Technical information

Chassis

Volvo 850 GLT

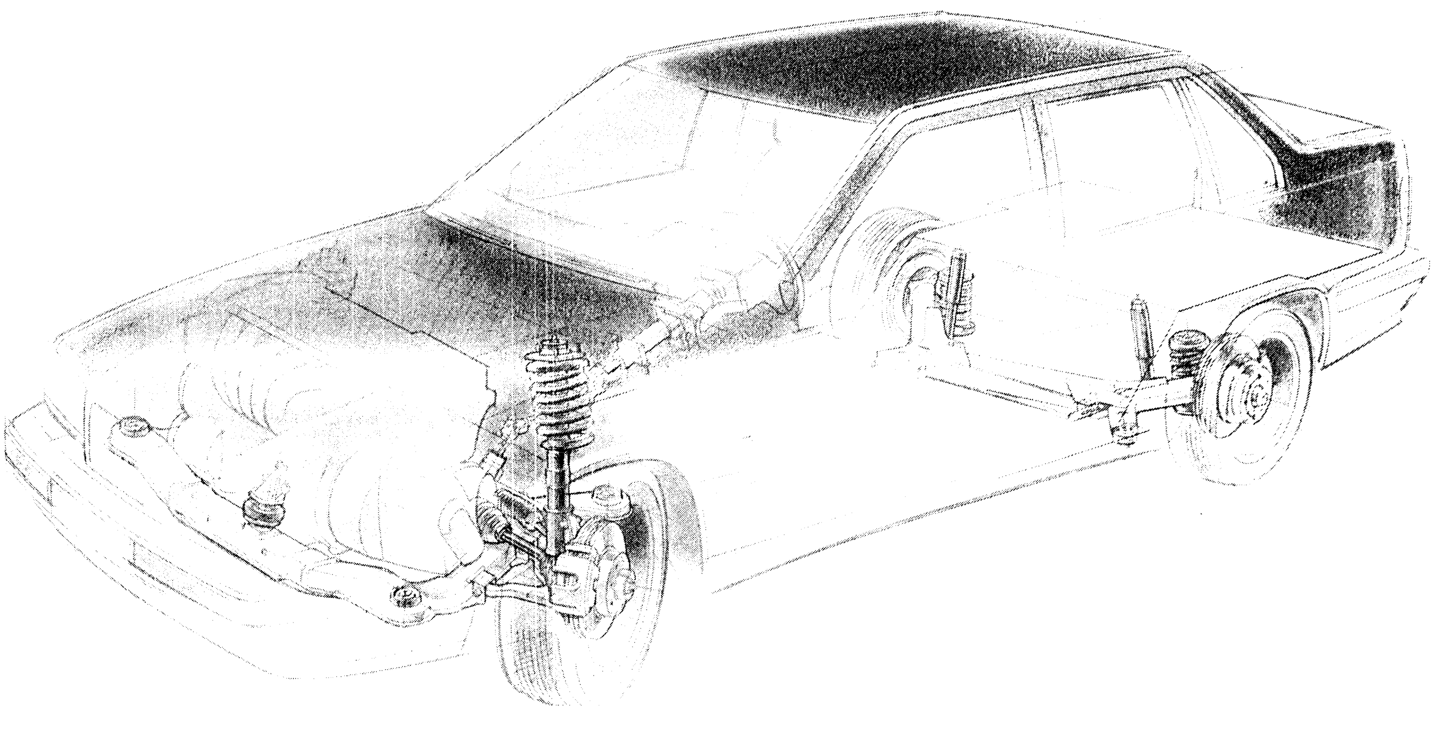
VOLVO

Introduction

The demands on the car of the 90's are very high in every respect. As vehicle manufacturer one can no longer concentrate only on a subset of all properties. To gain success, excellence is required in all areas.

Furthermore, the customer of the 90's will not accept having to adapt himself or herself to the vehicle. The vehicle must instead be adapted to man. This makes it necessary to study man-machine interactions when developing a new car.

These demands, coupled with the many properties affected by the chassis, create the need for a property oriented development process where the combination of all properties are taken into consideration from the very beginning.



Driver function

Driving a car is a complex task. However, by learning and practice most drivers achieve a competence that makes the driving appear and feel quite simple under normal conditions. During the learning process, as a beginner or under an adaptation period in the case of a new car, the driver gradually learns an automatic behaviour in the same way as when learning to walk. An analysis of factors affecting the driving task becomes very complicated. Figure 1 is one way of illustrating this for the example of steering.

Much effort is put into research of the human being as a car driver. Criterias for handling properties developed by Volvo and others, are used as a base for more or less comprehensive computer simulations in early stages of development.

It can be stated that feed back of car reactions, according to figure l, is of the utmost importance for the driver's ability to control the vehicle. The input to the driver come through vision, sound and balance organs, as well as through forces acting on the whole body supported by the seat. Also through the hands gripping the steering wheel. It is found from research that these signals have to be very close in time and that they have to be within certain values and have certain relationships. The more demanding the road and traffic environment, the more stringent these demands become.

Using clear feedback signals improves the driver's ability to act as an element in the control system. The driver will also feel clearly the im-. portant role he or she plays in this system and hence get a positive stimulance, maybe even satisfaction - driving pleasure.

The task of driving must be learnt. This means that the driver gets used to a certain response from his or her actions and will also be able to predict them. The leaning of the car's behaviour is effective under the most common circumstances. This means that the driver has good knowledge of how the car reacts when driving at moderate speed, at moderate manoeuvering and with small loads.

A surprisingly tight motorway exit during a holiday journey, with the car filled with people and luggage, may result in a very difficult situation if the response has changed too drastically. The tendency in such a situation is that the car is less stable and body roll will be more pronounced because of the heavier load. It will also be more sensitive to steering due to the higher speed. Put together, this can result in an unexpected and different response that may be very difficult for the driver to control.

