of these and other parameters that affect occupant response. Finally, this research is intended to identify the structural properties which are optimal for occupants protection in the real world environment. Initially the effort will consist of a simplified analytical approach. Follow up studies may employ more sophisticated techniques such as the Fiat Methodology (6) or the Safety System Optimization Model.

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Frontal Crash Protection in a Modern Car Concept

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ABSTRACT

Volvo's Safety Engineering Philosophy is described in detail starting with Volvo traffic accident investigations as one of the most important inputs to the safety characteristics specified for a new Volvo car. How the safety characteristics are transformed to measurable properties in laboratory environment is then explained and exemplified. The car specification is further broken down to system and subsystem specifications suitable and understandable to the engineer at the drawing board. The engineering follow-up procedure, including Crashworthiness Design Review Meetings and at the end certification tests and production control tests, is discussed.

How variations in test results affect the engineering procedure and methods to set engineering limits to be used during the different design phases are discussed.

How this Safety Engineering Philosophy is implemented into the development of a new Volvo car is then described step by step and exemplified by different technical solutions and test results.

INTRODUCTION

With the Volvo Safety Engineering Philosophy as a background this paper describes how the crashworthiness characteristics at the very first beginning of a project are built into a new car and how this is controlled through the total development programme.

VOLVO SAFETY ENGINEERING PHILOSOPHY

One of the primary characteristics of a Volvo car has for a long time been safety and with the safety characteristics Volvo has always meant safe transportation in the real traffic environment.

Volvo Safety Engineering Philosophy can be explained by a circle as in Figure 1.

As safety in the traffic environment is the primary goal, it is important to know the real performance of our cars in actual accidents.

Accident Analysis

Since 1965 Volvo has carried out traffic accident research on Volvo cars and the knowledge from this research is used to set up our own safety requirements.

Volvo's Traffic Accident Research consists of two main parts

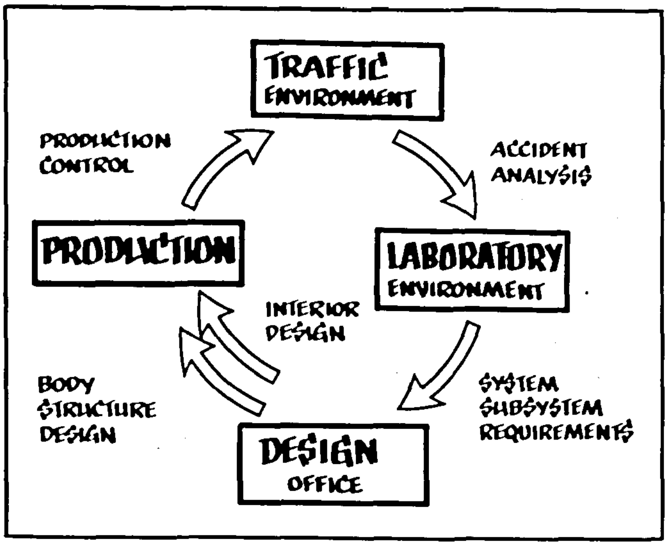

Figure 1. Volvo Safety Engineering Philosophy.

—multidisciplinary accident investigations
—data collection and statistical analysis

The multidisciplinary accident team is on call round the clock, seven days a week. All accidents with occupant injuries in a Volvo car, truck or bus are investigated. On the scene of the accident, the investigator looks for all information which can be of importance during his later analysis. This analysis consists of finding the cause of the accident and the consequences to the occupants and the vehicle. The medical expert of Volvo's investigation team gets in touch with his colleagues at the hospital to which the injured persons have been taken. With the help of data from the vehicle and information concerning the sustained injuries, it is possible to relate the pattern of injuries to the type of impact which caused them.

To get a material large enough to be used in a statistical analysis Volvo's unique insurance system has for a long time been used. All Volvo cars sold in Sweden are covered by a three-year motor vehicle damage warranty. This damage warranty is administrated by Volvo's insurance company. Through this motor vehicle warranty system Volvo has access to all data concerning the accidents. Each year, about 45,000 such accidents are reported to the warranty department. About 5,000 of the more seriously damaged vehicles are inspected by Volvo's staff of 12 damage assessors who are placed throughout the country. The basic information for our statistical accident research comes from this group of serious accidents.

Our own data in combination with data from different accident data files from all over the world are the basic background for setting our priorities.

Laboratory Requirement

The first step in the engineering procedure is to transform the accident scene to a controlled laboratory environment. The complex accident has to be transformed to a test which is repeatable and reproducible. Examples of these tests are frontal impacts into a rigid barrier, movable deformable barrier for side collisions and rollover simulations.

