressings
  - - Yield strength
  - - failure strength
  - - formability
  - - indentation resistance
  - - fabricability
  - - painting systems / requirements
- - Welding
  - - Heat - Treatment

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
- Some Comments / Observations
  - - Most automotive components are not loaded in pure tension, but where simple tensile properties are the design criteria, a steel with higher yield strength is capable of saving about 40% of weight and may be comparable .
  - - Functional requirements vary from simple bending or indentation resistance to complex twisting and structural loading of components. By changing to higher-strength steel, appreciable weight reductions

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
- Some Comments / Observations
  - can be obtained. The type of improvements generally achieved by increasing the product strength can be as high as 30%.
  - - Welding : Aluminum parts require increased thickness (1.4 times) and larger dia. Electrodes for welding & greater edge distances for equivalent weld-bond strength. Disparity increases as thickness increases. At about 2.2mm steel provides 2 times strength advantage

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
- Some Comments / Observations
  - Welding :
  - - In order to improve inherent lack of spot weldability of aluminum sheets the adhesive bonding & welding may be used to achieve satisfactory strength. This may have additional cost implications.
  - - Oxide coating of aluminum vary significantly and cause production of unacceptable welds

Material Requirements and Body Parts

- Comparison between Steel & Aluminum
- Some Comments / Observations
  - In summary, steel has many inherent advantages over aluminum for applications in pressings however, aluminum has advantage in castings for housings, engine blocks, etc.

Automotive Aerodynamics & Body Engineering

Unit IV

Vehicle Body Engineering
Body & Safety Considerations

Introduction

- Designer should ensure maximum safety of the driver, passenger, and other road users
- Vehicle should be designed to reduce the effects of collision and ensure minimum injury
- Stylists should avoid sharp ornaments, edges and projected elements. Careful attention to door handles, mirrors, hooks, control knobs,etc. reduces injury to pedestrians and also affects in reduction of aerodynamic drag & noise.

Body & Safety Considerations

Safety Features Of Vehicles can be grouped as :

- Vehicle Body Structure, its Systems & Parts
- Additional Safety Features & Systems
- General & other safety recommendations

Safety Features Of Vehicles :

- Vehicle Body Structure, its Systems & Parts
  - Basis of body design for safety
  - Safety features of Door system
  - Window Glasses & Windscreen
  - Bumpers
  - Seat back & head restraints
  - Rear view mirrors
  - Ventilation

Vehicle Body Structure, its Systems & Parts

- Basis of body design for safety
  - - The design of vehicle body for optimum characteristics should be based on basic energy relationship
  - - The kinetic energy of a vehicle destroyed during a collision is absorbed by the workdone on materials by elastic deformation

Basis of body design for safety

- The kinetic energy of a vehicle destroyed during
- a collision can be expressed as
  - $K.E = (m - \nabla m) V^2 / 2$
- where ;
- m = total mass of vehicle
- ∇m = moveable mass(passenger or load)
- V = Velocity

Body & Safety Considerations

Workdone on materials by elastic deformation is

$\int Pds = (\sigma^2 / 2E)\ A\ L$

where; P = force generated during collusion on

vehicle structure

S = distance traveled during the collision

E = Young's modulus, Stress/Strain

A = cross sectional area of the structure

σ = local stress in the material

L = deformation in cm

Vehicle Body Structure, its Systems & Parts

- Safety Features of Door System
  - - Photo - electric beam door closes automatically at pre - determined time
  - - Gear shift lock prevent selection of gear until all exit doors are closed
  - - Electrically sensitive edge on exist door causes automatic opening if obstruction is encountered
  - - Pneumatic - sensitive - edges give audible and visual warning to the driver of door obstruction

Vehicle Body Structure, its Systems & Parts

- **Safety Features of Door System**
  - **- Transmission interlock prevent opening of doors whilst vehicle is in motion**
- **Window Glasses**
  - **- Shatter proof glass should be used. When hit against any object the whole glass falls out and there will be no sharp edged pieces**

Vehicle Body Structure, its Systems & Parts

- **Window Glasses**
  - **- In bullet proof glass when hit there will be no normal angle of incident (inclination). The bullet is thrown out as there will always be some angle of incident.**
- **Reliability / Safety Requirements Windscreen**
  - **- Freedom from faults which interfere with vision**

Vehicle Body Structure, its Systems & Parts

- Reliability / Safety Requirements Windscreen
  - - High transparency & freedom from visual distortion
  - - External durability to reduce surface degradation & scoring from wipers, ice scrapers, road grit, etc.
  - - Vision not affected by normal road stone impacts