Figure 2 illustrates the combination of circumstances in which different drivers normally have experience compared to the car's performance limits.

The conclusion of this driver oriented approach gives the following guide lines for the development of the chassis:

- **the control properties of the car must be adapted to the driver**
- **the control properties must be as consistent as possible**
- **the effects of load, speed and friction etc must be minimized**
- **the driver shall get a distinct feedback of the car's reactions in different situations and manoeuvres**
- **the magnitude of disturbances must be small**
- **the ride comfort and noise level as well as seating position must be good in order to avoid unnecessary driver fatigue.**

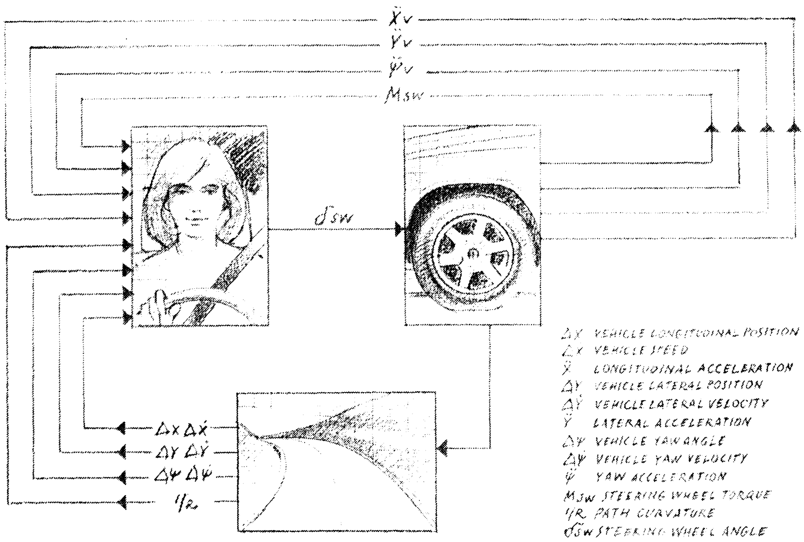


Figure 1

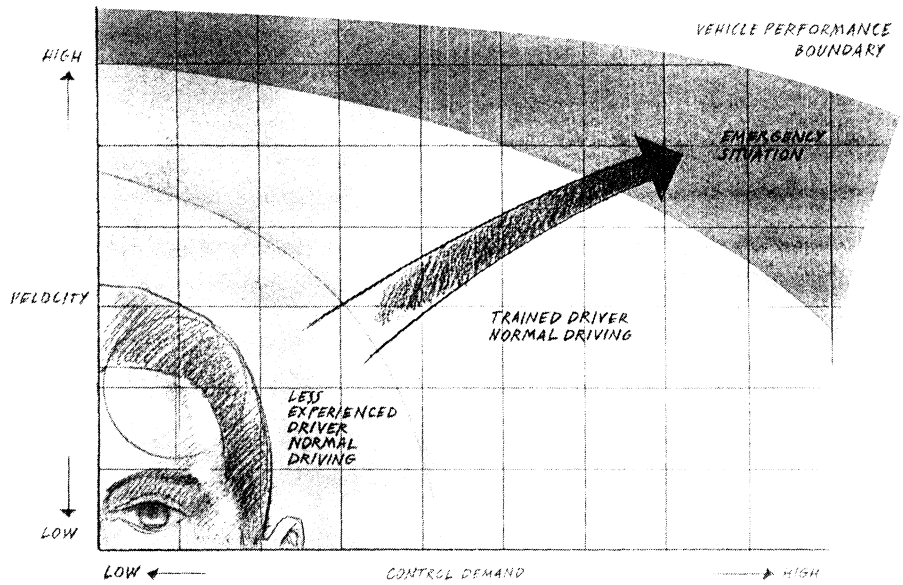


Figure 2

Chassis demands

The challenges that the chassis designer is confronted with when designing a new car do not only consist of requirements for certain chassis related properties, like in our case driving pleasure, driving safety, ride comfort and noise comfort, but also to a great extent of functional requirements within other areas.

For the Volvo 850, the main targets have been total efficiency and versatility. These properties have directly and indirectly influenced the choice of chassis concepts.

Versatility means the ability to transport a varying number of passengers and many different kinds of luggage in a safe and comfortable way, and in different environments: during high speed motorway driving, on slippery winter roads or in dense city traffic.

For the chassis, this means demands for loading capacity, consistent driving properties even on low friction surfaces, a small turning circle and low steering forces when parking.

The total efficiency can be divided in three main parts:

- space efficiency
- fuel efficiency
- cost efficiency

For the customer cost efficiency is not only decided by the purchasing price of the car but also by the running costs. These consist among other things of service cost and second hand value which in turn depend of the reliability of the car. Reliable and easily serviceable designs are therefore needed.

To meet the demand for space efficiency, the choice of front wheel drive is natural for a car of the Volvo 850's size. The space in the passenger compartment will be free of space otherwise occupied by prop shaft and final drive. In addition, by mounting the engine transversely, the longitudinal space of the car can be utilized optimally. A conflict arise here with the demands for a small turning circle and thereby wide wheel angles. When designing the suspension, attention must also be given to how much space will be required in the passenger and luggage compartments. Low positioned attachment points for the suspension is important and the axle geometry should be chosen in such a way that the need for wheel housing space is minimal.

The front wheel drive in itself has great influence on certain driving properties. Among the positive can be mentioned:

- improved traction during light load conditions due to the weight bias (more weight on the driven wheels)
- stable behaviour due to increased understeering during acceleration

Of course, special attention must be given to the problems that occur when the steered wheels are also driven. In order not to create unwanted steering wheel torque or influenced course stability of the car, the front axle and steering geometry and elasticities must be designed with this in mind.

Throttle-off effects when negotiating corners are also generally more emphasized in a front wheel drive car. A limitation of these effects is necessary in order to fully achieve our driving safety philosophy.