The occupants in the car have to be simulated with test dummies. These dummies are of course not in every detail copies of the human being but they are anthropometric and anthropomorphic. Dummies of different sizes are available (such as 5th percentile female, 50th percentile male, 95th percentile male and many different sizes of child dummies). Several different injury criteria are connected to the dummies, e.g., head injury criterion, chest injury criterion, femur injury criterion. These criteria have been found through biomechanical research. Within our function analysis staff Volvo has an expert in biomechanics who monitors this research in detail.

Engineering Requirements

Having the functional laboratory requirements on the complete car is not enough. The car must be divided into various systems and the system into various subsystems. With this technique the complete car requirement for different collisions could be broken down into a set of system and subsystem requirements which can be checked in laboratories and which are understandable to the draftmen and engineers.

The requirements on systems and subsystems form the basis for our development technique within the safety engineering procedure. The two major systems are the body structure system and the interior system. The body structure system covers the "body in white" and drive line (engine-transmission) and the interior system covers all the interior of the car such as instrument panel, steering wheel, seats and safety belts.

The requirements for the structure system are built up around a measuring technique using barrier tests, "body tests" and component tests. During the entire development procedure analytical tools such as structural mass/spring models and finite-element calculations are used to further optimize the mechanical engineering.

Two very important requirements for the structural system are intrusion and deceleration characteristics in the different crash tests. The reason is that these characteristics form the inputs to the interior system. The basic development technique for the interior system is a crash simulator in which the intrusion and deceleration can be reproduced. In this way the development of the interior is not depending on the possibilities to crashtest complete cars. As for the structure system the interior system uses several subsystem tests and in parallel calculations in mathematical models are made.

After a couple of loops between the structure and interior engineering departments in which an optimization of performance, weight and cost is done, the complete

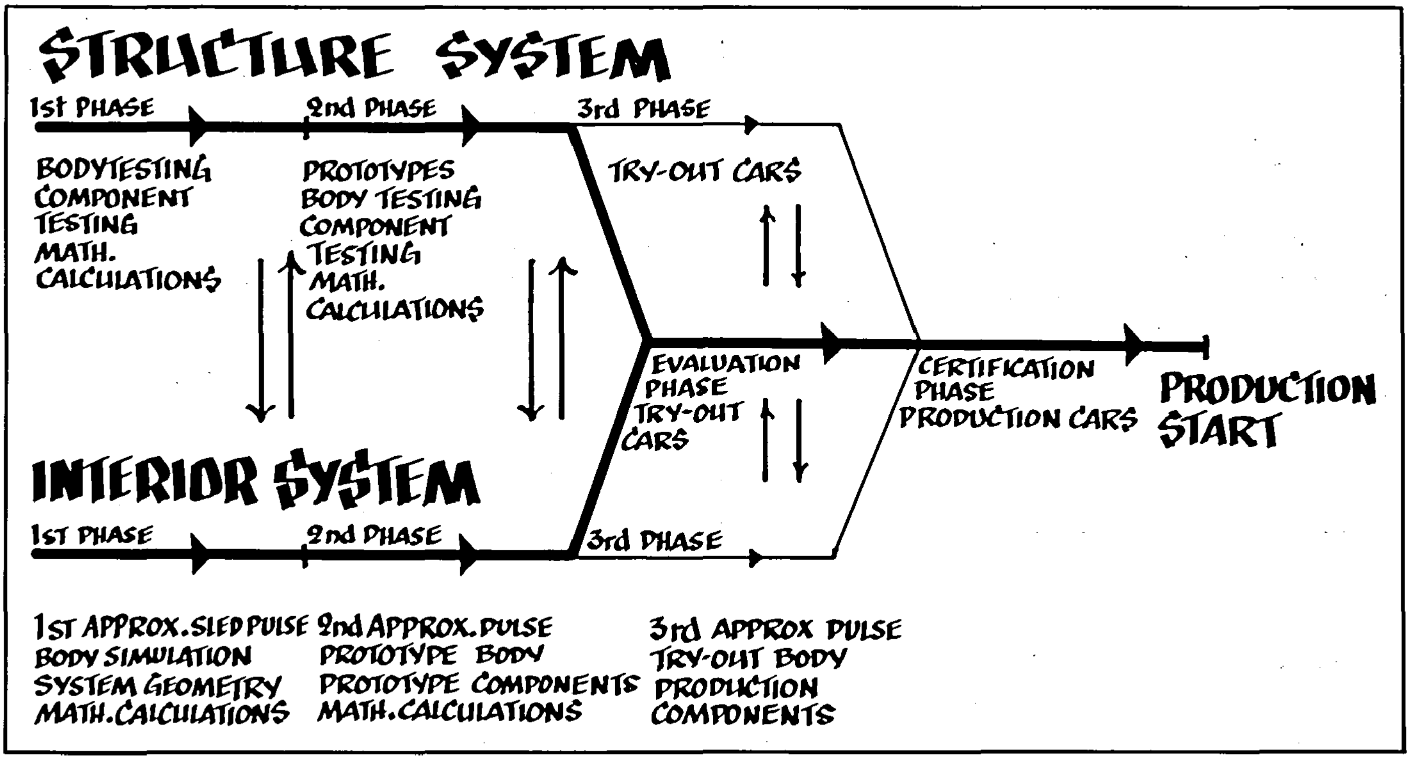

Figure 2. Development cycle for a new car.