Vehicle Body Structure, its Systems & Parts

- Reliability / Safety Requirements Windscreen
  - - Retention of impacting occupant with low
- deceleration to avoid brain damage
  - - Fragment formation should not expose the
- face & head to risk of severe laceration.
  - Bumper
  - - Shock absorbers behind the bumpers may be used. In some designs semi - circular

Vehicle Body Structure, its Systems & Parts

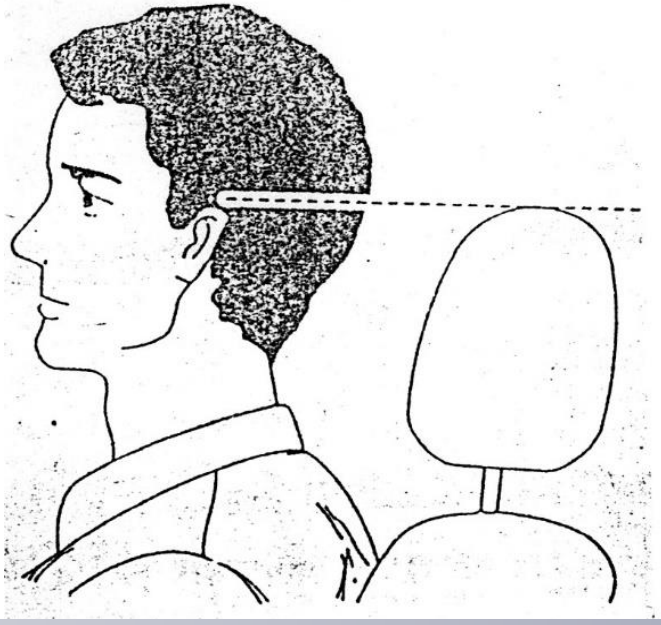
- **Bumper shape is adapted. This avoids direct collision and tilt of the vehicle.**
- **- Bumper design & height should be such that in case of accident it hits passenger below the knee. In this case the passenger will fall on to the vehicle otherwise on road which would be more dangerous.**

Vehicle Body Structure, its Systems & Parts

- Seat - Back & Head Restraints
- - Seat-backs should be in an upright position to get maximum protection from the seat belts
- - In reclined seat-back position the risk of sliding under the seat belt increases in a severe crash.
- - The front head restraints help from whiplash and other injures.

Vehicle Body Structure, its Systems & Parts

- Seat - Back & Head Restraints
- - For most effectiveness, the Head Restraint should be adjusted such that the top of the restraint is even with the top of the ears as shown



Vehicle Body Structure, its Systems & Parts

- Ventilation
- - Proper air vents directed towards the windscreen, side windows,passenger compartment, front and rear passenger foot walls should be provided.
- Rear View Mirror
- - Inside rear view mirror can be adjusted up, down or sideways to obtain the best view. Always adjust the mirror set to day positions

Vehicle Body Structure, its Systems & Parts

- Rear View Mirror
- - Outside rear view mirror can be folded flat against the side of the vehicle and can be inclined at an angle to position it properly. The size or distance of a vehicle or object seen in an outside convex mirror look smaller and appear farther away as compared to a flat mirror.

Body & Safety Considerations

Safety Features Of Vehicles can be grouped as :

- **Additional Safety Features & Systems**
  - **ABS braking system**
  - **Seat belts**
  - **Air bags**
  - **Flashers & horns**
  - **Child safety**

Additional Safety Features & Systems

- ABS braking system
- - The ABS braking system prevents the wheels from locking when braking
- - It makes the best road grip and provides safest control during emergency braking under difficult road conditions.
- - The driver can feel as ABS comes into play when the brake pedal pulsates slightly and the system gets noisier.

Additional Safety Features & Systems

- ABS braking system
- - This indicates that the ABS is working and vehicle is travelling at the limit of the road grip, and the vehicle speed should be changed to fit the type of road surface.
- - The ABS is in addition, if failure occurs the basic braking system continue to work.
- - The advantage of the system is to give maximum maneuverability by preventing the

Additional Safety Features & Systems

- **ABS braking system**
- **the wheels from locking.**
- **- The light on the dash board warns driver to reduce speed.**

Additional Safety Features & Systems

- **Seat Belts**
- **- Need & Requirements : Inside a moving car, if car suddenly stops, the occupant get hurled forward as the car has decelerated or stopped due to impact but occupant keep moving at about same speed as the car at the time of impact. So the body, particularly the head & chest smash into whatever is in front;windscreen,dash board, steering wheel**

Additional Safety Features & Systems

- Seat Belts
- Sometimes the occupant can be thrown out of the car through windscreen or opened door. It is not only the front seat passengers who are at risk but also the back seat passengers.
- *Seat Belts restrain occupant & holds back to the*
- *seat - preventing from hitting any hard structure in the car*