In order to combine driving pleasure in the form of engine performance with fuel efficiency, the drag must be kept low. By optimizing the body shape for low drag, the sensitivity for sidewind disturbances is generally increased. The choice of front wheel drive, with accordingly the centre-of-gravity position moved forwards, counteracts this drawback.

The overruling requirements for versatility and total efficiency thereby play an important role for the chassis design. The choice of concept provides good possibilities to reach high course and sidewind stability and good traction. However, the space for chassis components is very limited and much attention must be paid to minimize torque steer and throttle-off effects.

In the preceding part, "soft" terms like driving pleasure and driving safety have been used. To make an analytical development, these terms must be interpreted into objectively measureable entities, which then will form the requirements for the complete car.

Driving pleasure

This is an often used expression although it is seldom defined. It must be clear that it focus upon the driver and vehicle interaction, in the way described earlier.

Important examples are:

- time lags and gains regarding steering response
- degree of under and oversteer
- low control efforts

Driving safety

The most important ingredient of driving safety is the consistent behaviour vehicle in all driving situations.

Other examples are:

- limited addition of yaw motion at throttle-off
- high lateral movement capabilities combined with stability
- short braking distances combined with steerability

Ride comfort

Good ride comfort means absence of vibrations and car motions when driving on different types of roads. Extremities and body are sensitive to certain frequencies. The car body motions should be kept small as they affect the senses of balance and sight.

Noise comfort

Low noise levels are generally re- quired in order to minimize negative

noise experiences. Also a good balance between high and low frequency noise as well as between different noise sources (power train etc) are important.

Driving comfort

By this we mean the vehicle behaviour in common driving situations in order to achieve relaxed driving.

Examples:

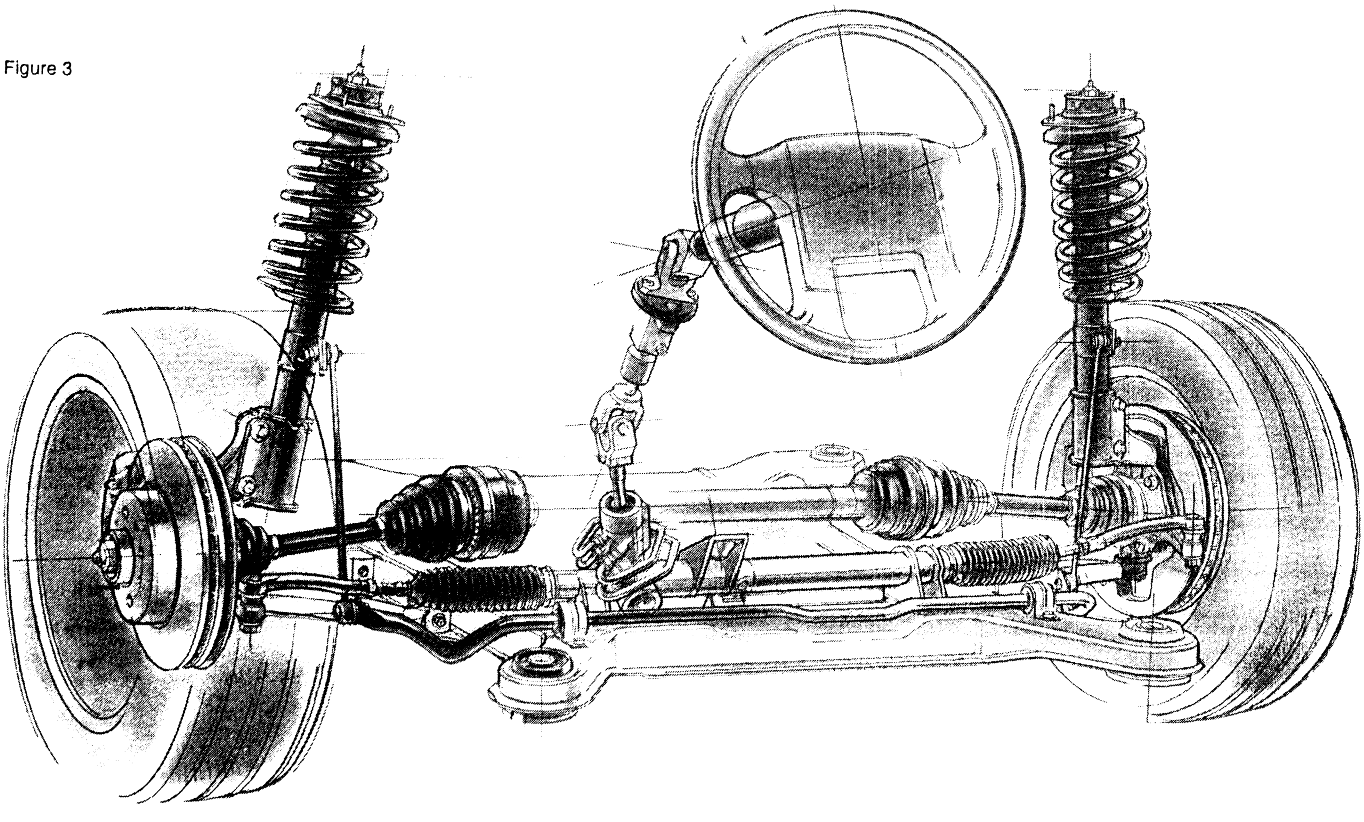
- good course stability also in side-winds
- small turning circle and small steering forces when parking
- small torque-steer effects

Chassis layout

Front suspension, figure 3

The spring struts have "wet" dampers and inclined coil springs. The strut-mounts to the body have separate isolators for damper and spring. The lower arm is connected to a rubber isolated subframe to which an anti-roll bar is also connected.

Figure 3



Rear suspension, figure 4

The Delta-link rear axle is of a unique Volvo design, combining the advantages of an independent semi-trailing suspension and a beam axle.