car is ready for the evaluation and certification phase. In this phase complete cars (try-out and preproduction cars) are tested with the specified test methods and controlled against the specified criteria. A few extra loops back to structure and interior system may be necessary during the evaluation phase. Certification tests against legal requirements are then made, sometimes with representatives from the authorities witnessing the actual tests. Figure 2 shows a typical development cycle for a new car.

Production Control

During the development many different types of documentation are produced to ensure the production quality. A special documentation system for Vital Safety Parts (VSP) is used to

—guide product engineering, manufacturing and assembly in accordance with government requirements
—demonstrate compliance with government requirements
—limit the number of vehicles affected by recall action in case of non-compliance or safety defect
—limit product liability exposure and demonstrate that due care has been exercised

During production control many systems and subsystems (e.g. safety belts, windshields, seats, sunvisor) are tested and complete cars are taken as samples for crash tests.

The circle (see Figure 1) is closed and the new car is ready for the actual traffic environment. The Volvo Traffic Accident Research can start its investigations to evaluate the safety performance and to gain more knowledge for further improvements.

FRONTAL COLLISION PERFORMANCE FOR THE NEW VOLVO 760

The above described engineering philosophy will now be repeated and the special considerations during the development of the new Volvo 760 will be accounted for.

From all international traffic accident statistics as well as our own (refs 1, 2) it is obvious that frontal collisions are the type of collision with the highest number of accidents as well as the highest total cost for the society.

This has since a long time been recognized by Volvo and since the early fifties Volvo has gradually introduced different kinds of technical solutions to improve frontal crash protection (ref 3). When the work to specify a new Volvo for the eighties started, one of the highest priorities was to engineer a car with outstanding performance in frontal collision.

Test Method

The first step in our safety engineering procedure was to transform the overall specifications to functional requirements measurable in laboratory environment. Different safety regulations have since a long time used impacts against fixed barriers as their test procedures. Of course these test procedures are very simple simulations of actual accidents and must be combined with careful analysis by experienced test engineers as well as by accident investigators. To limit development cost it was nevertheless decided to use these procedures (impact against a fixed barrier 0°, ± 30°) as the main laboratory tests as they must be used in the certification phase. It was decided to test at 35 mph.

Test Dummies

What type of dummies to use was the next decision to be taken. During the development of the Volvo 240/260 most of the tests were made with the Part 572 (50 percentile) male dummy. From our own experiences (ref 4) as well as others (ref 5) it is obvious that the total measurement chain with a dummy as "sensor" is a very complicated one and large variations in test results are to be expected. Careful analysis of test signals together with studies of the behaviour of the dummy during the test must be used to overcome the shortcomings of the dummy. As no other well documented dummies were available the Part 572 dummy was chosen.

Injury Criteria

The conventional measurements to be taken in the dummies are head and chest acceleration and femur forces. From these readings special injury criteria such as HIC, SI, Max Chest acceleration etc. can be derived.

In spite of heavy criticism the criteria stipulated in FMVSS 208, namely HIC, peak chest acceleration (3 ms) and maximum femur forces, are frequently used.

The protection levels of these criteria, HIC 1000, 60 g and 2250 lbf (10 kN) respectively have also been questioned, in particular the level of the HIC value. Patrick et al. (ref 6) suggested in 1974 that HIC of 3000 was below the acceptable limit and Walfish et al. (ref 7) recommends a tolerance limit of 1500.

To have consistency with all our previous experimental work it was nevertheless decided to use HIC 1000, chest acceleration 60 g and femur force 10 kN as protection levels.

During later years the problem of detecting submarining or penetration of lap belt into the abdomen has been focused. Our experience is that an optimal restraint system is heavily depending on the performance of the seat. One way to evaluate this performance is to measure submarining or submarininglike behaviour. Even if submarining is not a great problem in real life the benefits of a good support from the seat cushion in experimental work have been documented by several authors (refs 8–10).

Transducers on the iliac crest were therefore used in combination with high speed film analysis to evaluate the performance of the belt system.