Additional Safety Features & Systems

- Seat Belts
- - Construction : Seat belt comprise of a lap band and shoulder band held in place by single buckle, and bolts fastened to the car body.
- - Types : Seat belts are of two types ; non-retracting and automatic-retraction. First type do not adjust to wearer's movement & not convenient. The second type allows to

Additional Safety Features & Systems

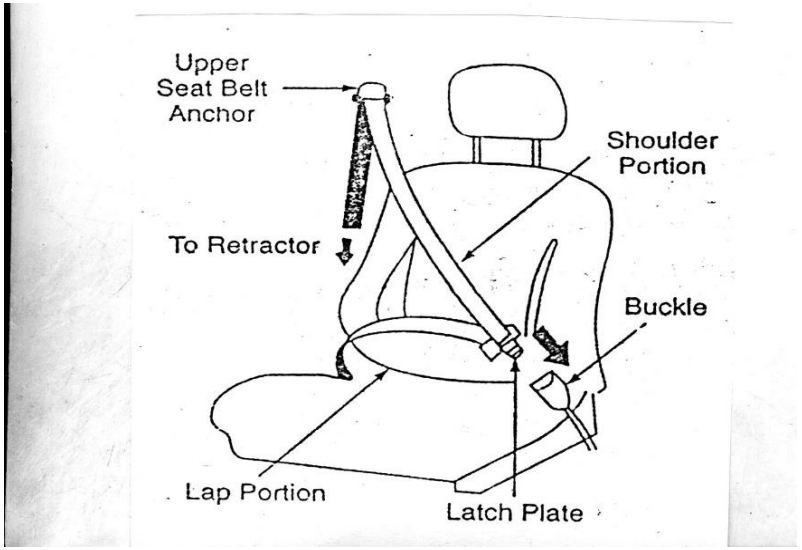
- Seat Belts
- move around freely. It has mechanism that restrains the occupant when car hits or stops suddenly.
- - Precautions to be observed : Seat belts are designed to bear upon the bony structure of the body, and should be worn low across the front of the pelvis, chest, and shoulders. Seat belts should be adjusted as firmly as

Additional Safety Features & Systems

- Seat Belts
- possible. Belt should not be worn with straps twisted. It is dangerous to put belt around a child being carried on the occupant's lap.
- Working of the Seat Belt System :
- - Lap/Shoulder Belt has a single belt that goes over the shoulder, across chest, and across pelvis as shown in figure.

Additional Safety Features & Systems

- **- In normal driving, the belt fitted with a locking retractor allows occupant move freely in the seat while keeps tension on the belt. During a collision or sudden stop the retractor automatically locks the belt to help**



restrain body.

- Before putting on the seat belt move seat as far back as possible,seat back to be up upright and there should be no twists in the belt.