The two axle halves are connected to each other by two rubber bushings. The body attachments consist of two angled links with rubber elements that control the side force steer and lateral as well as longitudinal compliances. All anti-roll bar is mounted between the two axle halves. Coil springs with concentric hollow buffers are fitted close to the wheels. Dampers of pressurized type are mounted between the arms and the underbody structure.

Steering, figure 3

The rack-and-pinion power assisted steering gear is solidly fixed to the subframe and positioned behind the wheel centre. The steering wheel is adjustable both axially as well as vertically. For crash safety reasons both the steering column and the lower shaft are collapsible.

Brake system 5

The dual circuit ABS brake system has disc brakes on all four wheels. The front discs are ventilated and have sliding calipers. The parking brake is a separate duo-servo drum brake. The ABS system is a three-channel system with individually controlled front wheels, "select low" at the rear and yaw torque control for stable braking on my-split surfaces. The brake force distribution between the front and rear wheels is controlled by a pressure-sensitive reduction valve.

Figure 3

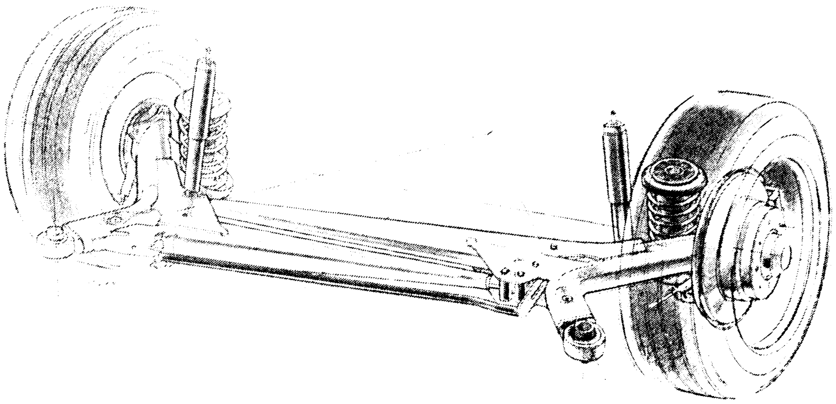
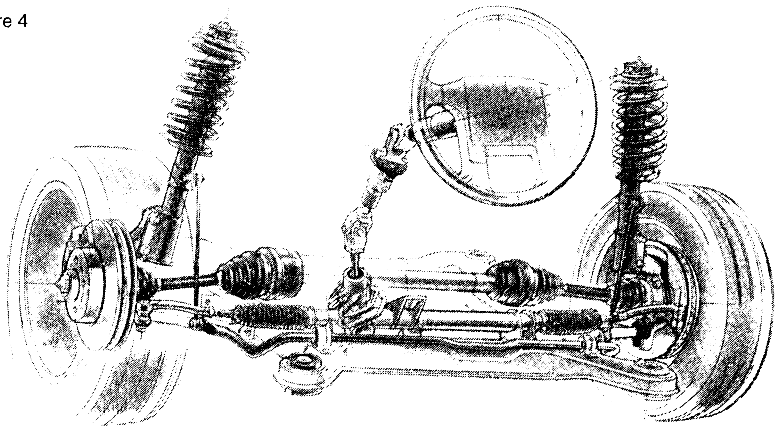


Figure 4



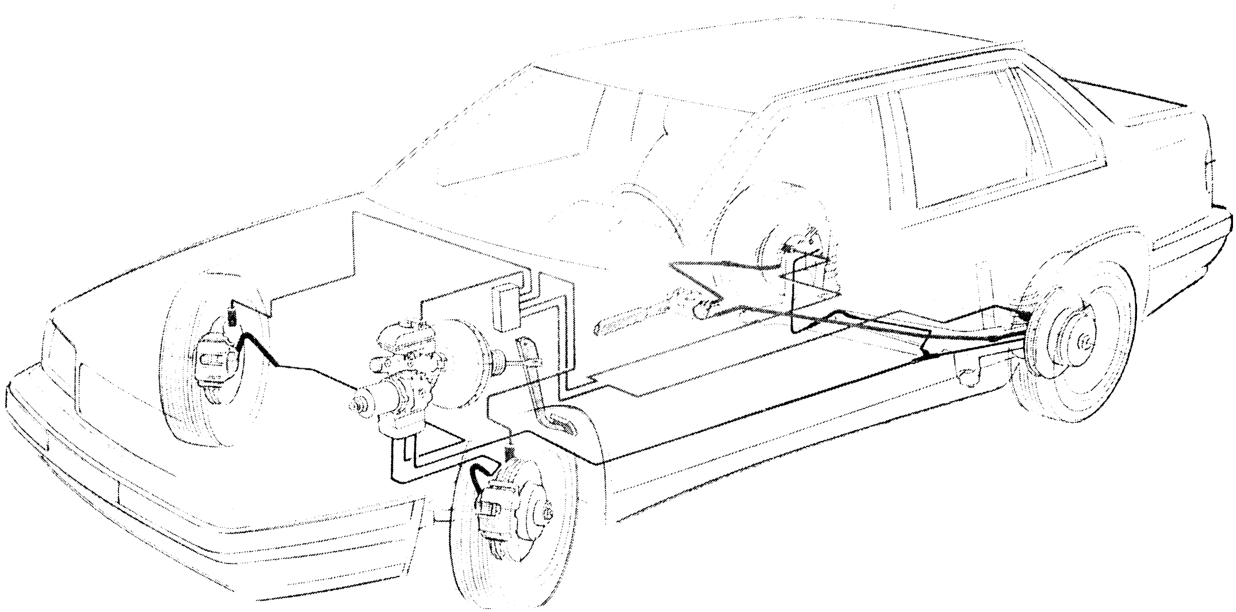


Figure 5

Combining properties

Several requirements on a car are contradictory. An important task, before hardware solutions are chosen and fixed, is to identify the factors that act in "common" or "opposite" directions. Some of the more important and well-known conflicts are:

- handling - ride and noise comfort
- steering properties - course stability
- lateral stiffness - longitudinal compliance of a suspension
- steering properties at low lateral ac celerations - at high lateral accelerations

The combination of the most important factors which make the car safe and enjoyable to drive was one of the Volvo 850 objectives and challenges. Without the use of more exclusive design solutions like four wheel steering and active suspension, the boundaries are set by on one side the human perception, on the other side by the laws of nature.