Vehicle Related Criteria

Vehicle criteria were also set up, such as FMVSS 212 Windshield Retention, FMVSS 219 Windshield Zone Intrusion, and FMVSS 301 Fuel System Integrity.

ENGINEERING METHODOLOGY

System and Subsystem Requirements

Having the functional requirements on the complete car was not enough. The draftsman at the drawing table cannot design for example a front side member only knowing that certain injury criteria in a dummy should be below a specified level. The car must be divided into various main systems and the main systems into various subsystems. For the frontal collision two main systems are body structure system and interior system (Figure 3).

The body structure system covers the "body in white" and driveline and the interior system covers all the interior such as instrument panel, steering wheel, seats and safety belts.

By using mathematical modelling technique, structural mass/spring models, finite element calculations as well as different models of occupant simulations, the complete car functional requirements were broken down into requirements for the two main systems.

Body Structure System

The body structure system was specified for example by body deceleration curves for 0° and 30° barrier tests, intrusion limits for different parts of the body such as floor pan, instrument panel and steering wheel intrusion and vertical movement. These requirements formed an

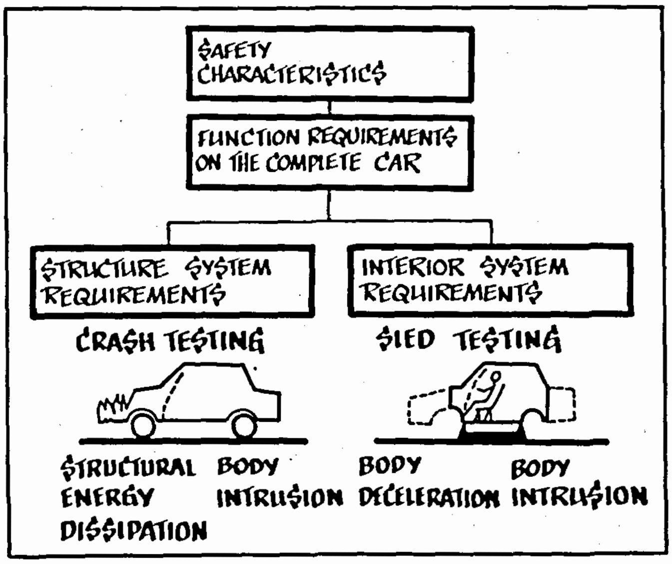

Figure 3. Body structure and interior system engineering methodology.

input to the body engineers for a further procedure broken down into subsystem requirements.

These systems and subsystems requirements were then controlled with test techniques such as component testing, subsystem testing, "body tests" and prototype tests. The "body test" is a technique used during early stages of development when no prototypes are available. By taking an existing car body and replacing specific parts in front of the A-pillar with prototype body concepts early test results such as force/deflection curves can be obtained. Our experiences from these body tests are that they are very useful both when different body concepts are to be evaluated as well as during the process of optimization between the structure design and material selection (ref 11).

Interior System

For the interior system the barrier test requirements are broken down to a sled test deceleration curve (the same as the body deceleration curve) and intrusion limits for body and interior parts such as the instrument panel and the steering wheel.

These requirements are the inputs to the interior engineering process which uses a HYGE crash simulation sled as an evaluation tool. From our early experiences of the use of the HYGE sled a good correlation between barrier tests and their simulations on the sled can be achieved at test speeds up to 30 mph (ref 12). Testing at higher velocities has however shown the need of further development of the simulation technique. Due to the higher test speed the body deceleration characteristics also in the vertical direction (pitch) and dynamic intrusions of body and interior panel including the steering wheel play an important role for the results in the dummies. Different techniques are used (max intrusion, intrusion at contact between dummy and interior, pitch simulations) but still much development has to be done to get an optimal simulation at speeds higher than 30 mph. In the meantime careful evaluation of test results from sled tests and a detailed comparison with results from barrier tests must be done during the development process. The importance of not being lost in these highly simplified simulations of actual traffic accident is obvious. For that reason our traffic accident analysis experts are involved also in the test evaluation process to ensure that not only good test results but also good performance in accidents will be achieved.

During both the structure and the interior engineering process mathematical calculations are used to back up the engineering and test work. Mathematical calculations have proven to be very helpful in concept evaluations and parameter optimizations.

The body structure and interior systems are developed in parallel during the early phases of a complete car project (see Figure 2). Several loops between the two systems are done in which performance, weight and cost are optimized. During the complete car evaluation phase tryout and preproduction cars are tested with specified test methods and controlled against specified criteria. A few extra loops back to the structure and interior systems may be necessary.

The number of complete cars crashed during the development of the Volvo 760 have been 50 and added to that around 70 body and component tests and 150 sled tests.