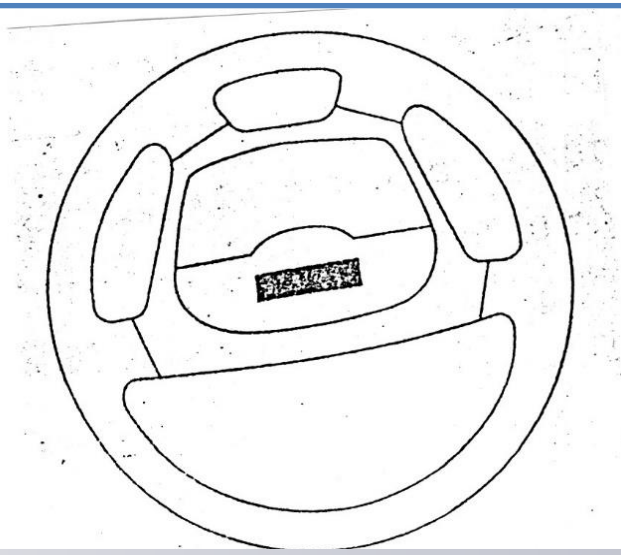
Air Bag

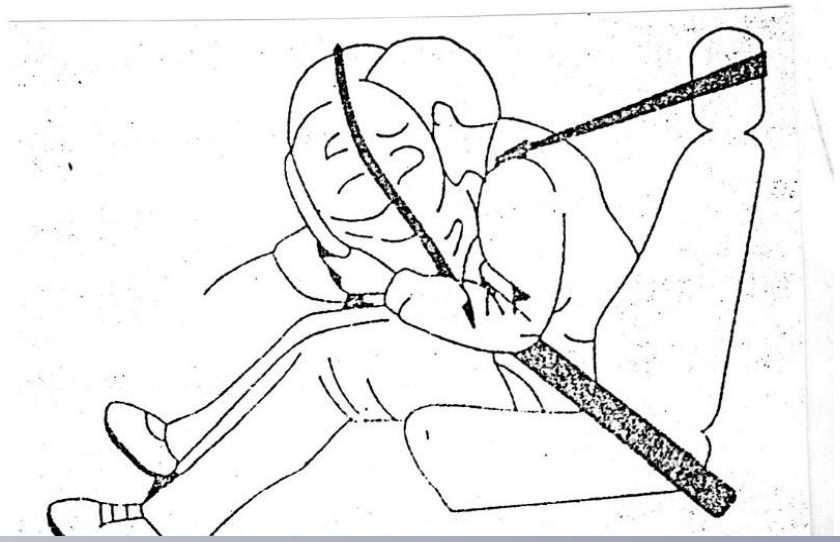
-Air bag is a safety device that protects the driver & the front seat passenger during head-on collision

- Air bag is an instantly inflatable cushion stored in the center pad of steering wheel and in the dash board on passenger side

Additional Safety Features & Systems

- - In case of a collision of magnitude exceeding the set value, the sensor activates the mechanism and cushion inflates instantly to act as a soft protecting
- barrier



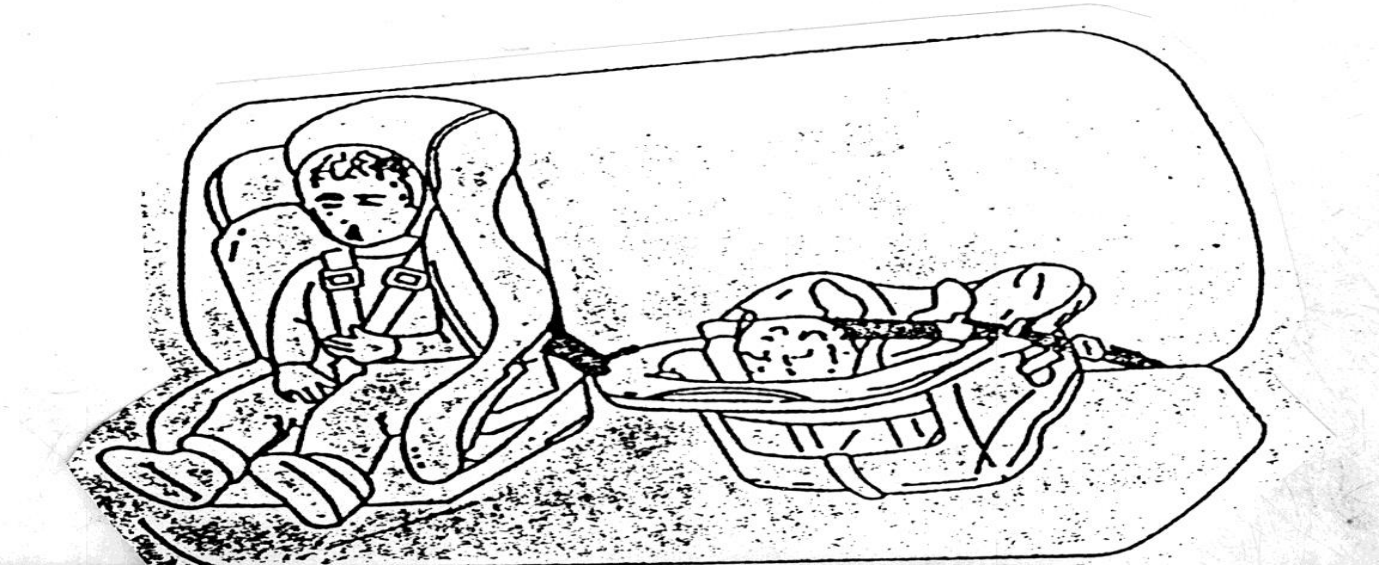


Additional Safety Features & Systems

- Hertomatic Flashers and Horn (beep noise)
- operate for every one minute, if not attended then ultimately the ignition will be automatically switched off.
- Child Safety
  - - Infants and young children should always be properly restrained whenever they ride in a car as shown

Additional Safety Features & Systems

- Children should ride in rear seat and not in lap of
- adults. Place the child restraint in the seat with a
- lap/ shoulder belt through the restraint (infants
- & toddler seat). Use child proof door locks



General & other safety recommendations

- There should be no loose items inside vehicle which could be thrown around and may hurt during accident or sudden braking / stops
- Luggage should be securely stored or tied downed
- Seats should be upright, head restrain adjusted, & seat belts fastened
- Vehicle operation control should not be obstructed
- First-Aid kits should be available

General & other safety recommendations

- Driver should not be under the influence of alcohol or drugs
- Ensure all doors are properly closed
- Ensure buckling up of children and child constraint system is properly installed