To achieve these goals, the front and rear axles must be designed to interact optimally with each other and with the tyres. The properties of the tyres were studied using the Magic Formula Tyre Model, developed by Volvo Car Corporation in collaboration with the Technical University of Delft in the Netherlands.

The results of the initial analysis showed that all the demands could only be met using a new rear axle design, the Delta-link, described later. For example, to add more driving pleasure it must be possible to aim the car quickly in a new direction. This is achieved by giving the car an oversteer at the beginning of the steering manoeuvre. To fulfill the apparent conflicting driving safety demands, the steering links of the Delta-link then counteracts the oversteering when the car has entered a corner and stabilizes it.

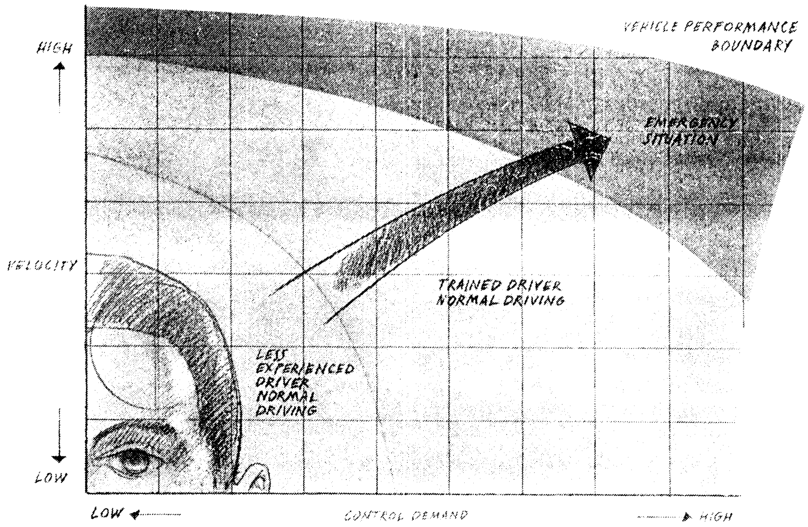
Another example of how to cope with conflicting demands is the steering response. It depends on the design of the suspensions and the tyres, but also on the steering system ratio. This ratio is also one of the significant factors for the steering wheel forces and steering wheel angles. A power steering serves to decouple these factors, i.e. gives the possibility to have a relatively low ratio for good steering response combined with low parking steer forces. Power steering is obviously a standard item on the Volvo 850. The power steering is also effective at higher speeds where reasonably high steer forces in relation to lateral acceleration are desired. The power steering characteristics are therefore accordingly carefully optimized.

The behaviour of the car during power-off in a corner is of utmost importance, especially considering the previous discussion regarding consistent properties. Although many drivers - especially those with front wheel drive cars - consider a certain amount of power-off effect as desirable, it is from a safety point of view necessary to limit the amount in order to support the untrained driver in an emergency situation, figure 2. This is a very plausible situation, for instance when a driver enters a corner too fast and instinctively releases the throttle. *In such* a situation it is important that the characteristics of the car, i.e, the path curvature and yaw velocity, change little and slowly. The desired amount of power-cuff is achieved using:

- appropriate front suspension anti-dive
- adequate steer angle changes at wheel movements
- small camber angle increase at the rear
- high roll stiffness
- tuned power steering characteristics

With these measures the sensitivity for throttle-off oversteer is kept on a level which allows full driver control without being too high for the less experienced driver.

Figure z



Tyres

The tyre is one of the most important vehicle components since all force interaction between the car and the road is transmitted through the tyre.

Therefore, the tyre can not be treated separately from the chassis since the tyre characteristics strongly contribute to the total cornering characteristics. The maximum side force that can be transmitted and the camber influence, at high lateral accelerations must of course be good enough for ex. avoidance manoeuvres.

For good noise and vibration isolation, tuning of resonances for the tyres and of the suspensions must be made. The self-aligning torque must be adequate to give a good feedback to the driver.

The chassis and the tyre must therefore be designed and optimized together and under different conditions. Car and tyre designers must work close together. The Volvo 850 is equipped with 195/60R15 or, as option, 205/55R15 tyres.

Front suspension and steering, figure 3

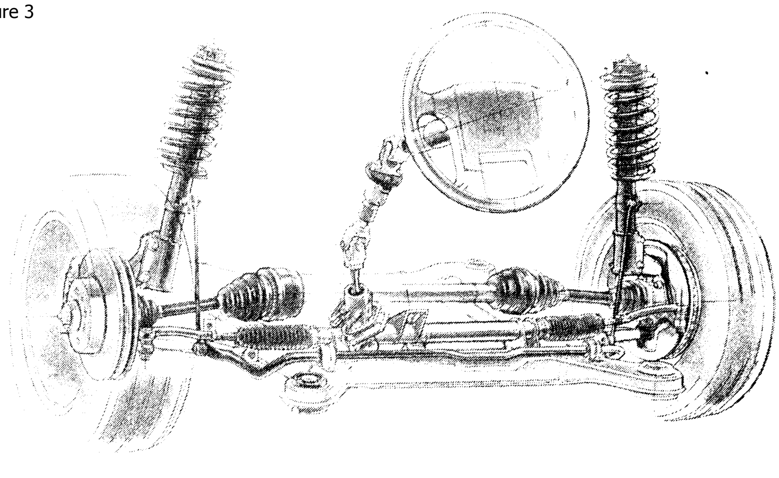
The front suspension has spring struts with a lower arm connected to a rubber isolated subframe. The rack-and-pinion steering gear is solidly mounted to the subframe, behind the wheel centre. The anti-roll bar is also mounted to the subframe, acting on the struts via balljointed links.