Crashworthiness Design Review Meeting

The safety characteristics influence more or less all the systems and subsystems in the car and consequently all departments in the organization have to be involved. Therefore a special steering committee meeting "Crashworthiness Design Review Meeting" was formed to control the implementation of the Volvo Safety Engineering Philosophy into the design process.

The responsibility to chair these meetings was given to the Crashworthiness Functional Analyst. The Functional Analyst is a person in the organization responsible for converting the crashworthiness characteristics set by the Product Planning Department into Functional Requirements of the complete vehicle.

In the case of crashworthiness the Functional Analyst is also responsible for the Volvo Automotive Safety Test Centre including Volvo Traffic Accident Research which ensures that neither test result nor actual traffic accident results are neglected during the development process.

The meetings have taken place every month and participants have been all of the managers in the line organization including representatives for Engine and Transmission Engineering, heads of different safety test departments, traffic accident experts and also representatives from Legal Requirement and Product Liability department.

The Crashworthiness Design Review Meeting was proven to be a very effective way to follow and control the development of the car safety characteristics during all stages of development. Optimization problems between different engineering areas have been possible to solve at the earliest possible time in the project.

ENGINEERING LIMITS

The various national and international requirements on safety characteristics are usually expressed as a maximum limit that no cars are allowed to exceed.

This implies that the average performance of the manufactured cars must be engineered with a margin to the limits.

The margin must include allowance for a number of factors. Some of these are

—uncertainty in the parameters that are used by the engineer in his work

—inaccuracies in the measurement techniques and data evaluation in the crash test
—unrepeatability of nominally identical crash test executions
—difference between prototype cars and production cars
—difficulties in making statistical inference from a small number of laboratory tests

Note that a single test outcome above the limit does not imply that the actual car value is outside the limit. It might equally well have been random fluctuations in the laboratory test procedures that have given this result.

A thorough treatment of the statistical consequences of some of these factors is given by Versace (ref 13). He has illustrated how the engineering limit can be related to the regulatory limit, by paying attention to all the above factors.

As input during the early stages of a new car project experience data from crash tests of previous models, data from the accident research and predictions on future technologies are used. If there is a larger technological step, say for instance a proposed change from belt restraints to airbag systems, due respect must be paid to the uncertainty concerning the behaviour of the new system. Based upon this, requirements are formulated which require the first tests with the prototype to exhibit values well below a limit. As the development continues and the test data accumulates for the new concept, the confidence increases in the soundness of the new product. This increased confidence makes it possible to revise the requirements so that the average performance is closer to the requirement than first permitted, even while the risk of having one car exceeding the limit is kept low.

It must be noted here that the requirement during development work is not, as some technicians may think, a more severe requirement than the requirement on the production cars. It is only an augmented and reformulated requirement on the engineers' work that must be achieved in order to get just the performance of the final car that the customers expect and the regulations require (ref 14).

TECHNICAL SOLUTIONS

The overall dimension and weight requirements for the 760 car were as such a challenge. The length from bumper to A-pillar was to be decreased some 10 cm as compared with the 240/260 car. The kerb weight should also be lowered some 50 kg. As a high crash performance was to be designed into the 760 car these goals demanded a thorough optimization between structure and interior engineering.

Structure

The 760 concept is a front engine, rear wheel drive, five-seat passenger car.

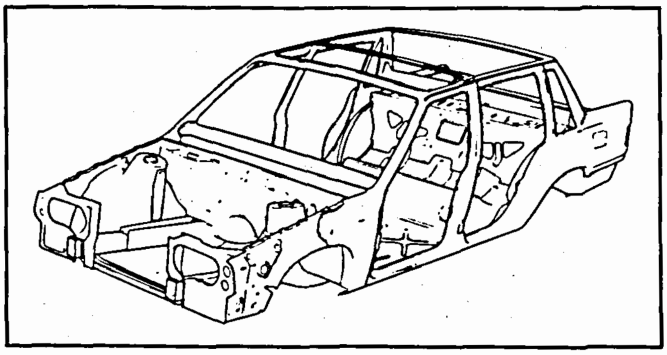

Figure 4. Structure design concept 760.

To optimize the stiffness and weight relationship, member design, sectional properties, welded joints and other joints have, for the monocoque body, been carefully calculated, analyzed and compared with experiences gained from previous designs (Figure 4).

The front side members (Figure 5) are designed as closed sections and from the front and backwards they form a continuously increasing cross section. The side members run under the floor with an outward angle and are connected to the doorsills with a cross member in order to distribute forces.

The front wheel housing and the suspension strut form together with the side member an integrated structure welded to the compartment.

The system is able to effectively absorb the kinetic energy in a frontal crash. The side members are at the front provided with "trigger swages" to initiate and control the buckling during deformation.