The subframe, figure 6, is made from pressed and seemwelded steel, forming a very rigid structure with closed box sections. The demands for rigidity have dimensioned the subframe to avoid noise peaks originating from internal resonances. The subframe is mounted to the body structure with four rubber isolaters. The stiffness and and damping characteristics of these are chosen to isolate high frequency vibrations generated by road surface roughness and transient impact forces on the front wheels. The rubber isolators are well spaced and have high lateral stiffness to reach the desired steering response and to minimize the steering effects due to asymmetric driving or braking forces.

A spring strut front suspension was chosen because of its qualities regarding reliability, the low sensitivity to the tolerances of the attachment points and the small forces that this type of suspension transmits to the body of the car.

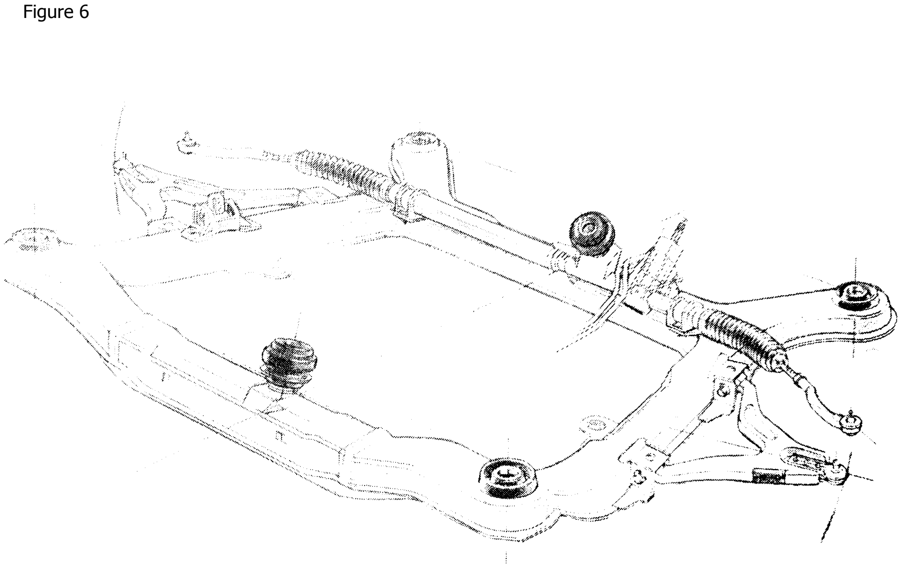
The measures on the front suspension to minimize the torque steer on a smooth surface as well as on longitudinal tracks and on cambered roads consist off:

Figure 3



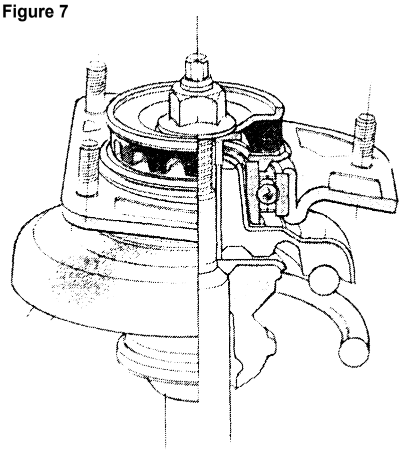
- optimized elastokinematics of the front suspension and steering system
- drive shafts of equal length and position
- small differential torque between the drive shafts, emanating from friction in the final gear
- high rigidity and low friction in the steering system, including a special strut mounting (described below)
- power steering with adequate assistance in straight-line position
- adequate anti-lift effect

Figure 6



The strut mounting, figure 7, has a ball bearing in the upper end of the shock absorber piston rod to allow for free steering rotation of the strut, even under large bending forces acting on the piston rod. Otherwise, the reaction forces that occur under acceleration acting on the rod could make the steering wheel "freeze".
The positioning of the king pin axis with negative steering radius in the ground contact patch, and a small lever to the wheel centre, gives low sensibility for unbalanced wheels and the possibility to bring about the desired elastokinematics for longitudinal forces.