The aim has been to construct a body which, despite a large body area, weighs less than its predecessor. High strength steel (HSLA) has therefore been used in the front section of the front side members and sheet metal thickness has in different parts of the body been varied in order to optimize strength and weight.

Interior

The interior restraint systems are engineered not only to meet the overall safety requirements but also to improve the systems performance in the following areas: belt comfort, webbing guidance to eliminate problems with pi-

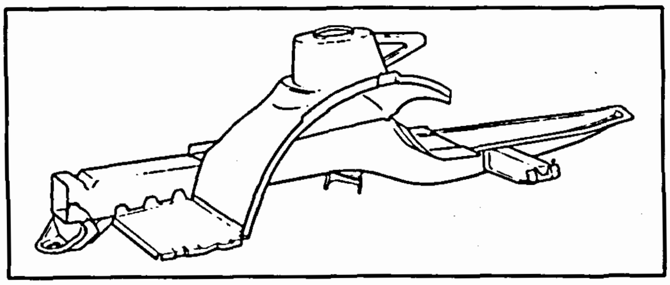

Figure 5. Front member system.

voting webbing guides, seat cushion yieldingness for front and rear seats optimizing the balance of the forces acting on the restrained occupant in a crash.

For the front seats a three-point manual belt with lower anchorage points in the seat frame was chosen. The system incorporates one reel and webbing guide fully covered behind a panel. The webbing guide in the B-pillar is inclined "aligned" and bolted to the pillar hereby giving consistent performance in crash testing.

The lower belt anchorages are located in the seat structure giving constant belt geometry of the lap belt independent of the seat position. The dynamic forces in a crash are transmitted through the rails which are engineered to withstand this extra loading.

The seat structure shown in Figure 6 has a special tube under the frontal part of the cushion which limits the vertical movement of the occupant during a crash.

To minimize steering wheel intrusion during a crash the system has at two locations a collapsible shaft, one for bending moments and one for axial loadings, in combination with a, for rearward forces, strong mounting of the upper shaft bearing.

Forces generated by chest impacts of unbelted occupants in a crash will be absorbed at a tolerable force level by deforming the steering wheel and the bracket for the upper shaft bearing.

The steering wheel with its four spokes, padded rim and hub is designed to mitigate head and face injuries on belted occupants in case of contact with the steering wheel during a crash.

The primary goal has been to keep the instrument panel away from the belted occupant during a crash. This has put special demands on the fire-wall and scuttle area as well as the attachments of the instrument panel.

At the same time efforts have been made to design an instrument panel without protruding parts, projecting a "clean" surface towards the occupant.

Sheet metal structure and padding characteristics have been combined to give tolerable forces if, in spite of all, a head contact would occur.

The three-point belt in the rear seat has the same fixed,

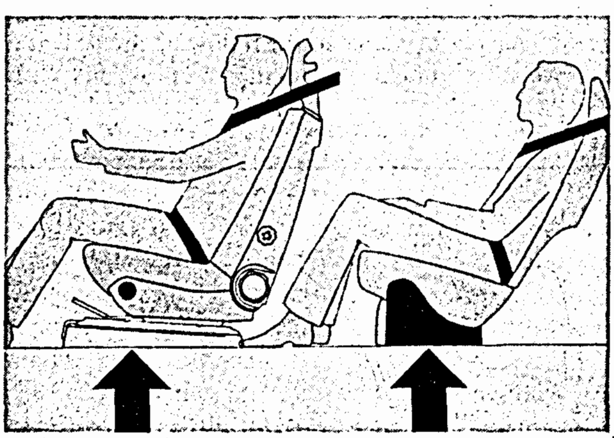

Figure 6. The interior design concept in the Volvo 760.

inclined webbing guide as described above. The floor under the seat cushion has a special ridge which prevents excessive vertical movement and submarining during a crash. This design was built on the experience from the Volvo Concept Car (ref 12).

All belt geometries have within the limits of existing regulations been elaborated to give good protection and comfort for occupants spanning from 5th female to 95th male percentile.

TEST RESULTS

During the complete development procedure (see Figure 2) a lot of testing was done at component, subsystem, system and complete car level.

At the end of the development it was decided to run three identical frontal barrier tests at 35 mph. The number of tests was chosen as a compromise between cost and the need to cover the repeatability and reproducibility problem. These three tests were run at MIRA (Motor Industry Research Association, England). They are identified by the numbers 227-229 in the following result presentation.

For comparison two previous tests done at the Volvo crash test laboratory are presented. The Volvo tests are taken from some early test series and the cars are prototypes not completely identical with the MIRA cars. The test numbers are 225 and 226. The test results are shown to illustrate the variation in test results during development.