Figure 7



The Delta-link rear suspension, figure 4

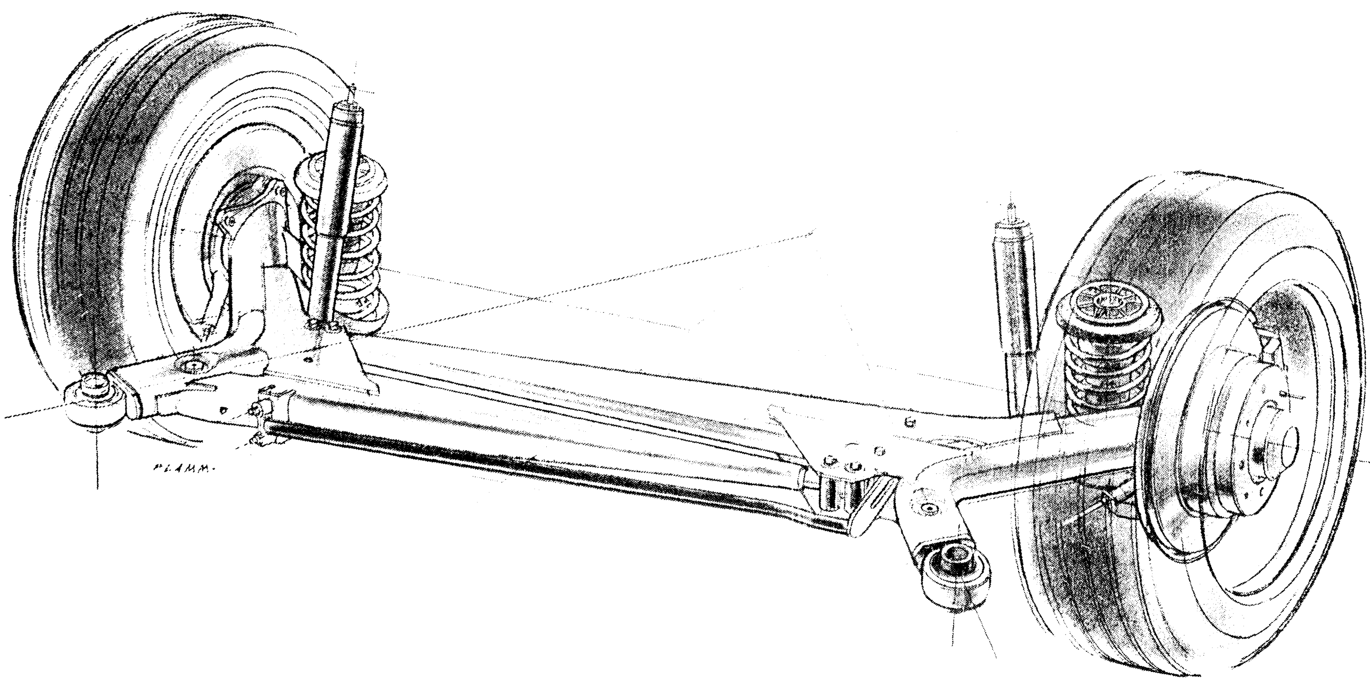
The combination of demands on cornering characteristics for handling, longitudinal compliance for isolation, low weight, low cost and little space required a special design.
To achieve the goals, two different approaches can be used:

- use an existing multi-link suspension, like the 960 suspension, that can give the required cornering and longitudinal compliances as a base and then reduce the space demand and cost.
- use a low weight, compact suspension as a base and then develop it, adding functions to give the required "high-level" cornering and longitudinal compliances.

The first alternative was excluded since the existing multi-link suspensions could not be made space efficient enough; also the reduction of cost would require an immense effort in detail design and production engineering. This in itself would result in a paradox of increased costs.

The second alternative could be realized with a relatively small effort and cost addition, and was thus chosen. It can be characterized as a trailing twist beam suspension. In its basic form it can fulfill either longitudinal compliance or cornering demands. However, the last is only true if the joints to the body and the axle structure itself are ideally rigid which is unrealistic.

Figure 4



The axle is equipped with two links called Delta links because their lines of action form the Greek letter Delta. During cornering the rear wheels are subjected to side forces. Thanks to the steering links, the rear axle is submitted to a motion pattern that compensates for elastic deformations of the axle and its bushings. The result is that the wheels move parallel in in the lateral direction without any steering angle, figure 8. The Delta links also give an increased longitudinal flexibility which contributes to the good ride comfort, figure 9.

Camber variation (figure 10) and roll steer characteristics are essential for the utilization of the cornering capacity of the tyres. They are designed by the basic kinematics of the suspension, i.e. the position of the body attachment points and the position of the transverse arm bushes, figure 11. The Delta-link suspension reduces the camber angle to the road and gives possibilities to select a roll steer that optimizes the handling properties.

Brake system

The brake system is of the ABS-type, chosen as standard equipment since it combines stability, steerability and short braking distances on all types of road surfaces. The brake force is distributed through a front/rear brake circuit split. The rear circuit contains a reduction valve that is automatically decoupled in case of a pressure loss in the front circuit. The brakes are dimensioned to give high braking performance/retardation and low pedal forces in all situations and high thermal resistance.

The system consists of;
- vacuum booster
- ABS tandem master cylinder
- hydraulic control unit
- four wheel speed sensors
- electronic controller
- pedal travel sensor

During ABS braking, excessive wheel brake pressure is released back to the reservoir when a wheel shows a tendency to lock. The front wheels are controlled individually. For stability reasons, both rear wheels are controlled by the rear wheel that has the the most locking tendency ("select-low") by one inlet/outlet valve pair.

Figure 8

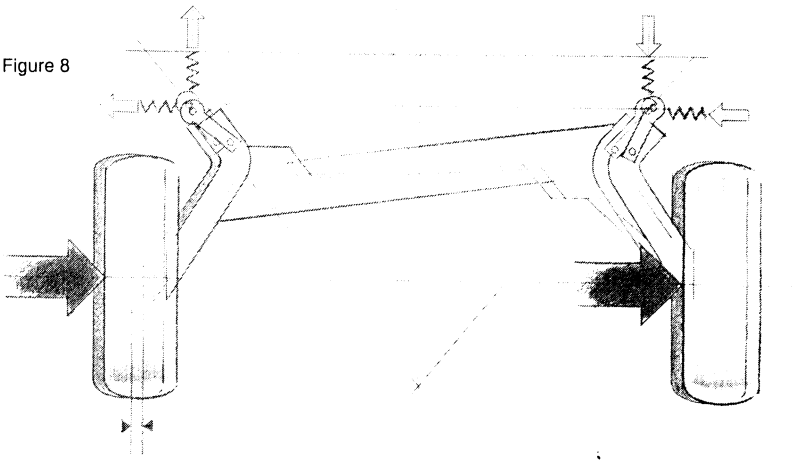


Figure 9

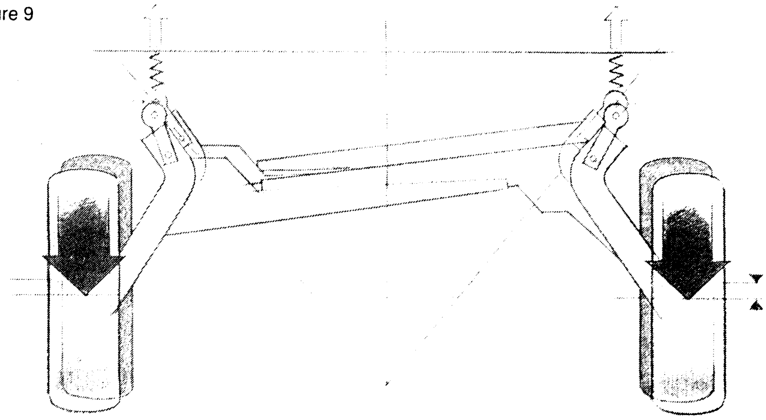


Figure 10

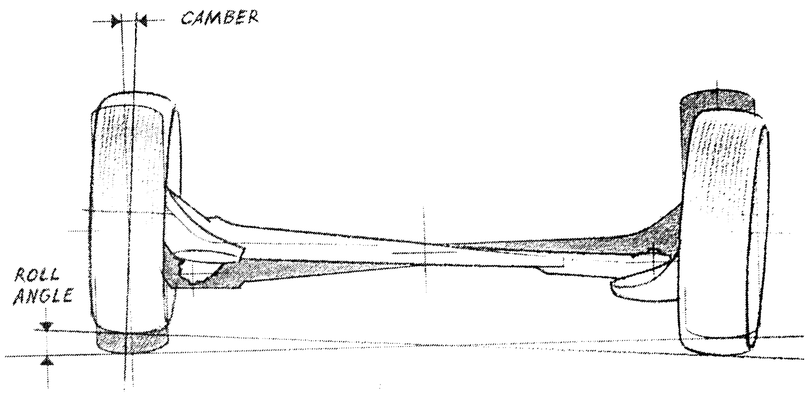
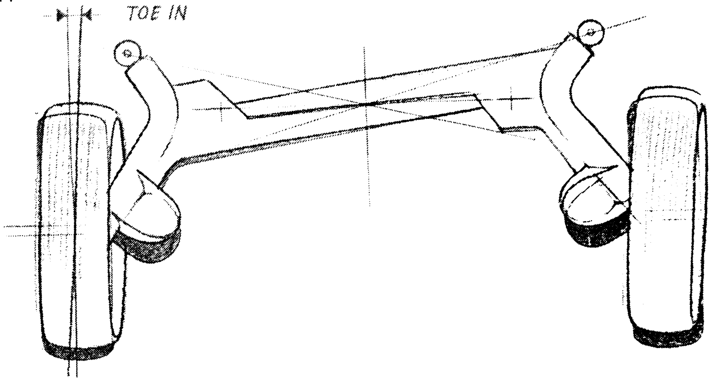


Figure 11



The vacuum booster is equipped with a pedal travel sensor. The information from the sensor is used to ensure sufficient brake fluid volume in the master cylinder and to provide good brake pedal comfort during ABS braking,

One situation that needs special attention is braking on different friction on the left and right wheel pairs, since the unequal braking forces on the left and right sides of the car creates a yawing moment. To ensure that the driver has maximum possibilities to cope with this, the yaw motions of the car should be slow. This is achieved partly by giving the front suspension adequate longitudinal compliance steering, partly by slowing down the pressure build-up in the front wheel cylinder on the high friction side using the ABS electronic controller.

For safety reasons, the ABS system is designed using a fail-safe concept, utilizing demands for continous signals and doubled electronic functions, including the comparison of sensor signals. Whenever a possible malfunction occurs, the system switches back to conventional brake function and a warning lamp is lit in the instrument panel.

Steering column

Apart from the main function of steering, the steering column has to meet two main requirements: to isolate the steering wheel from road and engine vibrations, and to ensure the driver a good road feel and steering precision. Other demands are for easy production assembly and for crash collapse.

Since the rubber-mounted subframe with the steering gear is subject to large motions in certain driving situations, the steering column is also affected by this motions. The isolation of large motions is done by a splines coupling between the lower and upper parts of the steering column. To eliminate the interplay, the splines has a special plastic coating. The design also permits the driver to adjust the steering wheel position vertically and axially according to individual requirements.

Smaller amplitudes, higher frequency vibrations and noise stemming from e.g. the power steering valve could however still be transmitted through the hysteresis in the splines coupling. These vibrations are therefore isolated by a disc-shaped rubber coupling which is soft axially and also initially soft in torsion. The torsional characteristics are strongly progressive in order to create a high rigidity whenever steering torque is applied. This has been carefully tuned in order to create the desired steering precision.

In production, the steering column is assembled after the marriage point(the joining together of the complete chassis with the body) by connecting the lower shaft between the universal joints. This ensures an effective and ergonomic correct assembly.

Volvo 850 GLT Chassis specifications

Dimensions

	Front	Rear	Total
Kerb weight (kgs)	815	531	1346
Max load (kgs)	917	880	1797
Max axle load/total weight (kgs)	1000	880	1820

Max trailer weight	1600 kgs
Max roof load	100 kgs
Wheelbase	2665 mm
Tyres	195/60R15 (205/55R15 optional)
Rims	6” steel (6,5” alloy optional)

Front suspension

Type	Spring struts (McPhearson-type)
Track	1520 mm
Ground offset	–12 mm
Anti-roll bar diam.	20 mm
Static camber angle	0
Anti-dive	9 %
Anti-lift	4 %
Camber compensation	23 %

Rear suspension

Type	Delta-link semi-individual
Track	1470 mm
Anti-roll bar diam.	21x3 mm
Static camber angle	– 1 deg
Anti-lift	48 %
Camber compensation	47 %

Steering system

Type	Rack-and-pinion, power-assisted
Turning circle	10.2 m
No of steering wheel turns lock to lock	3.2
Steering wheel diam.	375 mm

Brake system

Type	ABS-type, ventilated discs front, sliding calipers
Front disc diam.	280 mm
Thickness	26 mm
Rear disc diam.	295 mm
Thickness	9.6 mm