TEST PROCEDURES

The tests were run according to the test procedure specified in FMVSS 208. Both MIRA and Volvo crash test laboratories have a long experience with this test procedure and fullfill all instrument requirements including a well organized dummy calibration procedure. The main difference between the two laboratories is the propulsion system used. MIRA uses an electrical linear motor directly connected to the car and Volvo uses a tyristor controlled electrical rotational motor and an endless wire connected to the car.

The test cars were Volvo 760 GLE with automatic transmission (see Figure 7).

Test weight was as specified in FMVSS 208 (unloaded vehicle weight plus its rated cargo and luggage capacity weight plus two Part 572 dummies) which for the Volvo 760 means 1630 kg (3590 lb).

A total of 50 signals cover both the dummies and different car related measurements as well as a segmented force measuring barrier. The tests were covered by eight high speed cameras.

The dummies were calibrated before every single test. Table 1 shows some test parameters.

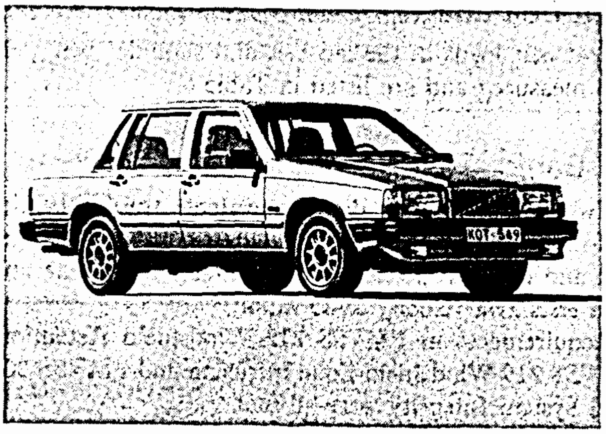

Figure 7. The Volvo 760 GLE.

Structure Related Test Results

A typical body deceleration pulse is shown in Figure 8.

A typical force/deflection curve is shown in Figure 9.

The following structure related regulations were checked: FMVSS 212 Windshield Retention, FMVSS 219 Windshield Zone Intrusion and FMVSS 301 Fuel System Integrity.

Table 2 shows results of the test.

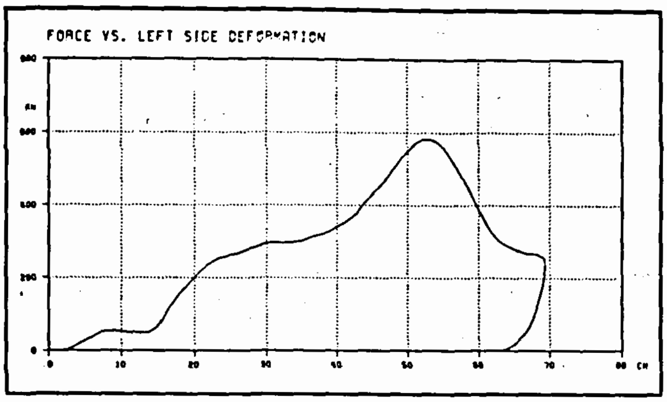

Figure 8. Body deceleration pulse.

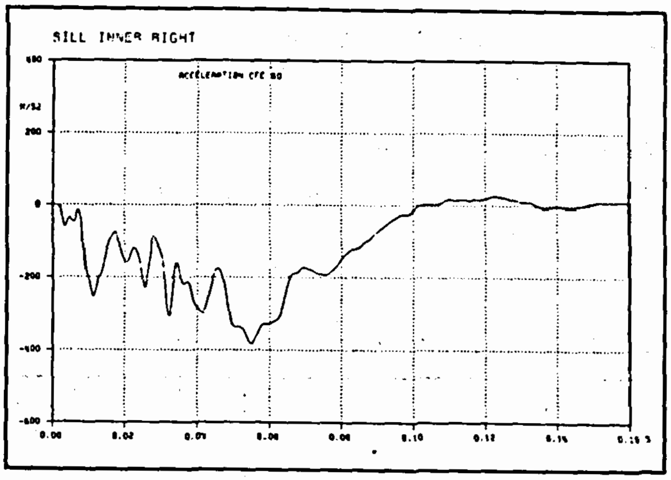

Figure 9. Dynamic Force/Deflection Curve during 35 mph barrier test.

Table 1. Test parameters.

	MIRA 227	MIRA 228	MIRA 229	Mean Value	SD*)	Volvo 225	Volvo 226
Test Weight kg	1630	1630	1630	1630	0.0	1630	1630
Test Speed mph	35.3	35.3	35.2	35.27	0.006	35.2	35.4
Test Temp °C	22.0	22.0	22.0	22.0	0.0	19	20

*) SD = standard deviation defined as SD = $\sqrt{\Sigma\frac{xi2 - n\bar{x}^2}{n-1}}$

Table 2. FMVSS 212, 219 and 301 test results.

Regulation	MIRA 227	MIRA 228	MIRA 229	Volvo 225	Volvo 226
FMVSS 212 % Retention	100	100	100	100	100
FMVSS 219 Penetration	OK	OK	OK	OK	OK
FMVSS 301 Leakage gram	0	0	0	0	0

Interior Related Test Results

The occupant crash protection was evaluated by measuring dummy signals as required in FMVSS 208.

Chest Injury Criteria

In Table 3 two chest injury criteria are shown.—Resultant chest acceleration duration longer than 3 ms, g_{3ms} and Chest Severity Index, CSI, (weighted time integral of chest resultant during crash).

Head Injury Criteria

Table 4 shows the Head Injury Criteria calculated as defined in FMVSS 208 (HIC) and also the same calculation but during head contact (HIC_c).

Femur Injury Criteria

In Table 5 femur injury criteria as defined in FMVSS 208 are presented.

Seat Belt Loads

Seat belt loads in the lap belt and shoulder belt were also measured and are listed in Table 6.

30° Barrier Test Results

Two tests were also done to evaluate the 30° barrier performance. One test 30° right—first contact passenger side and one test 30° left—first contact driver side and both tests at a velocity of 35 mph.

Requirements in FMVSS 212 Windshield Retention, FMVSS 219 Windshield Zone Intrusion and FMVSS 301 Fuel System Integrity were all met.

Dummy test results as for FMVSS 208 can be seen in Table 7.

CONCLUSIONS

This work has demonstrated that by integrating the desired safety properties from the very beginning of a new

Table 3. Dummy results—Chest injury criteria.

Chest Injury Criteria	MIRA 227	MIRA 228	MIRA 229	Mean Value	SD	Volvo 225	Volvo 226
Driver							
g_{3ms}	46.4	50.0	47.0	47.8	1.9	54.0	49.2
CSI	370	427	417	405	30	455	428
Passenger							
g_{3ms}	41.6	45.0	45.0	43.9	2.0	45.8	41.4
CSI	283	311	323	306	21	345	372

Table 4. Dummy results—Head injury criteria.

Head Injury Criteria	MIRA 227	MIRA 228	MIRA 229	Mean Value	SD	Volvo 225	Volvo 226
Driver							
HIC	945	697	820	821	124	898	825
HIC_c	645	676	820	714	93	898	825
Passenger							
HIC	729	890	990	870	132	1030	1290
HIC_c	27	209	87	108	93	349	686

Table 5. Dummy results—Femur injury criteria.

Femur Force kN	MIRA 227	MIRA 228	MIRA 229	Mean Value	SD	Volvo 225	Volvo 226
Driver							
F_L (Left)	4.96	4.74	4.24	4.65	0.37	5.8	4.4
F_R (Right)	0.61	1.76	1.07	1.15	0.58	2.0	1.3
Passenger							
F_L (Left)	3.91	5.52	3.36	4.26	1.12	3.6	3.1
F_R (Right)	1.31	2.98	0.87	1.72	1.11	1.0	2.3

Table 6. Dummy results—seat belt loads.

Belt load kN	MIRA 227	MIRA 228	MIRA 229	Mean Value	SD	Volvo 225	Volvo 226
Driver							
Lap	6.3	7.9	7.5	7.2	0.8	7.0	6.1
Shoulder	7.4	8.2	7.5	7.7	0.4	5.2	7.7
Passenger							
Lap	7.3	7.0	7.9	7.4	0.5	7.4	7.5
Shoulder	7.6	6.8	6.7	7.0	0.5	7.8	7.7

Table 7. Dummy results—30° barrier.

Test Parameters				
Velocity: 36.5 mph Right; 36.2 mph Left Weight: 1630 kg.				
	30° Right/MIRA		30° Left/MIRA	
	Driver	Passenger	Driver	Passenger
Chest g_{3ms}	35.0	31.0	47.0	44.0
CSI	216	227	388	315
HIC	418	517	762	570
HIC_c	285	258	361	73
Femur Forces			3.2	1.4
F_L kN	1.4	2.8		
F_R kN	2.8	2.4	2.6	0.8
Belt Loads			4.2	8.9
Lap kN	5.9	2.2		
Shoulder kN	6.9	5.1	6.8	7.6

car project and by continuously following up the engineering process it is possible to achieve an increased level of safety.

It has pointed out the inherent complexity of crash testing and the need to use statistical methods in order to make qualified judgments during a car development process.

Emphasis has also been placed on the necessity to use experience from field accidents in order to complement the laboratory simulation.

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